Volumetric and Sound Velocity Studies on L-Lysine and L-Arginine in Aqueous Sodium Benzoate Solution at Different Temperature

By

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science (M.Sc) in Chemistry

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Declaration

This is to certify that the thesis work entitled "**Volumetric and Sound Velocity Studies on L-Lysine and L-Arginine in Aqueous Sodium Benzoate Solution at Different Temperature**" has been carried out by Iffat Ara Mou in the Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work has not been submitted anywhere for the award of any degree or diploma.

Signature of Supervisor

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ABSTRACT

In this study, a general volumetric and sound velocity method was used to analyze the effects of sodium benzoate (SB) on the structure of essential amino acids (L-lysine, L-arginine). Densities and sound velocities of L-lysine and L-arginine in aqueous and in aqueous 0.05 mol.kg^{-1}, 0.2 mol.kg^{-1}, 0.35 mol.kg^{-1} and 0.5 mol.kg^{-1} SB solutions have been studied at 293.15K to 313.15K with an interval of 5K. 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 (E_φ^0) and Helper's constant $(\delta E_\varphi^0 / \delta T)_p$. 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 transfer ($\Delta_{tr}\varphi_k^0$), acoustic impedance (Z) 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 SB solutions are higher than that of amino acids in aqueous solution. The limiting apparent molar volumes (φ_v^0) and the values of experimental slope (S_v) are positive. The smaller values of S_v as compared to φ_v^0 values suggest the dominance of solute-solvent interaction over the solute-solute interaction.

The limiting apparent molar volume transfer ($\Delta_{tr}\varphi_v^0$) values of L-lysine and L-arginine in SB solutions are negative. This indicate that ion-hydrophobic and hydrophobic-hydrophobic group interaction are dominating over the hydrophilic-hydrophilic interaction. The values of limiting apparent molar expansion (E_φ^0) are positive. These trends in limiting apparent molar expansions for these amino acids in each concentration of SB solutions indicating the presence of solute-solvent interaction. The Hepler's constant $(\delta E_\varphi^0 / \delta T)_p$ values of binary system are entirely positive for all studied amino acids suggest the studied systems act as structure makers. In ternary system some values are small negative and some values are positive. Hepler's constant $(\delta E_\varphi^0 / \delta T)_p$ in ternary solutions

indicating the structure making properties of amino acids in SB solutions. The values of partial molar volumes ($\bar{V}_2$) increase with increasing of concentration of L-lysine, L-arginine for the studied systems.

As the concentration of amino acids increases, the adiabatic compressibility (β_s) decreases. 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 implying a greater ordering effect by the solute on the solvent. $\Delta_{tr}\varphi_k^0$ values of L-lysine are positive whereas $\Delta_{tr}\varphi_k^0$ of L-arginine are negative. This indicate that hydrophilic-hydrophilic and ion-hydrophilic interaction are dominating for L-lysine systems whereas hydrophobic-hydrophobic and ion-hydrophobic interactions are dominating for L-arginine systems. The small S_k values also indicates the solute-solvent interactions.

The increase in acoustic impedance Z, indicates the presence of effective solvent-solvent interactions with the increase in solution concentration. The positive hydration number (n_H) values indicate an admirable solubility of the solutes.

Water molecules around amino acids have less shrinkage than water molecules in bulk solutions. The compressive strength of the ternary solution is less than that of the binary solution. This result suggests that the proteins or peptides generated from the studied amino acids will be denatured in ternary SB solutions.

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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
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
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

Densities and viscosities are two very important physicochemical properties of solution in chemical process design. Meanwhile, the derivative thermodynamical and transport properties of solution from its densities and viscosities are usually used for describing the intermolecular interactions to understand their real behavior [1]. Ultrasonic technique has been found to be more accurate and comprehensive in understanding solute-solvent interactions. To understand the role played by the biological molecules in living organism [2, 3]. Sodium benzoate is the sodium salt of benzoic acid and exists in this form when dissolved in water. It is used as preservative. Zwitter-ion remains in amino acids and are the ingredients of the most essential class of biopolymers, i.e. Proteins. 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. [4].

1.2 Physical Properties and chemical constitutions

The study of volumetric properties of amino acids in aqueous and non-aqueous solvent is a significant step for understanding their behavior organic solutions containing different ionic species. The information about conformational stability and interaction in the ternary system is provided by it. 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 [5].

(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. 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.

1.3 Properties of solute in solvent

In chemistry, a solution is a homogeneous mixture composed of two or more substances. In such a mixture, a solvent is the component of a solution that is present in the greatest amount.it is the substance in which the solute is dissolved. The solution more or less takes on the characteristics of the solvent including its phase and the solvent is commonly the greatest amount 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 existing.

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 [6–8]. This puzzling behavior results from the combined effects of preferential solvation of the solute by one of the components in the mixture [9, 10] and of solvent–solvent interactions [11]. 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 fructose with amino acids in studying the solute-solvent and solvent-solvent interactions in ternary systems.

1.4 Amino Acids

Amino acids are well-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, of which 19 are α-amino acids and one is a cyclic α-amino acid (proline). Different 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. Amino acids have remarkably different biochemical properties and functions because of variations in their side chains [12].

Amino acid consists both of an amino group and a carboxylic group and it acts as a base as well as acid. The amino acid is therefore an ampholyte as 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 situated at the α-carbon atom of the carboxylic group as shown in Figure 1.1. The α-carbon atom has hydrogen and a side chain at the last two sites.

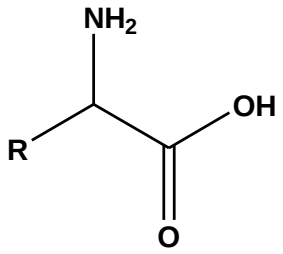

Figure 1.1: Basic structure of α-amino acids

Dipeptide is defined as when two amino acids are linked together by a peptide bond. Continuing this process will eventually lead to the formation of protein [13]. In polar solvents (e.g. water, ammonia), amino acids show higher solubility 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 [14].

1.5 Properties of L-lysine

Lysine is an α-amino acid that is used in the biosynthesis of proteins. It contains an α-amino group (which is in the protonated $-NH_3^+$ form under biological conditions), an α-carboxylic acid group (which is in the deprotonated $-COO^-$ form under biological conditions), and a side chain $(CH_2)_4NH_2$, classifying it as a charged (at physiological pH), aliphatic amino acid. It is essential for health but the body cannot synthesize it and thus it must be obtained from the diet. In hydrogen bonding, amino group often participates and as a general base in catalysis. The α-amino group (NH_3^+) is linked to the fifth carbon from the α-carbon, which is attached to the carboxyl group. The side chain of lysine has three methylene groups, so that even though the terminal amino group will be charged under physiological conditions, the side chain does have significant hydrophobic character. Lysine is often seen to be buried with only amino groups in contact with solvents [15]. Lysine is the building blocks of protein. Lysine is important for proper growth, and it plays an important role in carnitine production, a nutrient responsible for converting fatty acids into energy and helping to lower cholesterol. Calcium is absorbed by the body with the help of lysine and it plays an important role in the formation of collagen, an important substance for bone and connective tissues including skin, tendons and cartilage [16].

Anemia, blood clots in the eyes, enzyme problems, hair loss, density dysfunction, itching, lack of energy, loss of appetite, reproductive problems, increased resistance and weight loss can lead to L-lysine deficiency. Lysine is used to prevent and treat herpes infections and cold sores. It increases intestinal absorption of calcium and eliminates its excrement by the kidneys, suggesting that it may be helpful in osteoporosis. Lysine has been investigated for its effects on increasing muscle mass, lowering glucose and improving anxiety. The case report suggests that lysine may reduce angina. Lysine acetylsalicylate is used to treat pain and to detoxify the body after heroin use. For the treatment of migraine headaches and other painful conditions, lysine clonixinate has been used [17].

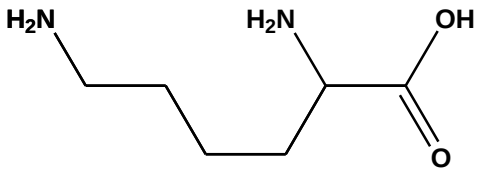

Figure 1.4: Structure of Lysine

1.6 Properties of L-arginine

Arginine is an α-amino acid that is used in the biosynthesis of proteins. It contains an α-amino group, an α-carboxylic acid group, and a side chain consisting of a 3-carbon aliphatic straight chain ending in a guanidino group. At physiological pH, the carboxylic acid is deprotonated (−COO−), the amino group is protonated ($-NH_3^+$), and the guanidino group is also protonated to give the guanidinium form ($-C-(NH_2)_2^+$). Charged, aliphatic amino acids. It is the precursor for the biosynthesis of nitric oxide.

Arginine is a semi-essential or conditionally essential amino acid for the human body, depending on a person's developmental stage and health status [18]. Young children are internally unable to synthesize or make arginine, which makes them essential amino acids for nutrition [19]. Preterm infants face a significant nutritional problem for the deficiency of arginine (hypoargininemia), which results in hyperammonemia, as well as cardiovascular, pulmonary, neurological, and intestinal dysfunction. The high rate of infant sickness and premature births cause arginine deficiency. Supplementation with arginine is not required for healthy people because it can be synthesized in the body from all protein-rich foods and from glutamine to citrulline [20].

Animal sources of arginine include meat, dairy products, and eggs, and plant sources include seeds of all types, for example grains, beans, and nuts.

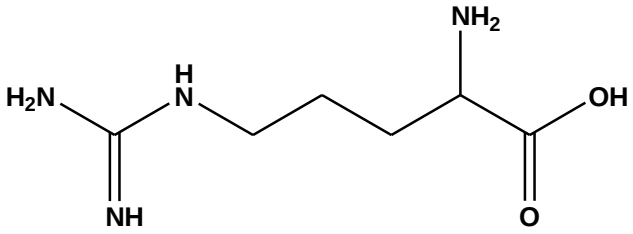

Figure 1.2: Structure of Arginine

1.7 Properties of Sodium benzoate

Sodium benzoate is a substance which has the chemical formula $NaC_7H_5O_2$. It is the sodium salt of benzoic acid and exists in this form when dissolved in water. Sodium hydroxide reacts with benzoic acid to produce sodium benzoate.

To prevent decompositions by microbial growth or undesirable chemical changes, preservatives are added to the food. Food industries use many preservatives which are contain benzoate group and used as bacteriostatic and fungistatic in acidic food and drink such as vinegar, carbonated drinks, jams, fruit juice, and condiments. Sodium benzoate is commonly used in wide-reaching food. Nowadays food and drink consumption involve with these preservatives, due to almost products even fresh or dried food are always added preservatives to extend lifespan. Food and Drug Administration (FDA) controls the amount of food additives permissible in foods or other goods to help make sure safety and reduce the possibility of overconsumption. For using benzoate group such as sodium benzoate and potassium benzoate in dairy products such as ice cream, pudding, and yoghurt, FDA allows using sodium benzoate at 300 mg/kg. If someone intake it as a long time even though it is small amount, the preservatives may cause damage to users within some infection and in genes level. The behind adverse effects of food preservatives are nausea, vomiting, diarrhea, rhinitis, bronchospasm, migraine, anaphylaxis, and hyperactivity in kids [21].

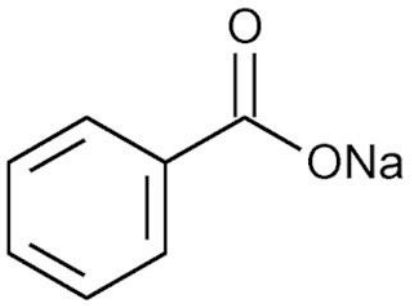

Figure 1.4: Structure of Sodium benzoate

1.8 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. Water is a powerful solvent and has a strong surface tension for its molecular polarity.

Water molecules arrange themselves in distinctly different configurations when the water molecule makes a physical phase change. 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.

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density. Expansion of the water molecule at freezing allows ice to float on top of liquid water.

It has been recognized that water is an 'anomalous' liquid, many of its properties differing significantly from those of normal structural fluids [22]. Deviations from regularity somehow indicate the attachment of water molecules. Significant unique physical properties displayed by liquid water are [23] : 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 long time physicists and chemists have thought of possible structural arrangements that could be responsible for giving very unusual properties to water. Knowledge of the structure of water is a prerequisite for understanding the most fundamental problem of solution chemistry in the interaction of dissolved water. It is recognized that a summary of the structural changes in the solvent is important for studying 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 continumm model and the mixture models. The continumm models [24, 25] 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 [26-28] 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, later developed by Nemethy and Scherage, is commonly adopted in solution chemistry [29, 23] . 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 tetrahedraly 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

$$(H_2O)_b \rightleftharpoons (H_2O)_d$$

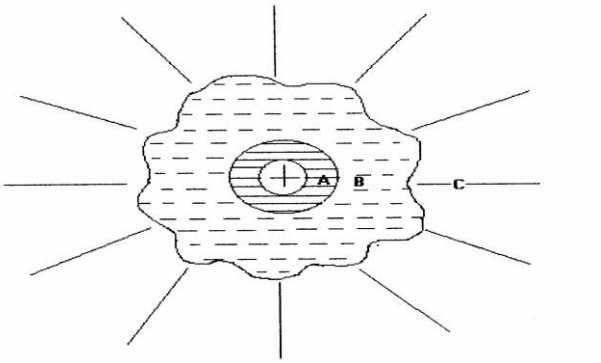


Fig 1.5: Frank and Wen model for the structure modification produce by an ion

The hydrogen bonding in the clusters is postulated [30] 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 portion 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.

1.10 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 [31].

1.11 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 [32]. 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 [33]. The tendency of relativity nonpolar molecules to “stick together” in aqueous solution is denoted as the hydrophobic interaction [34]. 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.

1.12 Amino 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 sodium benzoate are interacting. 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-Sodium benzoate with amino acids on the thermodynamic properties.

1.13 Aim of the present work

Developments in solution theory are still not large enough for the properties of material molecules. Accordingly it provides experimental information of various volumetric and ultrasonic properties which provides useful information for an accurate understanding of the specific interactions between the components and structures of the solution.The experimental method of measuring different macroscopic properties is also effective in providing directional theoretical approaches, as the experimentally determined values of the solution properties may illuminate some significance in the proposed model on the basis of which the theoretical treatment may be based. Volumetric and ultrasonic studies on ternary solutions have attracted a lot of attention and experimental data on several systems are available in various review articles [35-36]. 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.

In addition to the theoretical importance, knowledge of the physicochemical properties of many chemical compounds is essential for many chemical process industries. For example, the processes mentioned in the petroleum, petrochemical and related industries are commonly used to handle mixtures of hydrocarbons, alcohols, aldehydes, ketones, etc. 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 [37]. The studies of amino acids express the interaction of dipolar ions with other functions and components in the biological system [38]. 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 [39]. 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 SB with amino acids at six different temperatures (293.15-313.15K) have been determined. To the best of our knowledge, no data on density, sound velocity, apparent molar volume, partial molar volume, adiabatic compression and isobaric expansion of L-lysine and L-arginine in aqueous sodium benzoate 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-lysine and L-arginine with aqueous sodium benzoate which are focused in this study. In order to understand the issue of solute-solvent interactions in aqueous solution of sodium benzoate-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 L-lysine and L-arginine in aqueous sodium benzoate solution at different temperature,
ii. to understand the effect of sodium benzoate on the structure of L-lysine and L-arginine in solution,
iii. to predict about the structure making or breaking mechanism of L-lysine and L-arginine in aqueous and aqueous sodium benzoate 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,
v. to determine the hydration number of L-lysine and L-arginine in binary and ternary systems,
vi. to enrich the available data on physico-chemical properties of the system.

CHAPTER II

Literature review

A literature review discusses published information in a particular subject area within a period of time. The reports help to keep the professionals to update with what is current in the field. The literature review emphasizes the credibility of the writers in their fields.

Nowadays, volumetric and ultrasonic properties of systems consist of biologically important compounds in aqueous medium provides information about solute-solvent and solute-solute interactions that help us to understand several biochemical processes such as hydration, denaturation, aggregation, etc. It has been found out that solute-solvent solutions have large effects on the structure and the properties of biologically important compounds like proteins, carbohydrates, etc. In this chapter various fields where the solute-solvent interactions find applications and several aspects explored by the researchers has been reviewed in detail.

Palani *et al.,* 2010 performed volumetric studies of glutamine, arginine, and lysine in aqueous DMSO solutions at 303.15K. Using the 42 experimental values, the adiabatic compressibility and hydration number, apparent molar compressibility apparent molar volume, limiting apparent molar compressibility, limiting apparent molar volume and their constants and transfer volume were calculated. The experimental results have been discussed in terms of ion-solvent and solute-co-solute interactions on the basis of co-sphere overlap model [39].

Parvinder *et al.,* 2014 studied structure making and structure breaking capacity of amino acids in aqueous glucose solution is obtained from the sign of dB/dT values and the partial molar volume expansibility has been determined. The results found that amino acids shows structure making ability in aqueous glucose solution [40].

Ashwani *et al.,* 2016 reported apparent molar volume, limiting apparent molar volume, transfer volume, as well as apparent molar compressibility, limiting apparent molar compressibility, transfer compressibility, pair and triple interaction coefficients, partial molar expansibilities of L-arginine (0.025-0.2 $molkg^{-1}$) in aqueous + D-maltose (0-6% mass of maltose in water) were obtained at different temperatures. The results have been discussed in terms of solute–solute and solute–solvent interactions in these systems. Solute-solvent (hydrophilic-ionic group and hydrophilic-hydrophilic group) interactions were found to be dominating over solute-solute (hydrophobic-hydrophilic group) interactions in the solution, which increases with increase in maltose concentration [41].

Mirikar *et al*., 2015 studied adiabatic compressibility (βa), acoustic impedance (Z) and relative association (R_A) of amino acid (L-valine) in aqueous solution of NaCl at 308.15K temperature and at different concentrations of solutes. The variations of these parameters with composition of mixture indicate the nature and extent of interaction between unlike molecules & suggest that the interactions occurring between amino acid and water molecules [42].

Palani *et al.,* 2011 reported adiabatic compressibility, hydration number, apparent molal compressibility, apparent molal volume, apparent molal compressibility, limiting apparent molal volume of 2,3-dihydroquinazolin-4(1H)-ones in 70% DMF-Water at T= 303K were calculated. These parameters were used to study the ion-solvent interaction present in each solution [43].

Thirumaran et al., 2010 reported the ultrasonic velocity (u) and density (ρ) of three amino acids namely L-arginine, L-lysine and L-histidine in aqueous sodium butyrate solution as a function of composition at 303, 308 and 313 K. Using these experimental values, the acoustical parameters such as adiabatic compressibility, apparent molal compressibility, apparent molal volume, limiting apparent molal compressibility, limiting apparent molal volume were calculated for all the systems. The results are interpreted in the light of structure-making or structure-breaking effects of these amino acids in the mixture [44].

Palani *et al.,* 2010 performed volumetric studied of three amino acids viz., asparagine, histidine and lysine in aqueous K_2SO_4 solution (0.5 m) at 303.15K. Using the experimental

values, the adiabatic compressibility, hydration number, apparent molar compressibility, apparent molar volume, limiting apparent molar compressibility, limiting apparent molar volume and their constants transfer volumes were calculated. The results of the parameters have been discussed in terms of ion-ion and ion-solvent interactions [45].

Palani *et al.,* 2010 reported density (ρ), and ultrasonic velocity (u) for L-glutamine, L-asparagine and L-lysine in water and aqueous glycerin (0, 0.5 and 1 mol dm^{-3}) at 303.15K. These measurements have been performed to evaluate some important parameters viz. adiabatic compressibility, molar hydration number, apparent molar compressibility, apparent molar volume, limiting apparent molar compressibility, limiting apparent molar volume and their constants (S_K, S_V), and transfer volumes. The results have been discussed in terms of solute-co-solute and ion-solvent interaction [46].

Zhao *et al.,* 2005 reported partial molar volumes and viscosity B-coefficients of arginine in aqueous glucose, sucrose and L-ascorbic acid solutions at 298.15 K. Partial molar volumes of transfer and viscosity B-coefficients of arginine increase with increasing the mass concentration of sugar or L-ascorbic acid, and the hydration number of arginine decreases owing to the interaction of sugar or L-ascorbic acid and the zwitterionic groups [47].

Daofan Ma. et al, 2015, measured the densities and viscosities of glycine, L-alanine, L-valine, L-threonine, and L-arginine in (0.1 to 0.4) $mol \cdot kg^{-1}$ vitamin B6 aqueous solutions were measured and studied over the entire molality range at (293.15, 303.15, 313.15, and 323.15) K and atmospheric pressure [48].

Md. Golam Azam., 2017 reported the volumetric and sound velocity of L-proline and L-lysine in aqueous nicotinamide solution at different temperatures. Amino acids in presence of water and amino acids with aqueous 0.03 $mol.kg^{-1}$, 0.045 $mol.kg^{-1}$, 0.06 $mol.kg^{-1}$ and 0.09 $mol.kg^{-1}$ nicotinamide solutions were studied through the measurement of density and sound velocity at different temperatures [49].

Md. Tariquzzaman., 2018 reported the volumetric and ultrasonic properties of L-lysine, L-ornithine and glycine in aqueous fructose solution at different temperatures. The interaction of amino acids in water and aqueous fructose solution has been determined by using volumetric and sound velocity method [50]

Musharat Islam., 2018 reported the volumetric and sound velocity studies of L-serine, L-asparagine and L-glutamine in aqueous vitamin B6 solution at different temperatures. Simple volumetric and sound velocity method was used for the analysis of effect of vitamin B6 (pyridoxine) on the structure of amino acids (L-serine, L-asparagine and L-glutamine) [51].

From the above literature review, it is seen that volumetric and ultrasonic properties of L-arginine and L-lysine in aqueous Sodium benzoate solution at different temperatures were not reported previously. The literature survey suggests that volumetric and ultrasonic properties of systems consist of biologically important compounds remain a fruitful field of investigation. Literature survey also clearly shows the importance of the effects of added electrolytes to the molecular interactions thereby changing the volumetric and sound velocity properties.

CHAPTER III

Experimental

This chapter deals with the experimental methods for the investigation of molecular interactions of L-lysine and L-arginine with water and in aqueous solution of Sodium Benzoate.The studied systems are

1. Water+ L-lysine
2. Water + L-arginine
3. Water + L-lysine + 0.05 mol.kg^{-1}SB
4. Water + L-lysine + 0.2 mol.kg^{-1}SB
5. Water + L-lysine + 0.35 mol.kg^{-1}SB
6. Water + L-lysine + 0.5 mol.kg^{-1}SB
7. Water + L-arginine + 0.05 mol.kg^{-1}SB
8. Water + L-arginine + 0.2 mol.kg^{-1}SB
9. Water + L-arginine + 0.35 mol.kg^{-1}SB
10. Water + L-arginine + 0.5 mol.kg^{-1}SB

All experiments have been carried out at five equidistant temperatures as 293.15K, 298.15K, 303.15K, 308.15Kand 313.15K. The details of various information have been described in the following sections.

3.1 Materials

The chemicals used for study were L-lysine, L-arginine, and SB. 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
Sodium benzoate	$NaC_7H_5O_2$	144.1	Extra pure	LOBA Chemical, India
L-lysine	$N_4C_6H_{14}O_2$	182.65	99.0%	LOBA Chemical, India
L-arginine	$C_6H_{15}CIN_2O_2$	174.2	99%	Qualkems 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 5000M model high precision vibrating tube digital density meter and speed of sound measuring devicewith automatic viscosity 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^0C 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 5000M, Austria). The density and sound velocityvalues 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 5000M), the natural vibration period is automatically converted into the density value and display directly on the LC display monitor of the decimeter. The DSA 5000M 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 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.

3.6 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.

3.7 Molarity

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

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

$$\text{or, } C = \frac{n_2}{V} \quad \text{.....(3.1)}$$

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 $molL^{-1}$ [52].

3.8 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 [53]. Mathematically,

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

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

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

$$\text{or, } \mathrm{m} = \frac{a}{M_2} \times \frac{1000}{V_1 \times \rho_0} \qquad \text{.....(3.2)}$$

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}

$$\text{Specific volume, (V)} = \frac{1}{\rho} mLg^{-1} \qquad \text{.....(3.3)}$$

$$\text{and Molar volume, } (V_m) = \frac{M}{\rho} mLmol^{-1} \qquad \text{.....(3.4)}$$

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.

3.9 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 [53, 54]:

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

or, $$\varphi_v = \frac{1}{m\rho\rho_0}(\rho_0 - \rho) + \frac{M_2}{\rho} \quad \text{……..…...……(3.5)}$$

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,

$$m = \frac{1}{\left(\frac{\rho}{C} - \left(\frac{M_2}{1000}\right)\right)} \quad \text{…….. (3.6)}$$

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:

$$C = \frac{1}{M_2} \times \frac{a}{\text{vol. of solution in liter}} \quad \text{……..……..……...…… (3.7)}$$

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 [55].

$$\overline{V_1}^0 = \frac{\text{Molecular masses of solvent}}{\text{Density of solvent (at expt. temp.)}} \quad \text{…….……..……(3.8)}$$

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

$$\overline{V_2} = \varphi_v + \frac{\sqrt{m}}{2}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) = \varphi^0{}_v + \frac{3\sqrt{m}}{2}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) \quad \text{……..……(3.9)}$$

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

$$\text{And}\,\overline{V_1} = V_1^0 - \frac{M_1 m^{3/2}}{2000}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) \qquad \text{……..……(3.10)}$$

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 ($\varphi_v^0 \approx \overline{V}_2^{\,0}$) were determined from the intercept of the plot, at C equal to zero.

3.10 Limiting apparent molar volume of transfer

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

$\Delta_{tr}\varphi_v^0 = \varphi_v^0$ (in aq.SB solution) - φ_v^0 (in water) ……..……..……(3.11)

Where, φ_v^0 is limiting apparent molar volume.

3.11 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:

$\varphi_v^0 = A + B\,(T-T_m) + C\,(T-T_m)^2$……..……..……..……..(3.12)

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:

$E_\varphi^0 = B + 2C\,(T-T_m)$ ……..……(3.13)

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 [56]:

$(\delta E_\varphi^0/\delta T)_p = (\delta^2\varphi_v^0/\delta T^2)_p = 2C$ ……..(3.14)

3.12 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.

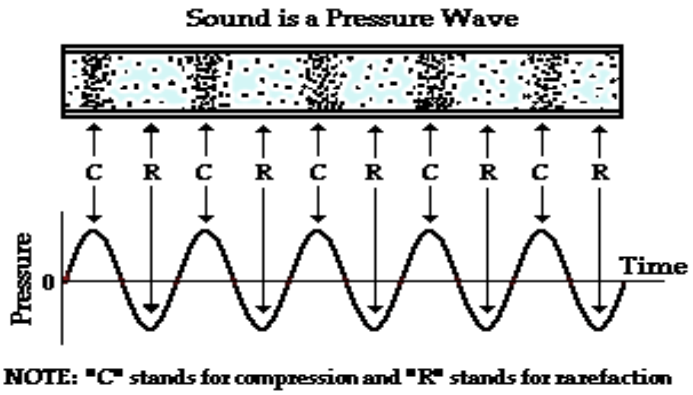


Figure 2.1:Schematic diagram of a longitudinal standing wave; C and R show positions of medium compressions and refractions (high and low densities) respectively.

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 [57] or sound velocity can be derived, which is expressed as,

$$u = \left(\frac{1}{\rho\beta}\right)^{1/2} \quad \text{..... (3.15)}$$

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

$$\beta = k^{-1} = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right) \quad \text{(3.16)}$$

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, $\beta_T$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,

$$\beta_s = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_s \quad \text{(3.17)}$$

Writing β_s instead of β in equation (3.36) gives the Newton-Laplace equation of the form

$$u = \left(\frac{1}{\rho\beta_S}\right)^{½} \quad \text{(3.18)}$$

Various attempts [58-63] have been made to calculate theoretically ultrasonic sound velocity through binary mixtures.

3.13 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,

$$\beta_s = \frac{1}{\rho u^2} \quad \text{(3.19)}$$

Where, ρ is the density of the experimental solution and u is the adiabatic compressibility of the solution.

3.14 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,

$$\varphi_v = \frac{M\beta_s}{\rho} + \left(\frac{\beta_{s,o}\rho - \beta_s\rho}{m\rho\rho_o}\right) \quad \text{(3.20)}$$

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.

3.15 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,

$$Z = u\rho \quad \text{(3.21)}$$

Where, ρ is the density of the experimental solution and u is the adiabatic compressibility of the solution.

3.16 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,

$$n_H = \frac{n_1}{n_2}\left(1 - \frac{\beta_s}{\beta_{s,o}}\right) \quad \text{(3.22)}$$

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.

CHAPTERE IV

Results and Discussion

Amino acids are the chemical units or "building blocks" of the body that make up proteins and proteins play an important role in the biological processes of nearly all living organisms. Sodium benzoate is commonly used as food additives. Our study included the interaction of amino acids (L-lysine and L-arginine) with SB in terms of measuring volumetric and sound velocity. Experimental results and features derived from experimental data are presented in this chapter. The results have been discussed in the light of recent events. The studied systems are:

1. L-arginine + water
2. L-lysine + water
3. L-arginine + water + 0.05 mol.kg^{-1} SB
4. L-arginine + water + 0.20 mol.kg^{-1} SB
5. L-arginine + water + 0.35 mol.kg^{-1} SB
6. L-arginine + water + 0.50 mol.kg^{-1} SB
7. L-lysine + water + 0.05 mol.kg^{-1} SB
8. L-lysine + water + 0.20 mol.kg^{-1} SB
9. L-lysine + water + 0.35 mol.kg^{-1} SB
10. L-lysine + water + 0.50 mol.kg^{-1} SB

The systems mentioned above have been accurately studied at five equivalent temperatures ranging from 293.15K to 313.15K at breaks of 5K by the method of density and sound velocity. 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 ($\Delta_{tr}\varphi_v^0$), limiting apparent molar expansibilities ($\delta\varphi_v^0/\delta T)_p$) and Hepler's constant ($\delta^2\varphi_v^0/\delta T^2)_p$ 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 ($\Delta_{tr}\varphi_k^0$), acoustic impedance (Z), and hydration

number (n_H) have been determined from sound velocity data. The information obtained from these systems is presented in various sections and discussed in the light of the theories described in the previous 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, and 313.15K) with an interval of 5K over the concentration ranging from 0.05 $mol.kg^{-1}$ to 0.50 $mol.kg^{-1}$. The densities of aqueous L-lysine and L-arginine have been shown in tables 4.1-4.2 and figures are graphically shown in 4.1-4.3 at different temperatures as a function of molality of aqueous amino acids. Figures 4.1-4.2 show that the densities of aqueous L-lysine and L-arginine increase with the increase of L-lysine and L-arginine concentration. These are due to the increase in number of particles in given region which leads to shrinkage in volume of solution [64-65]. The densities of the aqueous L-lysine and L-arginine decrease in the order of L-lysine > L-arginine for the same molality of amino acids and at the same temperature. The densities decrease with the increase of temperature in aqueous L-lysine and L-arginine 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-lysine and L-arginine in 0.05 $mol.kg^{-1}$, 0.20 $mol.kg^{-1}$, 0.35 $mol.kg^{-1}$ and 0.50 $mol.kg^{-1}$ aqueous SB solutions are listed in tables and figures are graphically shown in 4.3-4.10. The values of densities of amino acids (L-lysine and L-arginine) in aqueous SB systems has been found to be in the order of,

Amino acids in aqueous 0.50 $mol.kg^{-1}$ SB > Amino acids in aqueous 0.35 $mol.kg^{-1}$ SB > Amino acids in aqueous 0.20 $mol.kg^{-1}$ SB > Amino acids in aqueous 0.05 $mol.kg^{-1}$ SB

It is seen that the density increase with the increasing of SB concentration at a fixed amino acid concentration. The increase of density with concentration of SB can be attributed to solute-solvent interaction and weight of SB in solution. The densities of the L-lysine and L-arginine solutions increase in the order of L-lysine > L-arginine for the same molality of amino acids and SB at the same temperature. 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 [66].

Densities of amino acids in aqueous SB system are higher than that of amino acids in water systems. Increase in density in SB solution may be due to the imperious of structure-making properties after adding SB solution.

The apparent molar volumes (φ_v) of L-lysine and L-arginine in water are calculated from density data. The values of apparent molar volume of aqueous L-lysine and L-arginine at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15) K are given in tables 4.11-4.12 and the variation of φ_v with molality of L-lysine and L-arginine are graphically represented in figures 4.11-4.12. From the figure it is seen 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 positive values of φ_v are indicative of greater solute-solvent interactions [33]. The values of apparent molar volume (φ_v) of aqueous L-lysine and L-arginine solutions increase in the order L-arginine > of L-lysine which due to the increasing of number of carbon in alkyl group present in amino acids L-arginine and L-lysine at all temperatures and concentrations, due to the increase in surface of solute to interact with solvent. The value of φ_v increases with increase in temperature because of thermal agitation, which leads to the bond breaking.

The value of apparent molar volume of L-lysine and L-arginine in aqueous SB solutions (0.05 $mol.kg^{-1}$, 0.20 $mol.kg^{-1}$, 0.35 $mol.kg^{-1}$ and 0.50 $mol.kg^{-1}$) at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15) K are given in tables 4.11-4.20 and figures 4.11-4.30 show the plots of apparent molar volume as a function of molality of L-lysine and L-arginine at different temperatures. Plots of φ_v vs. molality of amino acids show linear relationship in aqueous SB system. For L-lysine and L-arginine in aqueous SB solutions systems, the values of apparent molar volume (φ_v) are also positive and linearly increase with the increase of concentration of L-lysine and L-arginine. It has been also found that apparent molar volumes for L-lysine and L-arginine increase with the increase of SB concentration (0.05 $mol.kg^{-1}$, 0.20 $mol.kg^{-1}$, 0.35 $mol.kg^{-1}$ and 0.50 $mol.kg^{-1}$). At a fixed SB 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. Comparatively the apparent molar volume, φ_v of L-lysine and L-arginine in aqueous SB solution is higher than aqueous L-lysine and L-arginine solution was found. The apparent molar volumes increase with an increase in the number of carbon in alkyl group present in amino acids i.e. from L-lysine and L-arginine at all temperatures and concentrations of SB due to the increase in surface of solute to interact with solvent which is also depend on structure [67].

The value of φ_v increases with increasing temperature. This cause may be: (i) due to the increase in thermal energy at high temperatures, relaxation in bulk of electrostatic water molecules from ion-dipole or dipole-dipole interaction zones results in positive volume change; (ii) The increase in temperature makes the ion-ion interaction relatively strong and gives rise to positive volume changes and (iii) SB-SB or SB-water or water-water interaction decreases with increasing temperature which leads to positive change in volume [68].

The limiting apparent molar volume (φ_v^0) which is also called the standard partial molar volume of L-lysine and L-arginine in aqueous solution at 293.15, 298.15, 303.15, 308.15 and 313.15K are reported in tables 4.21-4.22. 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 [69]. 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 L-lysine and L-arginine. Furthermore, increase in the molar mass and size of the amino acid with also increase the values of φ_v^0, with an, that is, higher values of φ_v^0 are obtained for L-arginine as compared to L-lysine. These trends in limiting apparent molar volumes (φ_v^0) indicate the presence of strong solute-solvent interactions. The release of some solvent molecules from the loose solvation layers of the solutes in solution for all amino acids may be explained by the increase values of φ_v^0 with the increase in temperature.

The values of limiting apparent molar volume (φ_v^0) for L-lysine and L-arginine in ternary solution at the studied temperatures are presented in tables 4.23-4.30. These tables show that values of limiting apparent molar volume (φ_v^0) are positive and increase with an increase in the SB 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 L-lysine from L-arginine. As per co-sphere overlap model [69, 70] 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 co-sphere of two ionic species takes place. By increasing, the molar mass and size of the amino acid with also increase the values of φ_v^0, that is, higher values of φ_v^0 are obtained for L-arginine. 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. The size of primary and secondary solvation layers around zwitterions can also be explained by it. 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 [67]. In simple terms, the electrostriction reduces with increase in temperature and hence φ_v^0 increases.

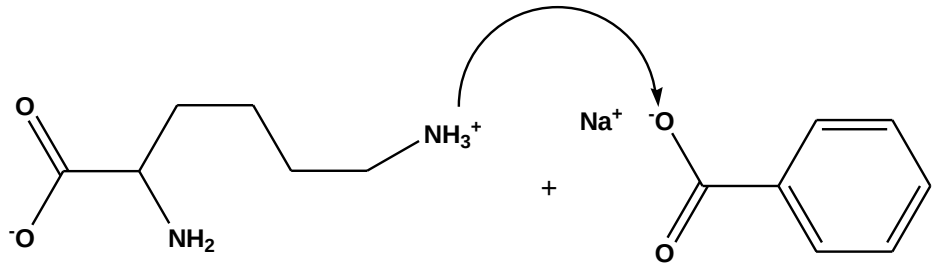
The values of experimental slope (S_V) for aqueous amino acids and amino acids in ternary solution at the experimental temperatures are reported in tables 4.21-4.30. The values of experimental slope (S_V) are positive for all the concentration of amino acids. The non-zero values of S_V indicate the presence of solute-solute interactions in solutions of amino acids. The solute-solute interaction is also influenced by other factors because there is no regular trend in the values of S_V. The smaller values of S_V as compared to φ_v^0 suggest the dominance of solute-solvent interaction over the solute-solute interaction [71].

S_V values are positive and decrease with an increase of temperature in amino acids in the aqueous solution (with some exception) but increase in aqueous SB 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 S_V increase with the increase in composition of aqueous SB solution showing strong solute-solute interactions.

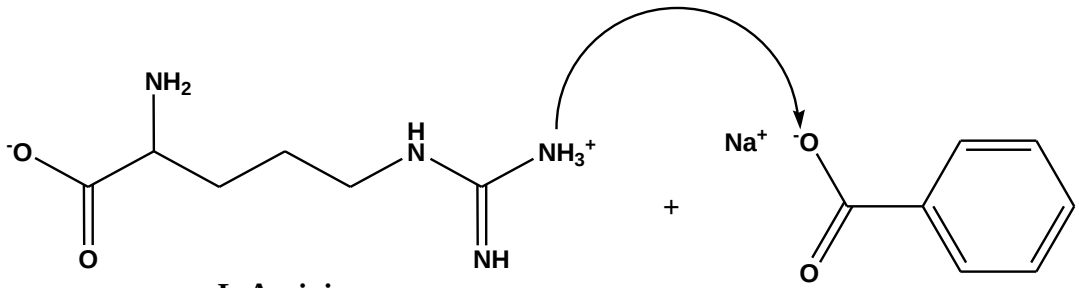
The values of limiting apparent molar volume transfer of amino acids from water to aqueous SB solutions at infinite dilution was calculated by using the equation,

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

The values of limiting apparent molar volume transfer ($\Delta_{tr}\varphi_v^0$) of L-lysine and L-arginine in aqueous SB solutions have been reported in tables 4.23-4.30. The limiting apparent molar volume transfer ($\Delta_{tr}\varphi_v^0$) values of L-lysine and L-arginine in (0.05 mol.kg^{-1}, 0.2 mol.kg^{-1}, 0.35 mol.kg^{-1} and 0.5 mol.kg^{-1}) SB are negative which suggest the dominance of ion-hydrophobic or hydrophobic-hydrophobic group interaction over the ion-hydrophilic and hydrophilic-hydrophilic interactions. But $\Delta_{tr}\varphi_v^0$ values of L-lysine in 0.5 mol.kg^{-1} aqueous SB solution are positive indicating the dominance of ion-hydrophilic and hydrophilic-hydrophilic interactions.

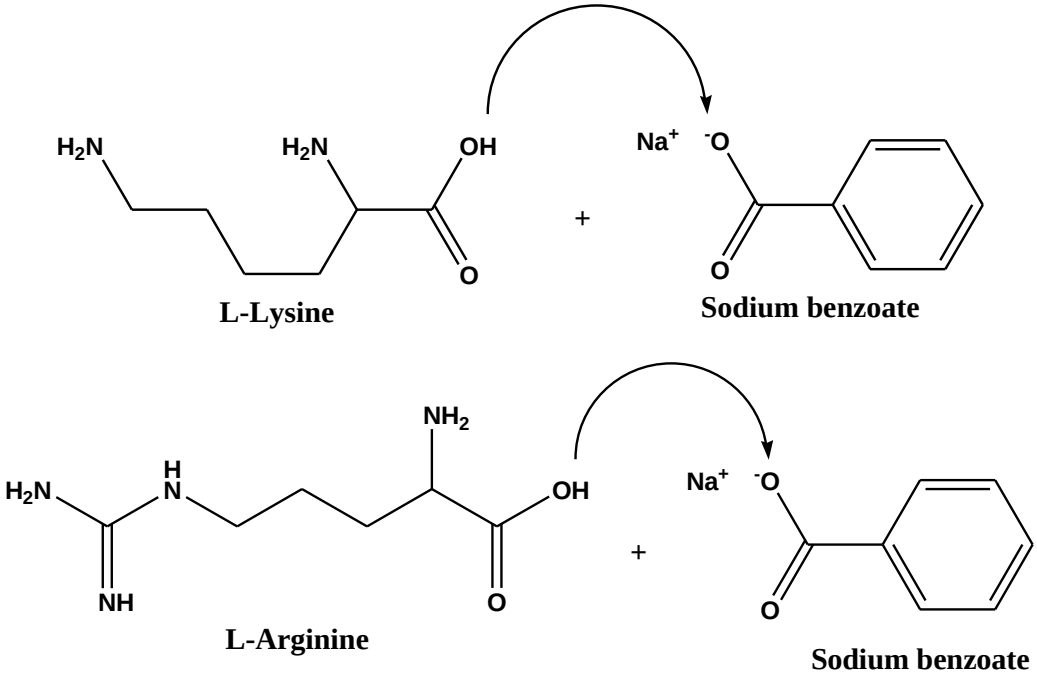


L-Lysine **Sodium benzoate**

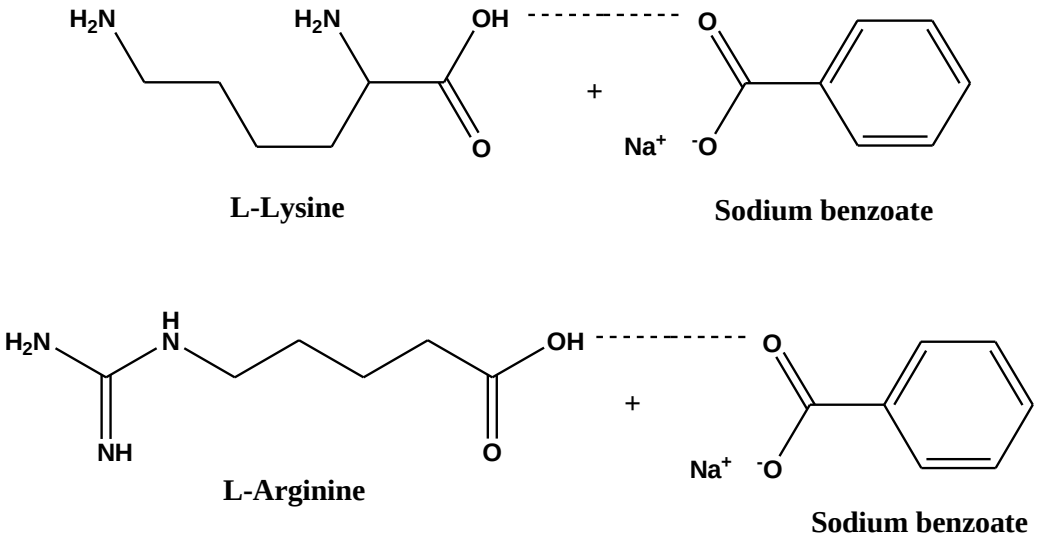


L-Arginine **Sodium benzoate**

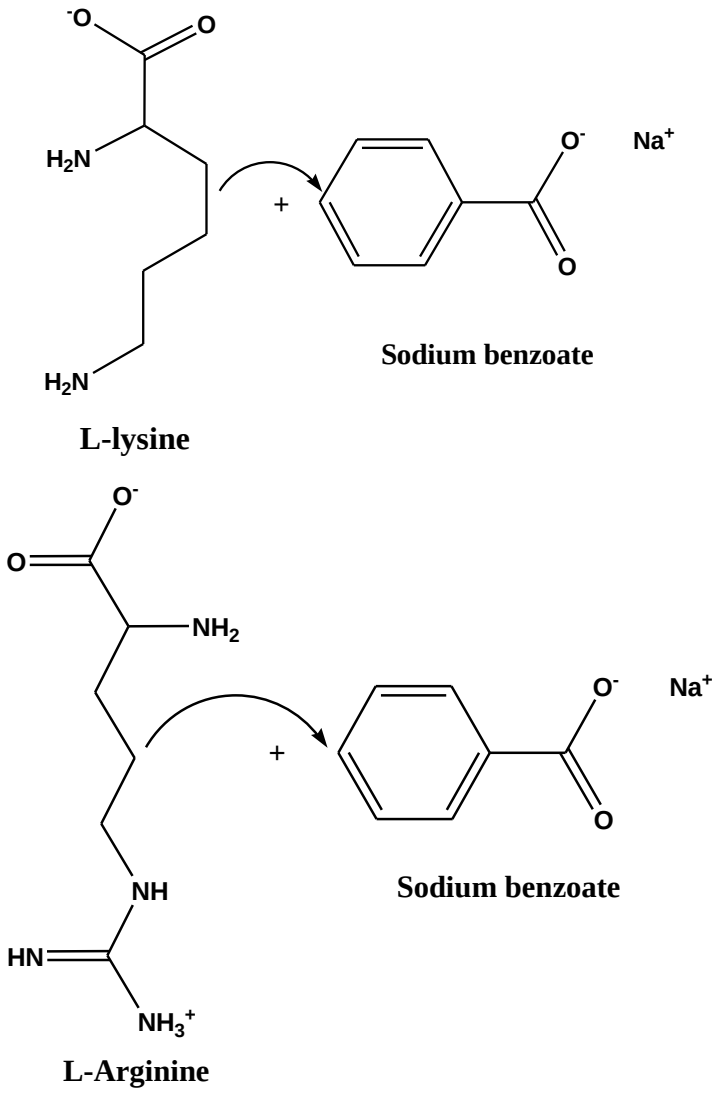
Scheme 1: Ion-ion interaction



Scheme 2: Ion - hydrophilic interaction



Scheme 3: Hydrophilic-hydrophilic interaction



Scheme 4: Hydrophobic- hydrophobic interaction

The values of limiting apparent molar volume expansibilities (E_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of aqueous L-lysine and L-arginine are reported in tables 4.21-4.30. 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 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. The small negative or positive $(\delta E_\varphi^0/\delta T)_p$ values suggest that the studied systems may act as structure making solute.

The values of limiting apparent molar volume expansibilities (E_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-lysine and L-arginine in ternary (aqueous SB) solutions are reported in tables 4.21-4.30. The E_φ^0 values are found to be positive at all temperatures and concentrations of amino

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

The values of Partial molar volume ($\overline{V}_2$) of aqueous amino acids and amino acids in ternary (aqueous SB) solutions are shown in tables 4.31-4.40. Figures 4.21-4.30 show the plots of partial molar volume as a function of concentration of aqueous amino acids and amino acids in aqueous SB solution. The value of partial molar volume ($\overline{V}_2$) increases with the increase of concentration of amino acid.

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 (aqueous SB) systems have been determined at temperatures ranging from (293.15K to 313.15K) with an interval of 5K over the concentration ranging from 0.05 $mol.kg^{-1}$ to 0.50 $mol.kg^{-1}$. The sound velocities of aqueous amino acids and amino acids in aqueous SB solution have been shown in tables 4.41-4.50 at different temperatures. Figures 4.31-4.40 show the plots of sound velocities as a function of molality of aqueous amino acids and amino acids in aqueous SB 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- arginine is higher than L-lysine. This is due to the molecular weight of L-arginine is higher than L-lysine. 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 recognized 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. Clearly, the geometric fitting of elements between hydrogen bonds, strong dipole-dipole interactions, and other structural networks reduces the ability of adiabatic compressibility.

The adiabatic compressibility (β_s) of aqueous L-lysine and L-arginine has been shown in tables 4.51-4.52 at different temperatures. Figures 4.41-4.42 show the plots of adiabatic compressibility as a function of molality of aqueous L-arginine and L-lysine. From the figures it is apparent that the values of β_s decrease with the increase of molar concentration of L-lysine and L-arginine. The value of β_s also decreases with the increases of temperature. The decrease in the β_s values with increasing concentration of L-lysine and L-arginine 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 which reduces the void space in solution.

The values of adiabatic compressibility, β_s of L-lysine and L-arginine in ternary (aqueous SB) solution are shown in tables 4.53-4.60 and figures 4.43-4.50 show the plots of adiabatic compressibility as a function of molality of L-arginine and L-lysine in aqueous solution of SB. From these figures it is apparent that the values of β_s decrease with the increase of concentration of L-lysine and L-arginine in SB 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-arginine and L-lysine in aqueous SB 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 βs may be due to the introduction of amino acids molecule into water and aqueous SB solutions which reduce the void space in solution.

The apparent molar adiabatic compressibility (φ_k) of aqueous L-arginine and L-lysine are calculated from density and sound velocity data. The values of apparent molar adiabatic compressibility (φ_k) of aqueous L-lysine and L-arginine at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15) K are given in tables 4.61-4.70 and the variation of φ_k with molality of L-lysine and L-arginine are graphically represented in figures 4.51-4.60. From the data it is observed that values of φ_k are negative at all temperatures and concentrations of L-lysine and L-arginine. 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. Water molecules around ionic charged groups of amino acids are less compressible than water molecules in the bulk solution because the negative values of φ_k. 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 [84].

The values of apparent molar adiabatic compressibility (φ_k) of amino acids in aqueous SB are higher than the values of amino acids in aqueous 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 (aqueous SB) solution at different temperatures (293.15, 298.15, 303.15, 308.15, 313.15) K are tabulated in tables 4.71-4.80. 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 are prevailing in the mixtures [84].

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 SB and water molecules induce the dehydration of amino acids and therefore at high SB concentrations the water molecules around the amino acids are more compressible than those at lower SB concentrations.

The values of apparent molar adiabatic compressibility of transfer ($\Delta_{tr}\varphi_k^0$) of L-lysine and L-arginine in SB solution at different temperatures are reported in tables 4.73-4.80. $\Delta_{tr}\varphi_k^0$ of L-lysine are positive whereas L-arginine is negative.

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 SB result the increase in the number of monomeric water molecules [86]. Negative values of $\Delta_{tr}\varphi_k^0$ indicate that increase in hydrophobic-hydrophobic group interactions results in disruption of hydration sphere of charged centers of amino acid thereby reducing the positive contribution to $\Delta_{tr}\varphi_k^0$ [87].

The values of acoustic impedance, Z of aqueous L-lysine and L-arginine and aqueous L-lysine and L-arginine in SB solution have been shown in tables 4.81-4.90 at different temperatures. Figures 4.61-4.70 show the plots of acoustic impedance as a function of molality of aqueous L-lysine and L-arginine and aqueous L-lysine and L-arginine in SB. It is evident from the figures 4.61-4.70 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 [88]. The values of acoustic impedance, Z of amino acids in aqueous SB are higher than the values of amino acids in aqueous systems. These higher values of ternary systems than the binary systems show strong solute-solvent interaction in ternary systems than binary systems.

The hydration number (n_H) of L-lysine and L-arginine in water are tabulated in tables 4.91-4.92 and figures are graphically shown in 4.71-4.72. The hydration numbers decrease with the increase of concentration for aqueous L-lysine and L-arginine system. The hydration numbers also decrease with the increase of temperature. 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 [89].

The hydration number (n_H) of L-lysine and L-arginine in aqueous SB (0.05, 0.20, 0.35 and 0.50) mol.kg^{-1} solutions at different temperatures are reported in tables 4.93-4.100. The variation of n_H with molality is graphically shown in figures 4.73-4.80. The hydration numbers decrease with the increase of concentration for L-lysine and L-arginine in aqueous SB systems which is similar with binary systems. The hydration numbers decrease with the increase of temperature. The hydration number of L-lysine is higher than L-arginine in aqueous and aqueous SB solution. The hydration number of amino acid at concentrate SB solution is lower than the dilute solutions. This is due to the decrease of water molecule around the amino acid at higher concentration. 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 SB molecules. This may enhance the interaction between solute and solvent molecules [90].

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

m/mol.kg^{-1}	L-lysine + water				
	Density, ρ/kg.m^{-3}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	998.377	997.225	995.825	994.207	992.386
0.0496	1001.519	1000.339	998.919	997.267	995.421
0.0996	1004.339	1003.135	1001.693	1000.018	998.151
0.1496	1007.089	1005.869	1004.399	1002.695	1000.816
0.1999	1009.799	1008.549	1007.069	1005.342	1003.439
0.2495	1012.403	1011.134	1009.641	1007.877	1005.968
0.2960	1014.792	1013.507	1011.989	1010.206	1008.281
0.3493	1017.463	1016.155	1014.619	1012.822	1010.862
0.3960	1019.758	1018.427	1016.881	1015.048	1013.089
0.4499	1022.322	1020.976	1019.415	1017.571	1015.604
0.4997	1024.645	1023.265	1021.695	1019.833	1017.827

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

m/mol.kg^{-1}	L-arginine + water				
	Density, ρ/kg.m^{-3}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	998.655	997.5	996.102	994.482	992.653
0.0499	1000.726	999.557	998.143	996.513	994.673
0.0999	1002.769	1001.586	1000.157	998.515	996.665
0.1499	1004.78	1003.583	1002.139	1000.483	998.626
0.1997	1006.754	1005.539	1004.081	1002.411	1000.548
0.2499	1008.712	1007.482	1006.009	1004.331	1002.458
0.2996	1010.619	1009.378	1007.888	1006.198	1004.318
0.3501	1012.526	1011.275	1009.769	1008.058	1006.181
0.3996	1014.368	1013.096	1011.579	1009.868	1007.974
0.4499	1016.212	1014.936	1013.397	1011.648	1009.771
0.4996	1018.007	1016.707	1015.17	1013.419	1011.521

Table 4.3: Density (ρ) of L-lysine in aqueous solution of 0.05 $mol.kg^{-1}$ SB as a function of molality at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.05 $mol.kg^{-1}$ SB				
	Density, $\rho/kg.m^{-3}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1001.335	1000.144	998.71	997.063	995.213
0.0499	1004.341	1003.139	1001.698	1000.046	998.195
0.1005	1007.291	1006.076	1004.631	1002.978	1001.121
0.1501	1010.091	1008.865	1007.411	1005.756	1003.896
0.1996	1012.793	1011.555	1010.099	1008.439	1006.577
0.2499	1015.448	1014.198	1012.731	1011.078	1009.214
0.3002	1018.009	1016.756	1015.278	1013.621	1011.758
0.3498	1020.459	1019.175	1017.707	1016.044	1014.184
0.4005	1022.862	1021.573	1020.106	1018.441	1016.578
0.4503	1025.144	1023.835	1022.363	1020.702	1018.839
0.4997	1027.301	1026.011	1024.527	1022.851	1021.005

Table 4.4: Density (ρ) of L-lysine in aqueous solution of 0.20 $mol.kg^{-1}$ SB as a function of molality at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.20 $mol.kg^{-1}$ SB				
	Density, $\rho/kg.m^{-3}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1009.739	1008.43	1006.897	1005.149	1003.148
0.0498	1013.071	1011.674	1010.051	1008.266	1006.217
0.1004	1016.125	1014.646	1012.949	1011.123	1009.029
0.1501	1018.919	1017.339	1015.588	1013.735	1011.601
0.1996	1021.529	1019.846	1018.001	1016.129	1013.948
0.2497	1023.955	1022.186	1020.273	1018.341	1016.141
0.3002	1026.179	1024.353	1022.367	1020.399	1018.162
0.3497	1028.143	1026.216	1024.193	1022.192	1019.961
0.4003	1030.004	1028.039	1025.898	1023.887	1021.608
0.4504	1031.576	1029.552	1027.421	1025.328	1023.007
0.4998	1033.079	1031.006	1028.694	1026.609	1024.309

Table 4.5: Density (ρ) of L-lysine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.35 mol.kg^{-1} SB				
	Density, ρ/kg.m^{-3}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1017.87	1016.445	1014.802	1012.871	1010.679
0.0499	1020.415	1018.989	1017.348	1015.421	1013.232
0.0996	1022.910	1021.483	1019.844	1017.921	1015.734
0.1497	1025.383	1023.955	1022.318	1020.399	1018.217
0.1999	1027.819	1026.391	1024.756	1022.842	1020.661
0.2499	1030.209	1028.781	1027.147	1025.236	1023.061
0.2998	1032.551	1031.121	1029.491	1027.585	1025.413
0.3499	1034.868	1033.437	1031.807	1029.907	1027.737
0.3994	1037.116	1035.690	1034.058	1032.164	1029.998
0.4496	1039.361	1037.936	1036.307	1034.418	1032.258
0.4999	1041.575	1040.143	1038.529	1036.636	1034.478

Table 4.6: Density (ρ) of L-lysine in aqueous solution of 0.50 mol.kg^{-1} SB as a function of molality at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.5 mol.kg^{-1} SB				
	Density, ρ/kg.m^{-3}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1025.361	1023.906	1022.019	1020.003	1017.653
0.0498	1028.154	1026.629	1024.684	1022.618	1020.225
0.0997	1030.851	1029.257	1027.249	1025.146	1022.709
0.1499	1033.461	1031.812	1029.725	1027.587	1025.105
0.1997	1035.955	1034.233	1032.105	1029.907	1027.405
0.2497	1038.367	1036.575	1034.388	1032.184	1029.617
0.2998	1040.663	1038.811	1036.574	1034.314	1031.709
0.3497	1042.863	1040.948	1038.656	1036.409	1033.756
0.3995	1044.959	1042.997	1040.663	1038.361	1035.708
0.4497	1046.989	1044.967	1042.576	1040.275	1037.549
0.4999	1048.927	1046.856	1044.402	1042.039	1039.451

Table 4.7: Density (ρ) of L-arginine in aqueous solution of 0.05 $mol.kg^{-1}$ SB as a function of molality at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.35 $mol.kg^{-1}$ SB				
	Density, $\rho/kg.m^{-3}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1017.87	1016.445	1014.802	1012.871	1010.679
0.0499	1020.415	1018.989	1017.348	1015.421	1013.232
0.0996	1022.910	1021.483	1019.844	1017.921	1015.734
0.1497	1025.383	1023.955	1022.318	1020.399	1018.217
0.1999	1027.819	1026.391	1024.756	1022.842	1020.661
0.2499	1030.209	1028.781	1027.147	1025.236	1023.061
0.2998	1032.551	1031.121	1029.491	1027.585	1025.413
0.3499	1034.868	1033.437	1031.807	1029.907	1027.737
0.3994	1037.116	1035.690	1034.058	1032.164	1029.998
0.4496	1039.361	1037.936	1036.307	1034.418	1032.258
0.4999	1041.575	1040.143	1038.529	1036.636	1034.478

Table 4.8: Density (ρ) of L-arginine in aqueous solution of 0.20 $mol.kg^{-1}$ SB as a function of molality at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.35 $mol.kg^{-1}$ SB				
	Density, $\rho/kg.m^{-3}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1009.869	1008.543	1006.997	1005.249	1003.248
0.0497	1012.531	1011.18	1009.606	1007.835	1005.808
0.0998	1015.163	1013.791	1012.187	1010.386	1008.332
0.1497	1017.734	1016.345	1014.699	1012.876	1010.801
0.1998	1020.278	1018.86	1017.175	1015.324	1013.218
0.2501	1022.765	1021.326	1019.617	1017.748	1015.595
0.2997	1025.188	1023.709	1021.982	1020.062	1017.902
0.3499	1027.593	1026.086	1024.291	1022.382	1020.161
0.3998	1029.923	1028.378	1026.589	1024.608	1022.357
0.4498	1032.231	1030.657	1028.819	1026.801	1024.526
0.4998	1034.479	1032.906	1031.045	1028.935	1026.632

Table 4.9: Density (ρ) of L-arginine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.35 mol.kg^{-1} SB				
	Density, ρ/kg.m^{-3}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1017.87	1016.445	1014.802	1012.871	1010.679
0.0499	1020.345	1018.900	1017.226	1015.271	1013.046
0.0997	1022.702	1021.235	1019.529	1017.552	1015.298
0.1496	1024.980	1023.486	1021.735	1019.732	1017.465
0.1998	1027.139	1025.615	1023.839	1021.827	1019.539
0.2497	1029.197	1027.652	1025.853	1023.808	1021.518
0.2999	1031.164	1029.611	1027.755	1025.742	1023.373
0.3497	1032.997	1031.428	1029.566	1027.484	1025.126
0.3996	1034.803	1033.164	1031.292	1029.142	1026.813
0.4498	1036.474	1034.819	1032.903	1030.741	1028.371
0.4999	1037.998	1036.319	1034.363	1032.252	1029.882

Table 4.10: Density (ρ) of L-arginine in aqueous solution of 0.50 mol.kg^{-1} SB as a function of molality at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.35 mol.kg^{-1} SB				
	Density, ρ/kg.m^{-3}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1031.601	1030.154	1028.434	1026.583	1024.557
0.0498	1028.169	1026.606	1024.591	1022.477	1020.032
0.0997	1030.763	1029.107	1026.956	1024.728	1022.207
0.1499	1033.141	1031.378	1029.088	1026.754	1024.138
0.1997	1035.288	1033.357	1031.009	1028.555	1025.894
0.2497	1037.175	1035.181	1032.664	1030.205	1027.444
0.2998	1038.899	1036.954	1034.322	1031.629	1028.886
0.3497	1040.416	1038.131	1035.510	1032.808	1030.052
0.3995	1041.695	1039.406	1036.432	1033.766	1030.706
0.4497	1042.598	1040.149	1037.301	1034.659	1031.560
0.4999	1043.488	1041.011	1038.081	1035.232	1032.158

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

m/mol.kg^{-1}	L-lysine + water				
	$\varphi_v \times 10^6$/m^3.mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0496	124.64	125.23	125.77	126.54	127.01
0.0996	124.96	125.54	126.08	126.76	127.28
0.1496	125.31	125.83	126.42	127.10	127.58
0.1999	125.60	126.16	126.68	127.34	127.85
0.2495	125.91	126.46	126.95	127.66	128.12
0.2960	126.19	126.73	127.24	127.93	128.40
0.3493	126.52	127.06	127.57	128.21	128.74
0.3960	126.78	127.33	127.81	128.49	128.97
0.4499	127.14	127.66	128.14	128.78	129.24
0.4997	127.43	127.98	128.45	129.08	129.59

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

m/mol.kg^{-1}	L-arginine+ water				
	$\varphi_v \times 10^6$/m^3.mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	132.54	132.93	133.39	133.74	134.13
0.0999	132.60	132.99	133.43	133.80	134.19
0.1499	132.65	133.04	133.48	133.88	134.24
0.1997	132.69	133.11	133.54	133.95	134.30
0.2499	132.75	133.16	133.60	133.99	134.34
0.2996	132.80	133.21	133.65	134.05	134.40
0.3501	132.86	133.25	133.70	134.13	134.44
0.3996	132.92	133.33	133.77	134.16	134.50
0.4499	132.97	133.36	133.81	134.27	134.56
0.4996	133.02	133.43	133.85	134.28	134.60

Table 4.13: Apparent molar volume (φ_v) of L-lysine in aqueous solution of 0.05 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.05 mol.kg^{-1} SB					
	$\varphi_v \times 10^6$/m^3.mol^{-1}					
	293.15K	298.15K	303.15K	308.15K	313.15K	318.15K
0.0499	121.96	122.25	122.48	122.69	122.82	62.57
0.1005	122.57	122.89	123.09	123.25	123.44	62.61
0.1501	123.15	123.46	123.69	123.85	124.04	62.68
0.1996	123.74	124.06	124.26	124.44	124.62	62.76
0.2499	124.33	124.65	124.88	125.02	125.20	62.83
0.3002	124.93	125.22	125.47	125.62	125.79	62.92
0.3498	125.48	125.84	126.04	126.20	126.36	63.00
0.4005	126.09	126.43	126.61	126.78	126.94	63.04
0.4503	126.66	127.02	127.21	127.36	127.53	63.08
0.4997	127.28	127.57	127.78	127.97	128.10	63.16

Table 4.14: Apparent molar volume (φ_v) of L-lysine in aqueous solution of 0.2 mol. kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.20 mol.kg^{-1} SB				
	$\varphi_v \times 10^6$/m^3.mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	123.09	123.87	125.11	125.77	126.47
0.1004	124.73	125.48	126.75	127.35	128.12
0.1501	126.21	126.99	128.20	128.90	129.74
0.1996	127.85	128.54	129.75	130.41	131.33
0.2497	129.42	130.10	131.30	132.02	132.75
0.3002	131.04	131.69	132.96	133.48	134.49
0.3497	132.51	133.20	134.42	135.15	136.06
0.4003	134.09	135.01	136.16	136.74	137.64
0.4504	135.64	136.57	137.59	138.55	139.25
0.4998	137.23	138.05	139.14	140.03	140.64

Table 4.15: Apparent molar volume (φ_v) of L-lysine in aqueous solution of 0.35 mol. kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.35 mol.kg^{-1} SB				
	$\varphi_v \times 10^6/m^3.mol^{-1}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	124.06	124.48	125.03	125.35	125.76
0.0996	124.48	124.91	125.47	125.72	126.22
0.1497	124.96	125.47	125.87	126.19	126.68
0.1999	125.43	125.84	126.26	126.61	127.16
0.2499	125.96	126.35	126.79	127.09	127.66
0.2998	126.38	126.69	127.20	127.56	128.06
0.3499	126.75	127.15	127.58	128.09	128.46
0.3994	127.30	127.63	128.00	128.49	128.92
0.4496	127.66	128.06	128.53	128.90	129.33
0.4999	128.20	128.36	128.96	129.30	129.81

Table 4.16: Apparent molar volume (φ_v) of L-lysine in aqueous solution of 0.5 mol. kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.50 mol.kg^{-1} SB				
	$\varphi_v \times 10^6/m^3.mol^{-1}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	124.45	125.90	127.15	128.27	129.28
0.0997	125.09	126.53	127.84	128.84	129.87
0.1499	125.74	127.10	128.53	129.48	130.52
0.1997	126.37	127.77	129.09	130.14	131.07
0.2497	126.98	128.40	129.72	130.62	131.67
0.2998	127.68	129.08	130.38	131.34	132.38
0.3497	128.34	129.74	131.03	131.85	132.91
0.3995	129.01	130.37	131.63	132.52	133.47
0.4497	129.65	131.02	132.29	133.09	134.14
0.4999	130.30	131.64	132.94	133.81	134.50

Table 4.17: Apparent molar volume (φ_v) of L-arginine in aqueous solution of 0.05 mol. kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.05 mol.kg^{-1} SB				
	$\varphi_v \times 10^6/m^3.mol^{-1}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0497	124.06	124.53	125.08	125.61	126.02
0.1001	124.28	124.73	125.33	125.78	126.21
0.1499	124.50	124.92	125.55	126.01	126.43
0.1998	124.72	125.14	125.74	126.22	126.63
0.2499	124.97	125.40	125.98	126.45	126.84
0.3002	125.20	125.60	126.20	126.67	127.05
0.3498	125.43	125.86	126.40	126.87	127.27
0.3996	125.65	126.09	126.59	127.03	127.43
0.4497	125.86	126.31	126.83	127.26	127.62
0.4999	126.08	126.55	127.00	127.47	127.85

Table 4.18: Apparent molar volume (φ_v) of L-arginine in aqueous solution of 0.20 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.20 mol.kg^{-1} SB				
	$\varphi_v \times 10^6/m^3.mol^{-1}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0497	119.66	120.25	120.91	121.49	122.15
0.0998	119.85	120.40	121.08	121.73	122.40
0.1497	120.05	120.55	121.32	121.95	122.59
0.1998	120.18	120.72	121.53	122.17	122.84
0.2501	120.40	120.94	121.70	122.31	123.07
0.2997	120.55	121.15	121.87	122.57	123.26
0.3499	120.71	121.32	122.15	122.74	123.53
0.3998	120.91	121.56	122.28	123.00	123.79
0.4498	121.07	121.72	122.49	123.23	124.01
0.4998	121.26	121.86	122.61	123.48	124.26

Table 4.19: Apparent molar volume (φ_v) of L-arginine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.35 mol.kg^{-1} SB				
	$\varphi_v \times 10^6$/m^3.mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	122.97	123.46	124.19	124.81	125.63
0.0997	123.78	124.29	125.04	125.64	126.43
0.1496	124.40	124.96	125.80	126.43	127.10
0.1998	125.22	125.82	126.61	127.17	127.83
0.2497	125.96	126.55	127.30	127.91	128.49
0.2999	126.70	127.24	128.08	128.52	129.30
0.3497	127.50	128.02	128.79	129.39	130.06
0.3996	128.11	128.77	129.48	130.20	130.75
0.4498	128.87	129.50	130.26	130.95	131.55
0.4999	129.71	130.35	131.13	131.68	132.24

Table 4.20: Apparent molar volume (φ_v) of L-arginine in aqueous solution of 0.50 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.50 mol.kg^{-1} SB				
	$\varphi_v \times 10^6$/m^3.mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	124.16	126.34	128.95	131.00	133.04
0.0997	125.93	127.98	130.68	132.90	134.77
0.1499	127.80	129.89	132.65	134.89	136.84
0.1997	129.60	132.03	134.43	136.76	138.51
0.2497	131.61	133.84	136.48	138.41	140.27
0.2998	133.42	135.15	137.77	140.20	141.74
0.3497	135.20	137.67	139.93	142.09	143.50
0.3997	137.08	139.29	142.19	144.03	146.07
0.4498	139.34	141.69	144.03	145.66	147.61
0.4996	141.13	143.33	145.65	147.57	149.32

Table 4.21: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume expansibilities (E_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of Aqueous L-lysine system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0 \times 10^6$ ($m^3.mol^{-1}$)	$S_V \times 10^6$ ($m^3.mol^{-2}.kg$)	$E_\varphi^0 \times 10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p \times 10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	124.36	6.16	17.13	-0.45
298.15K	124.93	6.09	14.88	
303.15K	125.50	5.89	12.63	
308.15K	126.23	5.70	10.38	
313.15K	126.72	5.69	8.13	

Table 4.22: Limiting apparent molar volume (φ_v^0), experimental slope (S_V), limiting apparent molar volume expansibilities (E_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of aqueous L-arginine system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0 \times 10^6$ ($m^3.mol^{-1}$)	$S_V \times 10^6$ ($m^3.mol^{-2}.kg$)	$E_\varphi^0 \times 10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E^0\varphi/\delta T)_p \times 10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	132.49	1.06	8.44	-0.04
298.15K	132.88	1.09	8.22	
303.15K	133.33	1.08	8.00	
308.15K	133.69	1.23	7.78	
313.15K	134.09	1.04	7.56	

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_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-lysine in aqueous solution of 0.05 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E_\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p\times10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	121.38	11.76	-2.98	6.06	-0.17
298.15K	121.69	11.82	-3.24	5.21	
303.15K	121.92	11.77	-3.58	4.36	
308.15K	122.09	11.73	-4.14	3.51	
313.15K	122.27	11.68	-4.45	2.66	

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_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-lysine in aqueous solution of 0.20 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E_\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p\times10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	121.56	31.34	-2.80	19.79	-0.25
298.15K	122.25	31.62	-2.67	18.54	
303.15K	123.55	31.23	-1.95	17.29	
308.15K	124.12	31.71	-2.11	16.04	
313.15K	124.95	31.62	-1.76	14.79	

Table 4.25: 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_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-lysine in aqueous solution of 0.35 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E_\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p\times10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	123.60	9.17	-0.76	9.75	-0.12
298.15K	124.09	8.74	-0.83	9.16	
303.15K	124.57	8.74	-0.92	8.57	
308.15K	124.86	8.98	-1.37	7.98	
313.15K	125.35	8.93	-1.36	7.39	

Table 4.26: 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_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-lysine in aqueous solution of 0.50 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E_\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p\times10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	123.78	13.04	-0.58	30.12	-0.55
298.15K	125.22	12.87	0.29	27.37	
303.15K	126.55	12.87	1.06	24.62	
308.15K	127.64	12.21	1.41	21.87	
313.15K	128.73	11.85	2.01	19.12	

Table 4.27: 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_φ^0) and $(\delta E^0\varphi/\delta T)_p$ of L-arginine in aqueous solution of 0.05 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E_\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p\times10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	123.83	4.53	-8.66	11.21	-0.10
298.15K	124.26	4.54	-8.62	10.72	
303.15K	124.90	4.54	-8.43	10.23	
308.15K	125.40	4.15	-8.29	9.74	
313.15K	125.82	4.06	-8.27	9.25	

Table 4.28: 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_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-arginine in aqueous solution of 0.20 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E_\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p\times10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	119.50	3.51	-12.99	11.82	0.03
298.15K	120.02	3.73	-12.86	11.98	
303.15K	120.73	3.73	-12.60	12.14	
308.15K	121.28	4.33	-12.41	12.30	
313.15K	121.91	4.66	-12.18	12.46	

Table 4.29: 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_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-arginine in aqueous solution of 0.35 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E_\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p\times10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	122.24	14.84	-10.24	10.95	0.24
298.15K	122.74	15.12	-10.14	12.15	
303.15K	123.51	15.12	-9.81	13.35	
308.15K	124.10	15.17	-9.59	14.55	
313.15K	124.90	14.68	-9.18	15.75	

Table 4.30: 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_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-arginine in aqueous solution of 0.50 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$S_V\times10^6$ ($m^3.mol^{-2}.kg$)	$\Delta_{tr}\varphi_v^0\times10^6$ ($m^3.mol^{-1}$)	$E_\varphi^0\times10^8$ ($m^3.mol^{-1}.K^{-1}$)	$(\delta E_\varphi^0/\delta T)_p\times10^8$ ($m^3.mol^{-1}.K^{-2}$)
293.15K	113.93	38.04	-18.56	50.56	-0.46
298.15K	116.02	38.34	-16.86	48.28	
303.15K	118.73	38.34	-14.60	46.00	
308.15K	121.03	36.82	-12.66	43.72	
313.15K	122.93	36.46	-11.16	41.44	

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

m/mol.kg^{-1}	L-lysine + water				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0496	125.29	125.87	126.39	127.15	127.61
0.0996	125.88	126.45	126.96	127.63	128.12
0.1496	126.44	126.94	127.49	128.18	128.62
0.1999	126.90	127.45	127.92	128.58	129.05
0.2495	127.37	127.90	128.34	129.05	129.47
0.2960	127.78	128.29	128.76	129.44	129.86
0.3493	128.25	128.76	129.21	129.85	130.32
0.3960	128.62	129.13	129.57	130.24	130.66
0.4499	129.09	129.59	130.01	130.65	131.04
0.4997	129.49	130.01	130.41	131.04	131.49

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

m/mol.kg^{-1}	L-arginine+ water				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	133.00	133.36	133.82	134.23	134.59
0.0999	133.24	133.59	134.05	134.50	134.84
0.1499	133.44	133.78	134.24	134.73	135.04
0.1997	133.61	133.96	134.42	134.94	135.22
0.2499	133.77	134.11	134.57	135.09	135.37
0.2996	133.92	134.25	134.72	135.25	135.52
0.3501	134.07	134.38	134.86	135.43	135.66
0.3996	134.21	134.53	135.00	135.55	135.81
0.4499	134.34	134.64	135.13	135.75	135.94
0.4996	134.46	134.78	135.23	135.84	136.06

Table 4.33: Partial molar volume ($\bar{V}_2$) of aqueous solution of 0.05 mol.kg^{-1} SB with L-lysine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.05 mol.kg^{-1} SB				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	123.20	123.50	123.73	123.93	124.06
0.1005	124.33	124.66	124.85	125.01	125.20
0.1501	125.31	125.63	125.85	126.00	126.18
0.1996	126.22	126.55	126.75	126.91	127.09
0.2499	127.11	127.45	127.66	127.79	127.96
0.3002	127.98	128.29	128.52	128.66	128.82
0.3498	128.77	129.15	129.33	129.48	129.63
0.4005	129.61	129.96	130.14	130.29	130.44
0.4503	130.39	130.77	130.94	131.08	131.24
0.4997	131.21	131.53	131.72	131.89	132.00

Table 4.34: Partial molar volume ($\bar{V}_2$) of aqueous solution of 0.20 mol.kg^{-1} SB with L-lysine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.20 mol.kg^{-1} SB				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0496	117.89	119.33	120.96	121.81	122.91
0.0996	119.66	121.19	122.79	123.69	124.77
0.1496	121.43	123.12	124.61	125.44	126.50
0.1999	123.06	124.85	126.48	127.24	128.34
0.2495	124.81	126.59	128.20	129.10	130.10
0.2960	126.65	128.32	129.95	130.85	131.86
0.3493	128.49	130.23	131.76	132.66	133.56
0.3960	130.22	131.84	133.52	134.36	135.31
0.4499	132.12	133.70	135.20	136.17	137.15
0.4997	133.69	135.21	136.97	137.86	138.73

Table 4.35: Partial molar volume ($\bar{V}_2$) of aqueous solution of 0.35 mol.kg^{-1} SB with L-lysine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.35 mol.kg^{-1} SB				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	130.32	130.42	130.52	130.61	130.74
0.0996	130.58	130.66	130.77	130.86	131.02
0.1497	130.81	130.88	130.99	131.08	131.23
0.1999	131.02	131.07	131.19	131.28	131.44
0.2499	131.20	131.24	131.37	131.46	131.62
0.2998	131.38	131.42	131.54	131.64	131.80
0.3499	131.55	131.58	131.71	131.80	131.97
0.3994	131.72	131.73	131.87	131.96	132.13
0.4496	131.88	131.88	132.02	132.11	132.28
0.4999	132.03	132.04	132.16	132.27	132.45

Table 4.36: Partial molar volume ($\bar{V}_2$) of aqueous solution of 0.50 mol.kg^{-1} SB with L-lysine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.50 mol.kg^{-1} SB				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	124.89	126.30	127.57	128.70	129.73
0.0997	125.71	127.10	128.43	129.44	130.50
0.1499	126.51	127.80	129.25	130.22	131.30
0.1997	127.25	128.58	129.92	130.99	131.97
0.2497	127.97	129.31	130.65	131.58	132.67
0.2998	128.76	130.08	131.40	132.39	133.48
0.3497	129.51	130.81	132.14	132.99	134.10
0.3995	130.26	131.52	132.82	133.72	134.74
0.4497	130.98	132.23	133.54	134.38	135.49
0.4999	131.70	132.92	134.26	135.16	135.92

Table 4.37: Partial molar volume ($\bar{V}_2$) of aqueous solution of 0.05 mol.kg^{-1} SB with L-arginine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.05 mol.kg^{-1} SB				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0497	124.50	124.93	125.50	126.04	126.47
0.1001	124.90	125.30	125.92	126.39	126.84
0.1499	125.26	125.63	126.28	126.75	127.21
0.1998	125.60	125.95	126.57	127.08	127.52
0.2499	125.95	126.30	126.91	127.41	127.85
0.3002	126.28	126.60	127.22	127.72	128.15
0.3498	126.59	126.93	127.50	128.00	128.46
0.3996	126.90	127.24	127.78	128.24	128.70
0.4497	127.18	127.52	128.08	128.54	128.97
0.4999	127.48	127.83	128.32	128.82	129.27

Table 4.38: Partial molar volume ($\bar{V}_2$) of aqueous solution of 0.20 mol.kg^{-1} SB with L-arginine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.20 mol.kg^{-1} SB				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0497	120.10	120.65	121.32	121.91	122.60
0.0998	120.48	120.97	121.67	122.34	123.04
0.1497	120.81	121.25	122.05	122.69	123.36
0.1998	121.06	121.53	122.36	123.02	123.74
0.2501	121.39	121.85	122.64	123.27	124.08
0.2997	121.63	122.14	122.89	123.62	124.36
0.3499	121.88	122.39	123.26	123.87	124.72
0.3998	122.16	122.70	123.47	124.21	125.06
0.4498	122.39	122.94	123.74	124.51	125.35
0.4998	122.66	123.14	123.93	124.83	125.68

Table 4.39: Partial molar volume ($\bar{V}_2$) of aqueous solution of 0.35 mol.kg^{-1} SB with L-arginine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.35 mol.kg^{-1} SB				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	123.41	123.87	124.61	125.24	126.08
0.0997	124.40	124.87	125.63	126.24	127.06
0.1496	125.16	125.66	126.52	127.17	127.88
0.1998	126.11	126.63	127.45	128.02	128.72
0.2497	126.94	127.45	128.23	128.87	129.49
0.2999	127.78	128.23	129.11	129.57	130.40
0.3497	128.66	129.10	129.89	130.52	131.24
0.3996	129.36	129.91	130.66	131.41	132.02
0.4498	130.19	130.72	131.51	132.23	132.90
0.4999	131.11	131.63	132.46	133.03	133.66

Table 4.40: Partial molar volume ($\bar{V}_2$) of aqueous solution of 0.50 mol.kg^{-1} SB with L-arginine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.50 mol.kg^{-1} SB				
	$\bar{V}_2\times10^6$/m^3·mol^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	123.41	123.87	124.61	125.24	126.08
0.0997	124.40	124.87	125.63	126.24	127.06
0.1496	125.16	125.66	126.52	127.17	127.88
0.1998	126.11	126.63	127.45	128.02	128.72
0.2497	126.94	127.45	128.23	128.87	129.49
0.2999	127.78	128.23	129.11	129.57	130.40
0.3497	128.66	129.10	129.89	130.52	131.24
0.3996	129.36	129.91	130.66	131.41	132.02
0.4498	130.19	130.72	131.51	132.23	132.90
0.4999	131.11	131.63	132.46	133.03	133.66

Table 4.41: Sound velocity (u) of aqueous L-lysine as a function of molality at different temperature

m/mol.kg^{-1}	L-lysine + water				
	Sound velocity, u/m.s^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1482.68	1496.51	1508.77	1519.4	1528.46
0.0496	1490.43	1504.18	1516.32	1526.82	1535.92
0.0996	1496.65	1510.25	1522.31	1532.63	1541.62
0.1496	1503.37	1516.81	1528.74	1538.94	1547.72
0.1999	1510.04	1523.37	1535.11	1545.12	1553.76
0.2495	1516.59	1529.65	1541.32	1551.18	1559.62
0.2960	1522.59	1535.47	1547.12	1556.72	1564.98
0.3493	1529.43	1542.08	1553.59	1562.98	1571.03
0.3960	1535.3	1547.79	1558.98	1568.34	1576.22
0.4499	1541.93	1554.21	1565.38	1574.58	1581.91
0.4997	1547.98	1559.98	1571.18	1579.91	1587.43

Table 4.42: Sound velocity (u) of aqueous L-arginine as a function of molality at different temperature

m/mol.kg^{-1}	L-arginine + water				
	Sound velocity, u/m.s^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1483.14	1497.01	1509.28	1519.92	1529.2
0.0499	1487.7	1501.41	1513.51	1523.95	1532.94
0.0999	1492.24	1505.73	1517.74	1527.97	1536.65
0.1499	1496.72	1510.04	1521.84	1531.89	1540.39
0.1997	1501.14	1514.36	1525.99	1535.82	1544.04
0.2499	1505.51	1518.46	1530.24	1539.79	1547.73
0.2996	1509.71	1522.62	1533.99	1543.48	1551.43
0.3501	1514.28	1526.59	1538.36	1547.21	1555.04
0.3996	1518.39	1530.58	1542.27	1550.85	1558.74
0.4499	1522.82	1534.43	1546.12	1554.69	1562.38
0.4996	1526.72	1538.28	1549.81	1558.59	1565.67

Table 4.43: Sound velocity (u) of L-lysine in aqueous solution of 0.05 $mol.kg^{-1}$ SB as a function of molality at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.05 $mol.kg^{-1}$ SB				
	Sound velocity, $u/m.s^{-1}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1489.22	1502.73	1514.68	1525	1533.77
0.0499	1496.17	1509.8	1521.91	1532.24	1540.97
0.1005	1502.91	1516.42	1528.37	1538.81	1547.47
0.1501	1509.58	1522.97	1534.83	1545.33	1553.79
0.1996	1515.83	1529.26	1540.94	1551.27	1559.89
0.2499	1522.28	1535.29	1546.92	1556.99	1565.38
0.3002	1528.33	1541.17	1552.77	1562.59	1570.62
0.3498	1534.22	1546.78	1557.98	1567.54	1575.18
0.4005	1539.91	1552.29	1563.19	1572.53	1579.55
0.4503	1545.39	1557.18	1567.87	1576.94	1583.49
0.4997	1551.01	1562.11	1572.61	1580.88	1587.01

Table 4.44: Sound velocity (u) of L-lysine in aqueous solution of 0.20 $mol.kg^{-1}$ SB as a function of molality at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.02 $mol.kg^{-1}$ SB				
	Sound velocity, $u/m.s^{-1}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1508.4	1520.78	1531.68	1541.02	1548.88
0.0498	1514.82	1527.1	1537.84	1547.05	1554.72
0.1004	1521.29	1533.33	1544.02	1553.06	1560.51
0.1501	1527.58	1539.53	1549.98	1558.85	1566.22
0.1996	1533.75	1545.54	1555.83	1564.49	1571.78
0.2497	1539.91	1551.56	1561.68	1570.19	1577.41
0.3002	1546.04	1557.51	1567.45	1575.72	1582.71
0.3497	1551.81	1563.19	1572.97	1581.01	1587.96
0.4003	1557.85	1568.74	1578.57	1586.07	1593.01
0.4504	1563.45	1574.34	1583.82	1591.08	1598.40
0.4998	1568.91	1579.56	1589.17	1595.68	1602.79

Table 4.45: Sound velocity (u) of L-lysine in aqueous solution of 0.35 $mol.kg^{-1}$ SB as a function of molality at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.35 $mol.kg^{-1}$ SB				
	Sound velocity, $u/m.s^{-1}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1526.58	1537.91	1547.83	1556.26	1563.27
0.0499	1532.51	1543.65	1553.46	1561.81	1568.72
0.0996	1538.36	1549.42	1559.12	1567.34	1574.13
0.1497	1544.19	1555.24	1564.77	1572.83	1579.51
0.1999	1550.29	1561.07	1570.38	1578.36	1584.87
0.2499	1556.19	1566.73	1576.04	1583.86	1590.23
0.2998	1562.03	1572.49	1581.49	1589.16	1595.48
0.3499	1567.90	1578.21	1587.06	1594.51	1600.65
0.3994	1573.33	1583.47	1592.19	1599.52	1605.55
0.4496	1578.92	1588.75	1597.28	1604.69	1610.61
0.4999	1584.57	1594.46	1602.95	1610.03	1615.82

Table 4.46: Sound velocity (u) of L-lysine in aqueous solution of 0.50 $mol.kg^{-1}$ SB as a function of molality at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.5 $mol.kg^{-1}$ SB				
	Sound velocity, $u/m.s^{-1}$				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1545.57	1556.33	1564.63	1572.45	1579.87
0.0498	1550.82	1561.41	1569.61	1577.28	1584.51
0.0997	1555.99	1566.42	1574.53	1582.03	1589.07
0.1499	1561.19	1571.47	1579.48	1586.81	1593.63
0.1997	1566.58	1576.65	1584.54	1591.69	1598.27
0.2497	1571.92	1581.81	1589.54	1596.53	1602.84
0.2998	1577.57	1587.28	1594.87	1601.72	1607.82
0.3497	1582.95	1592.51	1600.03	1606.51	1612.43
0.3995	1588.59	1597.89	1605.39	1611.68	1617.29
0.4497	1593.97	1603.28	1610.42	1616.43	1621.99
0.4999	1599.7	1608.73	1615.81	1621.56	1626.78

Table 4.47: Sound velocity (u) of L-arginine in aqueous solution of 0.05 mol.kg^{-1} SB as a function of molality at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.05 mol.kg^{-1} SB				
	Sound velocity, u/m.s^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1489.22	1502.73	1514.68	1525	1533.77
0.0497	1494.84	1508.18	1519.94	1530.12	1538.68
0.1001	1500.47	1513.59	1525.18	1535.19	1543.58
0.1499	1505.99	1518.88	1530.35	1540.18	1548.18
0.1998	1511.35	1524.11	1535.29	1545.02	1552.88
0.2499	1516.65	1529.30	1540.21	1549.61	1557.38
0.3002	1521.84	1534.26	1544.94	1554.25	1561.69
0.3498	1526.95	1539.28	1549.73	1558.64	1566.15
0.3996	1531.78	1544.11	1554.11	1563.00	1570.14
0.4497	1536.49	1548.51	1558.33	1566.81	1573.99
0.4999	1541.25	1552.76	1562.69	1571.08	1578.07

Table 4.48: Sound velocity (u) of L-arginine in aqueous solution of 0.20 mol.kg^{-1} SB as a function of molality at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.20 mol.kg^{-1} SB				
	Sound velocity, u/m.s^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1508.4	1520.78	1531.68	1541.02	1548.88
0.0497	1513.22	1525.52	1536.33	1545.51	1553.26
0.0998	1518.19	1530.38	1541.08	1550.12	1557.75
0.1497	1523.17	1535.25	1545.85	1554.78	1562.35
0.1998	1528.31	1540.29	1550.86	1559.58	1566.91
0.2501	1533.53	1545.37	1555.73	1564.38	1571.58
0.2997	1538.69	1550.39	1560.66	1569.25	1576.28
0.3499	1543.98	1555.61	1565.88	1574.24	1581.06
0.3998	1549.48	1560.88	1570.89	1579.31	1586.11
0.4498	1554.99	1566.31	1576.27	1584.36	1591.04
0.4998	1560.77	1571.92	1581.72	1589.43	1596.15

Table 4.49: Sound velocity (u) of L-arginine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.35 mol.kg^{-1} SB				
	Sound velocity, u/m.s^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1526.58	1537.91	1547.83	1556.26	1563.27
0.0499	1531.51	1542.64	1552.46	1560.74	1567.63
0.0997	1536.41	1547.34	1556.99	1565.11	1571.84
0.1496	1541.06	1551.78	1561.49	1569.37	1575.88
0.1998	1545.69	1556.22	1565.90	1573.61	1579.94
0.2497	1550.29	1560.64	1570.19	1577.60	1583.77
0.2999	1554.81	1564.87	1574.22	1581.64	1587.69
0.3497	1559.16	1569.16	1578.15	1585.43	1591.46
0.3996	1563.32	1572.89	1582.18	1589.38	1594.58
0.4498	1567.20	1576.58	1585.71	1592.78	1597.95
0.4999	1571.01	1580.52	1589.39	1596.61	1601.45

Table 4.50: Sound velocity (u) of L-arginine in aqueous solution of 0.50 mol.kg^{-1} SB as a function of molality at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.5 mol.kg^{-1} SB				
	Sound velocity, u/m.s^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1516.51	1528.86	1539.55	1548.68	1556.32
0.0498	1549.31	1560.06	1568.39	1576.19	1583.59
0.0997	1553.05	1563.76	1572.12	1579.89	1587.29
0.1499	1556.87	1567.61	1575.97	1583.73	1591.09
0.1997	1560.84	1571.55	1579.92	1587.64	1594.98
0.2497	1564.82	1575.52	1583.96	1591.54	1598.85
0.2998	1569.06	1579.62	1588.06	1595.76	1602.90
0.3497	1573.11	1583.82	1592.24	1599.81	1606.99
0.3995	1577.42	1588.01	1596.58	1604.14	1611.29
0.4497	1581.75	1592.30	1600.67	1608.22	1615.31
0.4999	1586.49	1597.05	1605.47	1613.01	1620.06

Table 4.51: Adiabatic compressibility ($\beta_s \times 10^{10}/Pa^{-1}$) of aqueous L-lysine as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-lysine + lysine				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.56	4.48	4.41	4.36	4.31
0.0496	4.49	4.42	4.35	4.30	4.26
0.0996	4.45	4.37	4.31	4.26	4.22
0.1496	4.39	4.32	4.26	4.21	4.17
0.1999	4.34	4.27	4.21	4.17	4.13
0.2495	4.29	4.23	4.17	4.12	4.09
0.2960	4.25	4.18	4.13	4.08	4.05
0.3493	4.20	4.14	4.08	4.04	4.01
0.3960	4.16	4.10	4.05	4.01	3.97
0.4499	4.11	4.05	4.00	3.96	3.93
0.4997	4.07	4.02	3.96	3.93	3.90

Table 4.52: Adiabatic compressibility ($\beta_s \times 10^{10}/Pa^{-1}$) of aqueous L-arginine as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-arginine+ water				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.55	4.47	4.41	4.35	4.31
0.0499	4.51	4.44	4.37	4.32	4.28
0.0999	4.48	4.40	4.34	4.29	4.25
0.1499	4.44	4.37	4.31	4.26	4.22
0.1997	4.41	4.34	4.28	4.23	4.19
0.2499	4.37	4.30	4.25	4.20	4.16
0.2996	4.34	4.27	4.22	4.17	4.14
0.3501	4.31	4.24	4.18	4.14	4.11
0.3996	4.28	4.21	4.16	4.12	4.08
0.4499	4.24	4.18	4.13	4.09	4.06
0.4996	4.21	4.16	4.10	4.06	4.03

Table 4.53: Adiabatic compressibility ($\beta_s \times 10^{10}/Pa^{-1}$) of L-lysine in aqueous solution of 0.05 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.05 $mol.kg^{-1}$ SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.50	4.43	4.36	4.31	4.27
0.0499	4.45	4.37	4.31	4.26	4.22
0.1005	4.40	4.32	4.26	4.21	4.17
0.1501	4.34	4.27	4.21	4.16	4.13
0.1996	4.30	4.23	4.17	4.12	4.08
0.2499	4.25	4.18	4.13	4.08	4.04
0.3002	4.21	4.14	4.09	4.04	4.01
0.3498	4.16	4.10	4.05	4.01	3.97
0.4005	4.12	4.06	4.01	3.97	3.94
0.4503	4.08	4.03	3.98	3.94	3.91
0.4997	4.05	3.99	3.95	3.91	3.89

Table 4.54: Adiabatic compressibility ($\beta_s \times 10^{10}/Pa^{-1}$) of L-lysine in aqueous solution of 0.20 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.20 $mol.kg^{-1}$ SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.35	4.29	4.23	4.19	4.16
0.0498	4.30	4.24	4.19	4.14	4.11
0.1004	4.25	4.19	4.14	4.10	4.07
0.1501	4.21	4.15	4.10	4.06	4.03
0.1996	4.16	4.10	4.06	4.02	3.99
0.2497	4.12	4.06	4.02	3.98	3.96
0.3002	4.08	4.02	3.98	3.95	3.92
0.3497	4.04	3.99	3.95	3.91	3.89
0.4003	4.00	3.95	3.91	3.88	3.86
0.4504	3.97	3.92	3.88	3.85	3.83
0.4998	3.93	3.89	3.85	3.83	3.80

Table 4.55: Adiabatic compressibility ($\beta_s \times 10^{10}$/Pa^{-1}) of L-lysine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.35 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.22	4.16	4.11	4.08	4.05
0.0499	4.17	4.12	4.07	4.04	4.01
0.0996	4.13	4.08	4.03	4.00	3.97
0.1497	4.09	4.04	3.99	3.96	3.94
0.1999	4.05	4.00	3.96	3.92	3.90
0.2499	4.01	3.96	3.92	3.89	3.87
0.2998	3.97	3.92	3.88	3.85	3.83
0.3499	3.93	3.88	3.85	3.82	3.80
0.3994	3.90	3.85	3.81	3.79	3.77
0.4496	3.86	3.82	3.78	3.75	3.73
0.4999	3.82	3.78	3.75	3.72	3.70

Table 4.56: Adiabatic compressibility ($\beta_s \times 10^{10}$/Pa^{-1}) of L-lysine in aqueous solution of 0.50 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.50 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.08	4.03	4.00	3.97	3.94
0.0498	4.04	4.00	3.96	3.93	3.90
0.0997	4.01	3.96	3.93	3.90	3.87
0.1499	3.97	3.92	3.89	3.86	3.84
0.1997	3.93	3.89	3.86	3.83	3.81
0.2497	3.90	3.86	3.83	3.80	3.78
0.2998	3.86	3.82	3.79	3.77	3.75
0.3497	3.83	3.79	3.76	3.74	3.72
0.3995	3.79	3.76	3.73	3.71	3.69
0.4497	3.76	3.72	3.70	3.68	3.66
0.4999	3.73	3.69	3.67	3.65	3.64

Table 4.57: Adiabatic compressibility ($\beta_s \times 10^{10}/Pa^{-1}$) of L-arginine in aqueous solution of 0.05 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-arginine+ aqueous solution of 0.05 $mol.kg^{-1}$ SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.50	4.43	4.36	4.31	4.27
0.0497	4.46	4.38	4.32	4.27	4.23
0.1001	4.41	4.34	4.28	4.24	4.20
0.1499	4.37	4.30	4.24	4.20	4.16
0.1998	4.33	4.26	4.21	4.16	4.13
0.2499	4.29	4.23	4.17	4.13	4.10
0.3002	4.25	4.19	4.14	4.10	4.06
0.3498	4.21	4.15	4.10	4.06	4.03
0.3996	4.18	4.12	4.07	4.03	4.00
0.4497	4.15	4.09	4.04	4.00	3.98
0.4999	4.11	4.06	4.01	3.98	3.95

Table 4.58: Adiabatic compressibility ($\beta_s \times 10^{10}/Pa^{-1}$) of L-arginine in aqueous solution of 0.20 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-arginine+ aqueous solution of 0.20 $mol.kg^{-1}$ SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.35	4.29	4.23	4.19	4.15
0.0497	4.31	4.25	4.20	4.15	4.12
0.0998	4.27	4.21	4.16	4.12	4.09
0.1497	4.24	4.17	4.12	4.08	4.05
0.1998	4.20	4.14	4.09	4.05	4.02
0.2501	4.16	4.10	4.05	4.01	3.99
0.2997	4.12	4.06	4.02	3.98	3.95
0.3499	4.08	4.03	3.98	3.95	3.92
0.3998	4.04	3.99	3.95	3.91	3.89
0.4498	4.01	3.95	3.91	3.88	3.86
0.4998	3.97	3.92	3.88	3.85	3.82

Table 4.59: Adiabatic compressibility ($\beta_s \times 10^{10}/Pa^{-1}$) of L-arginine in aqueous solution of 0.35 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-arginine+ aqueous solution of 0.35 $mol.kg^{-1}$ SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.22	4.16	4.11	4.08	4.05
0.0499	4.18	4.12	4.08	4.04	4.02
0.0997	4.14	4.09	4.05	4.01	3.99
0.1496	4.11	4.06	4.01	3.98	3.96
0.1998	4.07	4.03	3.98	3.95	3.93
0.2497	4.04	4.00	3.95	3.92	3.90
0.2999	4.01	3.97	3.93	3.90	3.88
0.3497	3.98	3.94	3.90	3.87	3.85
0.3996	3.95	3.91	3.87	3.85	3.83
0.4498	3.93	3.89	3.85	3.82	3.81
0.4999	3.90	3.86	3.83	3.80	3.79

Table 4.60: Adiabatic compressibility ($\beta_s \times 10^{10}/Pa^{-1}$) of L-arginine in aqueous solution of 0.5 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-arginine+ aqueous solution of 0.50 $mol.kg^{-1}$ SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	4.22	4.15	4.10	4.06	4.03
0.0498	4.05	4.00	3.97	3.94	3.91
0.0997	4.02	3.97	3.94	3.91	3.88
0.1499	3.99	3.95	3.91	3.88	3.86
0.1997	3.96	3.92	3.89	3.86	3.83
0.2497	3.94	3.89	3.86	3.83	3.81
0.2998	3.91	3.86	3.83	3.81	3.78
0.3497	3.88	3.84	3.81	3.78	3.76
0.3995	3.86	3.82	3.79	3.76	3.74
0.4497	3.83	3.79	3.76	3.74	3.72
0.4999	3.81	3.77	3.74	3.71	3.69

Table 4.61: Apparent molar adiabatic compressibility (φ_k) of aqueous L-lysine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + water				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0496	-5.9437	-5.6079	-5.2799	-4.9571	-4.6427
0.0996	-5.2141	-4.8584	-4.5776	-4.2547	-3.9888
0.1496	-5.1234	-4.7675	-4.4772	-4.1724	-3.8895
0.1999	-5.0250	-4.6799	-4.3777	-4.0669	-3.7918
0.2495	-4.9358	-4.5652	-4.2832	-3.9737	-3.6965
0.2960	-4.8362	-4.4659	-4.2024	-3.8769	-3.5978
0.3493	-4.7322	-4.3583	-4.0948	-3.7730	-3.4888
0.3960	-4.6371	-4.2672	-3.9782	-3.6761	-3.3976
0.4499	-4.5183	-4.1522	-3.8833	-3.5894	-3.2730
0.4997	-4.4160	-4.0406	-3.7930	-3.4700	-3.1956

Table 4.62: Apparent molar adiabatic compressibility (φ_k) of aqueous L-arginine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ water				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	-1.4859	-1.1988	-0.9183	-0.6324	-0.2576
0.0999	-1.4592	-1.1383	-0.9077	-0.6156	-0.2320
0.1499	-1.4200	-1.1093	-0.8494	-0.5671	-0.2323
0.1997	-1.3847	-1.0985	-0.8362	-0.5472	-0.2092
0.2499	-1.3392	-1.0301	-0.8417	-0.5377	-0.1971
0.2996	-1.2811	-1.0035	-0.7557	-0.4834	-0.1963
0.3501	-1.2885	-0.9398	-0.7840	-0.4379	-0.1716
0.3996	-1.2374	-0.9040	-0.7489	-0.4048	-0.1741
0.4499	-1.2293	-0.8519	-0.7061	-0.3895	-0.1613
0.4996	-1.1655	-0.8118	-0.6593	-0.3955	-0.1170

Table 4.63: Apparent molar adiabatic compressibility (φ_k) of L-lysine in aqueous solution of 0.05 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.05 mol.kg^{-1} SB				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	-5.6007	-5.5670	-5.6092	-5.5076	-5.3823
0.1005	-5.3253	-5.1565	-5.0267	-4.9933	-4.8547
0.1501	-5.2044	-4.9933	-4.8311	-4.8010	-4.6128
0.1996	-4.9837	-4.8007	-4.6027	-4.5119	-4.3995
0.2499	-4.8413	-4.5719	-4.3812	-4.2402	-4.0907
0.3002	-4.6444	-4.3701	-4.1889	-4.0148	-3.8193
0.3498	-4.4767	-4.1756	-3.9495	-3.7515	-3.5207
0.4005	-4.2820	-3.9824	-3.7362	-3.5276	-3.2401
0.4503	-4.1084	-3.7577	-3.5069	-3.2861	-2.9733
0.4997	-3.9743	-3.5788	-3.3253	-3.0358	-2.7112

Table 4.64: Apparent molar adiabatic compressibility (φ_k) of L-lysine in aqueous solution of 0.20 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.20 mol.kg^{-1} SB				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	-4.9796	-4.6299	-4.2340	-3.9647	-3.6361
0.1004	-4.7798	-4.3516	-4.0261	-3.7376	-3.4016
0.1501	-4.5763	-4.1684	-3.8097	-3.5237	-3.2372
0.1996	-4.3778	-3.9626	-3.5946	-3.3041	-3.0406
0.2497	-4.1695	-3.7627	-3.3979	-3.1057	-2.8682
0.3002	-3.9578	-3.5594	-3.1953	-2.8944	-2.6430
0.3497	-3.7255	-3.3372	-2.9854	-2.6805	-2.4568
0.4003	-3.5399	-3.1205	-2.7906	-2.4489	-2.2402
0.4504	-3.3066	-2.9178	-2.5815	-2.2333	-2.0811
0.4998	-3.1113	-2.7233	-2.4014	-2.0100	-1.8532

Table 4.65: Apparent molar adiabatic compressibility (φ_k) of L-lysine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.35 mol.kg^{-1} SB				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	-3.0471	-2.7671	-2.5970	-2.4788	-2.3532
0.0996	-2.9932	-2.7733	-2.6038	-2.4603	-2.3243
0.1497	-2.9367	-2.7629	-2.5740	-2.4131	-2.2797
0.1999	-2.9656	-2.7468	-2.5364	-2.3882	-2.2399
0.2499	-2.9373	-2.6994	-2.5214	-2.3642	-2.2149
0.2998	-2.9038	-2.6806	-2.4727	-2.3124	-2.1770
0.3499	-2.8749	-2.6526	-2.4463	-2.2743	-2.1305
0.3994	-2.8007	-2.5787	-2.3764	-2.2086	-2.0676
0.4496	-2.7483	-2.5106	-2.3062	-2.1638	-2.0257
0.4999	-2.7080	-2.4938	-2.3040	-2.1400	-2.0017

Table 4.66: Apparent molar adiabatic compressibility (φ_k) of L-lysine in aqueous solution of 0.5 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.50 mol.kg^{-1} SB				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	-2.5287	-2.1909	-1.9679	-1.7153	-1.4427
0.0997	-2.4176	-2.0891	-1.8693	-1.6188	-1.3474
0.1499	-2.3370	-2.0241	-1.7952	-1.5477	-1.2679
0.1997	-2.3264	-1.9990	-1.7748	-1.5168	-1.2372
0.2497	-2.2830	-1.9552	-1.7214	-1.4781	-1.1802
0.2998	-2.2780	-1.9524	-1.7177	-1.4749	-1.1813
0.3497	-2.2244	-1.9049	-1.6787	-1.4198	-1.1318
0.3995	-2.2023	-1.8770	-1.6656	-1.4037	-1.1132
0.4497	-2.1411	-1.8391	-1.6010	-1.3372	-1.0609
0.4999	-2.1153	-1.8055	-1.5741	-1.3015	-1.0401

Table 4.67: Apparent molar adiabatic compressibility (φ_k) of L-arginine in aqueous solution of 0.05 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.05 mol.kg^{-1} SB				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0497	-3.4717	-3.1292	-2.7875	-2.5318	-2.2295
0.1001	-3.3922	-3.0276	-2.6985	-2.4368	-2.1594
0.1499	-3.3247	-2.9520	-2.6461	-2.3763	-2.0282
0.1998	-3.2230	-2.8770	-2.5402	-2.2888	-1.9766
0.2499	-3.1273	-2.8021	-2.4527	-2.1647	-1.8866
0.3002	-3.0280	-2.6982	-2.3478	-2.0802	-1.7824
0.3498	-2.9484	-2.6345	-2.2880	-1.9859	-1.7336
0.3996	-2.8384	-2.5506	-2.1781	-1.9071	-1.6307
0.4497	-2.7287	-2.4240	-2.0617	-1.7662	-1.5242
0.4999	-2.6393	-2.2985	-1.9837	-1.7000	-1.4566

Table 4.68: Apparent molar adiabatic compressibility (φ_k) of L-arginine in aqueous solution of 0.20 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.20 mol.kg^{-1} SB				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0497	-2.6193	-2.4137	-2.2106	-1.9570	-1.7681
0.0998	-2.6519	-2.4336	-2.2190	-1.9721	-1.7783
0.1497	-2.6537	-2.4340	-2.2131	-1.9839	-1.8130
0.1998	-2.6841	-2.4615	-2.2576	-2.0083	-1.7978
0.2501	-2.6976	-2.4677	-2.2410	-2.0137	-1.7980
0.2997	-2.7041	-2.4643	-2.2454	-2.0252	-1.8097
0.3499	-2.7112	-2.4784	-2.2674	-2.0413	-1.8082
0.3998	-2.7392	-2.4880	-2.2637	-2.0547	-1.8391
0.4498	-2.7578	-2.5121	-2.2921	-2.0577	-1.8457
0.4998	-2.7934	-2.5472	-2.3234	-2.0552	-1.8618

Table 4.69: Apparent molar adiabatic compressibility (φ_k) of L-arginine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.35 mol.kg^{-1} SB				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	-2.1971	-1.8935	-1.6960	-1.4726	-1.2785
0.0997	-2.1093	-1.8062	-1.5730	-1.3478	-1.1376
0.1496	-1.9522	-1.6463	-1.4763	-1.2221	-0.9957
0.1998	-1.8157	-1.5142	-1.3611	-1.1183	-0.8917
0.2497	-1.7127	-1.4190	-1.2562	-0.9867	-0.7703
0.2999	-1.6030	-1.3000	-1.1110	-0.8941	-0.6716
0.3497	-1.4834	-1.2066	-0.9870	-0.7633	-0.5709
0.3996	-1.3660	-1.0510	-0.8930	-0.6721	-0.4044
0.4498	-1.2174	-0.9108	-0.7430	-0.5292	-0.2804
0.4999	-1.0736	-0.8056	-0.6203	-0.4500	-0.1925

Table 4.70: Apparent molar adiabatic compressibility (φ_k) of L-arginine in aqueous solution of 0.50 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.50 mol.kg^{-1} SB				
	$\varphi_k \times 10^{14}$/m^3.mol^{-1}.Pa^{-1}				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	-1.3306	-1.1196	-0.9336	-0.7479	-0.5715
0.0997	-1.1750	-0.9627	-0.7722	-0.5709	-0.4198
0.1499	-1.0365	-0.8414	-0.6388	-0.4436	-0.2787
0.1997	-0.9421	-0.7172	-0.5415	-0.3364	-0.1882
0.2497	-0.8095	-0.6036	-0.4227	-0.2272	-0.0707
0.2998	-0.7277	-0.5409	-0.3586	-0.1543	0.0010
0.3497	-0.6065	-0.3910	-0.2322	-0.0352	0.0966
0.3995	-0.5096	-0.3025	-0.1134	0.0551	0.2330
0.4497	-0.3710	-0.1536	0.0166	0.1646	0.3366
0.4999	-0.3032	-0.1018	0.0607	0.2277	0.3841

Table 4.71: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) of Aqueous L-lysine system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively

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	-5.6019	2.6125
298.15K	-5.2330	2.6171
303.15K	-4.9691	2.7001
308.15K	-4.6003	2.6154
313.15K	-4.2248	2.3663

Table 4.72: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) of Aqueous L-arginine system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

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	-1.5208	0.6975
298.15K	-1.2424	0.8510
303.15K	-0.9502	0.5441
308.15K	-0.6647	0.5953
313.15K	-0.2670	0.2625

Table 4.73: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of L-lysine in aqueous solution of SB 0.05 $mol.kg^{-1}$ SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta_{tr}\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)
293.15K	-5.7273	3.5743	-0.1254
298.15K	-5.6563	4.2206	-0.4233
303.15K	-5.6102	4.7060	-0.6410
308.15K	-5.6030	5.2209	-1.0027
313.15K	-5.5270	5.6953	-1.3021

Table 4.74: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of L-lysine in aqueous solution of 0.20 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta_{tr}\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)
293.15K	-5.2014	4.1782	0.4005
298.15K	-4.8036	4.1828	0.4294
303.15K	-4.4258	4.0878	0.5433
308.15K	-4.1760	4.3115	0.4243
313.15K	-3.8206	3.9084	0.4042

Table 4.75: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of L-lysine in aqueous solution of SB 0.35 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta_{tr}\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)
293.15K	-3.0750	0.6528	2.5269
298.15K	-2.8437	0.6323	2.3893
303.15K	-2.6730	0.7219	2.2962
308.15K	-2.5377	0.7899	2.0626
313.15K	-2.4048	0.8142	1.8200

Table 4.76: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of L-lysine in aqueous solution of SB 0.50 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta_{tr}\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)
293.15K	-2.5065	0.8050	3.0953
298.15K	-2.1715	0.7564	3.0615
303.15K	-1.9485	0.7713	3.0206
308.15K	-1.7048	0.8133	2.8954
313.15K	-1.7048	0.8133	2.5200

Table 4.77: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of L-arginine in aqueous solution of 0.05 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta_{tr}\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)
293.15K	-3.5884	1.8781	-2.0676
298.15K	-2.3321	1.7630	-1.0897
303.15K	-2.8947	1.8056	-1.9445
308.15K	-2.6410	1.8817	-1.9763
313.15K	-2.3148	1.7244	-2.0478

Table 4.78: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of L-arginine in aqueous solution of 0.20 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta_{tr}\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)
293.15K	-2.6072	-0.3422	-1.0864
298.15K	-2.4011	-0.2507	-1.1587
303.15K	-2.1929	-0.2199	-1.2427
308.15K	-1.9520	-0.2360	-1.2873
313.15K	-1.7624	-0.1803	-1.4954

Table 4.79: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of L-arginine in aqueous solution of 0.35 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta_{tr}\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)
293.15K	-2.3321	2.4334	-0.8114
298.15K	-2.0239	2.4304	-0.7815
303.15K	-1.8269	2.3607	-0.8767
308.15K	-1.5730	2.3144	-0.9083
313.15K	-1.3784	2.4207	-1.1114

Table 4.80: Limiting apparent molar adiabatic compressibility (φ_k^0), experimental slope (S_k) and transfer compressibility ($\Delta_{tr}\varphi_k^0$) of L-arginine in aqueous solution of 0.50 mol.kg^{-1} SB system at 293.15K, 298.15K, 303.15K, 308.15K and 303.15K respectively

Temp (K)	$\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)	$S_k \times 10^{14}$ ($m^3.mol^{-1}.kg$)	$\Delta_{tr}\varphi_k^0 \times 10^{14}$ ($m^3.mol^{-1}.Pa^{-1}$)
293.15K	-1.4006	2.2545	0.1202
298.15K	-1.1915	2.2498	0.0509
303.15K	-0.9961	2.1929	-0.0458
308.15K	-0.7863	2.1091	-0.1216
313.15K	-0.6266	2.1069	-0.3596

Table 4.81: Acoustic impedance ($Z \times 10^{-6}$/kg.m^{-2}.s^{-1}) of aqueous L-lysine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + water				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.4803	1.4924	1.5025	1.5106	1.5168
0.0496	1.4927	1.5047	1.5147	1.5226	1.5289
0.0996	1.5031	1.5150	1.5249	1.5327	1.5388
0.1496	1.5140	1.5257	1.5355	1.5431	1.5490
0.1999	1.5248	1.5364	1.5460	1.5534	1.5591
0.2495	1.5354	1.5467	1.5562	1.5634	1.5689
0.2960	1.5451	1.5562	1.5657	1.5726	1.5779
0.3493	1.5561	1.5670	1.5763	1.5830	1.5881
0.3960	1.5656	1.5763	1.5853	1.5919	1.5969
0.4499	1.5763	1.5868	1.5958	1.6022	1.6066
0.4997	1.5861	1.5963	1.6053	1.6112	1.6157

Table 4.82: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of aqueous L-arginine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ water				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.4811	1.4933	1.5034	1.5115	1.5180
0.0499	1.4888	1.5007	1.5107	1.5186	1.5248
0.0999	1.4964	1.5081	1.5180	1.5257	1.5315
0.1499	1.5039	1.5155	1.5251	1.5326	1.5383
0.1997	1.5113	1.5227	1.5322	1.5395	1.5449
0.2499	1.5186	1.5298	1.5394	1.5465	1.5515
0.2996	1.5257	1.5369	1.5461	1.5530	1.5581
0.3501	1.5332	1.5438	1.5534	1.5597	1.5647
0.3996	1.5402	1.5506	1.5601	1.5662	1.5712
0.4499	1.5475	1.5573	1.5668	1.5728	1.5776
0.4996	1.5542	1.5640	1.5733	1.5795	1.5837

Table 4.83: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-lysine in aqueous solution of 0.05 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.05 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.4912	1.5029	1.5127	1.5205	1.5264
0.0499	1.5027	1.5145	1.5245	1.5323	1.5382
0.1005	1.5139	1.5256	1.5354	1.5434	1.5492
0.1501	1.5248	1.5365	1.5462	1.5542	1.5598
0.1996	1.5352	1.5469	1.5565	1.5644	1.5701
0.2499	1.5458	1.5571	1.5666	1.5742	1.5798
0.3002	1.5559	1.5670	1.5765	1.5839	1.5891
0.3498	1.5656	1.5764	1.5856	1.5927	1.5975
0.4005	1.5751	1.5858	1.5946	1.6015	1.6057
0.4503	1.5842	1.5943	1.6029	1.6096	1.6133
0.4997	1.5934	1.6027	1.6112	1.6170	1.6203

Table 4.84: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-lysine in aqueous solution of 0.20 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.20 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.5231	1.5336	1.5422	1.5490	1.5538
0.0498	1.5346	1.5449	1.5533	1.5598	1.5644
0.1004	1.5458	1.5558	1.5640	1.5703	1.5746
0.1501	1.5565	1.5662	1.5741	1.5803	1.5844
0.1996	1.5668	1.5762	1.5838	1.5897	1.5937
0.2497	1.5768	1.5860	1.5933	1.5990	1.6029
0.3002	1.5865	1.5954	1.6025	1.6079	1.6115
0.3497	1.5955	1.6042	1.6110	1.6161	1.6197
0.4003	1.6046	1.6127	1.6195	1.6240	1.6274
0.4504	1.6128	1.6209	1.6272	1.6314	1.6352
0.4998	1.6208	1.6285	1.6348	1.6381	1.6418

Table 4.85: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-lysine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.35 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.5539	1.5632	1.5707	1.5763	1.5800
0.0499	1.5638	1.5730	1.5804	1.5859	1.5895
0.0996	1.5736	1.5827	1.5901	1.5954	1.5989
0.1497	1.5834	1.5925	1.5997	1.6049	1.6083
0.1999	1.5934	1.6023	1.6093	1.6144	1.6176
0.2499	1.6032	1.6118	1.6188	1.6238	1.6269
0.2998	1.6129	1.6214	1.6281	1.6330	1.6360
0.3499	1.6226	1.6310	1.6375	1.6422	1.6450
0.3994	1.6317	1.6400	1.6464	1.6510	1.6537
0.4496	1.6411	1.6490	1.6553	1.6599	1.6626
0.4999	1.6504	1.6585	1.6647	1.6690	1.6715

Table 4.86: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-lysine in aqueous solution of 0.50 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.50 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.5848	1.5935	1.5991	1.6039	1.6078
0.0498	1.5945	1.6030	1.6084	1.6130	1.6166
0.0997	1.6040	1.6122	1.6174	1.6218	1.6252
0.1499	1.6134	1.6215	1.6264	1.6306	1.6336
0.1997	1.6229	1.6306	1.6354	1.6393	1.6421
0.2497	1.6322	1.6397	1.6442	1.6479	1.6503
0.2998	1.6417	1.6489	1.6532	1.6567	1.6588
0.3497	1.6508	1.6577	1.6619	1.6650	1.6669
0.3995	1.6600	1.6666	1.6707	1.6735	1.6750
0.4497	1.6689	1.6754	1.6790	1.6815	1.6829
0.4999	1.6780	1.6841	1.6876	1.6897	1.6910

Table 4.87: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-arginine in aqueous solution of 0.05 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.05 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.4912	1.5029	1.5127	1.5205	1.5264
0.0497	1.5005	1.5121	1.5217	1.5293	1.5350
0.1001	1.5099	1.5212	1.5306	1.5381	1.5436
0.1499	1.5190	1.5301	1.5394	1.5466	1.5517
0.1998	1.5279	1.5389	1.5478	1.5550	1.5600
0.2499	1.5367	1.5476	1.5563	1.5631	1.5679
0.3002	1.5454	1.5560	1.5644	1.5712	1.5757
0.3498	1.5539	1.5644	1.5726	1.5789	1.5835
0.3996	1.5621	1.5726	1.5803	1.5866	1.5908
0.4497	1.5701	1.5803	1.5878	1.5937	1.5979
0.4999	1.5781	1.5878	1.5954	1.6012	1.6052

Table 4.88: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-arginine in aqueous solution of 0.20 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.20 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.5233	1.5338	1.5424	1.5491	1.5539
0.0497	1.5322	1.5426	1.5511	1.5576	1.5623
0.0998	1.5412	1.5515	1.5599	1.5662	1.5707
0.1497	1.5502	1.5603	1.5686	1.5748	1.5792
0.1998	1.5593	1.5693	1.5775	1.5835	1.5876
0.2501	1.5684	1.5783	1.5862	1.5921	1.5961
0.2997	1.5774	1.5871	1.5950	1.6007	1.6045
0.3499	1.5866	1.5962	1.6039	1.6095	1.6129
0.3998	1.5958	1.6052	1.6127	1.6182	1.6216
0.4498	1.6051	1.6143	1.6217	1.6268	1.6301
0.4998	1.6146	1.6236	1.6308	1.6354	1.6387

Table 4.89: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-arginine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.35 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.5539	1.5632	1.5707	1.5763	1.5800
0.0499	1.5627	1.5718	1.5792	1.5846	1.5881
0.0997	1.5713	1.5802	1.5874	1.5926	1.5959
0.1496	1.5796	1.5882	1.5954	1.6003	1.6034
0.1998	1.5876	1.5961	1.6032	1.6080	1.6108
0.2497	1.5956	1.6038	1.6108	1.6152	1.6178
0.2999	1.6033	1.6112	1.6179	1.6224	1.6248
0.3497	1.6106	1.6185	1.6248	1.6290	1.6314
0.3996	1.6177	1.6251	1.6317	1.6357	1.6373
0.4498	1.6244	1.6315	1.6379	1.6417	1.6433
0.4999	1.6307	1.6379	1.6440	1.6481	1.6493

Table 4.90: Acoustic impedance ($Z\times10^{-6}$/kg.m^{-2}.s^{-1}) of L-arginine in aqueous solution of 0.50 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.50 mol.kg^{-1} SB				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	1.5644	1.5750	1.5833	1.5898	1.5945
0.0498	1.5930	1.6016	1.6070	1.6116	1.6153
0.0997	1.6008	1.6093	1.6145	1.6190	1.6225
0.1499	1.6085	1.6168	1.6218	1.6261	1.6295
0.1997	1.6159	1.6240	1.6289	1.6330	1.6363
0.2497	1.6230	1.6309	1.6357	1.6396	1.6427
0.2998	1.6301	1.6380	1.6426	1.6462	1.6492
0.3497	1.6367	1.6442	1.6488	1.6523	1.6553
0.3995	1.6432	1.6506	1.6547	1.6583	1.6608
0.4497	1.6491	1.6562	1.6604	1.6640	1.6663
0.4999	1.6555	1.6625	1.6666	1.6698	1.6722

Table 4.91: Hydration number (n_H) of aqueous L-lysine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + water				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0496	13.29	13.00	12.76	12.42	12.02
0.0996	13.13	12.79	12.57	12.22	11.83
0.1496	12.95	12.62	12.39	12.03	11.67
0.1999	12.79	12.47	12.20	11.85	11.50
0.2495	12.61	12.27	12.02	11.65	11.35
0.2960	12.44	12.10	11.87	11.50	11.18
0.3493	12.25	11.91	11.65	11.29	11.00
0.3960	12.07	11.75	11.47	11.15	10.84
0.4499	11.88	11.56	11.26	10.93	10.66
0.4997	11.71	11.36	11.08	10.78	10.51

Table 4.92: Hydration number (n_H) of aqueous L-arginine as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ water				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0000	9.11	8.80	8.48	8.14	7.68
0.0999	9.02	8.67	8.41	8.07	7.60
0.1499	8.91	8.58	8.29	7.96	7.55
0.1997	8.82	8.51	8.22	7.89	7.48
0.2499	8.71	8.38	8.18	7.83	7.41
0.2996	8.59	8.29	8.03	7.71	7.37
0.3501	8.55	8.17	8.01	7.61	7.29
0.3996	8.44	8.08	7.92	7.52	7.25
0.4499	8.38	7.97	7.82	7.46	7.19
0.4996	8.25	7.88	7.72	7.43	7.10

Table 4.93: Hydration number (n_H) of L-lysine in aqueous solution of 0.05 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.05 mol.kg^{-1} SB				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	13.56	13.63	13.78	13.72	13.61
0.1005	13.29	13.19	13.11	13.13	13.00
0.1501	13.05	12.90	12.78	12.80	12.61
0.1996	12.75	12.63	12.46	12.40	12.30
0.2499	12.53	12.30	12.14	12.02	11.87
0.3002	12.24	12.00	11.85	11.68	11.48
0.3498	11.99	11.73	11.52	11.32	11.07
0.4005	11.72	11.45	11.22	11.01	10.68
0.4503	11.48	11.15	10.90	10.68	10.32
0.4997	11.25	10.87	10.62	10.31	9.94

Table 4.94: Hydration number (n_H) of L-lysine in aqueous solution of 0.20 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.20 $mol.kg^{-1}$ SB				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	12.99	12.69	12.32	12.04	11.68
0.1004	12.74	12.34	12.06	11.76	11.39
0.1501	12.49	12.13	11.79	11.49	11.18
0.1996	12.24	11.88	11.53	11.22	10.94
0.2497	11.99	11.64	11.29	10.99	10.74
0.3002	11.74	11.39	11.05	10.73	10.46
0.3497	11.47	11.13	10.80	10.47	10.24
0.4003	11.26	10.87	10.57	10.19	9.98
0.4504	10.99	10.64	10.32	9.94	9.80
0.4998	10.76	10.40	10.11	9.68	9.52

Table 4.95: Hydration number (n_H) of L-lysine in aqueous solution of 0.35 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-lysine + aqueous solution of 0.35 $mol.kg^{-1}$ SB				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	11.76	11.41	11.18	11.02	10.83
0.0996	11.59	11.32	11.09	10.90	10.70
0.1497	11.42	11.21	10.97	10.75	10.55
0.1999	11.36	11.10	10.83	10.63	10.41
0.2499	11.23	10.95	10.72	10.51	10.29
0.2998	11.10	10.84	10.57	10.36	10.16
0.3499	10.98	10.72	10.46	10.22	10.02
0.3994	10.80	10.54	10.29	10.06	9.86
0.4496	10.65	10.37	10.11	9.92	9.73
0.4999	10.52	10.28	10.03	9.82	9.62

Table 4.96: Hydration number (n_H) of L-lysine in aqueous solution of 0.5 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-lysine + aqueous solution of 0.50 mol.kg^{-1} SB				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	10.47	10.11	9.88	9.58	9.25
0.0997	10.39	10.03	9.81	9.51	9.17
0.1499	10.31	9.97	9.74	9.44	9.09
0.1997	10.25	9.90	9.66	9.36	9.01
0.2497	10.18	9.83	9.58	9.29	8.93
0.2998	10.11	9.76	9.51	9.23	8.87
0.3497	10.02	9.68	9.45	9.13	8.78
0.3995	9.95	9.61	9.39	9.08	8.72
0.4497	9.88	9.56	9.31	8.99	8.66
0.4999	9.81	9.49	9.24	8.92	8.59

Table 4.97: Hydration number (n_H) of L-arginine in aqueous solution of 0.05 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.05 mol.kg^{-1} SB				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0497	11.14	10.80	10.44	10.16	9.81
0.1001	10.98	10.61	10.27	9.99	9.66
0.1499	10.84	10.46	10.15	9.86	9.45
0.1998	10.67	10.32	9.97	9.70	9.33
0.2499	10.50	10.18	9.81	9.50	9.17
0.3002	10.33	10.00	9.63	9.34	9.00
0.3498	10.18	9.87	9.51	9.18	8.90
0.3996	10.00	9.73	9.33	9.04	8.72
0.4497	9.83	9.53	9.15	8.82	8.55
0.4999	9.67	9.33	9.01	8.70	8.43

Table 4.98: Hydration number (n_H) of L-arginine in aqueous solution of 0.20 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.20 mol.kg^{-1} SB				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0497	9.96	9.76	9.56	9.27	9.06
0.0998	9.95	9.73	9.52	9.24	9.03
0.1497	9.90	9.68	9.47	9.21	9.03
0.1998	9.88	9.67	9.47	9.20	8.97
0.2501	9.85	9.63	9.41	9.16	8.92
0.2997	9.81	9.58	9.37	9.13	8.90
0.3499	9.77	9.55	9.35	9.11	8.85
0.3998	9.76	9.52	9.30	9.08	8.85
0.4498	9.73	9.50	9.29	9.05	8.82
0.4998	9.73	9.49	9.28	9.00	8.80

Table 4.99: Hydration number (n_H) of L-arginine in aqueous solution of 0.35 mol.kg^{-1} SB as a function of molality (m/mol.kg^{-1}) at different temperature

m/mol.kg^{-1}	L-arginine+ aqueous solution of 0.35 mol.kg^{-1} SB				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0499	9.90	9.55	9.33	9.06	8.83
0.0997	9.70	9.42	9.15	8.88	8.62
0.1496	9.53	9.18	9.00	8.69	8.41
0.1998	9.34	8.99	8.83	8.54	8.26
0.2497	9.19	8.85	8.68	8.35	8.07
0.2999	9.03	8.67	8.47	8.20	7.93
0.3497	8.86	8.54	8.29	8.02	7.79
0.3996	8.68	8.32	8.15	7.89	7.55
0.4498	8.48	8.12	7.94	7.69	7.38
0.4999	8.28	7.98	7.78	7.58	7.26

Table 4.100: Hydration number (n_H) of L-arginine in aqueous solution of 0.50 $mol.kg^{-1}$ SB as a function of molality ($m/mol.kg^{-1}$) at different temperature

$m/mol.kg^{-1}$	L-arginine+ aqueous solution of 0.50 $mol.kg^{-1}$ SB				
	n_H				
	293.15K	298.15K	303.15K	308.15K	313.15K
0.0498	7.96	7.81	7.70	7.55	7.41
0.0997	7.88	7.71	7.60	7.44	7.32
0.1499	7.80	7.66	7.52	7.37	7.24
0.1997	7.71	7.55	7.43	7.27	7.14
0.2497	7.62	7.46	7.35	7.18	7.05
0.2998	7.52	7.37	7.25	7.09	6.95
0.3497	7.42	7.27	7.16	7.00	6.88
0.3995	7.34	7.18	7.07	6.92	6.78
0.4497	7.25	7.09	6.97	6.84	6.69
0.4999	7.16	7.00	6.89	6.76	6.62

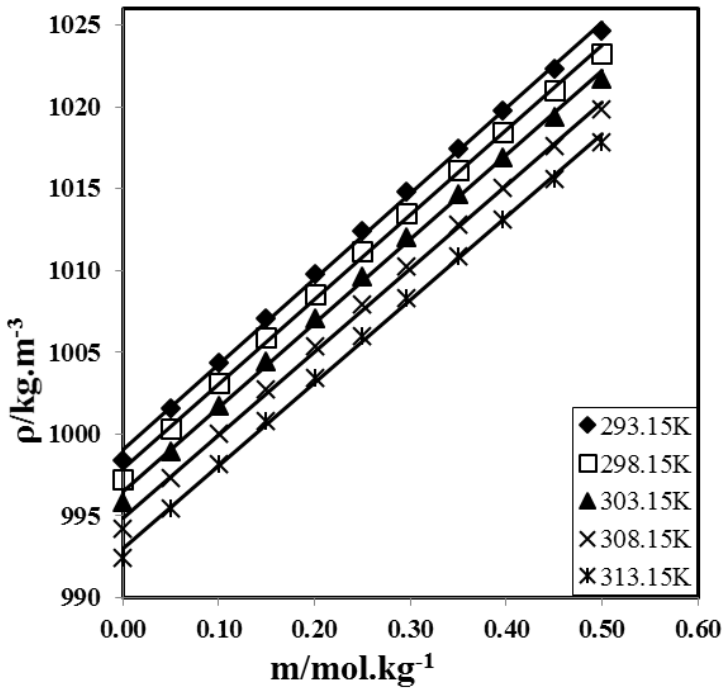


Figure 4.1**:** Plots of Density (ρ) vs. Molality (m) of L-lysine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

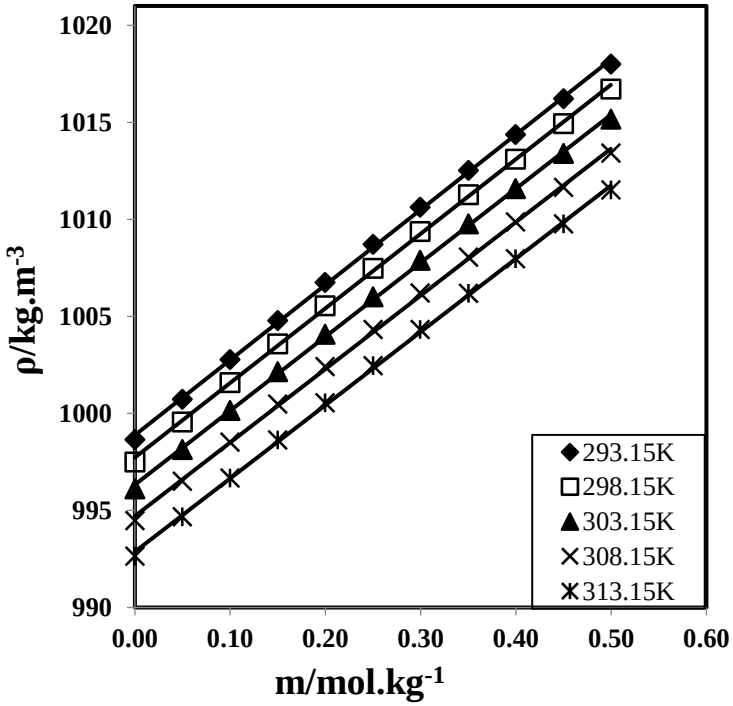


Figure 4.2**:** Plots of Density (ρ) vs. Molality (m) of L-arginine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

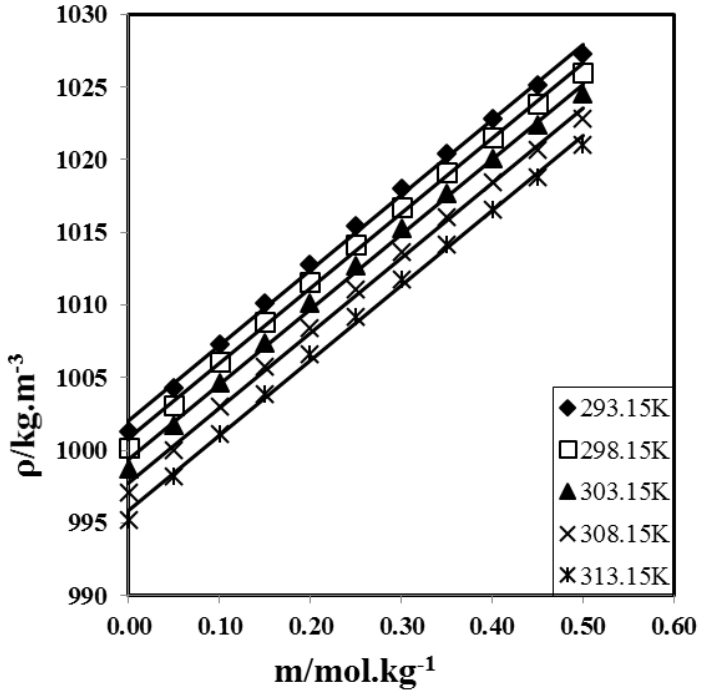


Figure 4.3: Plots of Density (ρ) vs. Molality (m) of L-lysine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

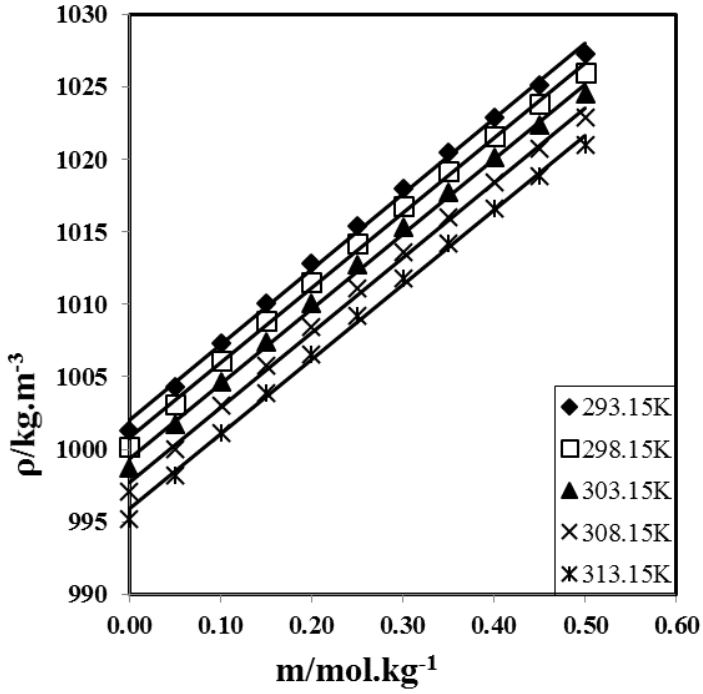


Figure 4.4: Plots of Density (ρ) vs. Molality (m) of L-lysine+ 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

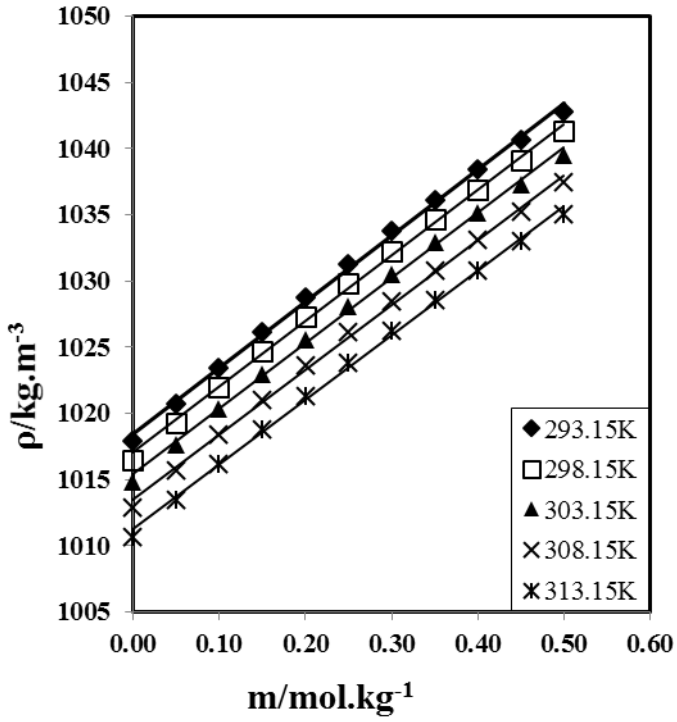


Figure 4.5: Plots of Density (ρ) vs. Molality (m) of L-lysine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

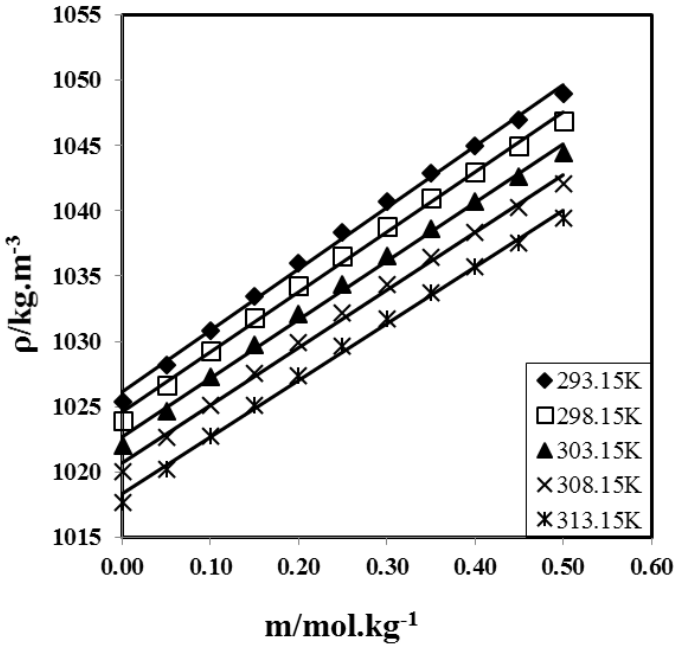


Figure 4.6: Plots of Density (ρ) vs. Molality (m) of L-lysine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

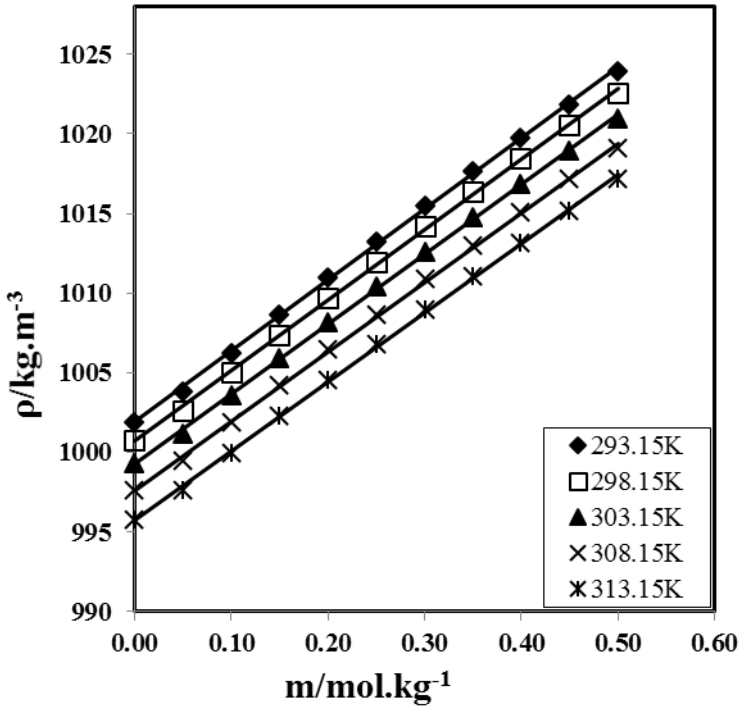


Figure 4.7: Plots of Density (ρ) vs. Molality (m) of L-arginine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

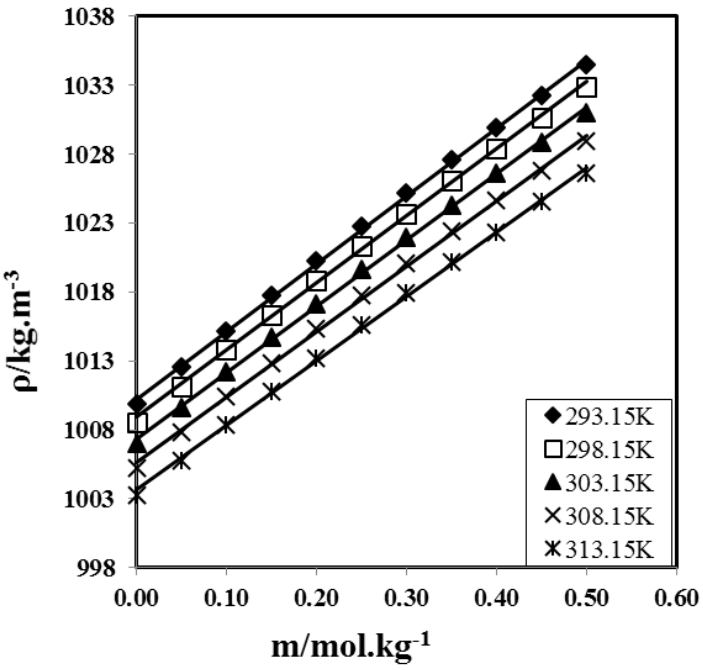


Figure 4.8: Plots of Density (ρ) vs. Molality (m) of L-arginine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

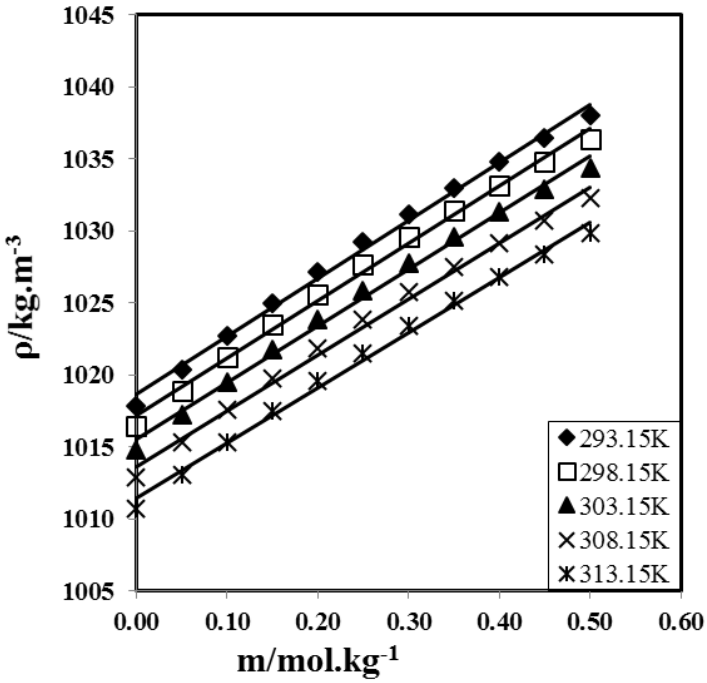


Figure 4.9: Plots of Density (ρ) vs. Molality (m) of L-arginine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

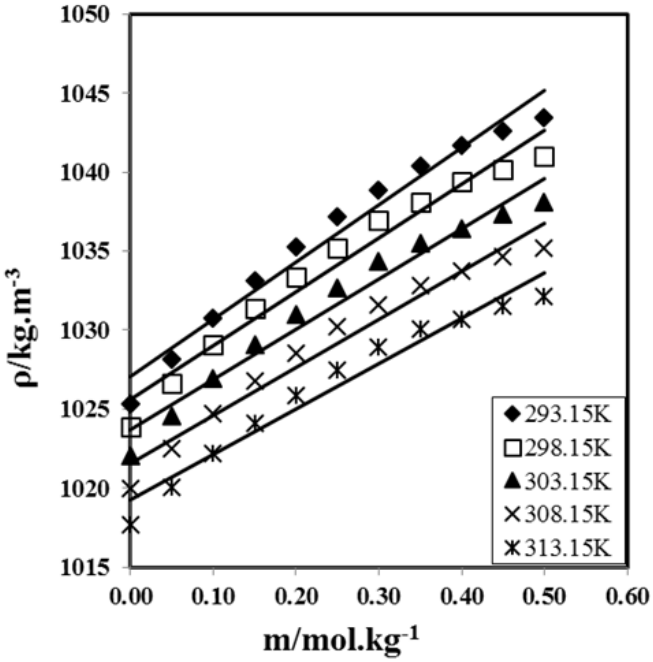


Figure 4.10: Plots of Density (ρ) vs. Molality (m) of L-arginine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K and 308.15K respectively.

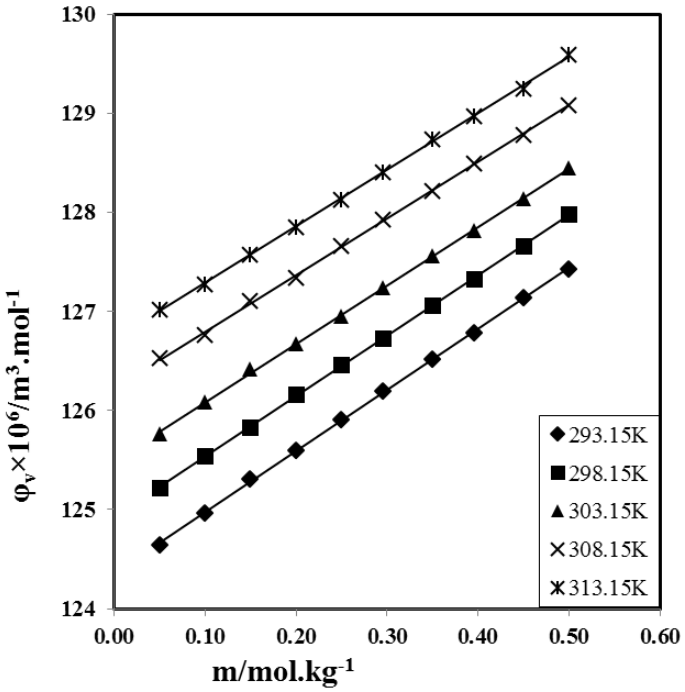


Figure 4.11: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-lysine system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

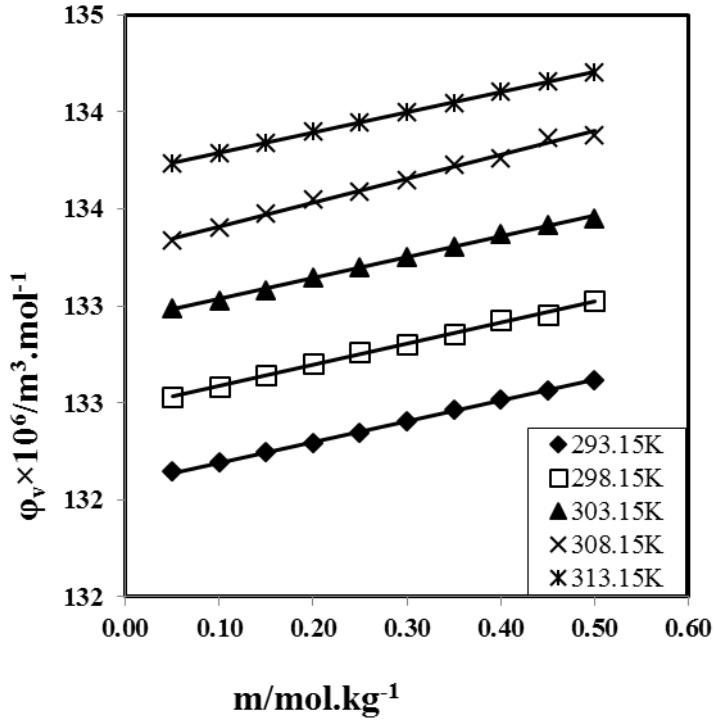


Figure 4.12: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-arginine systems at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

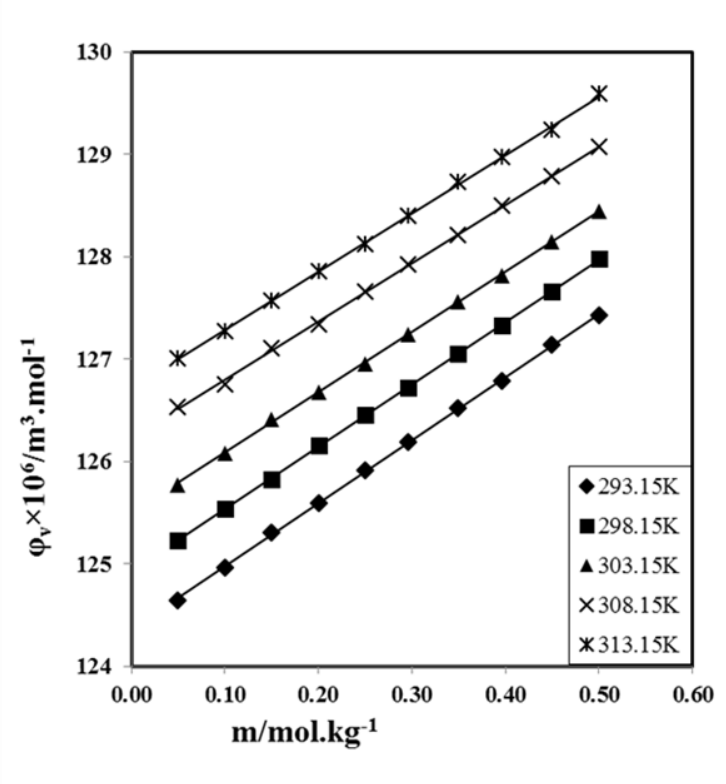


Figure 4.13: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-lysine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15Krespectively.

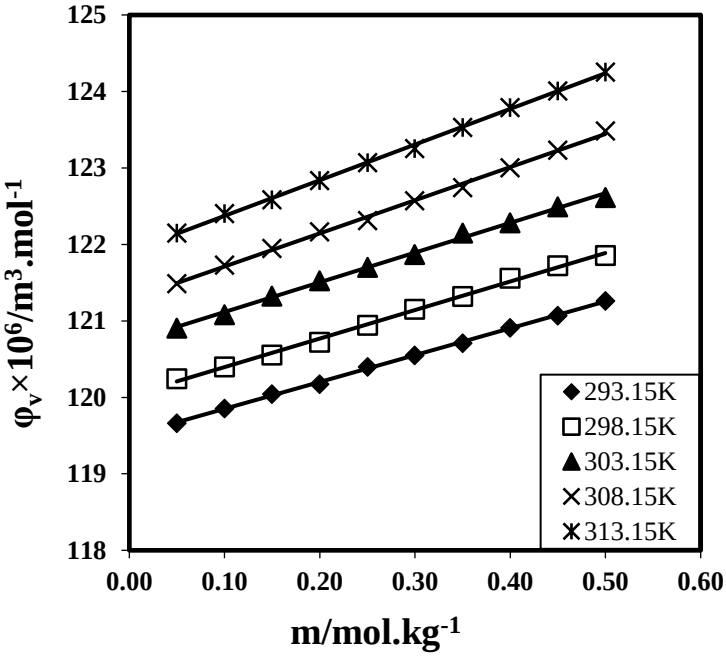


Figure 4.14: Plots of Apparent molar volume (φ_v) vs. Molality of L-lysine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

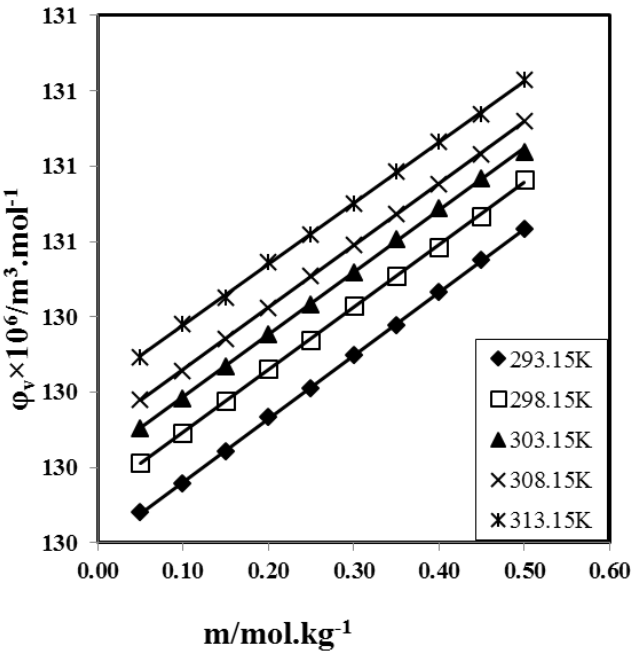


Figure 4.15: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-Lysine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

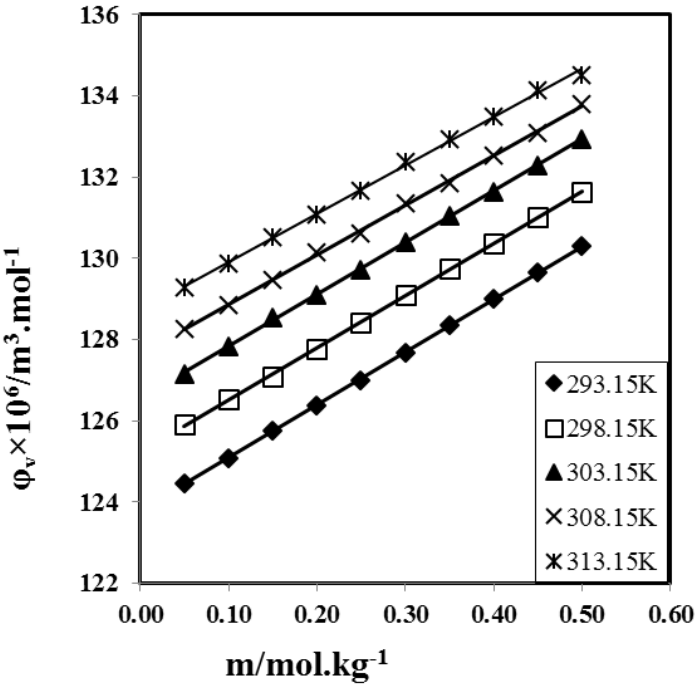


Figure 4.16: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-lysine+ 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

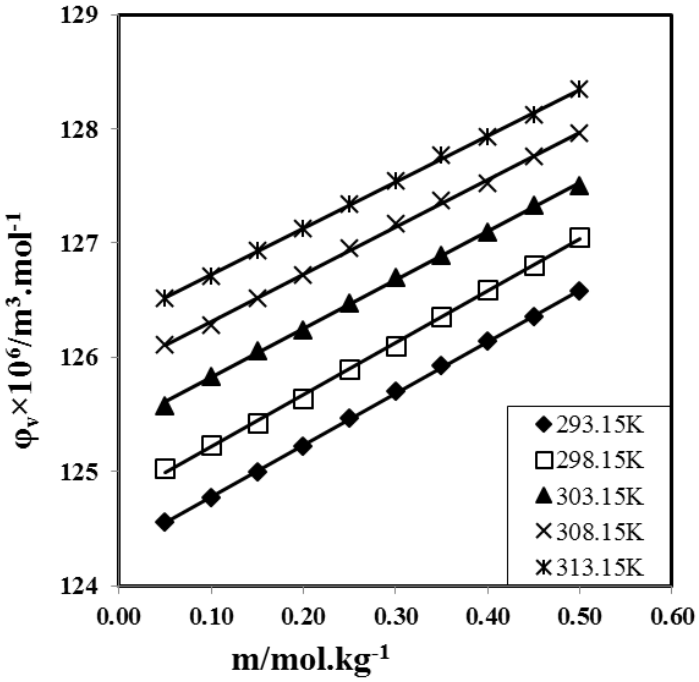


Figure 4.17: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-arginine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

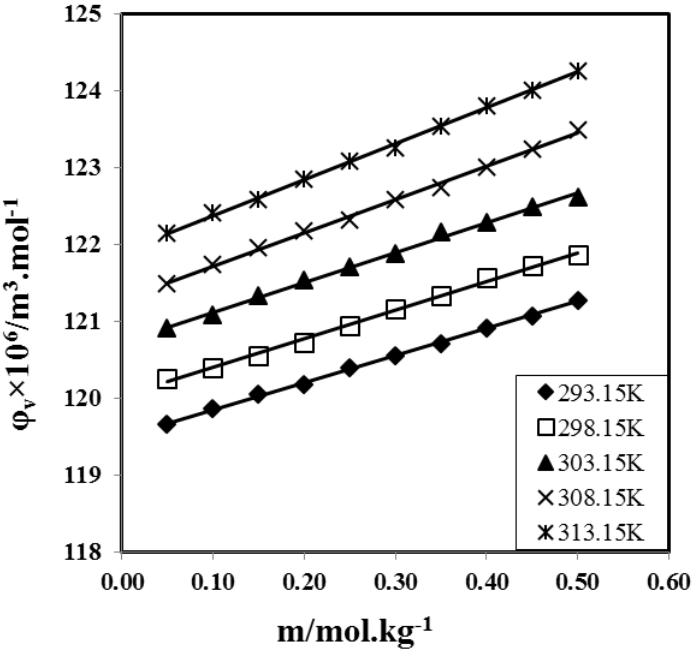


Figure 4.18: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-arginine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

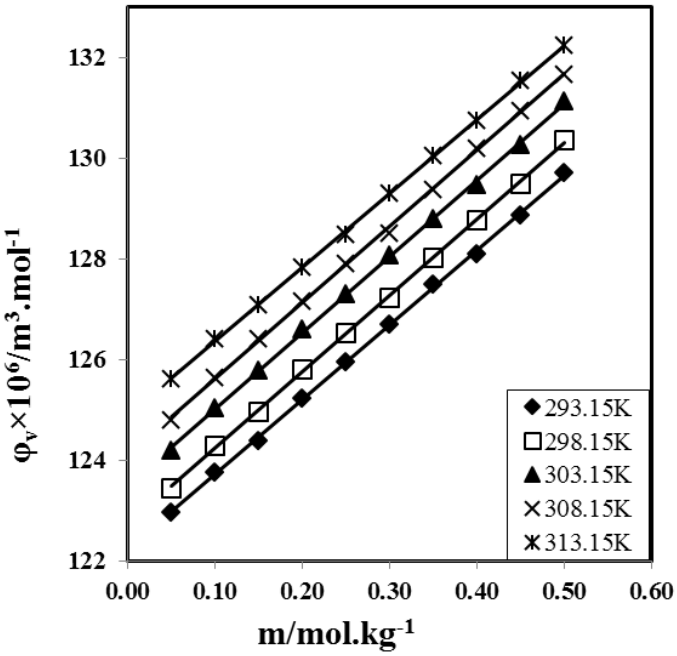


Figure 4.19: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-arginine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

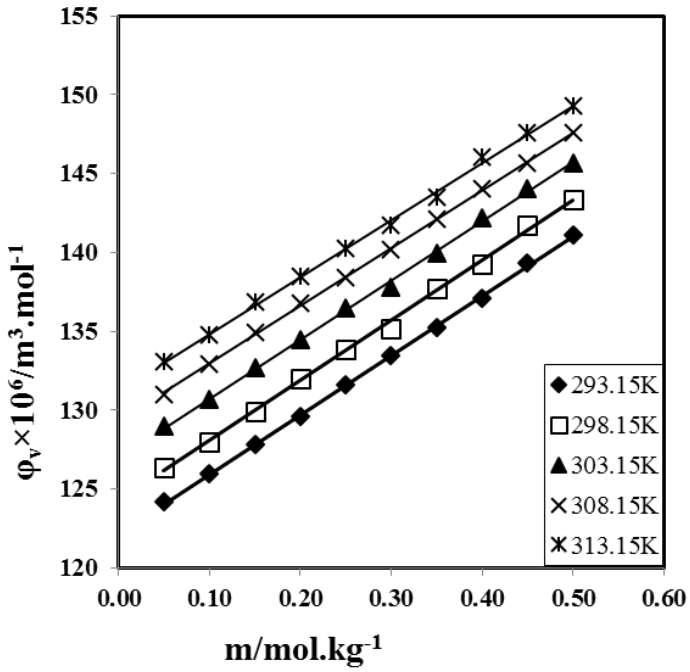


Figure 4.20: Plots of Apparent molar volume (φ_v) vs. Molality (m) of L-arginine + 0.50 mol.kg-^{1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

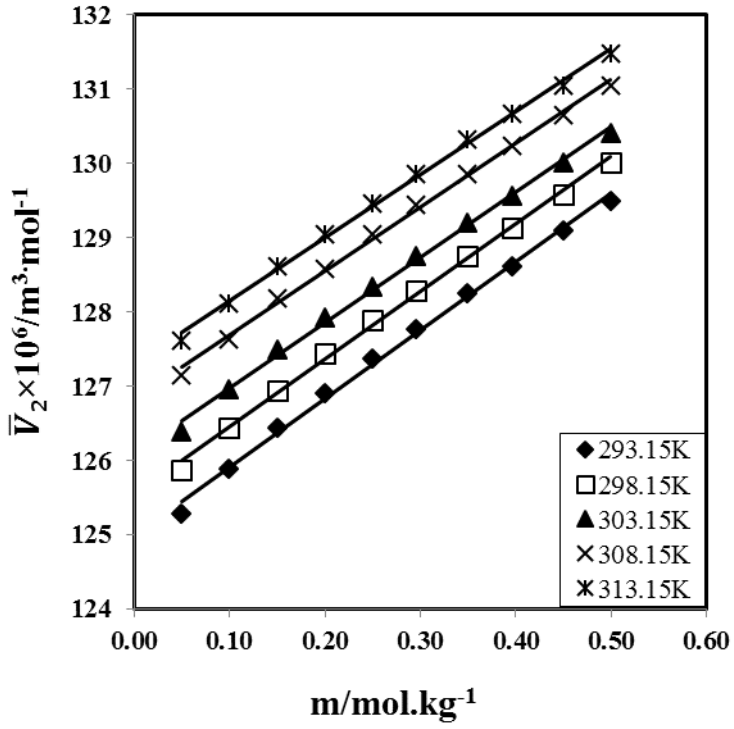


Figure 4.21: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-lysine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

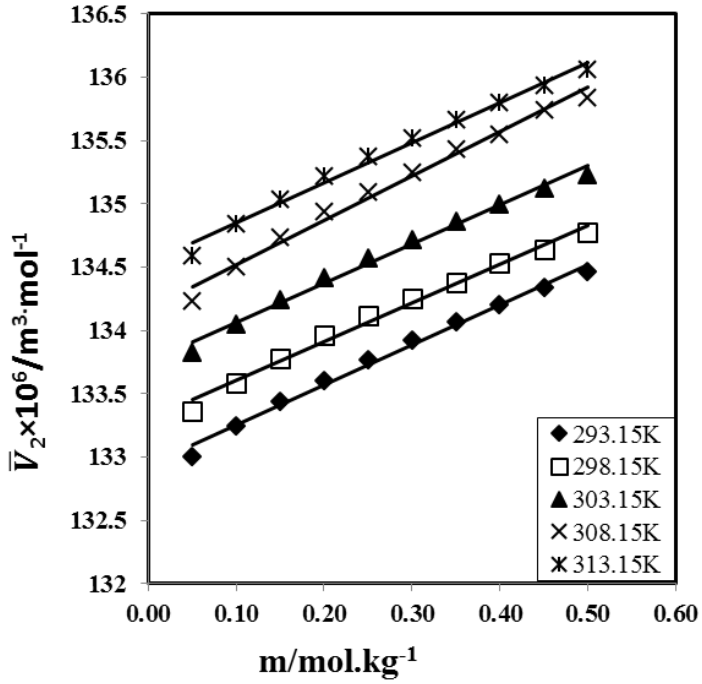


Figure 4.22: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) L-arginine system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

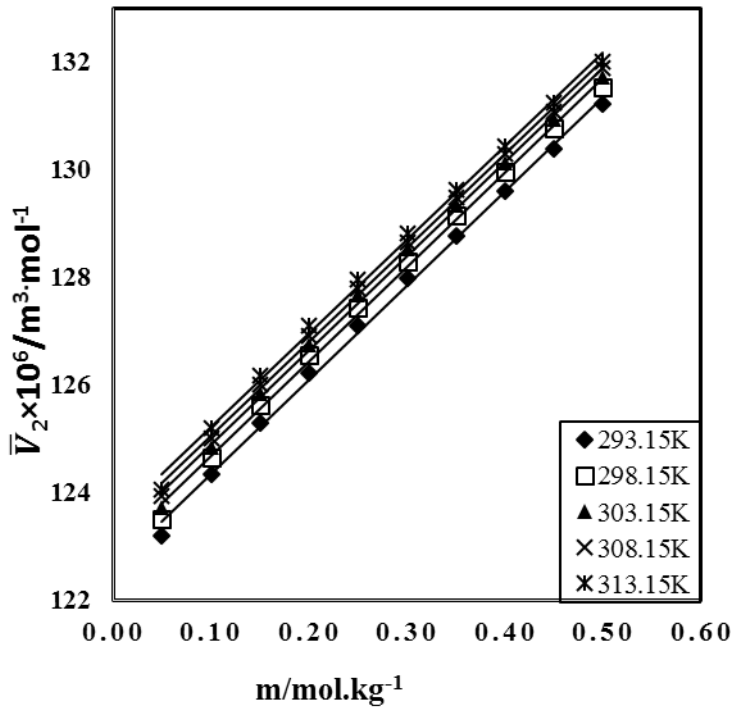


Figure 4.23: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-lysine+ 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

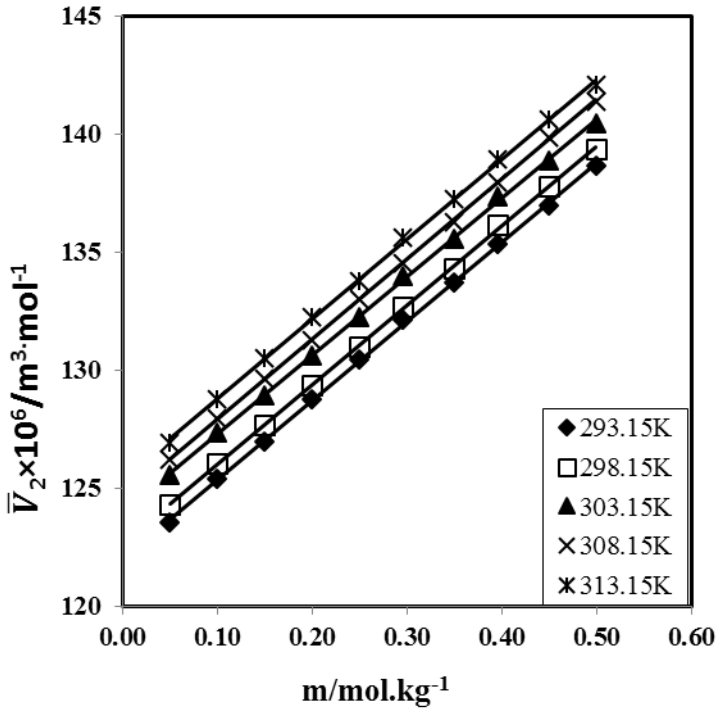


Figure 4.24: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-lysine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

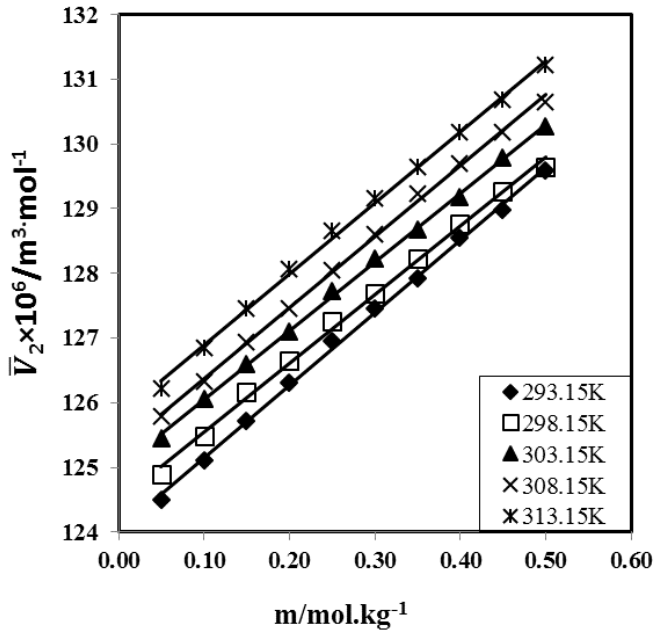


Figure 4.25: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-lysine+ 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

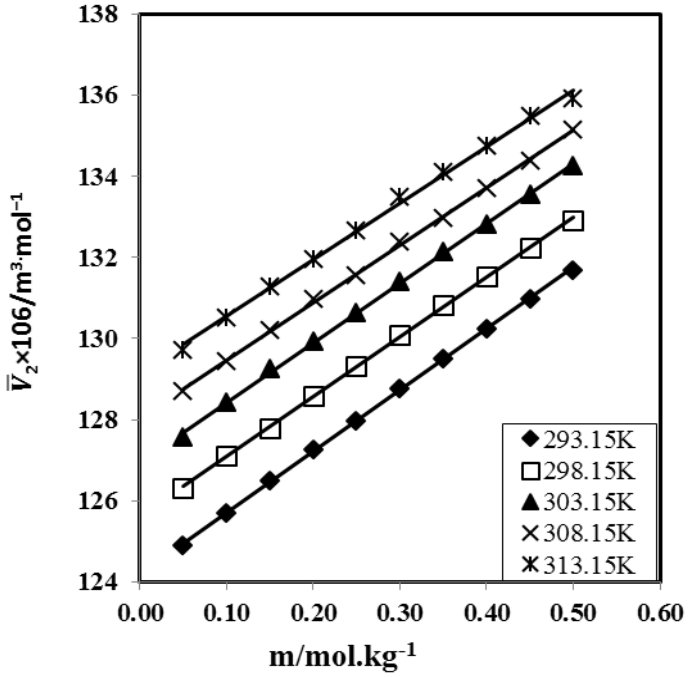


Figure 4.26: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-lysine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

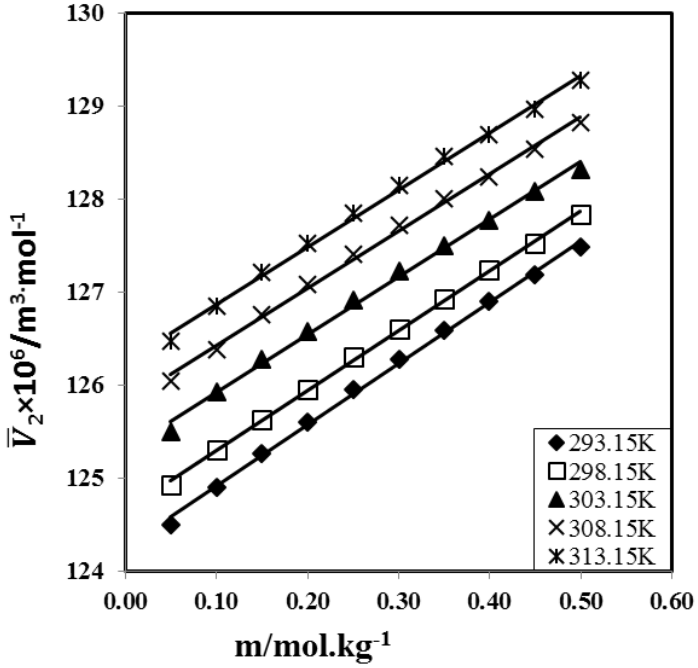


Figure 4.27: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-arginine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

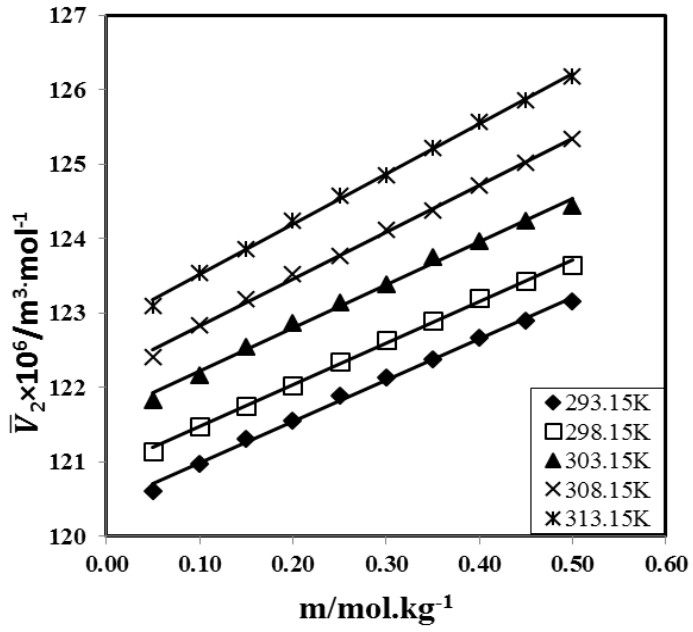


Figure 4.28: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-asparagine + 0.2 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

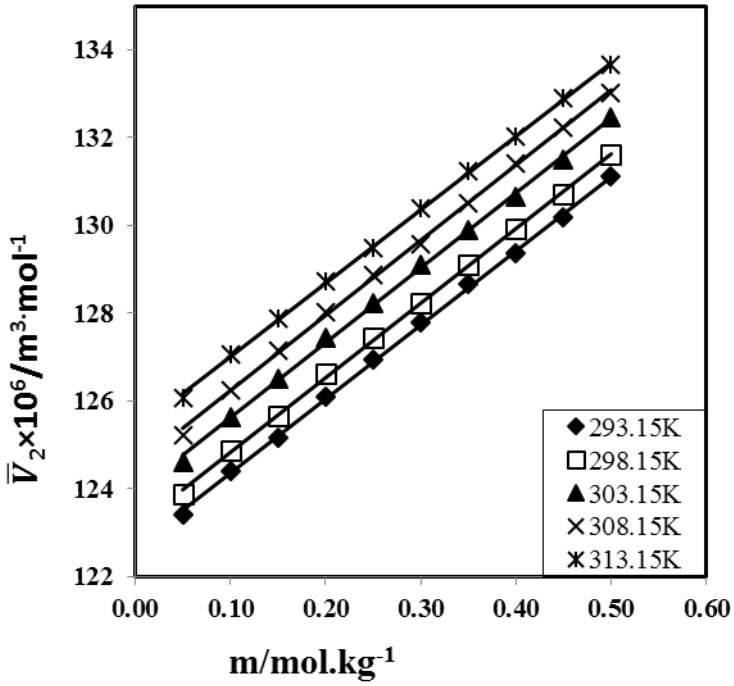


Figure 4.29: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-arginine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

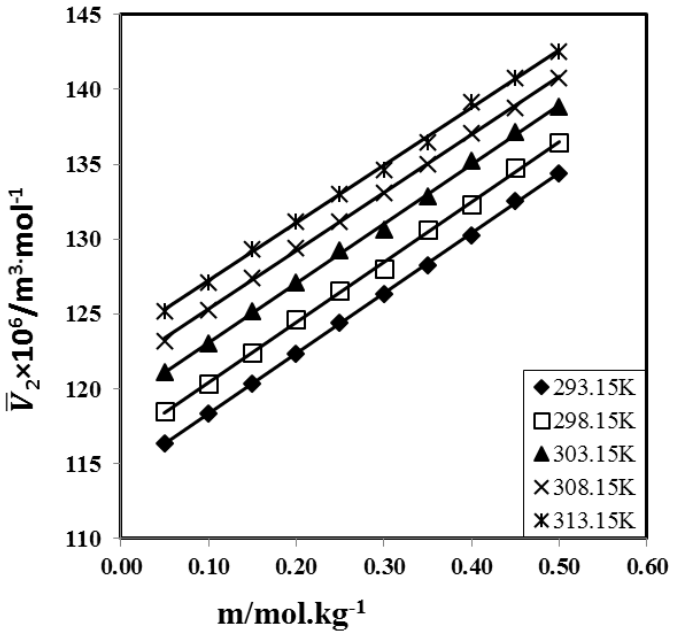


Figure 4.30: Plots of Partial molar volume ($\bar{V}_2$) vs. Molality (m) of L-arginine + 0.5 mol.kg^{-1} SB in water systems at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

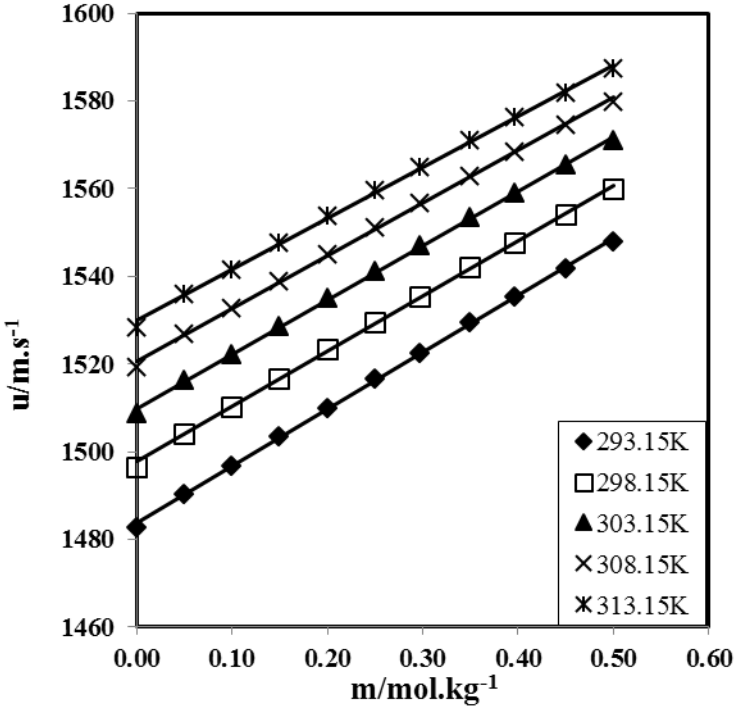


Figure 4.31**:** Plots of Sound velocity (u) vs. Molality (m) of L-lysine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

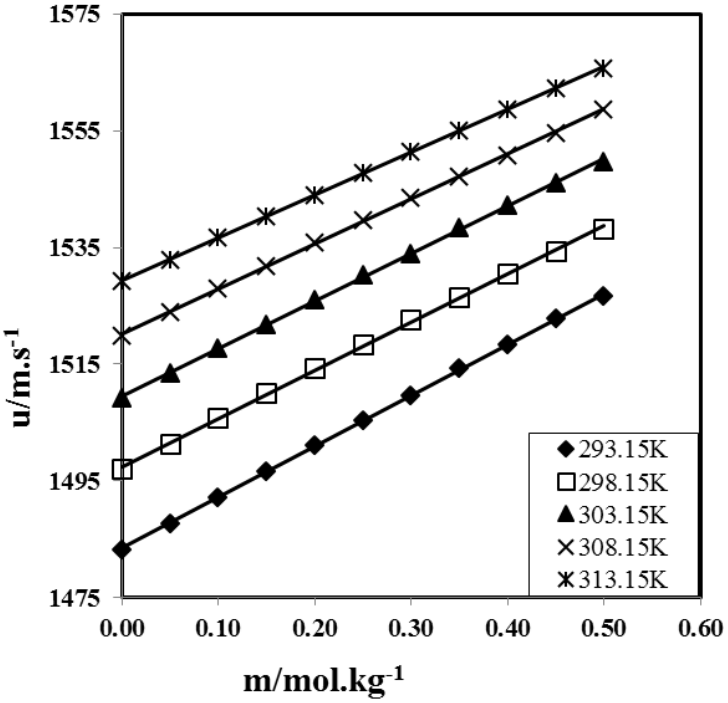


Figure 4.32: Plots of Sound velocity (u) vs. Molality (m) of L-arginine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

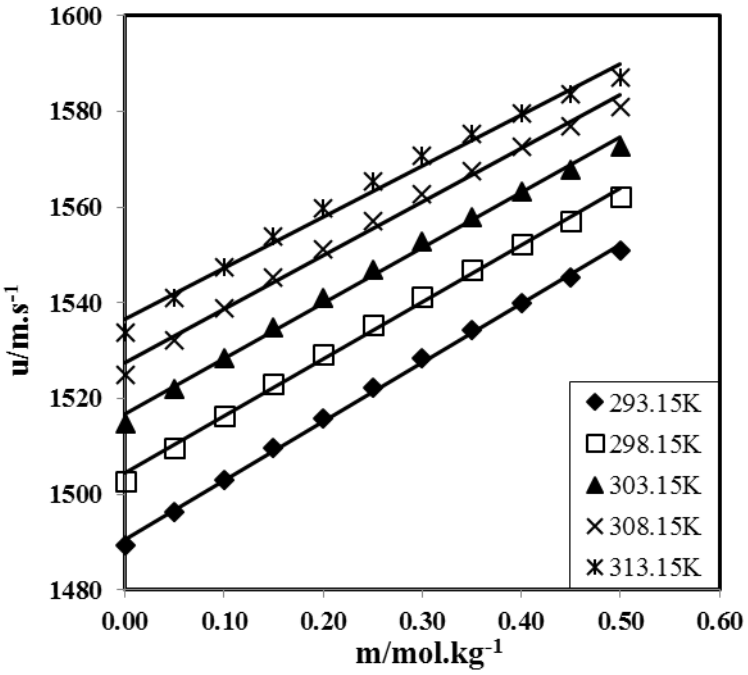


Figure 4.33: Plots of Sound velocity (u) vs. Molality (m) of L-lysine + 0.05 mol.kg^{-1}SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

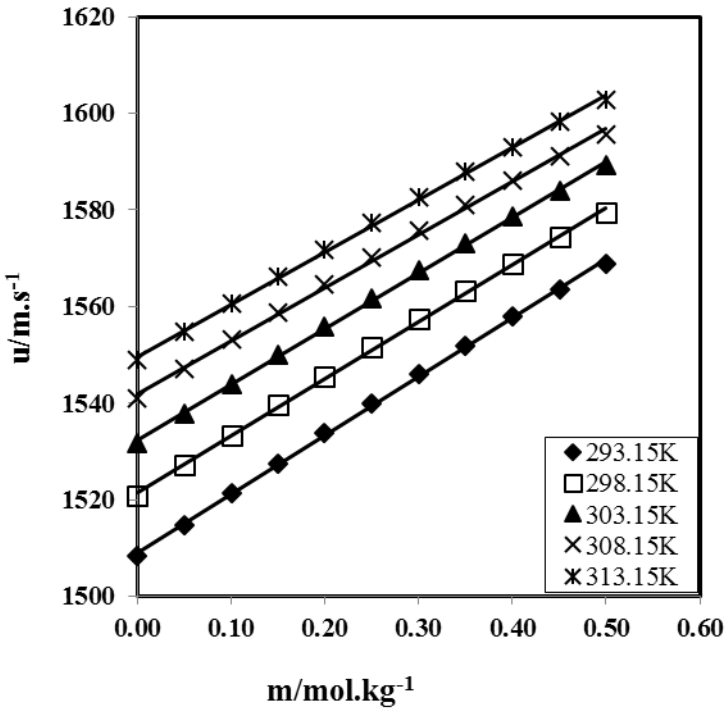


Figure 4.34: Plots of Sound velocity (u) vs. Molality (m) of L-lysine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively

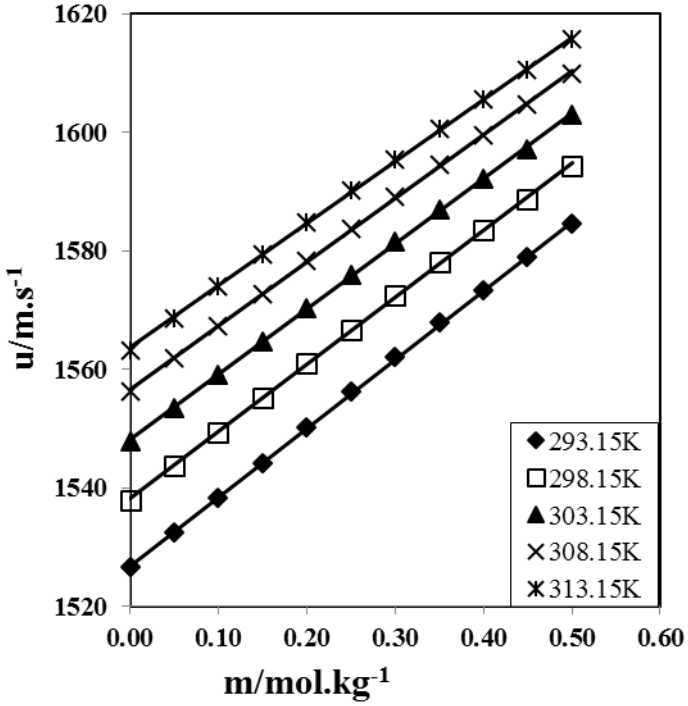


Figure 4.35: Plots of Sound velocity (u) vs. Molality (m) of L-lysine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

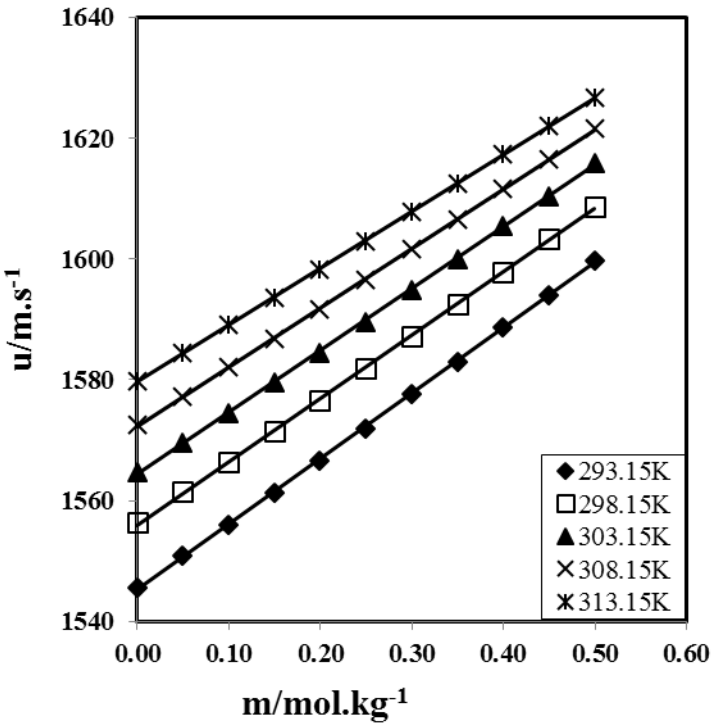


Figure 4.36: Plots of Sound velocity (u) vs. Molality (m) of L-lysine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

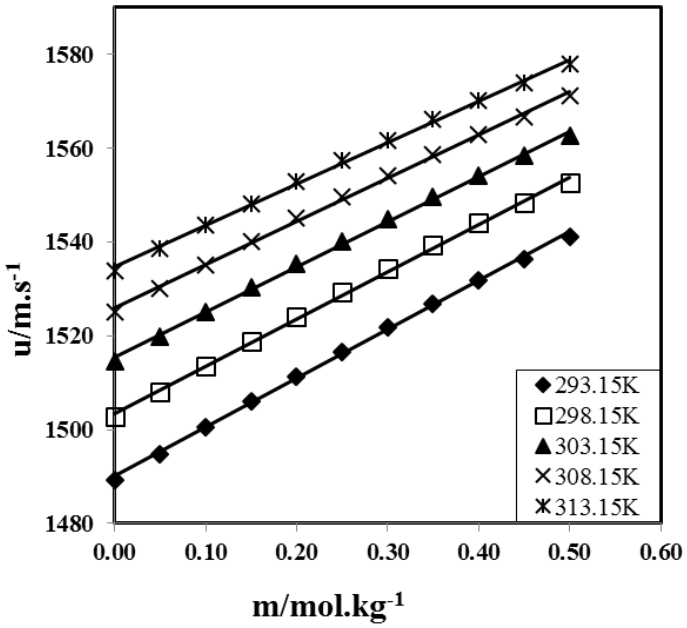


Figure 4.37: Plots of Sound velocity (u) vs. Molality (m) of L-arginine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

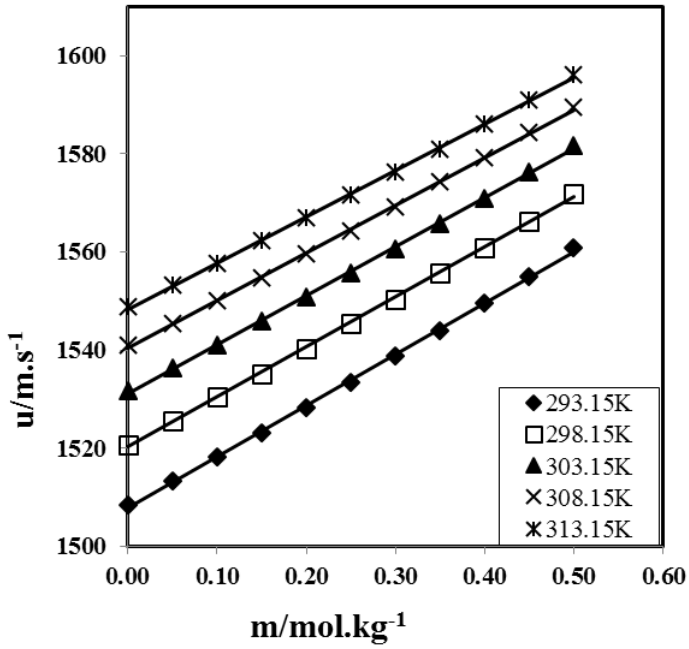


Figure 4.38: Plots of Sound velocity (u) vs. Molality (m) of L-arginine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

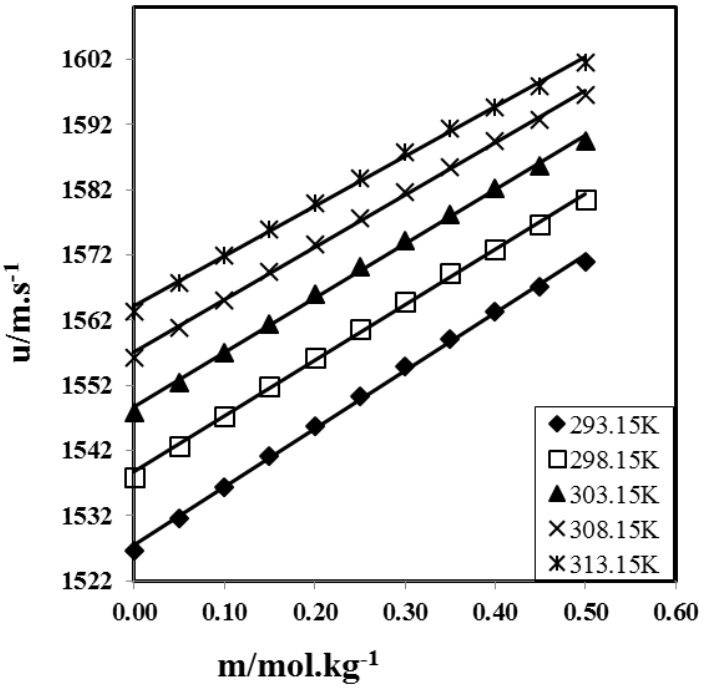


Figure 4.39: Plots of Sound velocity (u) vs. Molality (m) of L-arginine + 0.35 $mol.kg^{-1}$ SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

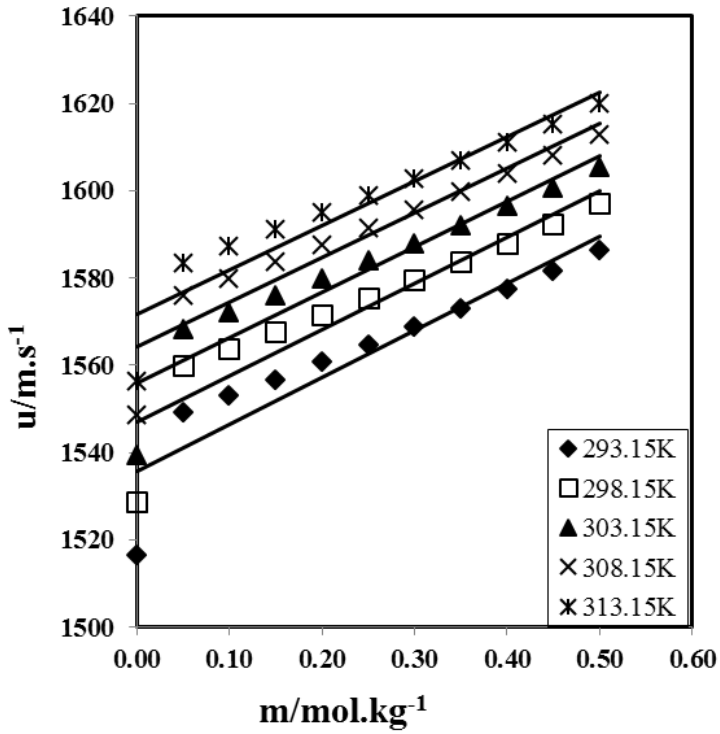


Figure 4.40: Plots of Sound velocity (u) vs. Molality (m) of L-arginine + 0.50 $mol.kg^{-1}$ SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

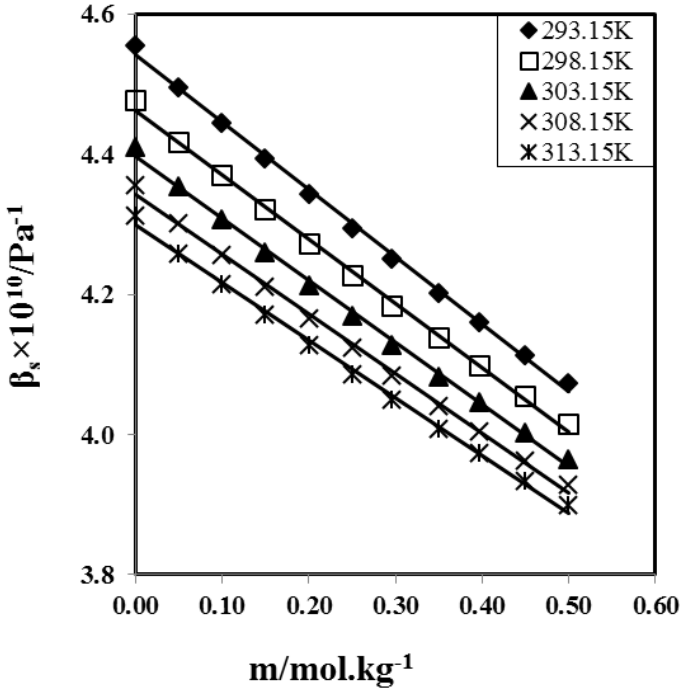


Figure 4.41**:** Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-lysine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

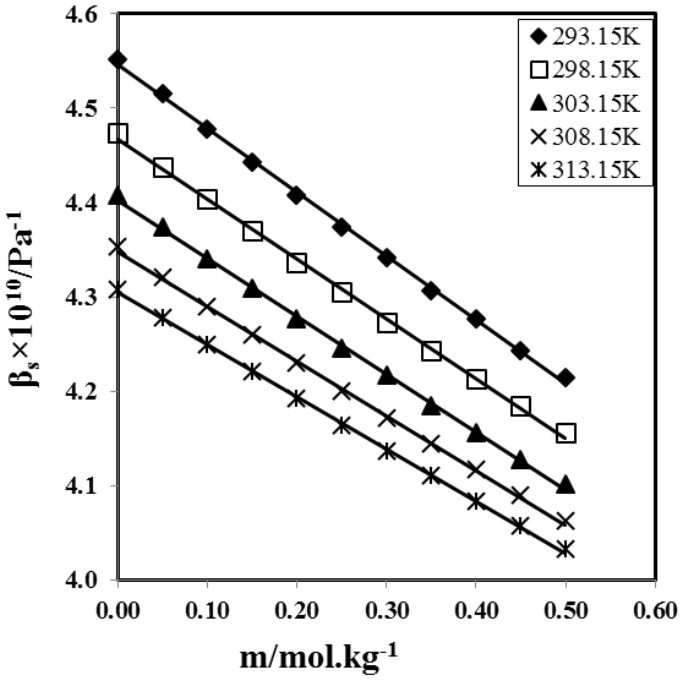


Figure 4.42: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-arginine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

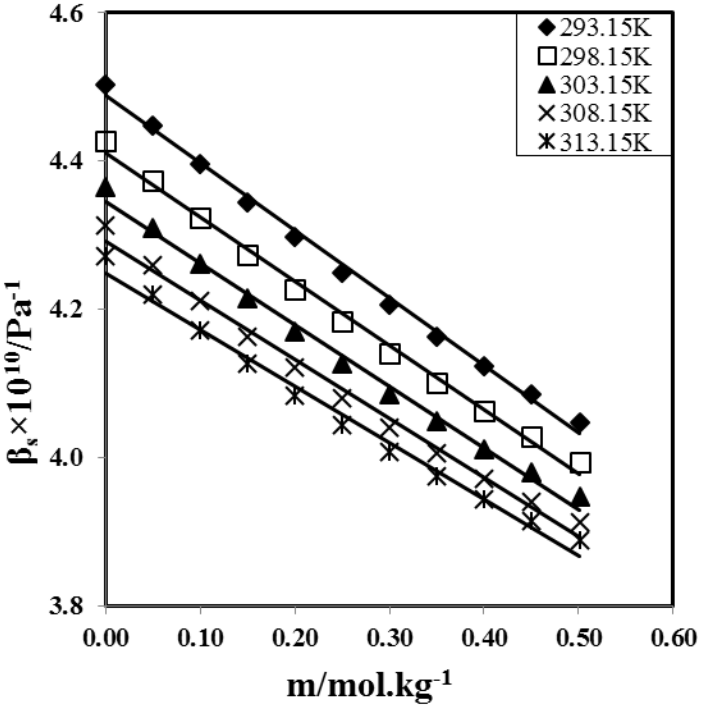


Figure 4.43: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-lysine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

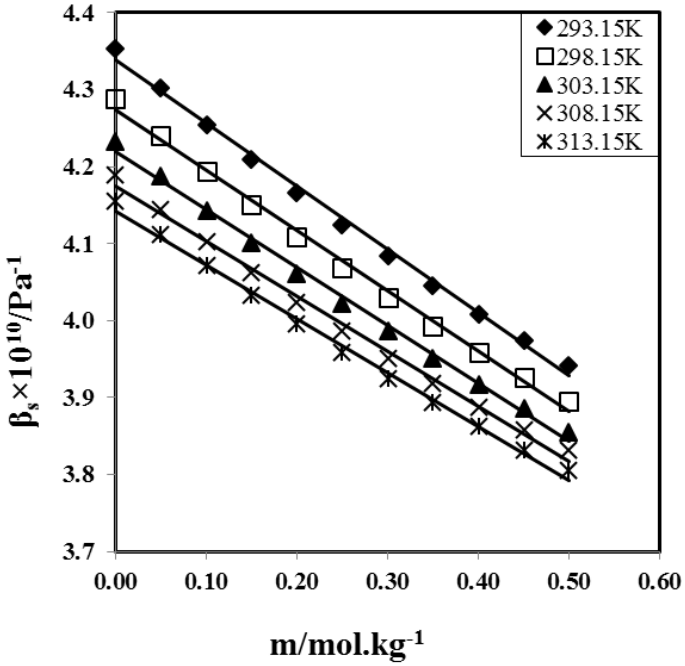


Figure 4.44: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-lysine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

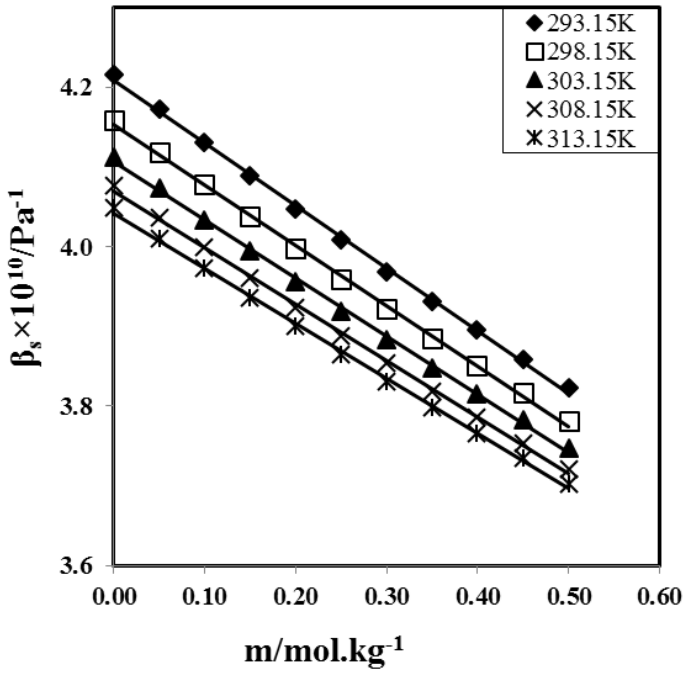


Figure 4.45: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-lysine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

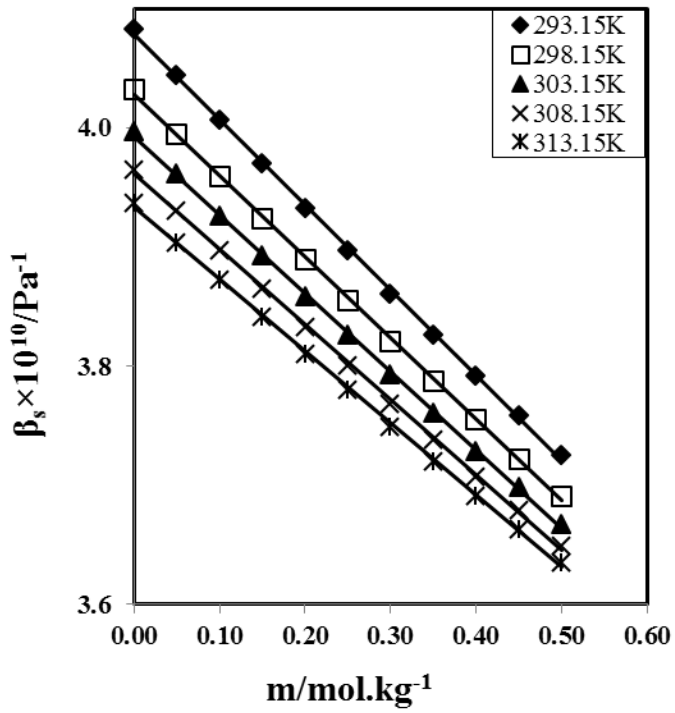


Figure 4.46: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-lysine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

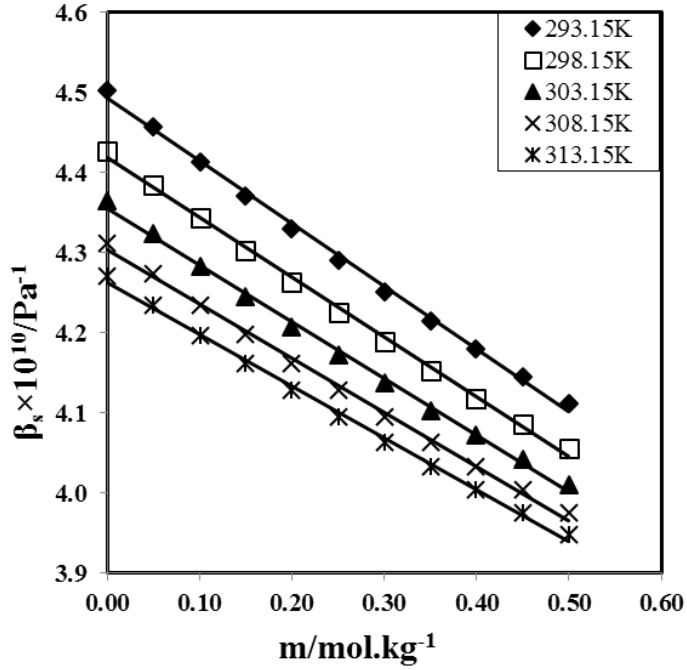


Figure 4.47: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-asparagine + 0.05 mol.kg-^{1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

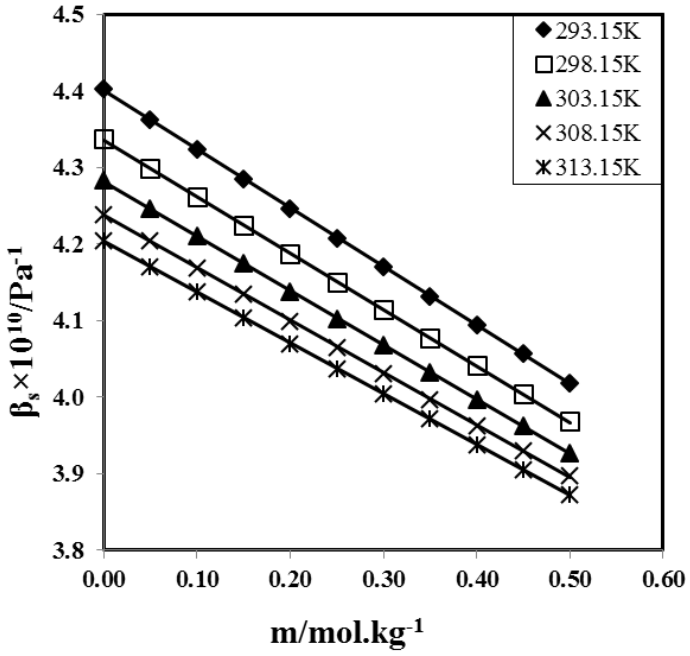


Figure 4.48: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-arginine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

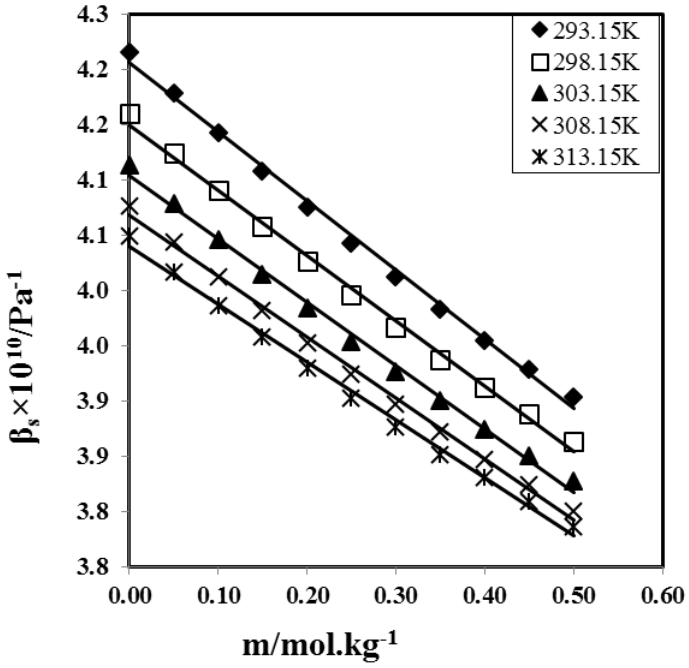


Figure 4.49: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-arginine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively

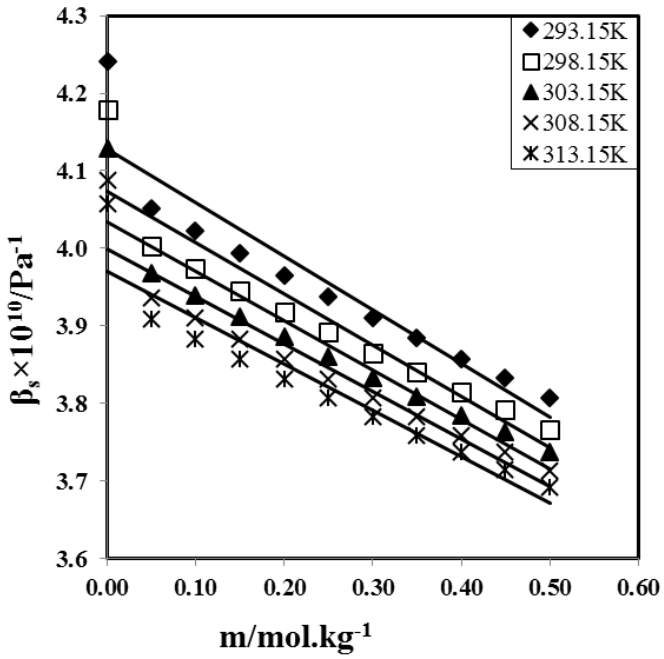


Figure 4.50: Plots of Adiabatic compressibility (β_s) vs. Molality (m) of L-arginine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively

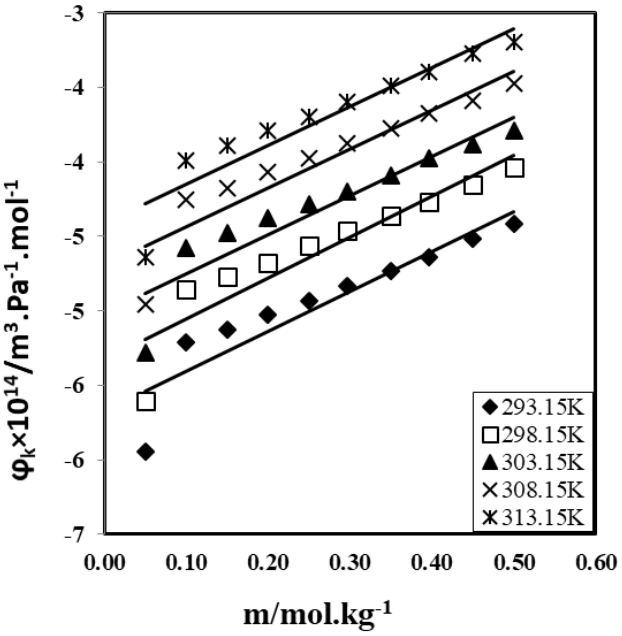


Figure 4.51**:** Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-lysine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

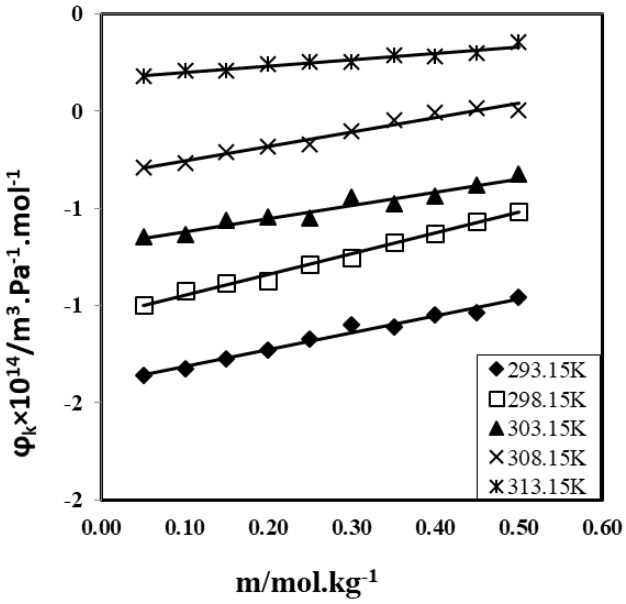


Figure 4.52: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-arginine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

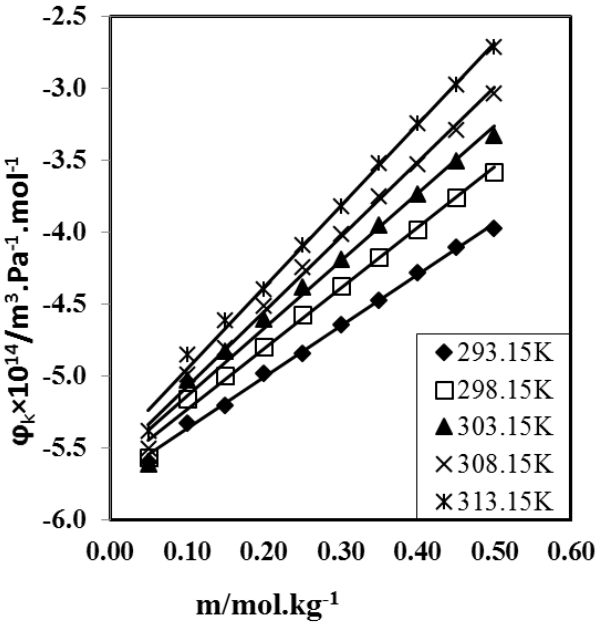


Figure 4.53: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-lysine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

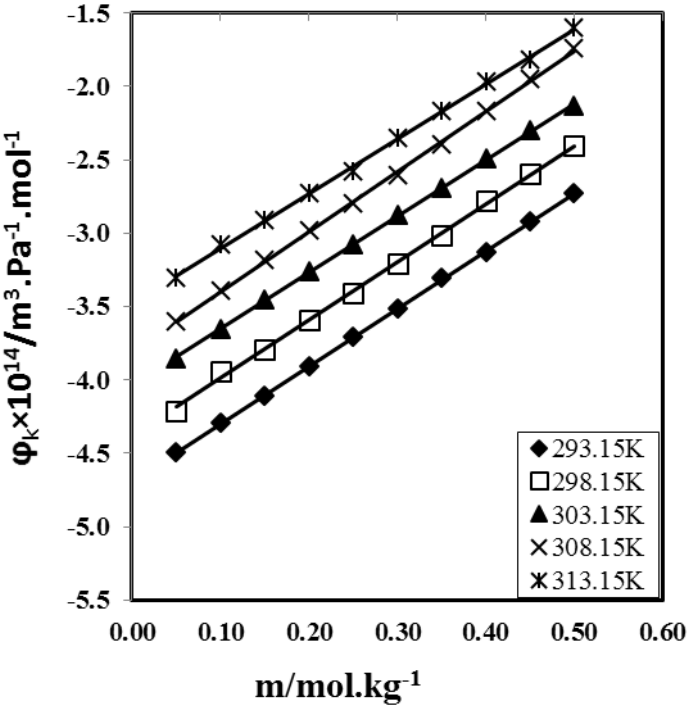


Figure 4.54: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-lysine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

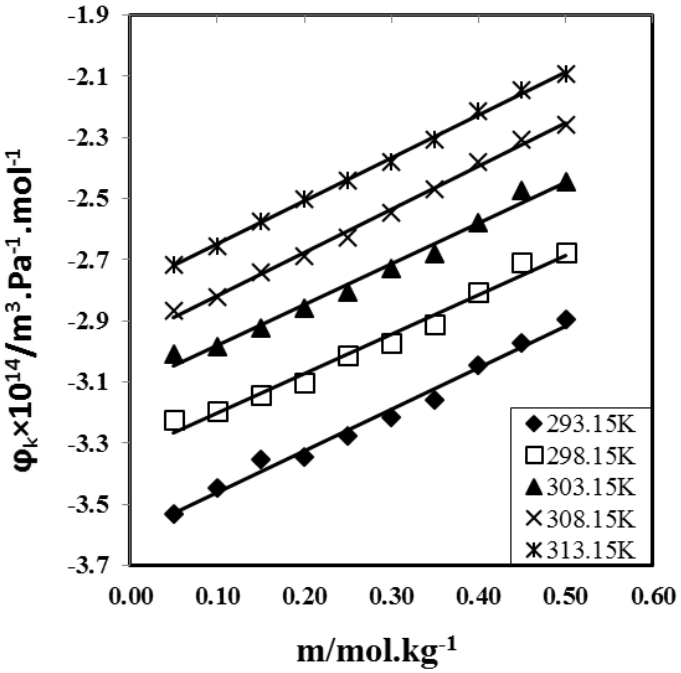


Figure 4.55: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-lysine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

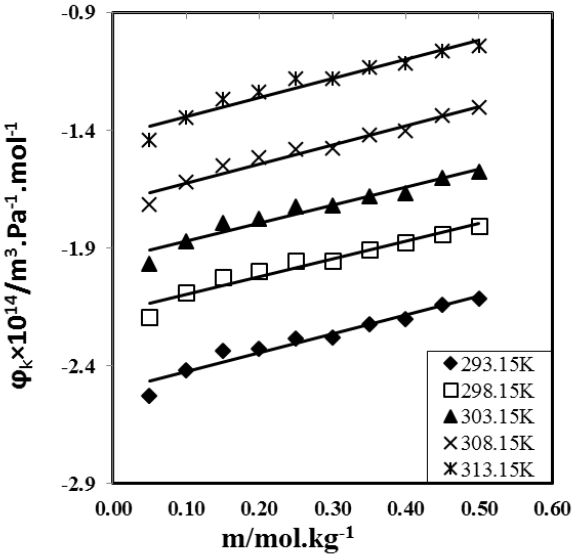


Figure 4.56: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-lysine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

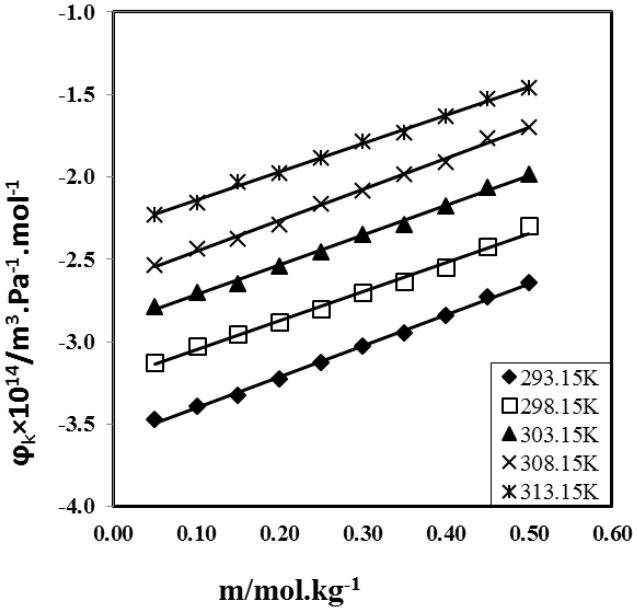


Figure 4.57: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-arginine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

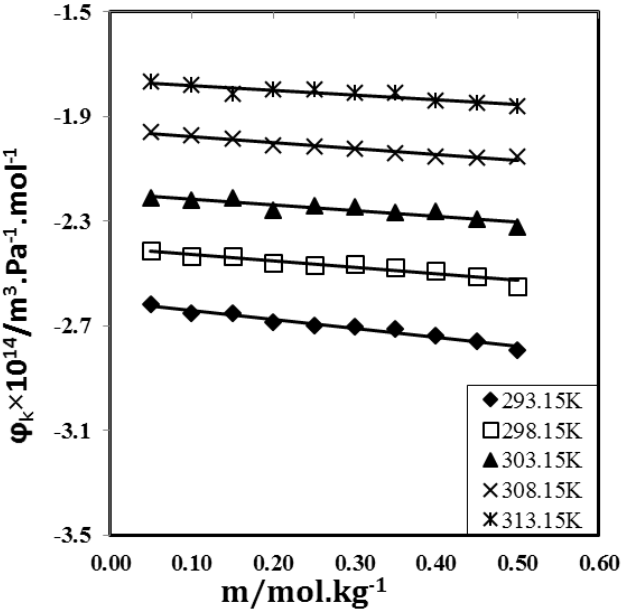


Figure 4.58: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-arginine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

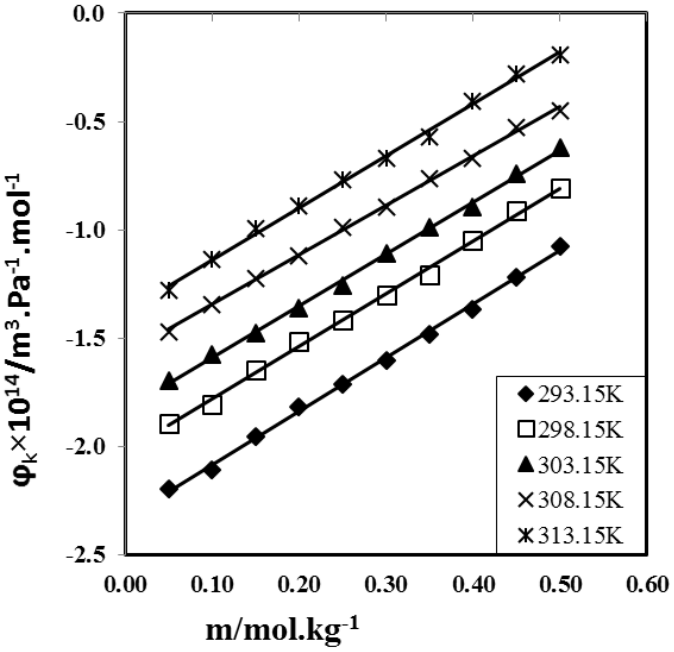


Figure 4.59: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-arginine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

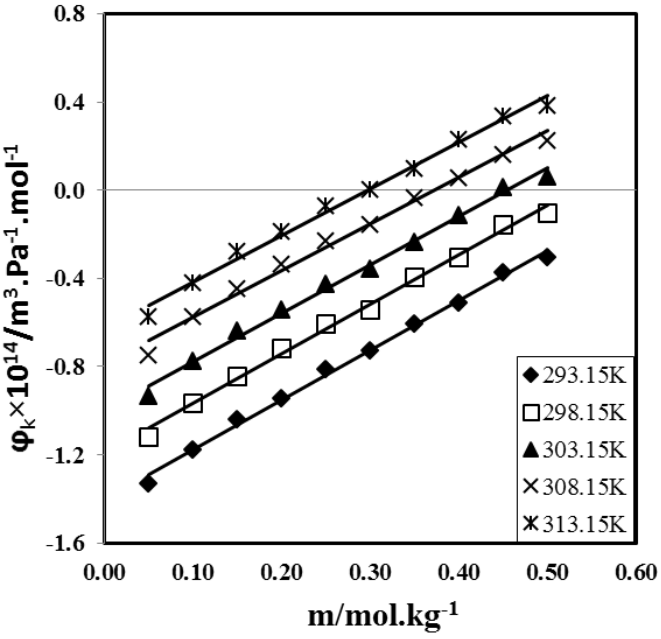


Figure 4.60: Plots of Apparent molar adiabatic compressibility (φ_k) vs. Molality (m) of L-arginine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

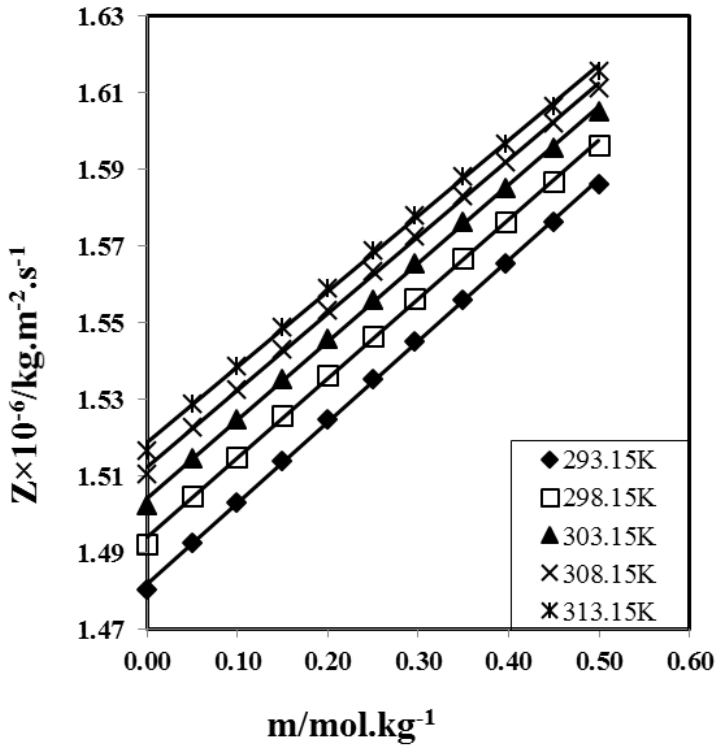


Figure 4.61**:** Plots of Acoustic impedance (Z) vs. Molality (m) of L-lysine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

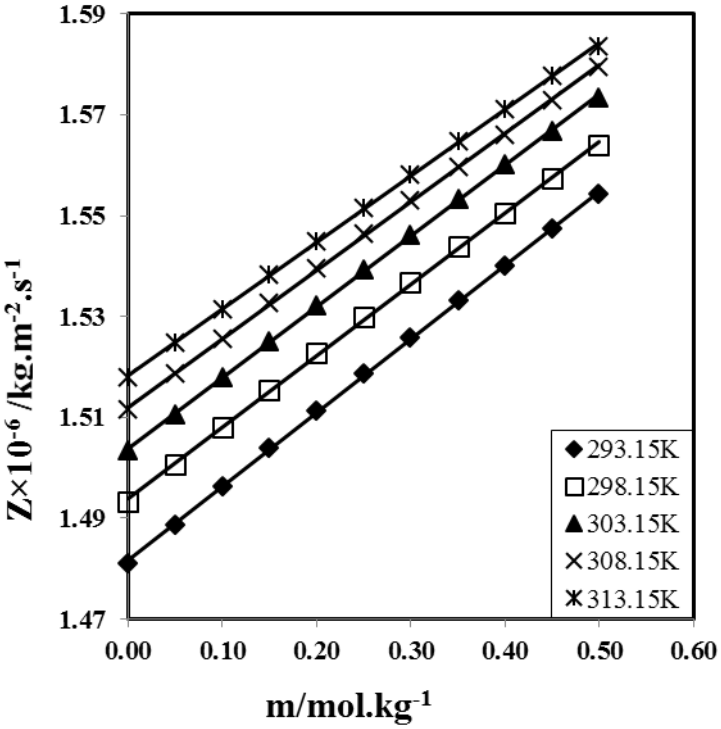


Figure 4.62: Plots of Acoustic impedance (Z) vs. Molality (m) of L-arginine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

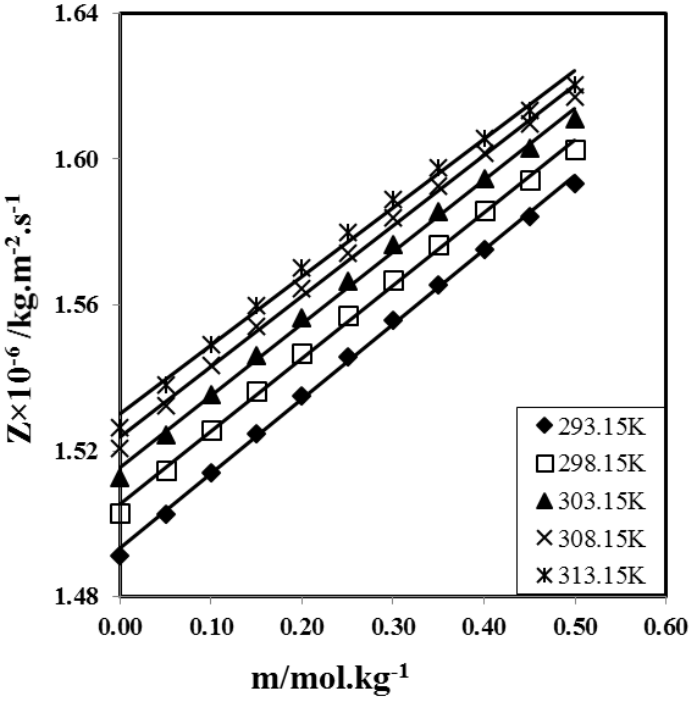


Figure 4.63: Plots of Acoustic impedance (Z) vs. Molality (m) of L-lysine+ 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

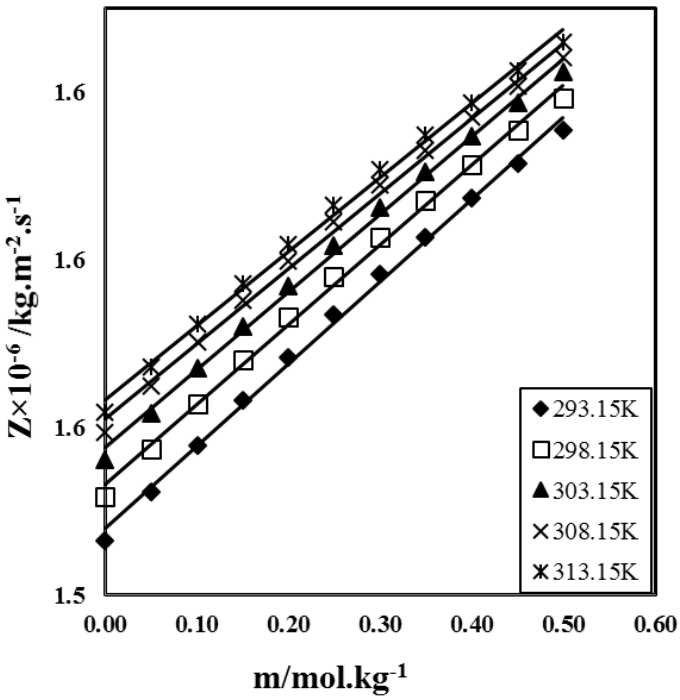


Figure 4.64: Plots of Acoustic impedance (Z) vs. Molality (m) of L-lysine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

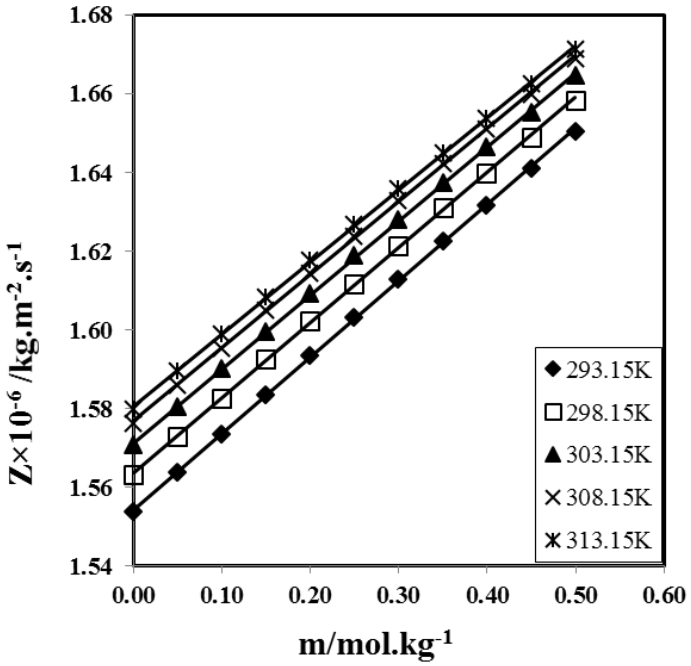


Figure 4.65: Plots of Acoustic impedance (Z) vs. Molality (m) of L-lysine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

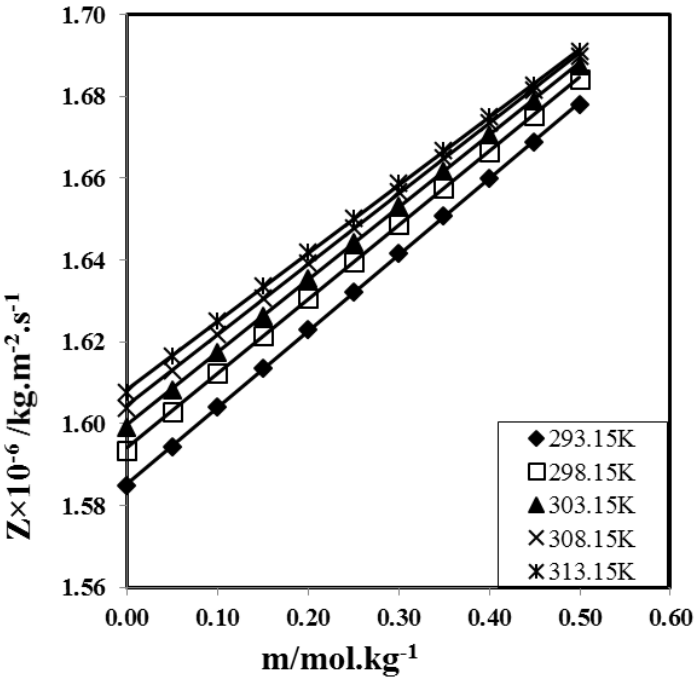


Figure 4.66: Plots of Acoustic impedance (Z) vs. Molality (m) of L-lysine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

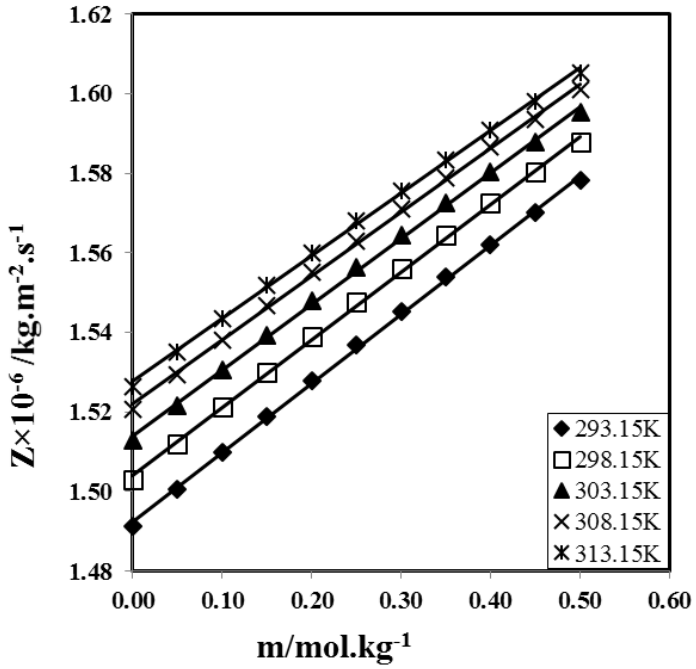


Figure 4.67: Plots of Acoustic impedance (Z) vs. Molality (m) of L-arginine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

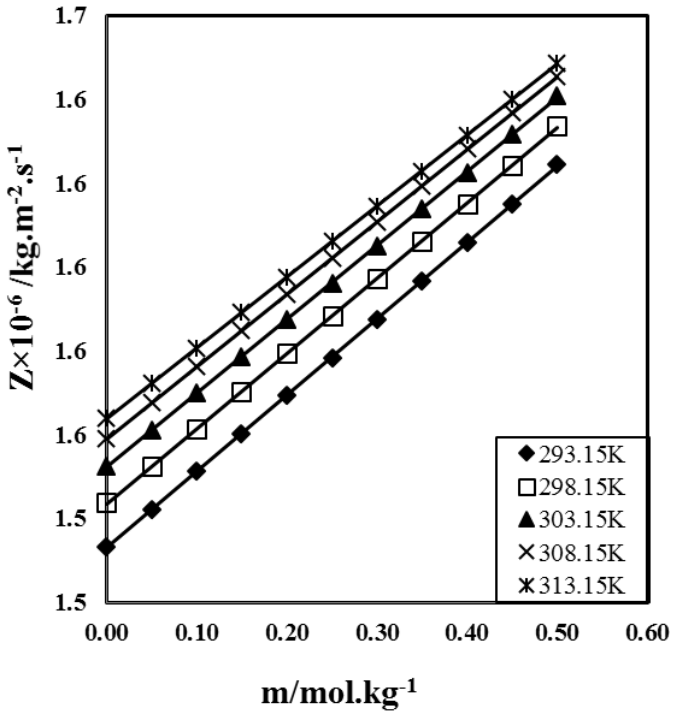


Figure 4.68: Plots of Acoustic impedance (Z) vs. Molality (m) of L-arginine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

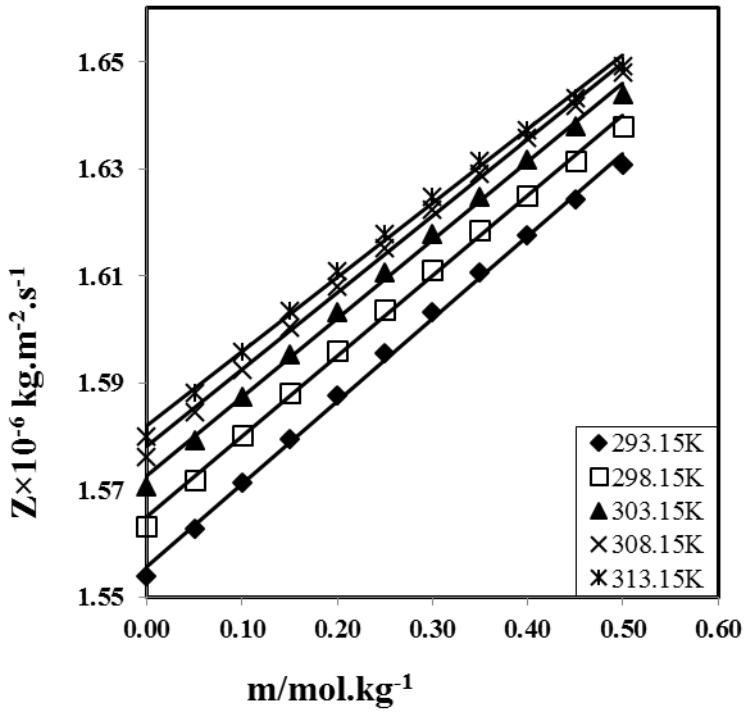


Figure 4.69: Plots of Acoustic impedance (Z) vs. Molality (m) of L-arginine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

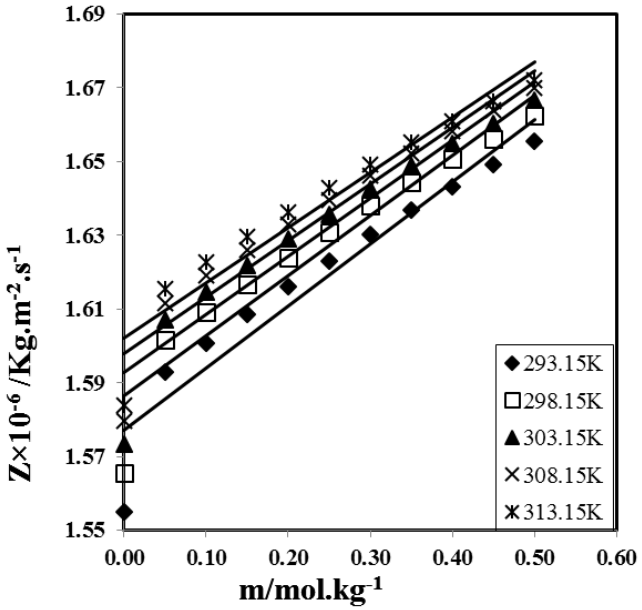


Figure 4.70: Plots of Acoustic impedance (Z) vs. Molality (m) of L-arginine + 0.5 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

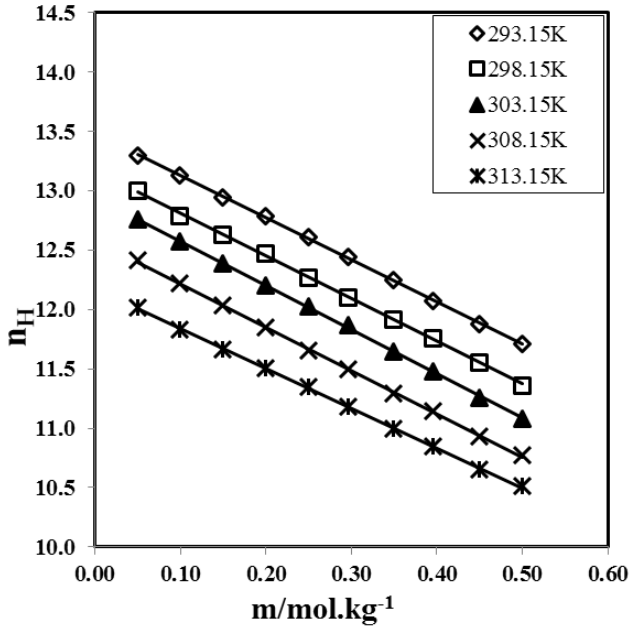


Figure 4.71**:** Plots of Hydration number (n_H) vs. Molality (m) of L-lysine in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

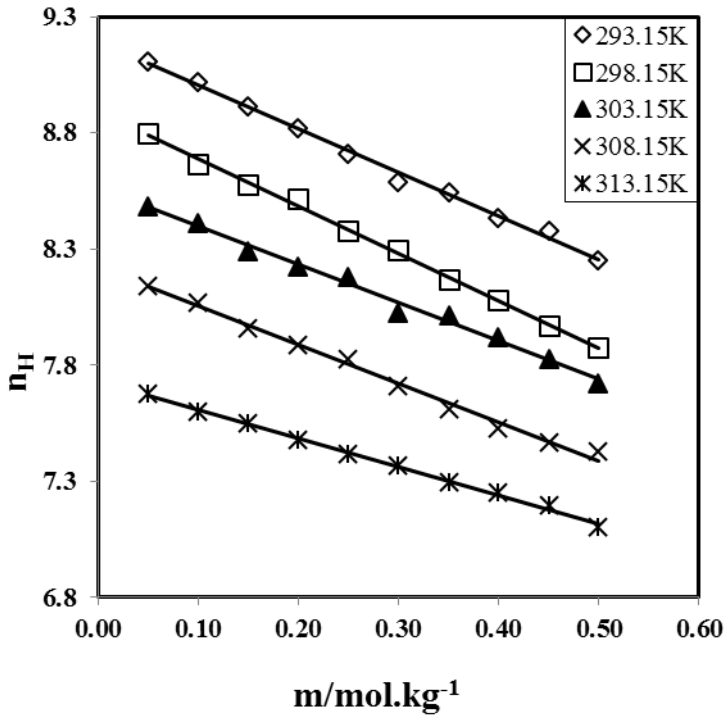


Figure 4.72**:** Plots of Hydration number (n_H) vs. Molality (m) of L-arginine + water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

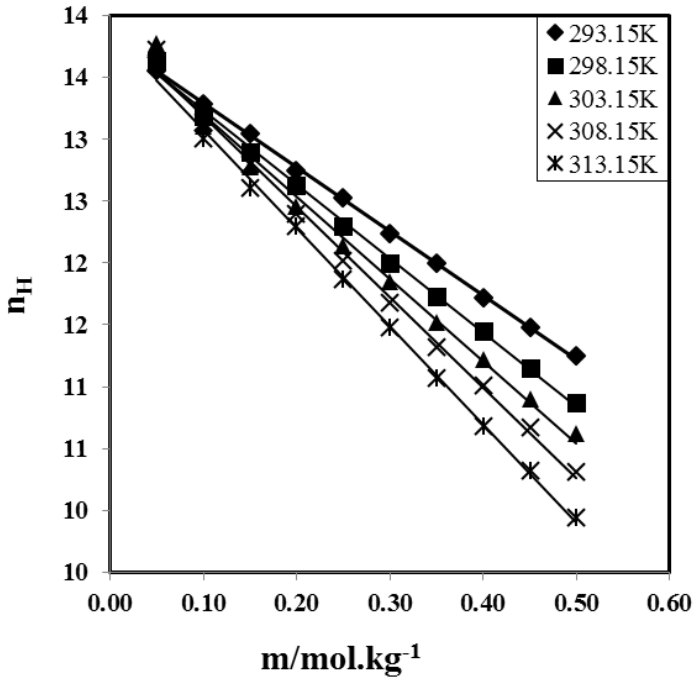


Figure 4.73: Plots of Hydration number (n_H) vs. Molality (m) of L-lysine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

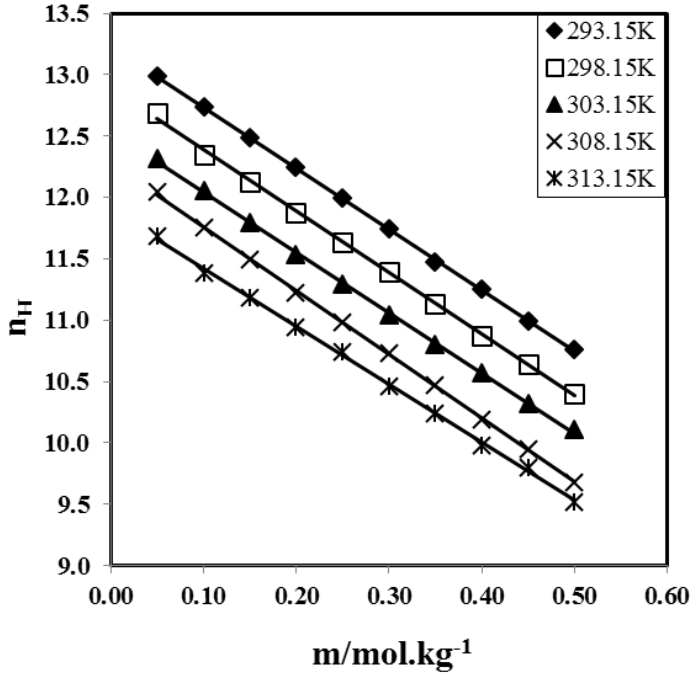


Figure 4.74: Plots of Hydration number (n_H) vs. Molality (m) of L-lysine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

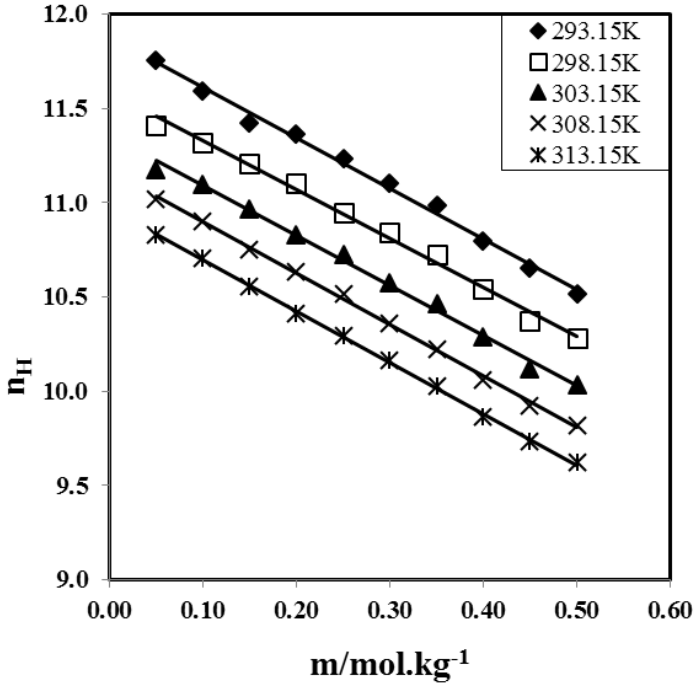


Figure 4.75: Plots of Hydration number (n_H) vs. Molality (m) of L-lysine+ 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

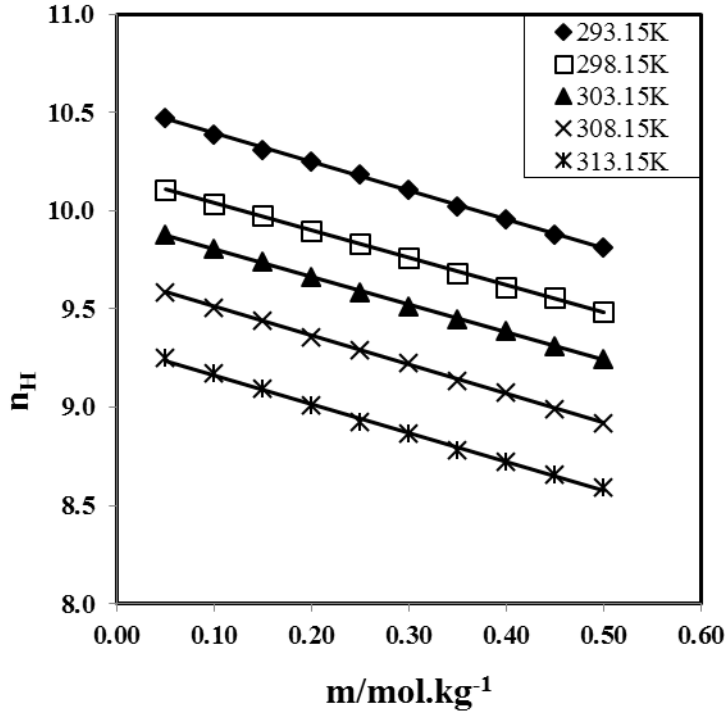


Figure 4.76: Plots of Hydration number (n_H) vs. Molality (m) of L-lysine + 0.50 mol.kg^{1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

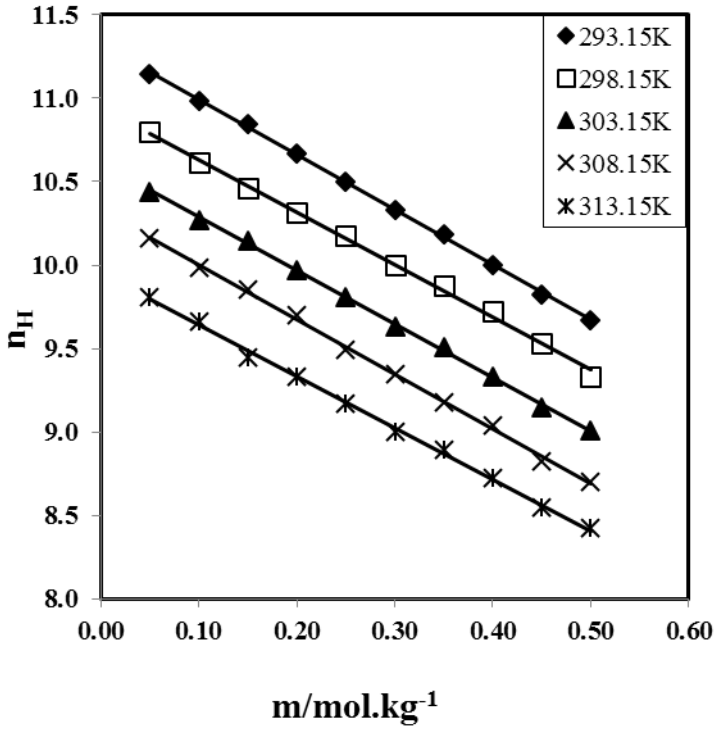


Figure 4.77: Plots of Hydration number (n_H) vs. Molality (m) of L-arginine + 0.05 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

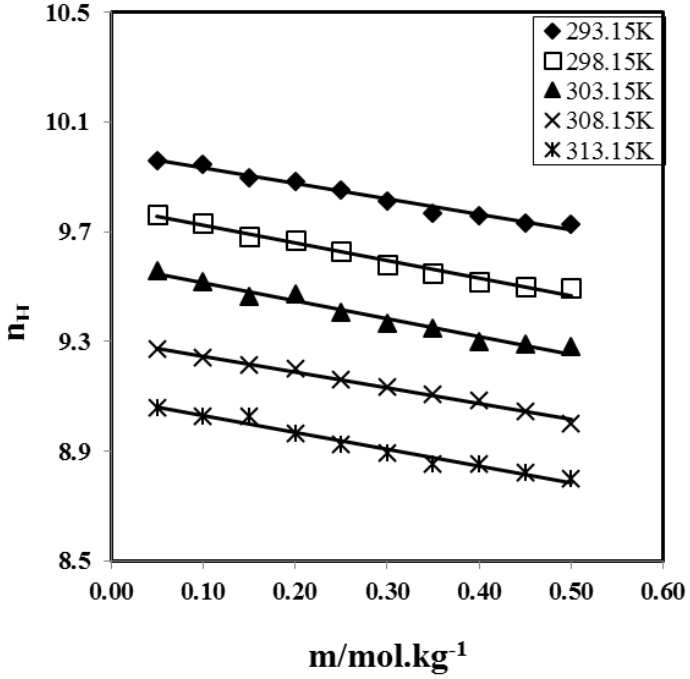


Figure 4.78: Plots of Hydration number (n_H) vs. Molality (m) of L-arginine + 0.20 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

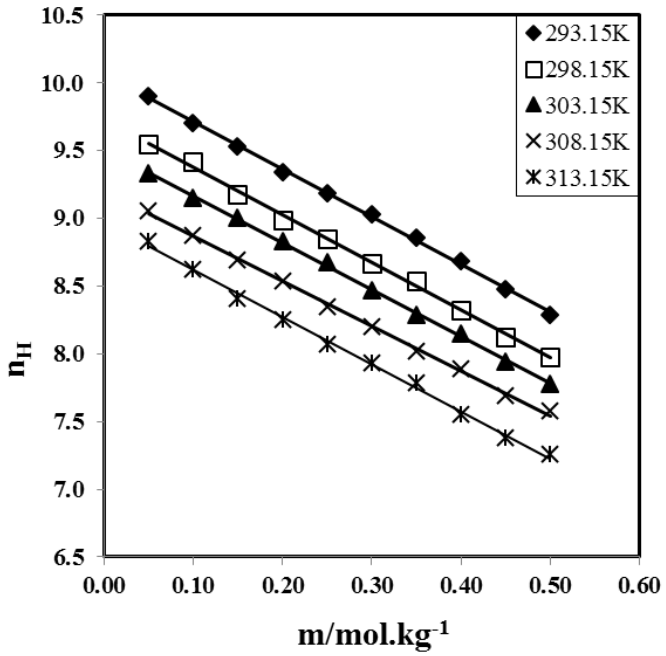


Figure 4.79: Plots of Hydration number (n_H) vs. Molality (m) of L-arginine + 0.35 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

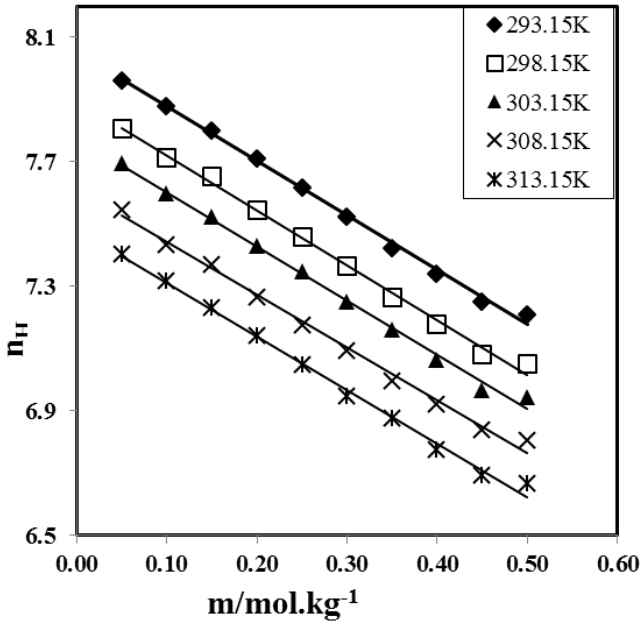


Figure 4.80: Plots of Hydration number (n_H) vs. Molality (m) of L-arginine + 0.50 mol.kg^{-1} SB in water system at 293.15K, 298.15K, 303.15K, 308.15K and 313.15K respectively.

CHAPTER V

Conclusion

Volumetric and sound velocity studies of L-lysine and L-arginine in water and in aqueous Sodium benzoate (0.05, 0.20, 0.35 and 0.50 $mol.kg^{-1}$) solutions have been carried out in the temperature range 293.15K to 313.15K with an interval of 5K. The densities increase with the increasing of concentration of amino acids and decrease with increasing of temperature. Sound velocity also increases with increasing of concentration of amino acids and temperature.

Apparent molar properties, limiting apparent molar properties and compressibility studies indicate the presence of strong solute-solvent interaction in the binary and ternary systems. The extent of interactions increases with increase in the concentration of SB solution. The Hepler's constant ($\delta^2\varphi_v^0/\delta T^2$) values suggest the structure making property of amino acids in water and SB solution. Hydrophilic-hydrophilic or hydrophilic-ionic interactions are dominating for L-lysine whereas hydrophobic-hydrophobic interactions are dominating for L-arginine in binary and ternary systems. The decrease of hydration number at higher concentrations of amino acids suggests that the strength of interaction gets weakened between the solute and water molecules. It also suggests that compressibility of the solution is less than that of pure solvent. From the above experimental results we can conclude:

- The densities and sound velocities of ternary solution are higher than binary solution.
- Strong interactions are happened in L-lysine and L-arginine with aqueous SB solution.
- For L-lysine, hydrophilic-hydrophilic and ion-hydrophilic interaction are dominating over hydrophobic-hydrophobic interaction. Hydrophobic-hydrophobic interactions are dominating for L-arginine.
- The water molecules around amino acids are less compressible than water molecules in the bulk solution.
- The true volume (φ_v^0) of amino acids in water and aqueous SB solution are found to be order of L-arginine > L-lysine.
- Positive values of hydration number indicate an appreciable solvation of solute.

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