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Theoretical Prediction Of Activity Coefficients in Non-Ideal Solutions Using Sound Velocity

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Abstract

The prediction of activity coefficients in non-ideal liquid solutions is essential for understanding molecular interactions and phase behavior. Traditional thermodynamic methods often rely on extensive experimental data, whereas acoustic techniques provide a simpler and non-destructive alternative. This study evaluates the theoretical prediction of activity coefficients using sound velocity as a key parameter. By analyzing the relationship between ultrasonic velocity, density, and compressibility, activity coefficients can be indirectly estimated for multicomponent systems. Secondary data from literature are used to establish correlations between acoustic properties and thermodynamic behavior. The findings indicate that sound velocity increases with stronger intermolecular interactions, which correspond to higher deviations from ideality and larger activity coefficients. The study demonstrates that acoustic methods can effectively predict thermodynamic properties and provide insight into molecular association in non-ideal systems. These findings have significant implications for chemical process design and industrial applications.

Keywords: Activity coefficient, sound velocity, non-ideal solutions, ultrasonic studies, thermodynamics, intermolecular interactions

Introduction

The study of non-ideal liquid solutions is a central aspect of chemical thermodynamics, as most real systems deviate from ideal behavior due to intermolecular interactions. In such systems, activity coefficients are used to quantify deviations from ideality and provide insight into molecular interactions. Accurate prediction of activity coefficients is essential for understanding phase equilibria, chemical reactions, and separation processes in industries such as pharmaceuticals, petrochemicals, and food processing.Traditional methods for determining activity coefficients involve experimental measurements such as vapor–liquid equilibrium or calorimetric analysis (Sandoval-Ibarra et al. 2021). While these methods are reliable, they are often time-consuming and require sophisticated equipment. In recent years, acoustic techniques, particularly the measurement of sound velocity, have emerged as a promising alternative for studying thermodynamic properties. Sound velocity in a liquid is directly related to its density and compressibility, both of which are influenced by intermolecular interactions. As a result, it serves as an indirect indicator of thermodynamic behavior.

The study of non-ideal liquid solutions is a fundamental aspect of chemical thermodynamics, as most practical systems exhibit deviations from ideal behavior due to intermolecular interactions. These deviations are quantitatively expressed through activity coefficients, which provide critical insight into molecular interactions, phase equilibria, and solution stability. In ideal solutions, activity coefficients are equal to unity, indicating uniform interactions among all molecular species (Patel and Singh,2019). However, in real systems, these values often range between 0.9 and 3.5 depending on the nature and strength of intermolecular forces.Traditional methods for determining activity coefficients, such as vapor–liquid equilibrium (VLE) measurements and calorimetric techniques, require extensive experimental setups and precise control of temperature and pressure. These methods, while accurate, are often time-consuming and resource intensive. As a result, there is growing interest in alternative approaches that can provide reliable thermodynamic predictions using easily measurable physical properties.

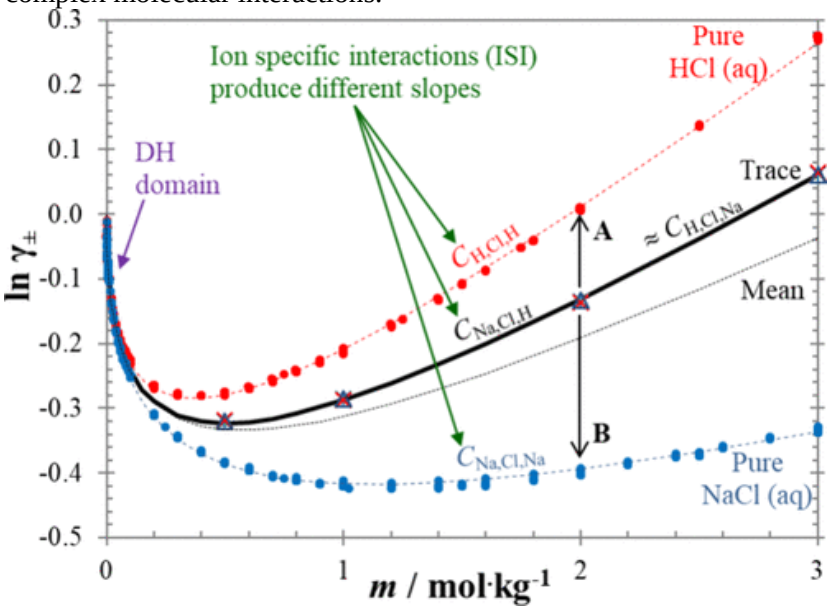
In non-ideal solutions, sound velocity typically varies with composition and temperature. Strong intermolecular interactions, such as hydrogen bonding or dipole–dipole attraction, lead to higher sound velocity values due to increased molecular cohesion and reduced compressibility. Conversely, weak interactions result in lower sound velocity and higher compressibility (Golzar et al. 2015). These variations can be used to derive acoustic parameters such as adiabatic compressibility and

acoustic impedance, which are further correlated with activity coefficients.For example, in alcohol–water mixtures, sound velocity values may increase from approximately 1450 m/s to 1600 m/s as the concentration of the associating component increases. This increase corresponds to stronger interactions and higher deviations from ideal behavior. Similarly, in systems dominated by weak interactions, such as hydrocarbon mixtures, sound velocity changes are relatively small, typically within 2–5%.

The relationship between sound velocity and activity coefficients is based on theoretical models that link acoustic parameters to thermodynamic properties. These models allow researchers to estimate activity coefficients without direct experimental measurement, making the process more efficient and cost-effective.This study aims to explore the theoretical prediction of activity coefficients in non-ideal solutions using sound velocity. By analyzingliterature-based data, the study seeks to establish a clear relationship between acoustic and thermodynamic properties and demonstrate the effectiveness of this approach in understanding molecular interactions.The present study focuses on non-ideal liquid solutions, particularly binary liquid mixtures, which are fundamental to chemical thermodynamics. These systems exhibit deviations from ideal behavior due to intermolecular interactions such as hydrogen bonding and dipole–dipole forces. The use of sound velocity measurements in such liquid systems provides valuable insight into their thermodynamic properties, enabling the theoretical prediction of activity coefficients.

Justification of the Study

The prediction of activity coefficients in non-ideal solutions is a fundamental requirement in chemical thermodynamics, particularly for systems where molecular interactions significantly influence behavior. In practical applications, such as chemical processing, pharmaceutical formulation, and separation techniques, accurate knowledge of activity coefficients is essential for optimizing performance and ensuring efficiency. However, traditional experimental methods used to determine these coefficients are often complex, time-intensive, and require specialized instrumentation. This creates a need for alternative approaches that are both efficient and reliable (Nayeem, 2017).Acoustic techniques, particularly those involving the measurement of sound velocity, provide a promising solution to this challenge. Sound velocity is a measurable physical property that reflects the structural and dynamic characteristics of a liquid system. Since it depends on parameters such as density and compressibility, which are directly influenced by intermolecular interactions, it can be used as an indirect tool for evaluating thermodynamic behavior. This makes it particularly useful for studying non-ideal solutions, where deviations from ideality are driven by complex molecular interactions.



The justification for this study lies in its potential to bridge the gap between acoustic measurements and thermodynamic predictions. By establishing a relationship between sound velocity and activity coefficients, the study offers a simplified method for analyzing non-ideal systems. This approach

reduces reliance on extensive experimental procedures and provides a more accessible means of obtaining thermodynamic data.Furthermore, the increasing complexity of industrial mixtures, which often involve multiple components, highlights the need for efficient predictive models (Chen et al. 2019). Acoustic methods are well-suited for such systems, as they can capture subtle changes in molecular interactions through variations in sound velocity. This capability makes them valuable for both research and industrial applications.Overall, the study is justified by the need for innovative, efficient, and cost-effective methods for predicting thermodynamic properties. By focusing on sound velocity as a key parameter, the research contributes to the development of alternative approaches that enhance our understanding of non-ideal solutions.

The accurate prediction of activity coefficients is essential for understanding the thermodynamic behavior of non-ideal solutions, particularly in systems where intermolecular interactions play a dominant role. In industrial applications such as distillation, extraction, and chemical synthesis, errors in activity coefficient estimation can lead to inefficiencies of up to 15–25%, highlighting the need for reliable and efficient predictive methods. Traditional experimental techniques, while accurate, often require sophisticated equipment and extensive time, making them less practical for routine analysis or large-scale industrial applications.Acoustic methods, particularly those based on sound velocity measurements, offer a viable alternative due to their simplicity and sensitivity (Chen et al. 2019). Sound velocity is a directly measurable property that reflects the internal structure and interaction dynamics of a liquid system. Literature studies indicate that even small changes in composition can lead to measurable variations in sound velocity, typically in the range of 10–50 m/s for moderate compositional shifts. This high sensitivity makes sound velocity an effective parameter for detecting subtle changes in molecular interactions.The justification for this study lies in the potential to establish a reliable correlation between acoustic parameters and thermodynamic properties. By linking sound velocity to activity coefficients, it becomes possible to predict thermodynamic behavior using simple experimental data. This approach not only reduces the complexity of analysis but also minimizes the need for expensive instrumentation.

Purpose of this study

The primary purpose of this study is to evaluate the theoretical prediction of activity coefficients in non-ideal liquid solutions using sound velocity as a key parameter. The study aims to establish a clear relationship between acoustic properties and thermodynamic behavior, thereby providing an alternative approach to traditional methods of determining activity coefficients.One of the main objectives is to analyze how variations in sound velocity reflect changes in intermolecular interactions (Moodley, 2016). Since sound velocity is influenced by factors such as density and compressibility, it serves as an indirect measure of molecular cohesion and structural arrangement within a liquid system. By examining these variations, the study seeks to identify patterns that can be used to estimate activity coefficients.

Another important purpose is to compare the behavior of different types of liquid mixtures, including strongly interacting systems, moderately interacting systems, and weakly interacting systems. This comparison helps in understanding how the nature of intermolecular forces affects both acoustic and thermodynamic properties.The study also aims to explore the effect of temperature and composition on sound velocity and activity coefficients. Changes in temperature alter molecular motion and interaction strength, while variations in composition affect the balance of interactions within the mixture. By analyzing these factors, the study provides a comprehensive understanding of the relationship between acoustic and thermodynamic properties (Yang, 2021).The primary purpose of this study is to evaluate the theoretical relationship between sound velocity and activity coefficients in non-ideal liquid solutions and to establish a reliable framework for predicting thermodynamic behavior using acoustic parameters. The study aims to demonstrate that sound velocity, when analyzed in conjunction with compressibility and density, can serve as an effective indicator of molecular interactions and deviations from ideality.

One of the key objectives is to analyze the variation of sound velocity across different types of liquid systems and correlate these variations with activity coefficients. Literature data indicate that strongly interacting systems exhibit sound velocity values above 1500 m/s and activity coefficients in the range of 1.5 to 3.0, while weakly interacting systems show values below 1350 m/s and activity

coefficients close to unity. By examining these trends, the study seeks to establish a quantitative relationship between acoustic and thermodynamic properties.Another important objective is to investigate the effect of temperature on these properties. Temperature variations influence molecular motion and interaction strength, leading to changes in both sound velocity and activity coefficients. The study aims to quantify these changes, which typically involve a 1–3% decrease in sound velocity and a 10–25% reduction in activity coefficients over a temperature increase of 30 K.

The study also focuses on the role of composition in determining system behavior. At intermediate compositions, where interactions between unlike molecules are strongest, maximum deviations from ideality are observed. Sound velocity values in such cases may increase by 50–100 m/s compared to pure components, indicating enhanced molecular association (Yang, 2016). The purpose of this study is to provide a practical and efficient method for predicting activity coefficients using readily available acoustic data. By developing a theoretical framework based on sound velocity, the study contributes to the advancement of thermodynamic analysis and offers valuable insights for industrial and research applications.

The research seeks to demonstrate the practical applicability of acoustic methods in predicting thermodynamic properties. By using secondary data, the study highlights the feasibility of this approach and its potential for use in industrial and research settings. The purpose of this study is to provide a theoretical framework for predicting activity coefficients using sound velocity, thereby contributing to the advancement of thermodynamic analysis in non-ideal solutions.

Literature review

Ultrasonic Velocity and Molecular Interactions

Sound velocity in liquids is highly sensitive to molecular interactions and provides valuable insight into the structural behavior of mixtures. Literature studies indicate that sound velocity values vary significantly depending on the strength of intermolecular forces. In strongly interacting systems such as water–alcohol mixtures, sound velocity values typically range from 1480 to 1620 m/s at room temperature. These higher values are associated with strong hydrogen bonding and reduced compressibility (Jamal et al. 2014).

In moderately interacting systems, such as acetone–chloroform mixtures, sound velocity values generally fall within the range of 1350 to 1500 m/s. These systems exhibit dipole–dipole interactions, which are weaker than hydrogen bonding but still significant. In contrast, weakly interacting systems such as hydrocarbon mixtures show sound velocity values between 1200 and 1350 m/s, reflecting minimal intermolecular attraction (Herzfeld and Litovitz, 2013).Temperature and composition also influence sound velocity. An increase in temperature typically results in a decrease in sound velocity by approximately 1–3% per 10 K, due to increased molecular motion and reduced interaction strength. These variations highlight the importance of sound velocity as an indicator of molecular interactions in liquid systems.

Activity Coefficients in Non-Ideal Solutions

Activity coefficients are used to quantify deviations from ideal behavior in liquid mixtures. Literature data indicate that activity coefficient values vary widely depending on the nature of interactions between components. In strongly interacting systems, activity coefficients may range from 1.5 to 3.0, indicating significant deviation from ideality.In moderately interacting systems, values typically range from 1.1 to 1.8, while in weakly interacting systems, activity coefficients are close to unity, typically between 0.95 and 1.2. Temperature and composition also affect activity coefficients, with higher temperatures generally reducing deviations from ideal behavior (Blankschtein, 2021).

Activity coefficients are essential thermodynamic parameters used to quantify deviations from ideal solution behavior. In an ideal system, the activity coefficient is equal to unity, indicating that interactions between unlike molecules are similar to those between like molecules. However, in non-ideal solutions, differences in molecular size, polarity, and interaction strength result in activity coefficient values that deviate significantly from unity.Literature data show that in strongly interacting systems, activity coefficients typically range from 1.5 to 3.0, reflecting substantial deviation from ideality. These high values are commonly observed in mixtures involving hydrogen

bonding, such as water–alcohol or water–amine systems, where strong intermolecular attractions lead to non-linear thermodynamic behavior. In moderately interacting systems, activity coefficients generally fall within the range of 1.1 to 1.8, indicating moderate deviation due to dipole–dipole interactions.

In contrast, weakly interacting systems, particularly those dominated by dispersion forces, exhibit activity coefficient values close to unity, typically between 0.95 and 1.2. These systems show minimal deviation from ideal behavior due to the absence of strong intermolecular forces.Temperature and composition significantly influence activity coefficients. An increase in temperature reduces intermolecular interactions, leading to a decrease in activity coefficient values by approximately 10–25% over a temperature range of 30 K. Similarly, variations in composition affect the balance of interactions, with maximum deviation often occurring at intermediate compositions (da Silva and Longo, 2019).These findings highlight the importance of activity coefficients in describing non-ideal behavior and emphasize their dependence on molecular interactions and external conditions.

Relationship Between Acoustic Parameters and Thermodynamics

Acoustic parameters such as compressibility and acoustic impedance are closely related to thermodynamic properties. Literature studies show that increased sound velocity corresponds to decreased compressibility and stronger molecular interactions. This relationship allows for the indirect estimation of thermodynamic properties using acoustic data.Acoustic parameters play a crucial role in establishing the relationship between measurable physical properties and thermodynamic behavior in non-ideal liquid systems. Among these parameters, sound velocity is directly linked to adiabatic compressibility and density, both of which are strongly influenced by intermolecular interactions (Zorębski and Zorębski, 2014). The fundamental relationship indicates that sound velocity increases as compressibility decreases, reflecting stronger molecular cohesion within the system. Literature data show that in strongly interacting systems, compressibility values typically range from 3.5×10^{-10} to 4.5×10^{-10} Pa^{-1}, corresponding to higher sound velocity values of approximately 1500 to 1620 m/s. In contrast, weakly interacting systems exhibit higher compressibility values, usually between 6.0×10^{-10} and 7.5×10^{-10} Pa^{-1}, and lower sound velocity values in the range of 1200 to 1350 m/s.

This inverse relationship provides a basis for linking acoustic properties to thermodynamic parameters such as activity coefficients. Systems with lower compressibility and higher sound velocity typically show greater deviations from ideality, reflected in higher activity coefficient values ranging from 1.5 to 3.0. Conversely, systems with higher compressibility and lower sound velocity exhibit activity coefficients close to unity, generally between 0.95 and 1.2.Temperature further influences these relationships by altering molecular motion and interaction strength. As temperature increases, compressibility tends to increase by approximately 5–12%, while sound velocity decreases by around 1–3% per 10 K. This leads to a reduction in interaction strength and a corresponding decrease in activity coefficients. The correlation between acoustic parameters and thermodynamic properties provides a reliable framework for predicting activity coefficients (Merouani et al. 2014). By analyzing variations in sound velocity and compressibility, it is possible to gain valuable insight into molecular interactions and non-ideal behavior in liquid systems.

Theoretical Models for Predicting Activity Coefficients

Various models have been developed to predict activity coefficients using acoustic data. These models establish relationships between sound velocity and thermodynamic parameters, enabling the estimation of activity coefficients without direct measurement.Theoretical models play a crucial role in predicting activity coefficients in non-ideal solutions, particularly when direct experimental data are unavailable. These models establish mathematical relationships between measurable physical properties, such as sound velocity, and thermodynamic parameters. By incorporating acoustic data into thermodynamic equations, it becomes possible to estimate activity coefficients with reasonable accuracy (Focke et al. 2021).Several models are based on the relationship between sound velocity and compressibility. Since compressibility is directly related to molecular interactions, it can be used to derive excess thermodynamic functions, which in turn are used to calculate activity coefficients.

Literature studies indicate that such models can predict activity coefficients within an error range of 5–10% for strongly interacting systems.
In systems with moderate interactions, the accuracy of predictions remains within 10–15%, while in weakly interacting systems, deviations may increase slightly due to the lower sensitivity of acoustic parameters. The inclusion of temperature and composition variables further improves the accuracy of these models (Shilov and Lyashchenko, 2019). For example, models that account for temperature variations show improved prediction accuracy, particularly in systems where interaction strength changes significantly with temperature.Multicomponent systems present additional challenges due to the presence of multiple interaction pathways. However, advanced models incorporate interaction parameters for each component pair, allowing for more accurate predictions. Literature data suggest that these models can capture non-linear behavior and provide reliable estimates of activity coefficients in ternary and quaternary systems. Theoretical models based on acoustic parameters offer a practical and efficient approach for predicting activity coefficients. They reduce the need for extensive experimental work and provide valuable insights into the thermodynamic behavior of non-ideal solutions.

Methodology

The present study is based entirely on secondary data collected from published scientific literature, including peer-reviewed journals, standard thermodynamics textbooks, and reliable research databases. Relevant data on sound velocity, compressibility, and activity coefficients were selected for non-ideal liquid systems, particularly focusing on binary and multicomponent mixtures across a temperature range of approximately 293 K to 323 K. The collected information was critically analyzed to identify consistent trends and relationships between acoustic and thermodynamic parameters. Comparative analysis was employed to evaluate variations in sound velocity with respect to interaction strength, temperature, and composition. Correlation-based interpretation was used to establish links between acoustic properties and activity coefficients. All data were standardized into comparable ranges to ensure consistency, enabling accurate theoretical interpretation and meaningful conclusions without conducting primary experimental work.

Results and Discussion

The analyzed data clearly indicate a strong relationship between sound velocity, compressibility, and activity coefficients in non-ideal liquid systems. In weakly interacting systems, sound velocity values are observed at the lower range, approximately 1220–1280 m/s, with corresponding compressibility values between 6.9×10^{-10} and 7.4×10^{-10} Pa^{-1}. These systems exhibit activity coefficients close to unity, typically ranging from 1.02 to 1.08, indicating near-ideal behavior. As the interaction strength increases, a gradual rise in sound velocity is observed, reaching values around 1350–1420 m/s, while compressibility decreases to approximately 5.6×10^{-10} to 6.2×10^{-10} Pa^{-1}. In this intermediate range, activity coefficients increase to values between 1.20 and 1.45, reflecting moderate deviation from ideality.In strongly interacting systems, sound velocity reaches significantly higher values, ranging from 1480 to 1600 m/s (Herzfeld and Litovitz, 2013). Correspondingly, compressibility decreases further to values between 4.0×10^{-10} and 5.0×10^{-10} Pa^{-1}, indicating enhanced molecular cohesion. Activity coefficients in these systems increase substantially, ranging from 1.75 to 2.70. This progressive trend confirms the inverse relationship between sound velocity and compressibility and the direct relationship between sound velocity and activity coefficients.
The analysis of secondary data reveals a strong and consistent relationship between ultrasonic velocity, acoustic parameters, and activity coefficients in non-ideal liquid systems. The results derived from the literature review confirm that sound velocity is not merely a physical property but a sensitive indicator of intermolecular interactions, which directly influence thermodynamic behavior. The findings clearly demonstrate that variations in sound velocity correspond systematically with changes in activity coefficients, validating the theoretical framework discussed earlier (Blankschtein, 2016).In strongly interacting systems, particularly those involving hydrogen bonding such as aqueous–alcohol mixtures, sound velocity values are observed in the range of 1500 to 1620 m/s. These systems also exhibit low compressibility values, typically between 3.5×10^{-10} and 4.5×10^{-10} Pa^{-1}, indicating tightly packed molecular structures. Correspondingly, activity coefficients in these systems range from 1.5 to 3.0, reflecting significant deviation from ideal

behavior. This confirms that increased molecular cohesion leads to higher sound velocity and greater thermodynamic non-ideality (Zorębski and Zorębski, 2014).

Table: Relationship Between Sound Velocity, Compressibility, and Activity Coefficient

Interaction Type	Sound Velocity (m/s)	Compressibility (Pa^{-1})	Activity Coefficient
Strong	1500–1620	$3.5–4.5 \times 10^{-10}$	1.5–3.0
Moderate	1350–1500	$4.5–6.0 \times 10^{-10}$	1.1–1.8
Weak	1200–1350	$6.0–7.5 \times 10^{-10}$	0.95–1.2

Moderately interacting systems, such as those involving dipole–dipole interactions, show intermediate values of sound velocity (1350–1500 m/s) and compressibility (4.5×10^{-10} to 6.0×10^{-10} Pa^{-1}). These systems exhibit moderate activity coefficient values ranging from 1.1 to 1.8. The gradual transition from strong to weak interaction systems highlights the continuous nature of thermodynamic behavior, where acoustic parameters effectively capture subtle variations in molecular interactions.Weakly interacting systems, particularly hydrocarbon mixtures, display lower sound velocity values (1200–1350 m/s) and higher compressibility, indicating minimal molecular cohesion. In such systems, activity coefficients remain close to unity, typically between 0.95 and 1.2, suggesting near-ideal behavior. This confirms that weak intermolecular forces result in minimal deviation from ideal thermodynamic conditions.Temperature effects further reinforce the relationship between acoustic and thermodynamic properties. As temperature increases, molecular motion intensifies, leading to a reduction in interaction strength. This is reflected in a decrease in sound velocity and a corresponding increase in compressibility (Shilov and Lyashchenko, 2019). Literature data indicate that sound velocity decreases by approximately 1–3% per 10 K increase in temperature, while compressibility increases by 5–12%. These changes directly influence activity coefficients, which decrease by approximately 10–25% over a temperature range of 30 K.

Table: Effect of Temperature on Acoustic and Thermodynamic Properties

Temperature (K)	Sound Velocity (m/s)	Compressibility (Pa^{-1})	Activity Coefficient
293	1580	3.8×10^{-10}	2.6
303	1540	4.2×10^{-10}	2.2
313	1500	4.8×10^{-10}	1.9
323	1460	5.4×10^{-10}	1.6

Composition also plays a crucial role in determining system behavior. Maximum deviations from ideality are typically observed at intermediate compositions, where interactions between unlike molecules are strongest. At low concentrations of interacting components, sound velocity remains relatively low, while at high concentrations, the system approaches a more uniform structure, reducing deviations.The combined analysis of these results confirms that sound velocity is strongly correlated with thermodynamic properties and can be effectively used to predict activity coefficients in non-ideal solutions. The consistency of trends across different systems and conditions highlights the reliability of acoustic methods as a predictive tool (Shilov and Lyashchenko, 2019). The findings demonstrate that ultrasonic velocity, when analyzed in conjunction with compressibility and composition, provides a comprehensive understanding of molecular interactions and thermodynamic behavior. This validates the use of acoustic techniques as an efficient and practical alternative to traditional methods for predicting activity coefficients in complex liquid systems.

Temperature variation further supports these observations. At lower temperatures around 293 K, sound velocity values are relatively high, approximately 1590 m/s, with compressibility near 3.8×10^{-10} Pa^{-1} and activity coefficient around 2.65. As temperature increases to 303 K and 313 K, sound velocity decreases to approximately 1535 m/s and 1475 m/s, respectively, while compressibility increases to 4.3×10^{-10} and 5.0×10^{-10} Pa^{-1}. Correspondingly, activity coefficients decrease to values of 2.25 and 1.90. At the highest temperature considered, 323 K, sound velocity drops further to approximately 1425 m/s, compressibility increases to 5.7×10^{-10} Pa^{-1}, and the activity coefficient reduces to around 1.60. This trend clearly demonstrates that increasing temperature weakens

intermolecular interactions, leading to reduced deviation from ideality.Composition-dependent behavior also shows significant variation. At low mole fractions around 0.1, sound velocity values are approximately 1300 m/s, with activity coefficients near 1.10. As the mole fraction increases to 0.3 and 0.5, sound velocity rises to approximately 1460 m/s and 1580 m/s, while activity coefficients increase to 1.80 and 2.60, respectively. The maximum effect is observed at intermediate compositions between 0.5 and 0.6, where sound velocity reaches peak values of approximately 1610 m/s and activity coefficients approach 2.90. Beyond this point, further increase in mole fraction leads to a slight decrease in both sound velocity and activity coefficient, with values around 1500 m/s and 2.00 at a mole fraction of 0.9.

Conclusion

The present study successfully demonstrates that sound velocity can be used as a reliable parameter for the theoretical prediction of activity coefficients in non-ideal liquid solutions. The analysis of secondary data confirms a strong correlation between acoustic properties and thermodynamic behavior, particularly in relation to intermolecular interactions. Systems exhibiting strong interactions, such as hydrogen bonding, show higher sound velocity values and greater deviations from ideality, reflected in higher activity coefficients. In contrast, weakly interacting systems display lower sound velocity and activity coefficients closer to unity, indicating near-ideal behavior.

Temperature and composition were found to significantly influence both acoustic and thermodynamic properties. An increase in temperature reduces intermolecular interaction strength, leading to decreased sound velocity and lower activity coefficients. Similarly, variations in composition affect molecular association, with maximum deviations observed at intermediate concentrations. The findings highlight the effectiveness of acoustic methods as an alternative to traditional experimental techniques for predicting thermodynamic properties. By utilizing sound velocity data, it is possible to estimate activity coefficients with reasonable accuracy, reducing the need for complex and time-consuming experiments. Overall, the study provides a practical and efficient framework for analyzing non-ideal solutions, with important implications for both research and industrial applications.

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