Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 9, No.1, September : 2024

ACOUSTIC PARAMETERS OF LI, NA, K ION SALTS IN AQUEOUS SOLUTION AT 303K

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Abstract

It is evident that ultrasonic velocity measurements help in the determination of thermodynamic properties and intermolecular interactions in solutions. It gives information about the solution's behavior in a compact form. The density, velocity and viscosity of aqueous solution of lithium, sodium and Potassium salt in different concentrations are measured at 303K. Acoustic parameters were calculated from experimental data which help to predict molecular interaction.

Key Words: Lithium aqueous solution, Sodium aqueous solution, Potassium aqueous solution, Ultrasonic, Molecular interaction, acoustic parameter.

Introduction

The principle of ultrasonic work depends on the degree of reflection of sound waves in tissues or substances of different densities. High-frequency sound investigations of liquid solutions containing polar and nonpolar parts give information about molecular relations and structural characteristics. This technique has been employed by several researchers to study the properties of inorganic salts dissolved in different solvents. Some experiments suggest that low charge density ions disrupt molecular structures while high charge density ions reinforce molecular structures. Ion-dipole attraction between ions and polar solvent molecules is a function of the size and charge of the ion, the solvent dipole moment and the distance between the ion and solvent molecules. Solvents can either help in maintaining the ion pairs by encapsulating them (structure maker) or rupture the ion pairs (structure breaker). These solvent properties define the solubility of electrolytes.

By using ultrasonics when examining binary liquid mixtures, information regarding intermolecular interactions is relevant. It is important to understand that the behavior of ions with solvents depends on the kind of ions and solvents in question. The ultrasonic velocity along with some other acoustic parameters gives useful information about the intermolecular forces. Various investigations have been carried out that explain the effect of concentration changes in binary mixtures regarding association, molecular mobility, interaction modes, and interaction forces concerned with ion sizes and solvents.

The present investigation measured ultrasonic velocities and their corresponding acoustic parameters of LiCl, NaCl, and KCl aqueous solution at 303 K with varying molar fraction concentrations. The thermodynamic acoustic parameters were employed to explore the relationships, molecular dynamics, types of interactions and the extent of the interactions due to the variation of ion size in water.

Therefore, ultrasonic velocity measurement of liquid mixtures provides a scope to assess the structural molecular characteristics and behavior. Scientists have focused on inorganic salt solutions and have analyzed the effects of various ions and the concentration of the solution on molecular interactions and structure of the solution. The present work determined ultrasonic velocities of three chloride salt solutions in water over concentration range as a way of evaluating interactions as affected by dissolving different size ions in a solvent. Acoustic characteristics gave information on relations, movements, types of interactions, and interaction forces.

Material and Experimental Method

In the present experimental work, the different mole fractions of LiCl, NaCl and KCl in water have been prepared. All the salt and solvents used are AR Grade samples. The solutions were prepared with deionized and distilled water to eliminate the presence of any substances that might interfere with the reaction. A set of characteristics, such as pH, conductivity, solubility, and concentration, was defined for each solution. These values were also taken at a constant condition and then compared between solutions to assess the effects of fluctuating concentrations. Solution properties can be understood with the help of the data.

Velocity measurement

The velocity of ultrasonic waves passing through binary solutions of lithium chloride, sodium chloride and potassium chloride in water was determined using mittal F-81 ultrasonic interferometer. Response: The interferometer employed in this study had a frequency of 2 MHz and was capable of determining velocities of ultrasounds with a precision of ± 0.1 m/s. The samples were maintained at a fixed 303 K temperature in a double-walled steel measuring cylinder. To keep the temperature constant, the cell was connected to a digital constant temperature water bath apparatus. When the ultrasonic waves propagated through the liquid, specific interference patterns produced in the liquid allowed the F-81 interferometer to measure the speed of the waves with high precision. In this manner, it was possible to accurately study the influence of the various chloride salts on ultrasonic velocities in aqueous solutions at a constant temperature of 303K. It is very important to keep the room temperature as stable as possible to ensure consistent results of acoustic measurements. The temperature control is achieved through a water bath and heat exchange with the steel measurement cell. The experimental approach allows for accurate determination of the ultrasonic velocity for aqueous salt solutions, which helps in understanding solution properties, molecular interactions, and solute-solvent interactions. This arrangement enables students to probe as to how such characteristics of solutions such as the concentration of salt solution affect the nature of aqueous solutions at the molecular level.

Density Measurement

In densities of the samples, a 25-milliliter density bottle was used to obtain the relative specific gravity at 0.01 Newton-seconds per meter squared with plus or minus 0.01. To determine the mass of each sample, an electronic digital balance with an accuracy of plus or minus 0.1 milligrams was used. Thus, using the ratios of the sample mass to the volume of the density bottle, the density values for each sample were determined with the help of the measurement instruments and within the measurement errors.

Viscosity Measurement

A flow of a liquid was characterized using Ostwald Viscometer. A digital stopwatch with an accuracy of 0.1 seconds was used to time the flow. From viscosity data, other liquid properties such as adiabatic compressibility (β), intermolecular free length (Lf) and acoustic impedance (Z) were determined using the following equations. In particular, the obtained viscosity values were substituted into equations connecting viscosity with β, Lf, and Z to estimate the values of those parameters for the test liquid. This made it possible to have more extended characterization of the liquids via a simple measurement of viscosity. The development of these other physical properties is made possible by the fact that the viscosity of a fluid is based on the microstructure as well as bonding forces present in a liquid. Accurate viscosity numbers are therefore necessary to pinpoint additional qualitative characteristics that give more information on a fluid’s innate physical attributes (1- 3).

$$\beta = (U^2\rho)^{-1} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$L_f = K_T\ \beta a^{1/2} \ldots\ldots\ldots\ldots (2)$$

$$Z = U\rho \quad \ldots\ldots\ldots\ldots \quad (3)$$

Result and Discussion

Experimental data on ultrasonic velocity, density and viscosity of 0.01 to 0.09 molar aqueous solutions of LiCl, NaCl and KCl at 303K is given in tables I, II and III. It is also included the calculated values of the adiabatic compressibility, acoustic impedance and inter- molecular free length of these solutions based on the measured velocity, density and viscosity. The data covers the molar concentrations between 0.01 and 0.09 mole fraction of each salt at the chosen temperature.

These additional parameters offer even another degree of acoustic characterization of these electrolyte solutions.

The figures illustrate the relation of the ultrasonic velocity with the concentration of LiCl, NaCl and KCl in water. This indicates that there is improved interaction between solute and solvent molecules with an increase in concentration. Among all the concentrations, LiCl solutions exhibit the maximum ultrasonic velocities. This suggests that the LiCl aqueous system has the strongest intermolecular forces among the three salts. In conclusion, it was found that with the increase in salt concentration, the solvent-solute molecular interaction becomes stronger with LiCl showing the greatest effect on water molecules.

With an increase in salt, the intermolecular free length which is the distance between the solvent and solute also decreases. This implies that the two should increase their interactions. However, solution viscosity increases with concentration, and this means that there would be increasing intermolecular forces within the solution. On the other hand, acoustic impedance or the measure of how well objects resist compression in sound waves rises as concentration levels rise. This opposes adiabatic compressibility with intermolecular spacing where both reduce as the density of the particles increase. Consequently, for all three of the salt solutions tested, increasing the concentration of the mixture enhanced the intermolecular forces of adhesion, which reduced the free space around the molecules, increased the viscosity of the liquid, and increased the depth of its resistance to acoustic compression.

From the values of the calculated adiabatic compressibility and intermolecular free length parameters given in Tables I, II and III, we note that these parameters decrease as the solution concentration increases and this is suggestive of enhanced interactions between the ionic solutes and the solvent. Therefore, the values for Li ions are comparatively lower and this suggests that lithium salts have a stronger interaction than sodium and potassium salts in the aqueous medium.

Therefore, the experimental results and the calculated values of acoustic parameters confirm that the molecular interactions between the salts and water molecules are most favorable for LiCl, and slightly less for NaCl and KCl at the equivalence molar concentrations. Lithium salts are known to have larger interionic forces than sodium and potassium salts. The analysis also shows that with an increase in the proportion of dissolved solute in the solvent, then the viscosity and acoustic impedance of the solution rise. This suggests that there is an increase in interactions between the molecules of the solute and those of the solvent. As the concentration of the dissolved solute increases, the solution viscosity and its acoustic impedance also increase gradually. This relationship gives information about the type and strength of ion-solvent interactions present in these electrolyte systems.

Examining the method of solution properties that include viscosity and impedance with a difference in solute concentration it is possible to describe the kind of interactions that happen between the ions of solute and solvent molecules and their concentrations. This helps to explain the solvation processes occurring in these electrolyte solutions.

Coulomb’s law explains the nature of the electrical force that exists between two charges. It says that the intensity of force is proportional to the product of the charges on the particles and is inversely proportional to the square of the distance between the two particles. In an ion dipole, an ion engages the polarized end of a polar molecule such as water. If the ion is small, its charge can be near the polarized water molecules, which is also possible for larger ions. A smaller size means that the distance between the charge of the ion and the molecules it polarizes according to Coulomb’s law is shorter, which creates a stronger attractive or repulsive force. This made it possible to have stronger electrostatic attractions between the ion charge and the water dipoles. Lithium ions (Li+) are much smaller than other common alkali metal cations such as sodium (Na+) and potassium (K+). This means that when the lithium ions are dissolved in water, they experience the strongest ion-dipole forces with water molecules due to their ability to approach them. Sodium and potassium ions are bigger, hence the forces with which they interact with the water molecules are significantly weaker because the ionic charge is carried further away from the dipoles of water molecules.

Table I: Measured values of ultrasonic velocity (U), Density(ρ), Viscosity(η), Adiabatic compressibility(β), Acoustic Impendence(z), Mean Free length (Lf)) of aqueous solution LiCl at 303K

Mole Fraction	Velocity	Density	Viscosity	β	Z 106	Lf
X	ms-1	Kg m-3	Nsm-2	m 2N-1	Kgm-2s-2	m
0.01	1563.36	1016.31	0.9988	4.03x	1.5888	0.01258
0.02	1568.28	1018.18	1.0152	3.99 x	1.5967	0.012529
0.03	1572.32	1019.36	1.0517	3.97 x	1.6027	0.01249
0.04	1576.4	1021.02	1.0732	3.94 x	1.6095	0.012448
0.05	1580.21	1022.02	1.0942	3.92 x	1.6150	0.012411
0.06	1586.32	1022.02	1.1204	3.89 x	1.6212	0.012364
0.07	1592.32	1031.21	1.1485	3.82 x	1.6420	0.012262
0.08	1596.14	1035.06	1.1531	3.79 x	1.6521	0.01221
0.09	1601.02	1037.41	1.1841	3.76 x	1.6609	0.012159

x- E-10

Table II: Measured values of ultrasonic velocity (U), Density(ρ),Viscosity(η),Adiabatic Compressibility (β), Acoustic Impendence (z), Mean Free length(Lf) of aqueous solution of NaCl at303K

Mole Fraction	**Velosity**	**Density**	**Viscosity**	**β**	**Z**	**Lf**
X	ms^{-1}	Kg m^{-3}	Nsm^{-2}	m ^{2}N^{-1}	Kgm^{-2} s^{-2}	m
0.01	1513.12	1010.23	0.9732	4.32E-10	1528599	0.013037
0.02	1520.32	1012.32	0.9966	4.27E-10	1539050	0.012962
0.03	1527.41	1013.32	1.0206	4.23E-10	1547755	0.012896
0.04	1535.47	1015.51	1.0516	4.18E-10	1559285	0.012814
0.05	1542.32	1017.15	1.0726	4.13E-10	1568771	0.012747
0.06	1550.31	1019.61	1019.61	4.08E-10	1580712	0.012666
0.07	1554.12	1021.26	1.1246	4.05E-10	1587161	0.012625
0.08	1560.71	1023.18	1.1486	4.01E-10	1596887	0.012559
0.09	1565.32	1025.82	1.1675	3.98E-10	1605737	0.012506

Table III: Measured values of ultrasonic velocity (U), Density(ρ),Viscosity(η),Adiabatic compressibility(β), Acoustic Impendence(z), Mean Free length(Lf) of) of aqueous solution KCl at 303K

Mole Fraction	Velosity	Density	Viscosity	β	Z	Lf
X	ms-1	Kg m-3	Nms-2	m 2N-1	Kgm-2 s-2	m
0.01	1483.23	1006.12	0.9532	4.52x	1492307	0.013327
0.02	1485.62	1007.89	0.9782	4.5x	1497342	0.013294
0.03	1492.51	1009.64	1.0062	4.45 x	1506898	0.013221
0.04	1495.62	1010.85	1.0332	4.42 x	1511847	0.013186
0.05	1499.52	1012.58	1.0572	4.39 x	1518384	0.01314
0.06	1534.34	1014.56	1.0832	4.19 x	1556680	0.012829
0.07	1542.32	1015.23	1.1042	4.14 x	1565810	0.012759
0.08	1551.25	1018.96	1.1272	4.08 x	1580662	0.012662
0.09	1557.41	1019.45	1.1572	4.04 x	1587702	0.012609

x - E-10

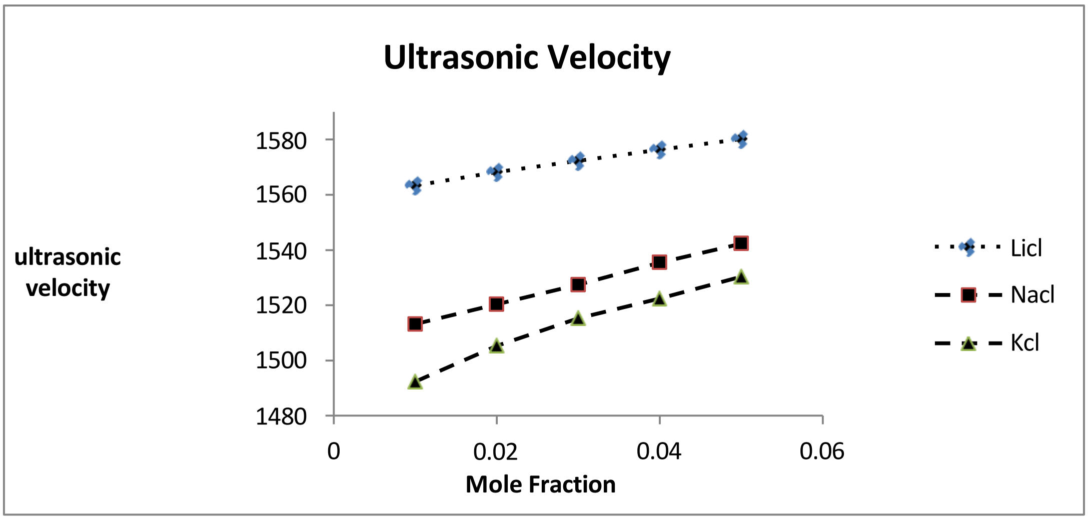

Fig.1 Ultrasonic velocity of aqueous solution of LiCl, NaCl and Kcl at 303K

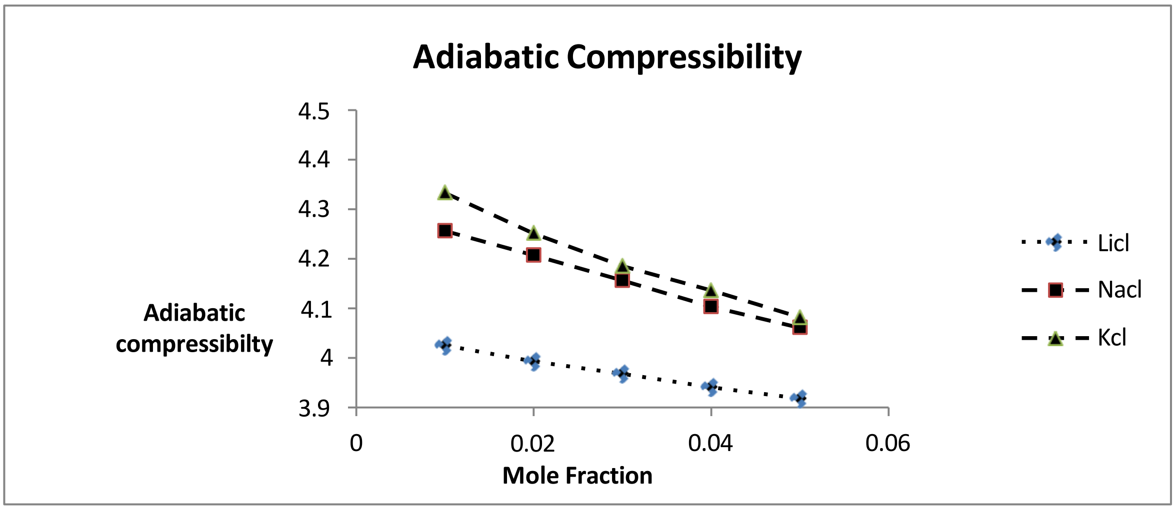

Fig.2 Adiabatic Compressibility of aqueous solution of LiCl, NaCl and Kcl at 303K

Conclusion:

The current study contrasted ultrasonic velocity, density, viscosity, adiabatic compressibility, intermolecular free length and acoustic impedance of LiCl, NaCl and KCl solutions at different concentrations at 303K. With the increase in concentration for all the three chloride solutions, the ultrasonic velocity, viscosity, and the acoustic impedance was found to be increased gradually and the intermolecular freeing length and adiabatic compressibility was found to be decreased. This shows that the amount of interaction between the solute and the solvent increases as the concentration of the salt increases. The likely mechanism is that when solute molecules are added to the solvent, there are fewer solvent-solvent interactions that are replaced by solute- solvent interactions. Therefore, there is an increase in solute-solvent binding with increase of salt concentrations in these solutions. The quantitative variation of these acoustic parameters proves the enhancement of molecular interaction density and offers information about the solute-solvent interaction.

This study also reveals that LiCl has the most significant impact on the acoustic parameters with increasing concentration among all the three salts under investigation. This implies that Li+ ions have the highest affinity for water molecules among the cations in this study. Due to its smaller ionic radius, Li+ gets closer to the water dipoles and forms more effective solute-solvent interactions than both Na+ and K+. Hence, molecular interactions are inferred to be highest in LiCl solutions, the second highest in NaCl and the least in KCl, in consonance with the assumption that the ability to form strong hydrate structure is enhanced by the small size of the cation.

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