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Review of Acoustic Parameters of Various Electrolytes

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ABSTRACT

Acoustic parameters are used to describe the behaviour of sound waves in different media. In chemistry, these parameters are used to study the properties of liquids and gases. Some of the acoustic parameters used in chemistry include adiabatic compressibility, free length, molecular interaction parameter, molar compressibility, acoustic impedance, molar volume, available volume, Leonard Jones potential, molar sound velocity, and relative association. These parameters are useful in elucidating ion-solvent interaction. The changes occur in ultrasonic velocity and its related parameters have focused much more upon the structural changes associated with liquid mixtures of weakly and strongly interacting molecules.
This paper gives review of contribution of the prompt investigation of acoustic thermodynamic properties undertaken by many research groups [1]
Acoustical parameters like compressibility, intermolecular free length and acoustic impedance are calculated using density, viscosity, conductometry, ultrasonic velocity, isoentropic compressibility and the results are discussed. The various calculated acoustic parameters are used as analyses in amplification and conductivity.

Keywords: Acoustic parameters, density, viscosity, conductometry, ultrasonic velocity, isoentropic compressibility.

INTRODUCTION

Conductometry is key in analyzing ionic substances and tracking chemical reactions through electrolytic conductivity. It's a pivotal technique in analytical chemistry, applied via meters or conductometric titration [2].
In the realm of fluid properties, viscosity, influenced by solvent interactions, composition, temperature, and salt concentration, is significant. It affects ion diffusion and conductivity. Measured by various viscometers, viscosity has implications across industries. This synthesis highlights Conductometry, density, and viscosity, elucidating material behavior and real-world applications, from analytical chemistry to industrial processes [3].
Ultrasonic velocity in copper and silver pertains to the speed of ultrasonic waves passing through these metals. Influenced by their properties, copper's high conductivity contributes to its higher velocity, while silver's unique atomic structure influences its own velocity. Measuring this velocity unveils insights into their mechanical traits, crystal structures, and responses to external factors.
The isentropic compressibility (K_s) and apparent molal isentropic compressibility (K_s, Φ) in various solvent systems have been calculated by using ultrasonic velocity (u) and partial molal volume (VΦ) data, respectively. The apparent molal isentropic compressibility (K_s, $Φ_0$) of various salts was determined by plotting (K_s, $Φ_0$) against $m^{1/2}$ and then analyzing the contributions of individual ions. Copper (I) and silver (I) ions displayed consistently negative (K_s, $Φ_0$) values across all solvent compositions,

implying significant solvation. Moreover, as the ADN composition increased, the (K_s, Φ_0) values for these ions became progressively more negative, suggesting an augmentation in solvation extent with higher adiponitrile composition.

Mass density and bulk modulus are two key parameters of acoustic materials. Traditionally, for composites these two parameters are both positive and restricted by their constituents' parameters [4]. A family of di-, tri-, and tetranuclear copper(I) complexes supported by length-controlled silaamidinate ligands have been synthesized to show short Cu^1– Cu^1 distances (2.43–2.62 Å) and feature a linear or bent metal–metal arrangement, which is elucidated by a relativistic density functional theory calculation [5].

OVERVIEW:

CONDUCTOMETRY:

Conductivity data for electrolytes in non-aqueous or aqueous solvents at temperatures other than 298 K are often unavailable. Therefore, researchers conducted measurements on molar conductivities of various substances, such as copper and silver complexes within a concentration range of (1-70) x 10^{-4} , mol dm^{-3} at temperatures of 298, 308, and 318 K in cyanobenzene, pyridine, and cyanomethane [6]. Before modern techniques molar concentrations, equivalent conductance and solvent specific conductance were analysed by using equation of Fuoss-Onsager theory, i.e.

$\Lambda = \Lambda_0 - SC^{1/2} + EClogC + JC$

And equation for salts that are not connected, and in the case of salts where association was observed, through

$\Lambda = \Lambda_0 - S(C\gamma)^{1/2} + EClogC\gamma + JC\gamma - K\lambda C\gamma\Lambda f^2$

Calculation procedures were carried out using the least-squares computer program provided by Kay13, which was adapted for use on an IBM 360/67 computer [7].

Shedlovsky analyzed the data for limiting molar conductivities (Λ°) and ion-association constants (K) . Due to the absence of transference number data at different temperatures, we indirectly calculated limiting ionic conductivities using an alternative method.

$\lambda^0 Cu^+ + \lambda^0 ClO^-_4 = \Lambda_0 (CuClO_4)$

The solvated radii of various ions were computed using an equation

$r_i = \frac{|Z|F^2}{6\pi N\eta \overset{\circ}{i}} + 0.0103\,\varepsilon_r + r_y$

involving the Avogadro number (N),relative permittivity(ε_r) ,Farady constant (F), solvent viscosity (η) and an adjustable parameter(r_y) assumed to be 0.085 nm, remains consistent across all three solvents [6]. By analysing conductivity data for different copper and silver complexes in various solvents, it is deduced that silver exhibits higher conductivity than copper, and copper, in turn, surpasses the conductivity of sodium and other metals.

VISCOSITY:

Viscosity measurements were conducted on copper perchlorate across diverse organic solvents. Subsequently, viscosity studies were extended to copper(I) nitrate and copper(I) sulfate, challenging to synthesize, within cyanobenzene, pyridine, acetonitrile, and cyanomethane solvents at varying temperatures. Viscosity values were acquired for the pure solvents at different temperatures. To ensure salt purity, chemical and spectroscopic analyses were employed.

Following proper calibration, readings were collected using different solvents and temperatures for copper(I) complexes. Copper(I) nitrate and sulfate viscosity measurements in AN, DMF, DMSO, Acetone, Methanol, and DMA employed an Ubbelohde suspended level viscometer, with a flow time of 231 s for water at 298K.

Viscosities for $CuClO_4$ were obtained using an Ubbelohde suspended bulb viscometer, with a flow time of 540 s for water. Overall, viscosity measurements aligned well with theoretical data, covering salt concentrations of 0.01-0.45 $molKg^{-1}$.

The study on viscosity measurements of copper(I) complexes reveals a direct relationship between increasing copper complex molality and viscosity, while viscosity decreases with rising temperature [6]. Regarding silver complex, its viscosity measurement primarily focuses on silver chloride. Using an Ubbelohde viscometer, viscosity is determined by measuring the flow time of a specific melt volume. Kinematic viscosity 'v' is derived from flow time 't' as

$v = Kt - B/t$,

where the cell constant K is 8.547 × 10^{-9} ms^{-2} , and the Hagenbach correction factor B is 2.0 × 10^{-6} m². Notably, the viscosity measurement for silver chloride occurs at high temperature of 823 K, challenging under standard conditions. The measured viscosity of silver chloride is 1% lower than the recommended NSRDS data [8].

ULTRASONIC VELOCITY :

Ultrasonic Velocity Measurements:

Measurements of ultrasonic velocity were conducted at a frequency of 2MHz using a variable path interferometer, at a temperature of 300°C. Temperature stability within 0.1K was ensured by circulating thermostated water around the interferometer cell containing the sample, facilitated by a circulating pump. The velocity of ultrasonic waves within the liquid was determined through the equation:

$c = f/\lambda$

Where 'f' represents the frequency of the generator, and 'λ' denotes the wavelength of the ultrasonic wave measured from the interferometer.

Acoustical Parameter Calculations:

The acquired data of ultrasonic velocity and the density of the nanofluid were utilized to compute key acoustical parameters including adiabatic compressibility (β), intermolecular free length (L_f), and acoustic impedance (Z) [9], employing the following relationships:

Adiabatic Compressibility (β):

$\beta = (C^2 \rho)^{-1}$

Intramolecular free length (L_f):

$L_f = K\beta^{1/2}$

Acoustic Impedance (Z):

$Z = \rho C$

The temperature-dependent constant 'k' is expressed as $[93.875 + (0.375T)] \times 10^{-8}$, where 'T' signifies the absolute temperature.

In essence, these equations allow us to extract valuable acoustical insights, such as compressibility, molecular interactions, and impedance, from ultrasonic velocity data and density measurements.

The objective of this research was to ascertain density (ρ) and ultrasonic velocity (u) for copper (I) nitrate complexes within varying concentrations ($0.02 - 0.28 m. Kg^{-1}$) across diverse solvents, including dimethylsulfoxide (DMSO), pyridine (Py), and their binary mixtures. Concurrently, the investigation aimed to derive isentropic compressibility (K_s) and apparent molal isentropic (K_s, Φ_0) using gathered density and ultrasonic velocity data.

Utilizing the DSA 5000 M by Anton Parr, density and ultrasonic velocity measurements were conductedat 298 K and a frequency of 2MHz. Notably, the study assessed apparent molal isentropic compressibility (K_s, Φ_0), distinguishing contributions from individual ions ($K°_s$,Φ)±. Furthermore, ultrasonic velocity studies were performed on prepared nanofluids at 303 K. Acoustical parameters encompassing adiabatic compressibility, intermolecular free length, and acoustic impedance were calculated, offering insights into the interaction between nanoparticles and water molecules. Notably, interactions between Ag+ ions and water molecules were comprehensively investigated. The analysis revealed intriguing dynamics; in microfluids, particle fluid interaction weakened with increasing particle loading. However, within nanofluids, a distinctive trend emerged: particle-fluid interaction strengthened with concentration until a critical point of 2ml, beyond which strong particle-particle interactions weakened particle-fluid interaction. This phenomenon was observed to impact velocity. Ultimately, particle fluid interaction studies provided insight into anomalous enhancements in the physical properties of nanofluids on the nanoscale.

ISOENTROPIC COMPRESSIBILITY:

Compressibility data play a crucial role in predicting the pressure-dependent properties of electrolyte solutions. However, precise compressibility data for electrolytes in nonaqueous solvents, particularly in the acetonitrile (AN) + adiponitrile (ADN) system, are scarce. Various investigative techniques including conductance [10] [11], viscosity [12] [13] [14], solubility [15] [16], electromotive force (emf) [17] [18], ESR, Fourier transform infrared (FTIR) [19], NMR [12] [18] [20] and transport no. [21] studies have been employed to explore the solvation behaviour of ions in mixed solvents. Additionally, enthalpy [22] and Gibbs energy of transfer [23] from a reference solvent to a solvent mixture have been utilized to offer meaningful insights into ion solvation within mixed solvent environments. Conversely, copper(I) and silver(I) cations exhibit a distinctive form of solvation through a specialized interaction with certain solvents. This particular interaction pattern is notably observed for copper(I) and silver (I) cations with nitrile solvent, where their dπ-pπ-interactions align with the nitrile group present in the solvents [24] [25] [26] . When Cu(1), Ag (1) & other ions dissolved in AN and ADN exhibit dipolar aprotic characteristics and possess nearly identical relative permittivities, with AN at 36.0 and ADN at 33.7. However, they differ in terms of viscosity, with AN having a viscosity of 0.341 mPa·s and ADN with a higher viscosity of 5.99 mPa·s. Both solvents, AN containing a single -CN group and ADN containing two -CN groups, demonstrate an affinity for interacting with Cu(I) and Ag(I) ions. Such studies could prove valuable in identifying a suitable solvent for the hydrometallurgical purification of copper . Compressibility, Ultrasonic velocities (u) and densities (ρ) were determined for various complexes across different salt concentrations. The measurements were conducted within the concentration range of 0.002 to 0.28 m, using mixtures of AN + ADN solvents at a temperature of 298.15K. The isentropic compressibilities (K_s) of the electrolytes within each solvent system were determined using the equation

$K_s = u^{-2}\rho^{-1}$

It was observed that the Ks values exhibit a linear decrease as the salt concentration increases across all cases. This trend suggests that the electrolytes do not form associations within the AN + ADN mixtures at the studied range of salt concentrations. Molal isentropic compressibility can be measured by ($K_{s,}\Phi$):

$$V_\phi = \frac{M}{\rho} - \frac{(\rho-\rho°)}{m\rho\rho°}$$

$$K_{s,\,\phi} = V_\phi\, K_s + \frac{10^3\,[K_{s-}\ K_0]}{m\rho}$$

'm' represents molality and 'M' stands for the molecular mass of the solute, while Ks and K_0 refer to the isentropic compressibilities of the solution and pure solvent or solvent mixtures, and ρ and ρ_0 represent the densities of the solution and pure solvent or solvent mixtures. The graphs depicting K_s,Φ against $m^{1/2}$ displayed a linear relationship within the studied concentration range. The limiting apparent molal isentropic compressibilities ($K°_s$,Φ_0) were obtained from the linear plots of (K_s ,Φ) versus $m^{1/2}$ by the least-squares method by:

$K_{s,\phi} = K^0{}_{s,\phi} + A_{s,\phi}\, m^{1/2}$

$K°_s$,Φ values for $[Cu(CH_3CN)_4]ClO_4$, $[Cu(C_6H_5CN)_4]ClO_4$, $[Cu(DMPhen)_2]ClO_4$, and $AgNO_3$ are negative whereas for Bu_4NBPh_4, Bu_4NClO_4, and Bu_4NNO_3 are positive in AN + ADN binary mixtures.

Evaluation of Limiting Ionic Apparent Molal Isentropic Compressibilities (K°s,Φ)± :

To gain a deeper understanding of how each ion contributes to structural or solvation effects, the K°sΦ values of the salts have been separated into the individual ion's (K°s,Φ)± contributions.

Splitting of K°sΦ value is not possible due to large size so as suggested by Gill and co-workers [27] in which they used reference electrolytes.

Negative values are generally obtained due to stronger ion-solvent interactions while positive values are primarily obtained for tetraalkylammonium ions because of interactions that are hydrophobic or dispersive in nature.

DENSITY:

It was found that new cell is suitable for high temperature measurement of liquid metals density at temperatures from 700 to 1520°C. Measurement results are in a good agreement with the literature values. Density deviates by 0.5-1% depending on the metal.

***Composition*:**

Copper has a density of 8.94 g/cm^3, exceeding that of aluminum (7.9 g/ cm^3) in air and iron (7.8 g/cm^3) in pure iron metal.

The standard electrode potential for the element is 1.58 volts. Metallic copper is stable at temperatures from 4000 K to 300 °C; it begins to deform at 750 °C and becomes unstable at 1000 °C. The physical properties of pure copper are second only to those of its close relative silver; this high resistance to corrosion is owing to its form and structure as an alpha transition metal-oxo complex ion crystal, whose molecules are linked by oxygen atoms in such a fashion that each copper atom has three oxide ligands attached to it, as well as four more from the other ions that make up the unit cell: two from oxygen and two from copper itself.

Calculations:

To calculate the density of copper, you'll need to know its atomic mass. The atomic mass is given as:

A = 0.006427 amu

Now, in order to find out how much matter there is in a sample of copper, you will multiply the atomic mass by Avogadro's number. This number is given as:

N = 6.02214 x 1023

The density (ρ) of a substance is then calculated using the formula for specific volume:

$\rho = \mathrm{N} \times \frac{V}{A}$

Temperature, pressure, purity, and the presence of other metals:

The density of copper is affected by its atomic weight (0.286 g/cm^3), melting point (−270 °C or −454 °F), boiling point (1400 °C or 2625 °F), surface tension (at 25 °C in air) and viscosity of the liquid at that temperature. Copper has a low vapor pressure because its vaporization temperature is high enough to prevent evaporation. With no solid form at atmospheric pressure at room temperature, copper exists in a gaseous phase with a density less than 1% that of water, which can float it.

BIOLOGICAL IMPORTANCE:

Importance of Copper:

Copper, an essential trace metal in the human body, is primarily absorbed in the stomach and small intestine and later excreted in bile. The typical quantity of copper in healthy adults is 50–150 mg. Around 50%–70% of this is found in muscles and bones, while 20% is present in the liver, and 5%–10% circulates in the blood. Copper is primarily present in the forms of ceruloplasmin and cuprase within the body, with only a small amount existing as free copper ions [28] [29]. It plays a crucial role as a catalyst in numerous enzymes and proteins, facilitate the metabolism of glucose, amino acids, and cholesterol, thereby affecting human health through various mechanisms [30] [31]. Due to its biological functions and advantages, a growing number of biomaterial researchers are concentrating on the development of innovative biomaterials containing copper. These materials offer distinct properties that safeguard the cardiovascular system, accelerate bone fracture healing, and exhibit antibacterial effects. Additionally, copper has potential applications in enhancing wound healing, targeting cancer cell and radiotherapy.

It play significant roles in bodily growth, development, and the maturation of systems like the nervous, hematopoietic, and bone systems [32] [33]. Similar to other trace elements, maintaining a balance of copper within the body is essential. Disruptions in copper metabolism or levels can lead to various diseases, including those linked to weakened immune function, diabetes, coronary heart disease, and osteoporosis [34]. Research has indicated that metallic biomaterials containing copper offer promising qualities in safeguarding the cardiovascular system, displaying antibacterial properties, and enhancing the recovery of bone fractures [35] [36] [37].

Benefits

Stent placement is a crucial treatment method for atherosclerotic occlusive diseases, involving the use of a minimally invasive technique to clear blood vessels and restore proper blood circulation. One significant challenge following stent insertion is stent restenosis, a complication that has been on the rise recently [38]. Factors contributing to stent restenosis include:

(1) significant damage to the blood vessel lining during stenosis or occlusion treatment; and

(2) the proliferation of smooth muscle cells and formation of blood clots after stent placement [39].

Nevertheless, studies on stents containing copper suggest that adding an appropriate amount of copper to the stent material could offer a promising strategy for reducing the occurrence of stent restenosis.

Vascular endothelial growth factor (VEGF) stands out as the most potent growth factor for stimulating angiogenesis. The pathway through which VEGF signals can considerably enhance the growth, movement, and directional movement of endothelial cells across different bodily tissues. Rigiracciolo and colleagues [40] suggested that copper ions might trigger the EGFR/ERK/c-Fos pathway, leading to an elevation in VEGF expression within cancer cells. Ma and colleagues demonstrated that the Ti–5Cu alloy displayed impressive antibacterial characteristics and resistance to corrosion, suggesting its significant potential for use in dental implant applications [41]. Orthopaedic grafts composed of materials containing copper have the ability to stimulate the growth of osteoblasts while preventing bacteria from adhering. This dual effect aids in enhancing the healing of bone fractures and lowering the chances of infection [42]. Ghosh Deepanjan and colleagues discovered that the release of copper ions from sutures might enhance the healing process of incisional wounds. They also suggested that fibers releasing copper could be useful for speeding up the recovery of surgical and trauma wounds [43].

Importance of Silver:

The antibacterial properties of silver have been known for centuries and the threat of antibiotic-resistant bacteria has led to renewed focus on the noble metal. Silver is now commonly included in a range of household and medical items to imbue them with bactericidal properties. Despite this, the chemical fate of the metal in biological systems is poorly understood. Silver(I) is a soft metal with high affinity for soft donor atoms and displays much similarity to the chemistry of Cu(I). In bacteria, interaction of silver with the cell wall/membrane, DNA, and proteins and enzymes can lead to cell death. Additionally, the intracellular generation of reactive oxygen species by silver is posited to be a significant antimicrobial action. While the antibacterial action of silver is well known, bacteria found in silver mines display resistance against it through use of a protein ensemble thought to have been specifically developed for the metal, highlighting the need for judicious use.

The agriculture applications:

Silver nanoparticles (AgNPs) are the most prominent nanoparticles incorporated with wide-ranging applications, owing to their distinct characteristics. Different methods have been employed for nanoparticles synthesis like chemical method, physical method, photochemical method, top-down/bottom-up approach and biological methods.

Properties of Silver:

Silver (Ag) is a white, soft, lustrous, very ductile and malleable metal.

It is a very good conductor of electricity and heat.

It has the highest electrical conductivity of all metals, but the high cost of it has restricted us from using it in all electrical devices.

Applications and Effects of Silver:

The principal use of this metal is precious, including jewellery and decorative items.

The other applications include:

a. Currency – still in some countries silver coins are used as currency.

b. Jewellery and silverware

c. It is used in the manufacturing of solar panels

d. Air conditioning – It is used in the manufacturing of typical air conditioners

e. Water purification – It is used in water purifiers to prevent the growth of algae and bacteria in filters. f. Photography and electronic devices

g. Used as an antibiotic coating on medical devices. Thermal or infrared coatings use silver as it reflects some wavelengths better than aluminum.DNA, proteins, and enzymes, ultimately leading to cell death. Moreover, silver's creation of reactive oxygen species within cells is believed to contribute significantly to its antimicrobial action. While silver's antibacterial properties are established, bacteria in silver mines have evolved resistance using specific proteins, underscoring the importance of careful usage.

CONCLUSION

The study conducted viscosity measurements on copper (I) complexes across diverse solvents, temperatures, and concentrations, revealing a viscosity decrease with rising temperature through linear viscosity-molality plots. In contrast, limited data exists on viscosity in silver(I) complexes, with a predominant focus on silver nanoparticles. This underscores the need for more comprehensive research on silver(I) complexes' viscosity and the research provides insights into temperature-dependent viscosity patterns in copper (I) complexes. However, understanding silver(I) complexes' viscosity is constrained by the emphasis on other silver compounds.

Remarkably, silver boasts outstanding electrical conductivity, surpassing copper and gold.

Copper (I) complex ultrasonic velocities vary linearly with molality. Copper I complexes have a lower ultrasonic velocity in AN than in BN. decrease in the ultrasonic velocity may be due to the decrease in molecular interaction in the ternary mixture. With rising temperatures, ultrasonic velocities drop [13]. Ultrasonic velocity measurement of silver(I) complex aqueous solution shows that the velocity decreases with concentration [30].

Large and negative values $(K°s,\Phi)\pm$ for Cu^+ and Ag^+ result in strong interaction that increases with increase in ADN composition in binary mixture. ClO^{4-} exhibit weak solvation in mixture.

The density of copper varies depending on the purity of the metal and the alloy used to make the copper. Copper is a soft and malleable metal that is a good conductor of heat and electricity. It has a density of about 8.9 g/cm^3.

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