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Anjali B Gudpalle
P.G. Student, Department of Physics, S.P. College, Chandrapur, Maharashtra, India

Urvashi P Manik
Professor, Department of Physics, S.P. College, Chandrapur, Maharashtra, India

Paritosh L Mishra
Department of Physics, S.P. College, Chandrapur, Maharashtra, India

Corresponding Author:
Anjali B Gudpalle
P.G. Student, Department of Physics, S.P. College, Chandrapur, Maharashtra, India

Volumetric and acoustical properties of dextrose in aqueous solution of inorganic salts (NaCl/KCl) at various temperatures using ultrasonic tactic

Anjali B Gudpalle, Urvashi P Manik and Paritosh L Mishra

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Abstract
Ultrasonic density and velocity for dextrose have been calculated in 0.2 and 0.5 mol/kg aqueous NaCl and KCl solutions at 283.15, 288.15, 293.15 and 298.15 K for various molal concentrations from 0.001 to 0.1 molal. Thermodynamic parameters such as acoustic impedance (Z), adiabatic compressibility (β), relaxation strength (r), specific heat ratio(ϒ), change in an adiabatic compressibility (Δβ), relative change in an adiabatic compressibility (Δβ/β), non-linearity parameter (B/A), an isothermal compressibility (K_{T1}), an internal pressure (Л_i), molecular radius(R_m), an enthalpy (H), relative association (R_A), intermolecular free length (L_f), surface tension (σ), and Lennard Jones potential (n) have been an obtained from literature formulae. To investigate the exact kind of molecular interaction NaCl and KCl interact with Dextrose at various concentrations and temperatures, an ultrasonic tactic was used. The result and discussion of all the parameters conclude that due to the higher changes present in KCl, the interaction is greater in the 0.5KCl solution among all systems.

Keywords: Density, dextrose, molecular interaction, inorganic salts, ultrasonic velocity

Introduction

Nowadays, development has initiated the use of ultrasonic energy in agriculture, medicine, Engineering, etc. [1]. This technique plays a prime character in understanding the kind of molecular interconnection [2]. In this research work, Ultrasonic velocity and density were experimentally deliberated. A lot of research was built on the molecular interaction in the aqueous composition of several organic and inorganic aqueous compositions [3].

Ultrasonic investigation of Carbohydrates/saccharides in an aqueous solution of sodium chloride and potassium chloride at various temperatures provides detailed information for determining the kind of mixture [4] Sugar, starches, and fibres consist of carbohydrates as a necessary nutrition. It plays the main character in the human-balancing biotic-based cycle. It is the building block in living existence. Saccharides are the leading creator of energy depleted by human beings [5]. Dextrose is an example of saccharides and it is the simplest form of Carbohydrate. It is a white or colourless, odourless stable, ordinary form of sugar. Dextrose is a monosaccharide and it works for two main purposes inside the cell, they are helps to store and produce energy. Which has the molecular formula $C_6H_{12}O_6$. As much as carbohydrates are important for the body likewise salts are also essential for earthlings. Saccharides and salts are brought together for the reason of the likeness in their types of action in preserving foods. However, no efforts become visible to assemble the ultrasonic research work data of an aqueous and mixed aqueous solution of Dextrose with inorganic salt. Consequently, an investigational work will be performed and describe different acoustic and thermodynamic parameters of dextrose in double distilled water and aqueous mixture of NaCl and KCl following systems where consideration for characterisation at 283.15, 288.15, 293.15 and 298.15 K temperatures [6].

System I-Aqueous 0.2 NaCl + H_2O + Dextrose
System II-Aqueous 0.5 NaCl + H_2O + Dextrose
System III- Aqueous 0.2 KCl + H_2O + Dextrose
System IV-Aqueous 0.5 KCl + H_2O + Dextrose

The present Research work discloses the interaction between saccharides and inorganic salts.

Experimental Details

Chemical and Equipment

AR grade dextrose (99.8%), sodium chloride (99.9%) and potassium chloride (98%) are getting from Himedia Laboratories Private Limited Mumbai. Without any refinement, every chemical is dried in the desiccator before being used. Double distilled water was used in the present investigation. Solutions were used within 12 hours after preparation, to keep down decomposition due to bacterial contagion, it kept in a special air-tight bottle.

The equipment used in the present work is as follows

- Ultrasonic velocity, digital interferometer of 2MHz frequency.
- A 10 ml specific gravity density bottle.
- Automatic thermostatic water bath.
- Electronics weighing machine having four decimal accuracies.

Procedure

Ultrasonic velocity was calculated at a frequency of 2 MHz by the single-crystal interferometer. A quartz crystal was a source of ultrasonic waves. The present research work was performed at four various temperatures (*viz*.283.15, 288.15, 293.15 and 298.15k). The present experimental value and literature value of ultrasonic velocity at different temperatures are as follows:

Temperatures (K)	283.15K	288.15K	293.15K	298.15K
Experimental Value	1447.1 ms^{-1}	1466.03 ms^{-1}	1481.49 ms^{-1}	1498.1 ms^{-1}
Literature value	1448.16 ms^{-1} [7]	1466.250 ms^{-1} [8]	1482.63 ms^{-1} [9]	1496.940 ms^{-1} [10]

Using a 10 ml specific density gravity bottle the weight of the solutions was determined accurately. An electronic balance is $\pm 1 \times 10^{-4}$g is used to weigh samples.

Defining Relation

Ultrasonic velocity and density of dextrose in double distil water and an aqueous solution of NaCl and KCl at various temperatures are noted in Table 1 and Table 2 respectively. Thermodynamics parameters such as adiabatic compressibility, acoustic impedance, etc. were calculated from empirical Jacobson's relation.

1. **Acoustic Impedance (Z):** Acoustic impedance depends on density and velocity. it is derived using the formula [11]. $Z = U\rho$ ------- (Kg- m^2s^{-1})
2. **Adiabatic Compressibility(β):** Helps to understand physicochemical properties and its formula is given as,[12] $\beta = \frac{1}{\rho * U^2} \dots \dots (m^2N^{-1})$
3. **Relaxation Strength(r):** It depends on the velocity of the solution and its formula is given as,[13] $r = 1 (\frac{U}{U_\infty})^2$
4. **Specific Heat Ratio(ϒ):** The specific heat ratio gives information about the pressure of interaction in the solution it derived using the formula, $\gamma = \frac{17.1}{T^{\frac{4}{9}} \times \rho^{1/3}}$ ---------$(K^{4/9})^{-1}(kg^{1/3}m^{-1})^{-1}$
5. **Surface tension (ϭ):** Surface tension determines the composition of the molecule on the surfaces. Its formula is given as [14]. $\sigma = (6.3 \times 10^{-4})\rho U^{3/2}$ ------ (Nm^{-1})
6. **Change in an Adiabatic Compressibility(Δβ):** It is derived using the formula, $\Delta\beta = \beta - \beta_0 \dots \dots (m^2N^{-1})$
7. **Relative Change in Adiabatic Compressibility (Δβ/β):** relative change in Adiabatic Compressibility is derived using the following formula. $\Delta\beta/\beta = \frac{\beta - \beta_0}{\beta}$
8. **Intermolecular Free Length (L_f):** An intermolecular free length measures the solidity of interaction among the two molecules. It is derived using the formula [15]. (L_f) : $K \times \beta^{1/2}$ ………………{meter}
9. **Relative Association (R_A):** Relative association depends on. Velocity and density. And it gives information about interaction in solution. It is derived using the following formula, $R_A = \{\frac{\rho}{\rho_0}\}\{\frac{U_0}{U}\}^{1/3}$
10. **Non-Linearity Parameter $(B/A)_1$:** A non-linearity parameter helps to exist intermolecular force in the solution. (Hartmann-Balizar method) [16]. $(B/A)_1 = 2 + [\frac{0.98 \times 10^4}{U}]$. ($m^1s$)
11. **Non-Linearity Parameter $(B/A)_2$:** The formula for Non-Linearity Parameter is given as (Ballou's method) [17]. $(B/A)_2 = 0.5 + [\frac{1.2 \times 10^4}{U}]$. ($m^{-1}s$)
12. **Isothermal Compressibility (KT_1):** An isothermal compressibility depends on velocity and density and it helps to understand the geometry of the solution. (McGowan method) [14]. $KT_1 = \frac{1.33 \times 10^{-8}}{(6.4 \times 10^{-4} U^{3/2} \rho)^{3/2}}$ (m^2N^{-1})
13. **Internal Pressure (π_i):** it helps to understand intermolecular force in solution and its formula is given as,[18]. $\pi_i = \frac{\alpha T}{K_T}$ ------(Nm^{-2})
14. **Molecular radius (R_m):** it helps in the reduction of the internal pressure of the solution. It is derived using the given formula, [19]. $R_m = \{\frac{3b}{16\pi N_A}\}^{1/3}$ ------ (m)
15. **Enthalpy (H):** Enthalpy is the sum of internal energy in any thermodynamic system and the product of its volume & pressure. It is derived using the formula, $H = V_m \times \pi_i$……… {J/Kg}
16. **Lennard Jones Potential (n):** Lennard-John potential explains the interaction between two molecules at a particular distance and it gives a formula as follows, $n = \{6(\frac{V_m}{V_a})$ -13……. ($J\ mol^{-1}$)

Result and Discussion

The variation in the investigational value of ultrasonic velocity, density and the various thermo-acoustical parameters of dextrose in an aqueous solution of NaCl and KCl gave the information of all systems mentioned.

The experimental value of the ultrasonic velocity of dextrose in both solutions increases with an increasing concentration from 0.001 to 0.1. The solution of 0.2 and 0.5 molal concentrations of NaCl and KCl at different temperatures were calculated and it concluded that, as an increasing molal concentration and temperature, the ultrasonic velocity also increased as shown in fig. (1). This modified an interaction between molecules of solute and solvent so, concentration is directly proportional to the ultrasonic velocity. As compared to aqueous NaCl, the value of ultrasonic velocity in aqueous KCl is greater [20, 21].

Density is the calculation of the weight of a substance to its size. In the present exploration, different molal concentrations from 0.001 to 0.1M in the solution of 0.2 and 0.5 molal concentrations at different temperatures were calculated and observed. The density of the solute increases with an increasing molal concentration and decreases with an increase in temperature as seen in Fig (2), solute molecules are combined or added with the solvent to enhance the parking structure of the solvent these specify the relationship between solute and solvent [22].

Relaxation strength is directly proportional to adiabatic compressibility when we add solute to a solvent, the value of relaxation strength decreases then it is noted that, in all four systems, the interaction between solute & solvent is seen. the relaxation strength of Dextrose + H_2O + NaCl /KCl solution decreases as increasing molal concentration and temperature as depicted in fig. (3). It indicates the highest molecular relation between solute and solvent molecule [23]. The product of density and velocity is known as acoustic impedance. The variation in the acoustic impedance is related to the concentration and temperature, as represented in Fig. (4). The acoustic impedance of the solution increases with both molal concentration and temperature, indicating that a notable relation takes place in the solution [24].

Adiabatic compressibility is a visible quantity, which is responsive to solute solvent interaction. The variation in the adiabatic compressibility is related to the concentration and temperature as shown in fig. (5). An Increase in both concentration and temperature gives decreasing adiabatic compressibility. It will indicate an observable relationship among solute & solvent molecules from this the systemic presentation in the region of essential ions is much impacted [25]. Specific heat ratio is a quantitative relationship among the specific heat of a gas at constant pressure and volume. The change in specific heat ratio is related to the concentration and temperature depicted in Fig. (6). It is constantly decreasing with increasing concentration and temperature which is, to disclose the actuality that specific heat is decreasing constantly with rising concentration [26].

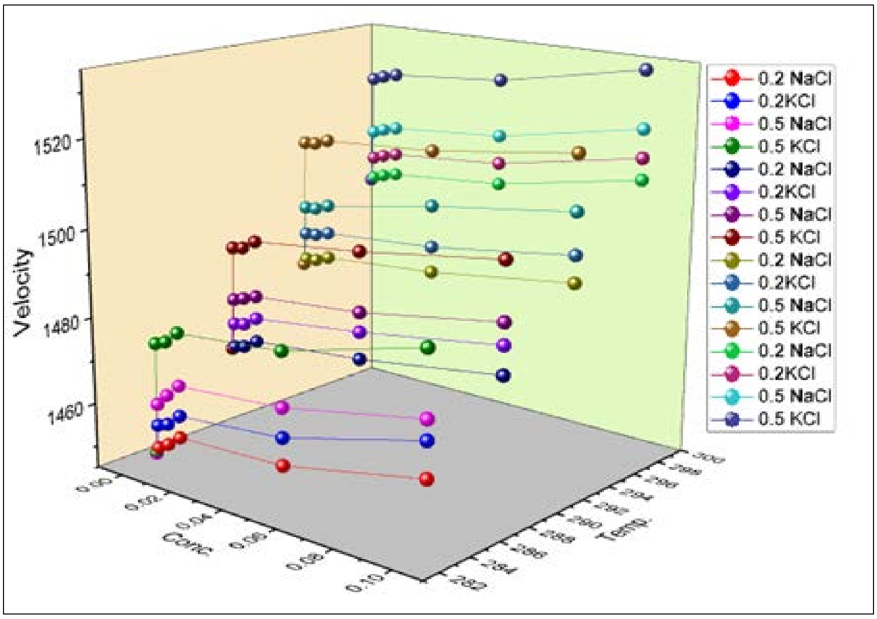

Fig 1: Variation of velocity with concentration

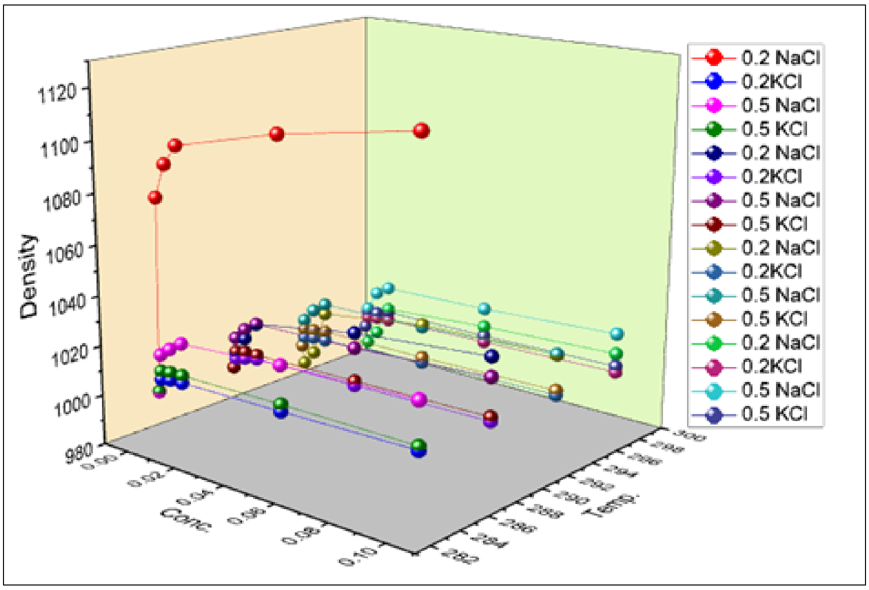

Fig 2: Variation of density with concentration

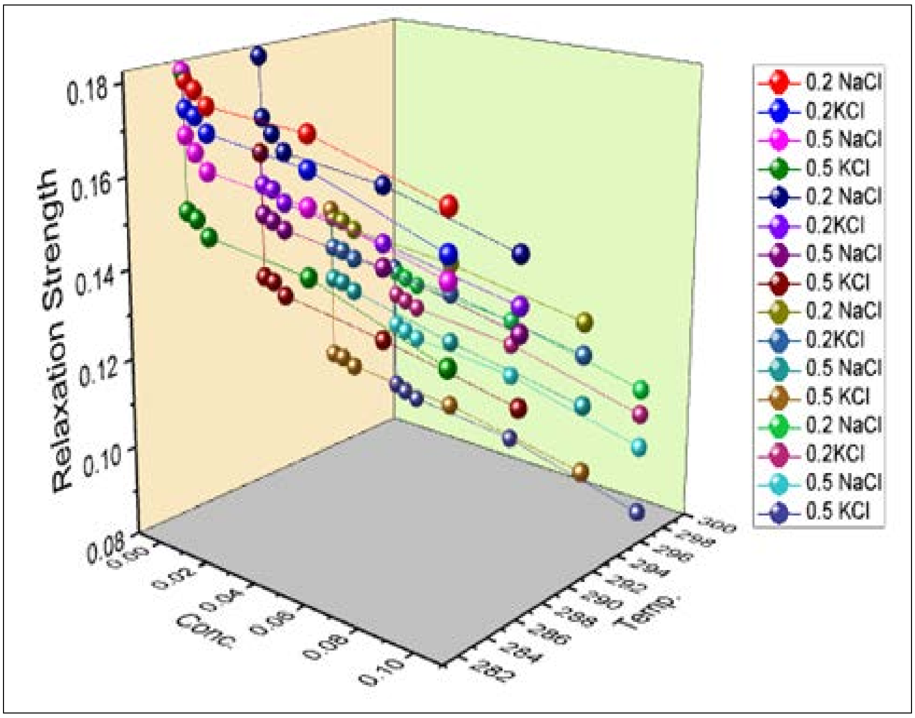

Fig 3: Variation of Relaxation Strength with concentration

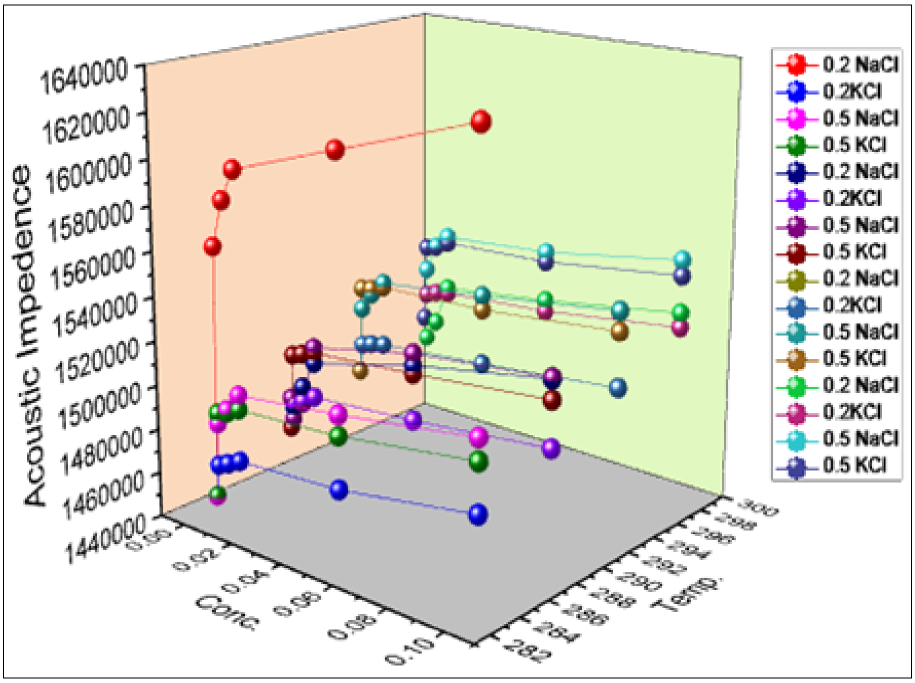

Fig 4: Variation of Acoustic Impedance with concentration

Several biological and commercialised processes are conditional for the surface tension and an aqueous composition. As the increase in the concentration and temperature, the value of surface tension increases as shown in fig. (7). When a solute is added, the increasing tendency of the surface tension is revealed it is commonly higher because of hydrogen bonding between solute-solvent [27].

After measuring and computing a graph of change in adiabatic compressibility as opposed to molal concentration as depicted in fig. (8). A negative value of change in adiabatic compressibility is because of the solute and solvent interaction. The value of change is rising with concentration. It improved the part which difficult to compress inter-ionic interaction in this system [28].

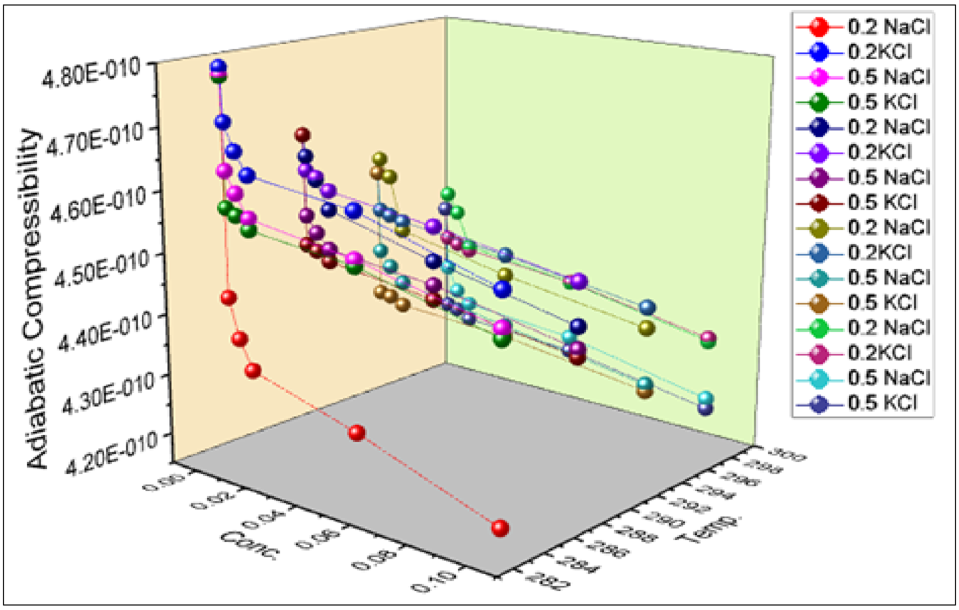

Fig 5: Variation of Adiabatic Compressibility with concentration

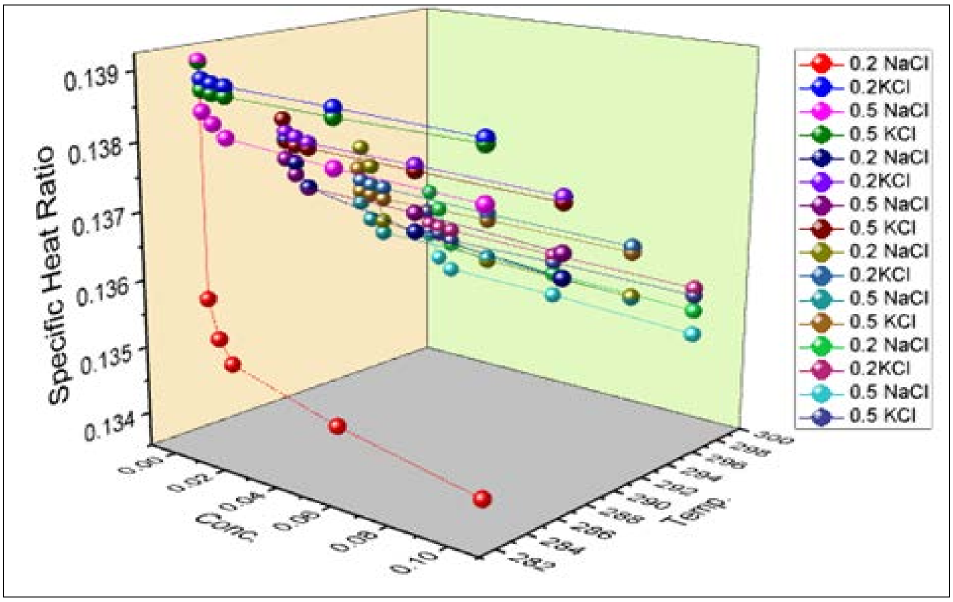

Fig 6: Variation of Specific Heat Ratio with concentration

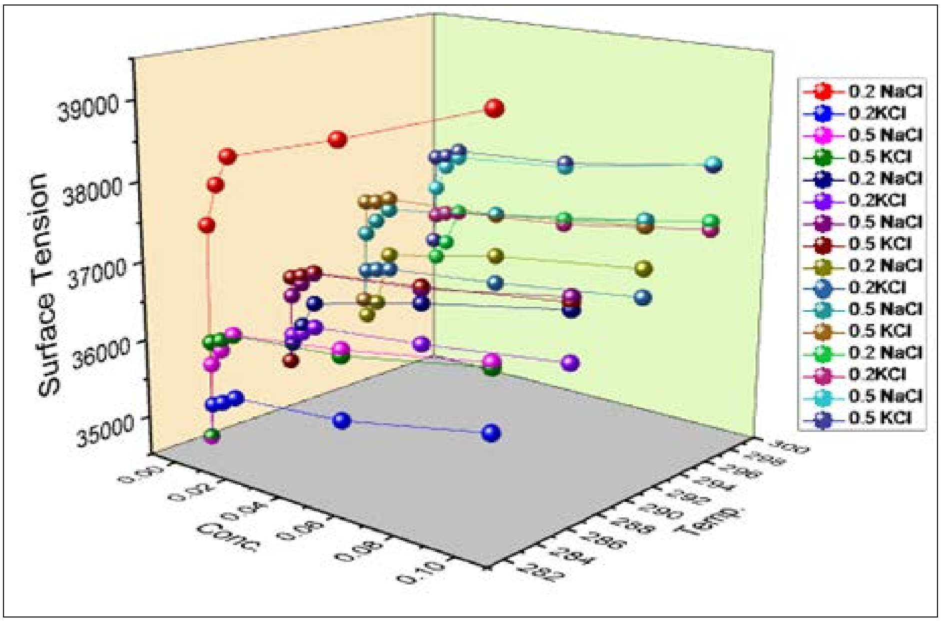

Fig 7: Variation of Surface Tension with concentration

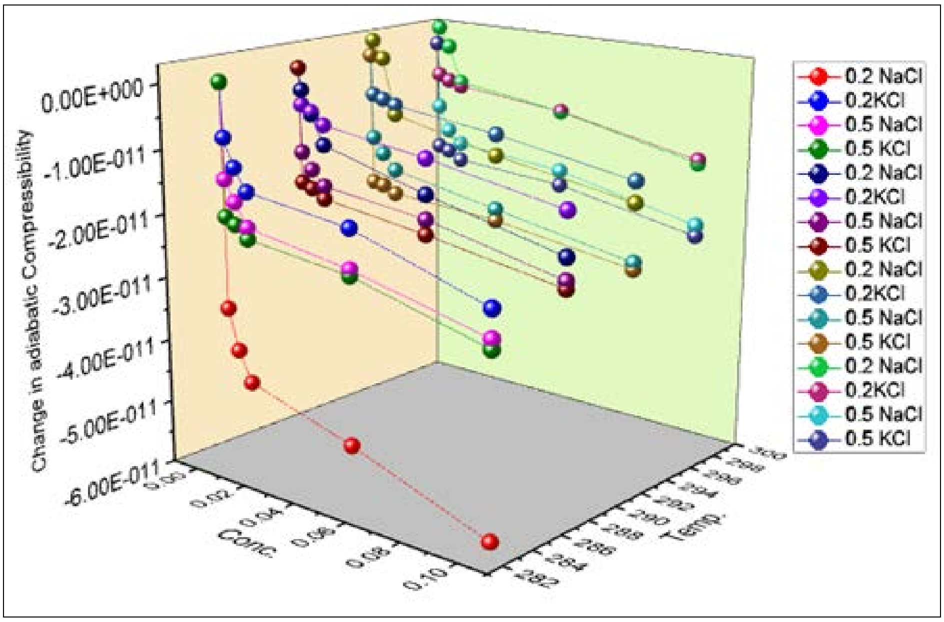

Fig 8: Variation of Change in Adiabatic Compressibility with Concentration

After measuring and computing a graph of relative change in the change in an adiabatic compressibility opposed to molal concentration as represented in fig. (9). It's calculated from an adiabatic compressibility. A negative value of change in adiabatic compressibility is because of the solute-solvent interaction. A value of change in an adiabatic compressibility is increasing with molal concentration with the increasing value of relative change in an adiabatic compressibility with increasing concentration, perhaps assigned to an overall rise in cohesive forces. It indicates hydrogen bonding with unlike components in the solution increases [28]. The intermolecular free length is the most important part as it establishes the sound velocity liquidated and fluid state. The increasing concentration gives a decreasing intermolecular free length and decreases with an increasing temperature as seen in fig. (10) It reveals the significant relation between dextrose and both salts (NaCl/KCl) [29].

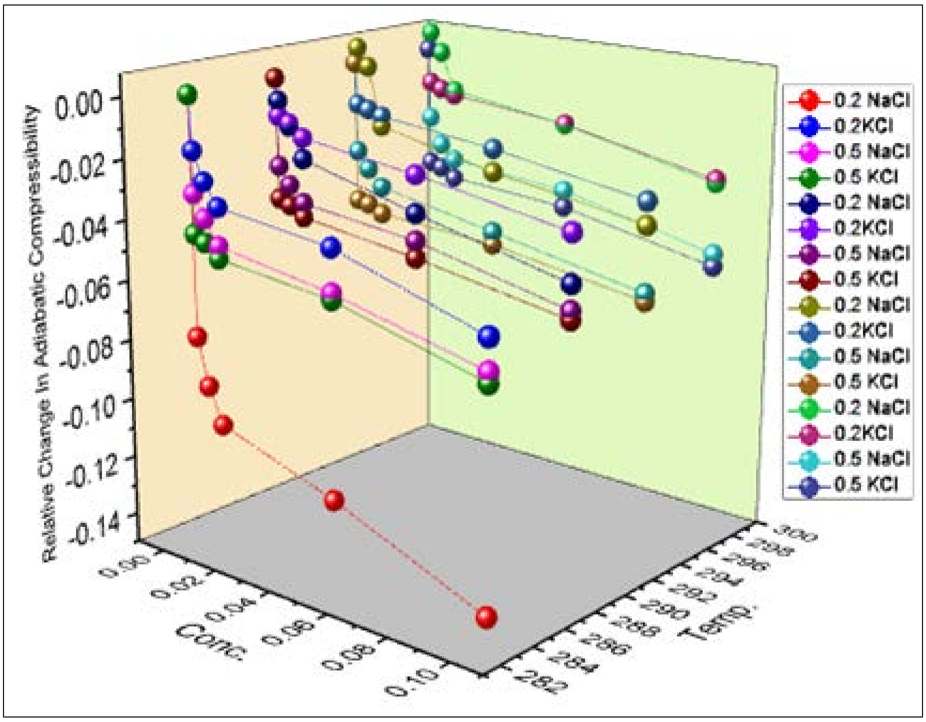

Fig 9: Variation of Relative Change in Adiabatic Compressibility with Concentration

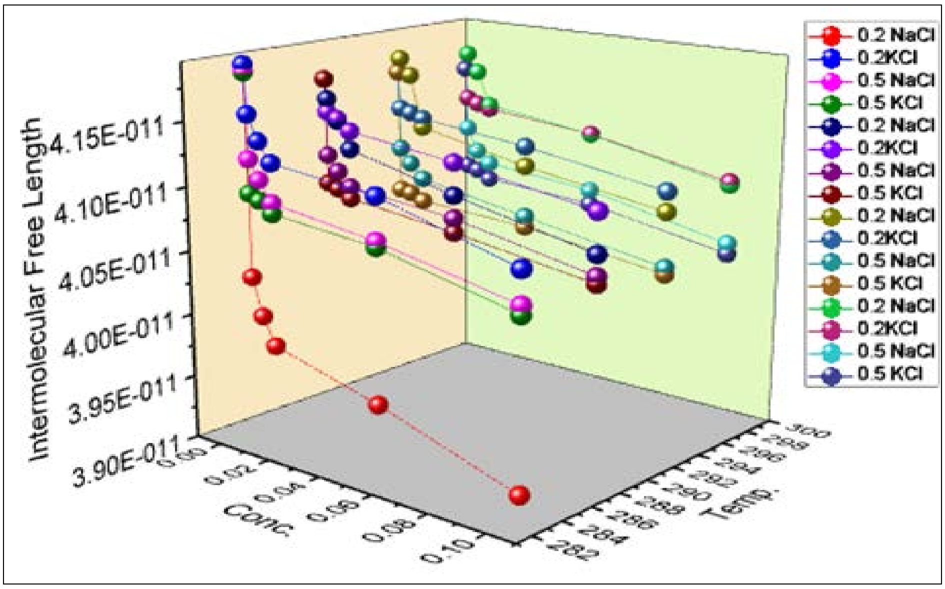

Fig 10 Variation of Intermolecular Free Length with Concentration

Relative association depends on two factors: (1) A shatter of solvent formation is combined with solute and (2) The preservation of solutes that are presented at the same time. with increasing in concentration, a relative association also increases as in fig. (11). It is revealed that there is a close relation between a compound of the molecule and Intermolecular interaction [30]. Non-linearity parameters are related to the molecular interaction of liquid, internal pressure, solidity, etc. Non-linearity parameters for both (B/A)1 and (B/A)2 decrease with increasing concentration and temperature as shown in fig. (12) and (13), from this it is revealed that an interaction between the component of solute-solvent is powerful while mixing rising concentration [31].

After measuring and computing a graph of an isothermal compressibility as opposed to molal concentration and temperature as seen in fig. (14). The value of an isothermal compressibility decreases with increasing molal concentration and temperature this shows that there is a stronger molecular relation [32]. Internal Pressure is related to Internal energy and volume. It is a calculation of, at constant temperature how the internal energy of the system changes. It increases with increasing concentration and temperature as represented in fig. (15). From this it’s revealed that when we added dextrose with salts then intermolecular space decreased [33]. The value of molecular radius increases with increasing concentration and temperature, as shown in fig. (16). Which indicates greater association among the components of the mixture and enhances solute-solvent interaction [34].

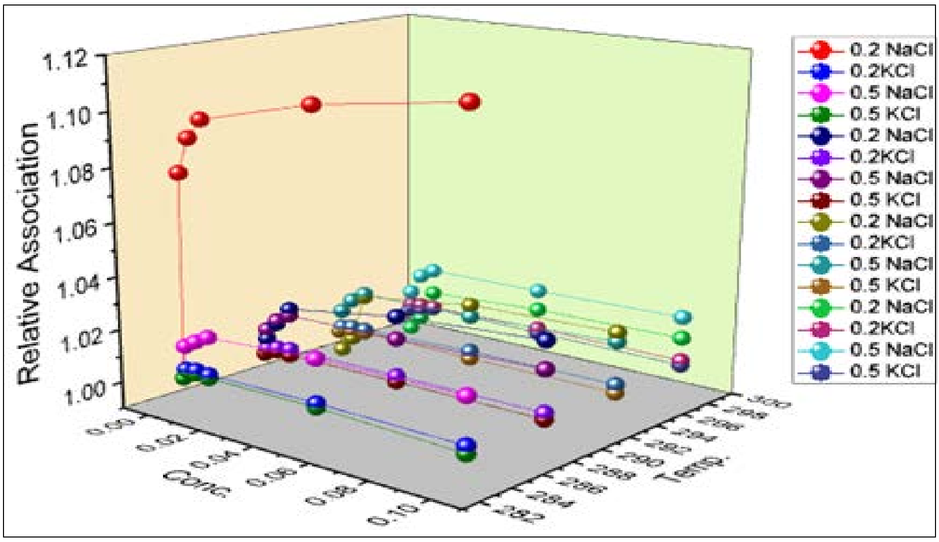

Fig 11: Variation of Relative Association with concentration

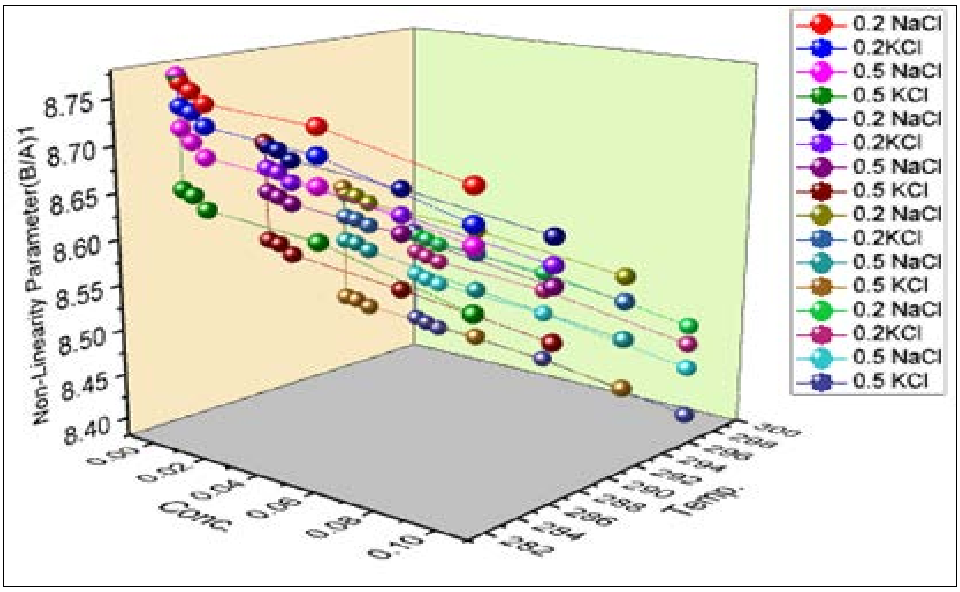

Fig 12: Variation of Non-linearity parameters (B/A)1 with concentration

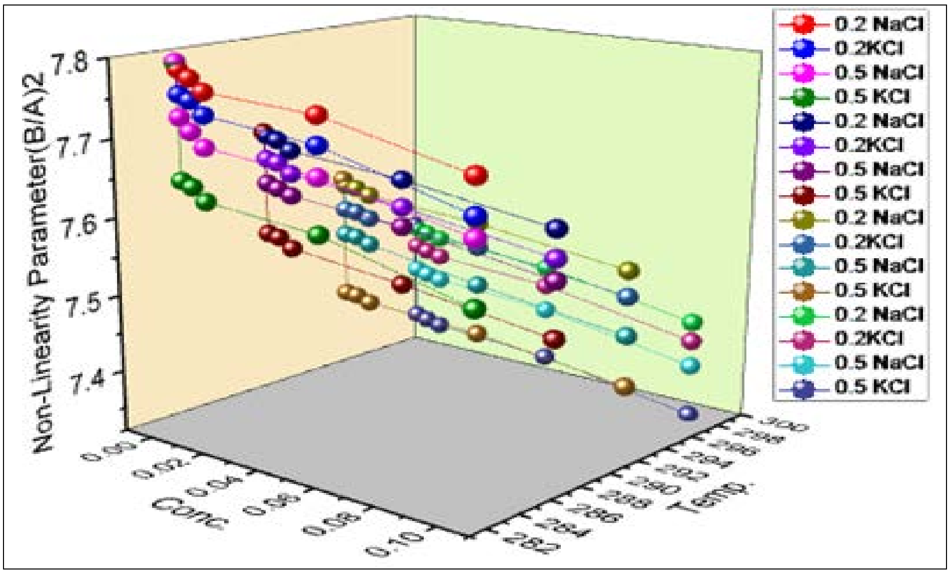

Fig 13: Variation of Non-linearity parameters for both (B/A)2 with concentration

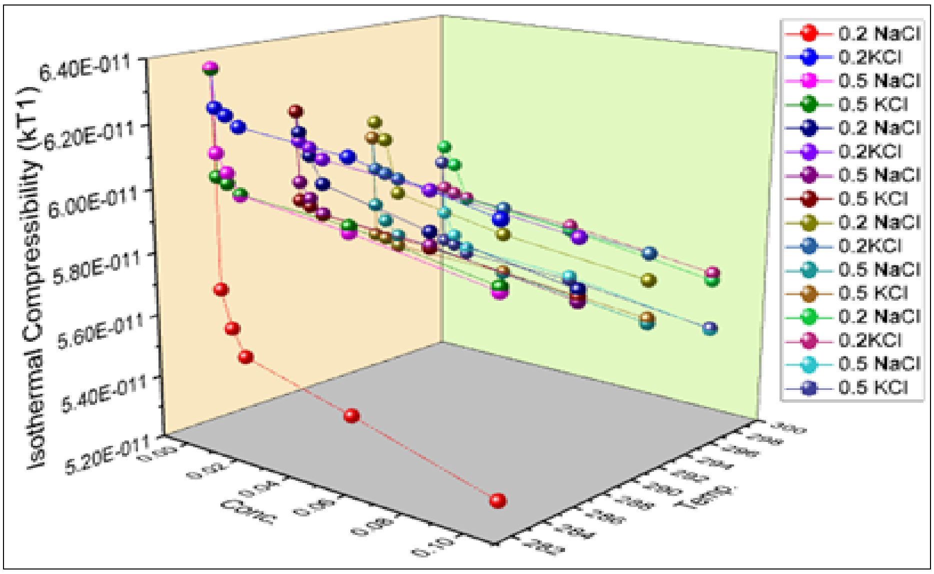

Fig 14: Variation of Isothermal Compressibility with concentration

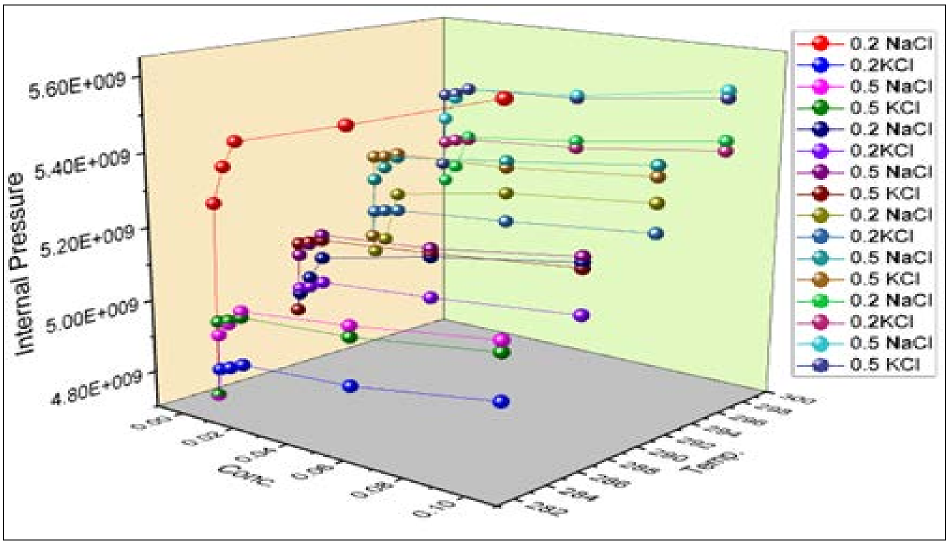

Fig 15: Variation of Internal Pressure with concentration

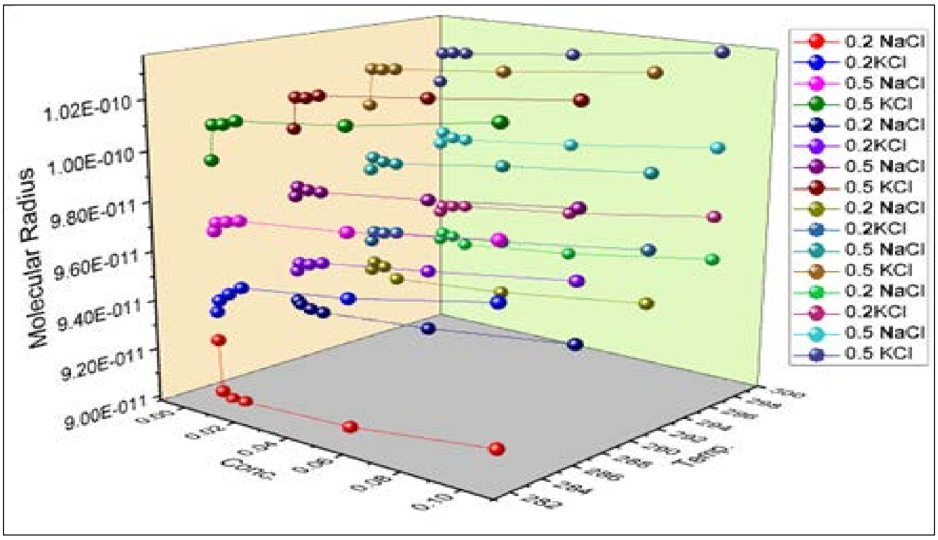

Fig 16: Variation of Molecular Radius with concentration

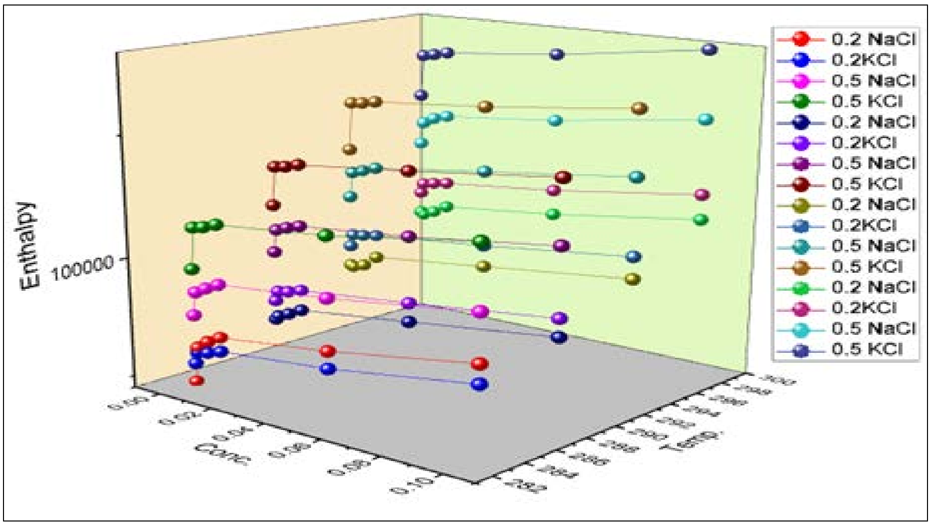

Fig 17: Variation of Enthalpy with concentration

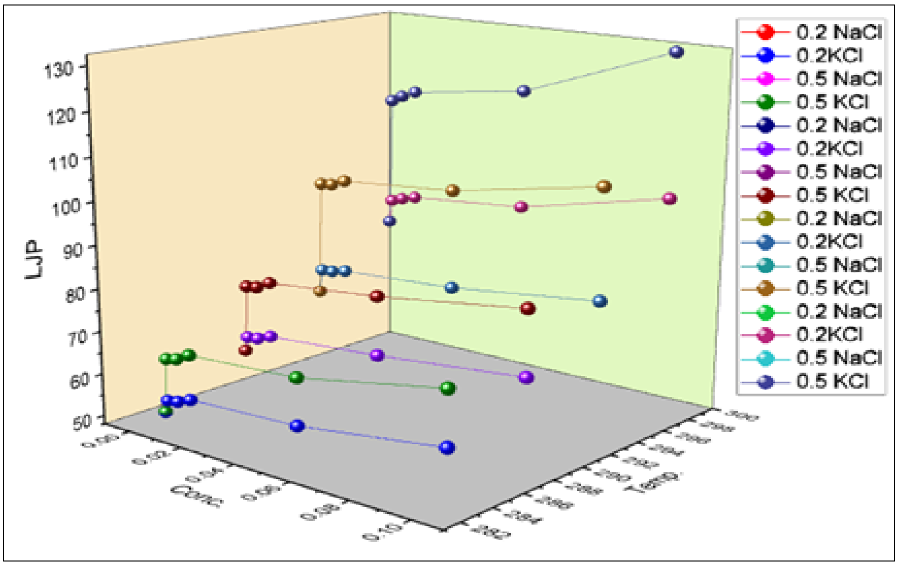

Fig 18: Variation of Lennard -Jones Potential with concentration

Enthalpy is the sum of the internal energy of any thermodynamic system and the multiple of its volume and pressure. When we added solute to a solvent, the value of enthalpy increased with increasing concentration and temperature as depicted in fig. (17). From this it reveals that the solute and solvent interaction happened in the system [35]. Lennard-John's potential explains the interaction between two molecules at a specific distance. It is a pair potential and it has two parameters σ and ε. A value of Lennard Jones's Potential increases with increasing concentration and temperature as represented in fig. (18). Lennard Jones's potential determines what type of force acts between solute-solvent Interaction. This interaction is of two types i.e. soft repulsive and soft attractive that's why it is electronically neutral [35].

Conclusion

The random variation of thermo-acoustical parameters with change in molar concentration disclosed that there consist of intermolecular forces between the mixture of solute and solvent i.e. Dextrose and salts (NaCl and KCl). This molecular relation in solute and solvent mixture may be because of the hydrogen bonding between a molecule and the inclination of solute-solvent interaction. Aqueous NaCl is less ionic than aqueous KCl. The molecular interaction between dextrose with NaCl is weaker as compared to KCl. Thus, the observed trend of the all system is found to be:

0.5M KCl+H_2O+Dextrose > 0.2M KCl+H_2O+Dextrose > 0.5M NaCl+H_2O+Dextrose > 0.2M NaCl+ H_2O+Dextrose.

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