World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Thermo-acoustic properties of glucose in the aqueous solution of ionic salts at various concentration and temperature

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World Journal of Advanced Research and Reviews, 2024, 21(03), 1602–1610

Publication history: Received on 08 February 2024; revised on 16 March 2024; accepted on 19 March 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.21.3.0878

Abstract

Glucose and salts are two essential elements exist in human body. The Ultrasonic characterization on the mixture containing glucose and salt helps to understand the various thermo-acoustical properties of the solution. This approach exposes to find the more efficient medicine having the combination of glucose and magnesium or potassium to treat the patients suffering from deficiency of both as well as hypoglycemia disorder. The computed thermo-acoustical parameters exhibit a good interaction between glucose and potassium chloride solution as compared to glucose and magnesium chloride.

Keywords: Density; Electrolyte Salt Solutions; Hypoglycemia; Saccharide; Velocity

1. Introduction

Early Physicists observed that sugar had molecular formula which could be represented as $C_x(H_2O)_y$. Carbohydrates are considered as compounds in which carbon is surrounded by water molecules; hydrates of carbon, hence the name carbohydrates .After the analysis it shows that all the compounds of mixture are not categorized as carbohydrates for example, Methanal (HCHO), vinegar (CH_3COOH)[1]. "Carbohydrates are optically active in nature i.e. polyhydroxy aldehydes or ketones or the compounds that can be hydrolyzed to polyhydroxy groups. Carbohydrates are categorized on the behalf of their behavior of hydrolysis broadly, as simple carbohydrates and complex carbohydrates".[2] Simple carbohydrates are known as monosaccharides. One of the most popular examples of monosaccharides is Glucose. Glucose is a sugar with a molecular formula $C_6H_{12}O_6$. The postfix '-OSE' is a categorization which denotes a carbohydrate.[3] Glucose occurs in ripe grapes hence the name grape sugar and it is found in most of the sweet fruits. It is also present in honey and is an essential component of human blood. In combined form; it is present in sugar plant and in polysaccharides like starch and cellulose. It is probably the easiest organic compound in nature. Glucose is pentahydroxy aldehyde containing 4 chiral carbon atoms. Simply the natural glucose is dextrorotatory and is also called as dextrose.[4]

As much as carbohydrates important for body the salts are also essential for living creatures. The salts are used as food additives and have various applications in the pharmaceutical branch. [5] Sugar with salts ($MgCl_2$, KCl) these mixtures are combined together because of the linkness in their manner of activity in preserving foods. At large engrossment salts endeavor drying effect on both food and micro-organisms. Many more experimenter have made experiment by composing, with the help of ultrasonic technique to express the way of behavior of carbohydrates and salts in aqueous and non-aqueous mixtures.[6] Glucose and metal salts simultaneously exists in biotic fluids. There are many approaches which helps the medical field in view to create the more efficient medicine containing the mixture of Glucose+Magnesium/Potassium. Among from all of these, Ultrasonic velocity determination provides a main tool for

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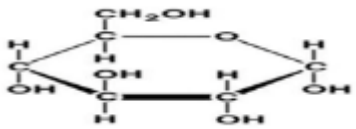
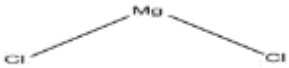
studying the fluids state. Many of the Ultrasonic and thermodynamic parameters calculated from observed data is broadly helpful to learn the molecular interconnections between liquor aqueous solutions & liquids solution.[7] The Ultrasonic analysis is of great significant in serving to understood the nature and scope to the influence of molecular group which exists in solutions of glucose with salts resulting in intermolecular interactions. Apart from all this information we are trying out to find the other parameters by using the measured values of ultrasonic velocity and density like Adiabatic Compressibility, Change in Adiabatic Compressibility, Relative Change in Adiabatic Compressibility, Thermal Conductivity, Surface Tension, Internal Pressure, Isothermal Compressibility, Apparent molal Volume, Solubility Parameter and all these parameter gives information about bonding, strength, interactions, geometry of molecules and many more which help to treat the patients suffering from disorder hypoglycemia.

2. Materials and Methods

All Chemicals are AR grade with 99% purity of mass fraction, purchased from Himedia Lab Private Limited, Mumbai.

Chemical Name	Molecular Weight (g/mol)	CAS No.	Molecular Formula	Molecular Structure
Glucose	180.16	50-99-7	$C_6H_{12}O_6$	
Water	18	7732-18-5	H_2O	
Magnesium Chloride	203.30	7786-30-3	$MgCl_2$	
Potassium Chloride	74.55	7440-09-7	KCl	

2.1. Methods

- The overall work was carried out at four various temperatures varying from 283.15- 298.15K that has to be controlled by using digital water bath with accuracy having $\pm$1K.
- For determining the ultrasonic velocity, we can use a digital ultrasonic interferometer operating at a frequency of 2MHz, which is from Vi Microsystems Private Limited, Chennai whose overall operating accuracy is 0.0001m/s.
- In order to determine the densities of solutions, the 10ml specific gravity bottle was used whose accuracy is $\pm 2*10^{-3}$ Kg/m^3.
- For weighing the compound, we have to use digital electronic balance having a precision of $\pm$0.0001 gm which is supplied from Wensar company.

2.2. Defining Relations

From the calculated data the following parameters will have to be determined:

- Adiabatic Compressibility (β) = $\frac{1}{\rho \times U^2}$…… {m^2/N}

Where, ρ= Density of liquid (liquid mixture)
U= Velocity of sound
It is a fractional fall in volume per unit rise in applied pressure when no heat flows into the system.

- Change in Adiabatic Compressibility ($\Delta\beta$)=$\beta - \beta_0$…..{m^2/N}

Where, β =Adiabatic Compressibility of solvent
β_0=Adiabatic Compressibility of solute
It is a quantity that can be used for the examine of interactions among the complexes.

- Relative Change in Adiabatic Compressibility= $\frac{\Delta\beta}{\beta_0}$

Where, $\Delta\beta$=Change in Adiabatic Compressibility
β_0=Adiabatic Compressibility of solute

- Specific Heat Ratio (γ)= $\frac{17.1}{T^{\frac{4}{9}}\times\rho^{1/3}}$ …….. $\{K^{4/9}\}^{-1}\{Kg^{1/3}/m\}^{-1}$

Where, T= Temperature
ρ=Density of liquid (liquid mixture)
It determines the quantity of energy needed to rise per degree in temperature.

- Isothermal Compressibility (K_T)=$\frac{1.33\times10^{-8}}{(6.4\times10^{-4}U^{3/2}\rho)^{3/2}}$……$\{m^2/N\}$

Where, U= Velocity of sound
ρ=Density of liquid (liquid mixture)

- Internal Pressure (π_i) =$\frac{\alpha\times T}{K_T}$……..$\{N/m^2\}$

Where, α =Thermal Expansion of coefficient
T = Absolute Temperature
K_T= Isothermal Compressibility
It is remarkable parameter which gives us information about the structural and intermolecular interactions among the fluids.

- Thermal Conductivity (k)= $\{3.0\times (\frac{\rho N_A}{M})^{2/3}K_B U$…….. $\{\frac{W}{mK}\}$

Where, ρ= Density of solution
N_A= Avogadro's number = 6.022×10^{23} molecules
M= Molecular mass of solution
K_B= Boltzmann Constant = 1.381×10^{-23} m^2-Kg-s^{-2}-K^{-1}
U = Ultrasonic Speed
This Formula gives us information about heat transmission from one lattice into the other.

- Surface Tension (σ) = $(6.3\times10^{-4})\rho U^{3/2}$…….. {N/m}

Where, U= Velocity of sound
ρ=Density of liquid (liquid Mixture)
This formula is used to study the configuration of the molten solutions.

- Apparent Molal Volume (V_φ) = $\frac{1000}{m\rho_0}(\rho_0-\rho)+\frac{M}{\rho_0}$…….$\{m^3/mol\}$

Where, ρ =Density of liquid (liquid mixture)
ρ_0= Density of solvent
m= Molality of liquid (liquid mixture)
M= Molar mass of solute.
This formula helps us to understand the dimensions of the solute molecules.

- Solubility Parameter (δ)=$\sqrt{\pi_i}$…….$\{N/m^2\}^{1/2}$

Where, π_i= Internal pressure
From this we can determine the various phenomena like solubility.

- Pseudo-Gruensian Parameter (r) = $\frac{\gamma-1}{\alpha\times T}$

Where, γ= Specific heat rate
α= Thermal Expansion of coefficient
T = Temperature
This Parameter suggests the association among the molecules.

- Enthalpy (H)= L_i/M_{eff}…… {J/Kg}

Where, Li = Latent heat of Vaporization.
M_{eff} =Effective molar mass of solution.
This Parameter suggests the absorption of energy in the solution.

- Relative Association (R_A) = $\{\frac{\rho}{\rho_0}\}\{\frac{U_0}{U}\}^{1/3}$

Where, ρ =Density of liquid (liquid Mixture)
ρ_0= Density of solvent
U= Velocity of sound
U_0=Velocity of solvent
It measures the interrelation existing in between the water and solvent.

- Relaxation Strength (r) = 1- $(\frac{U}{U_\infty})^2$

Where, U= Velocity of sound.
U∞= 1600 m/sec.
This is used to calculate the interaction after the addition of solute into the solvent.

- Intermolecular Free Length (L_f)= K× $\beta^{1/2}$…….{m}

Where, K= Jacobson's temperature = $(93.875+0.345T)\times 10^{-8}$ {at any temperature T}

β= Adiabatic Compressibility.

This helps us to understand the knowledge of temperature dependence on the free length.

3. Result and Discussion

The Ultrasonic Velocity of Glucose at various concentration (0 .001M-0.1 M) in the solution of 0.2 and 0.5M solution of $MgCl_2$ and KCl at different temperatures (283.15K - 298.15K) were measured .It is observed that ultrasonic wave affect the existing system (Glucose + H_2O+Salts).The observed data reveals that the ultrasonic speed of the solution rises along the rising of molality and temperature as express in Figure(1).So, by rising carbohydrates concentration in the saturated aqueous salt solutions the ultrasonic velocity rises. So, this suggests that there is an intermolecular interaction occurs in between the glucose and salts ($MgCl_2$ and KCl) solution through hydrogen bonding.[8]

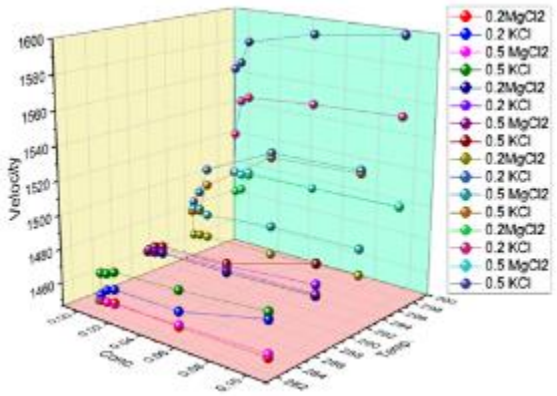


Figure 1 Velocity v/s Concentration at different temperature

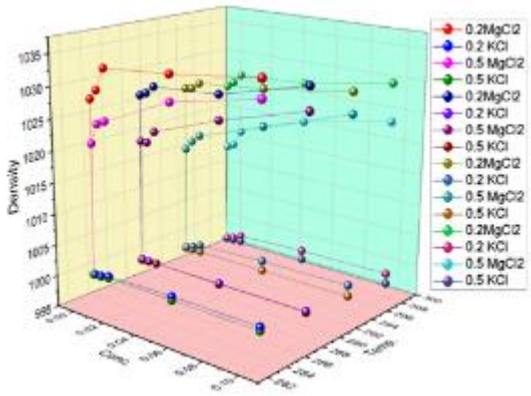


Figure 2 Density v/s Concentration at different temperature

Density is said to be tightness in system with the matter and is widely linked to closeness of material in the solutions and therefore variant materials possessing varying densities. The density of glucose at various concentrations (0.001-0.1M) in the solution of 0.2M and 0.5M solution of $MgCl_2$ and KCl and at various temperatures (283.15K - 298.15K) was measured. The data confirms that the density of the solution decreases with rising in temperature and increases with increasing in concentration due to the compacting figure of solvent after the combining of solvent ions. This specifies that there is a strong association occurs among the solute and solvent ions. The increasing trend of density specify that there is a rise in molar volume which confirms the structural arrangement in between the molecules.[9] Because of the adiabatic compressibility the physio-chemical effects of fluids can be understood, as the hydrogen bonding between the different mixtures falling with the compressibility. In the recent research, it is clear that the adiabatic compressibility falling with increasing in temperature and concentration, but as we know that water is a universal ionic solvent and when salts and glucose combined with each other there is well intermolecular interactions takes place which results a solidity of ions. The falling in the value of adiabatic compressibility is shown in Figure (3) which confirms that there is a strong association takes place in between glucose and salts molecules.[10]

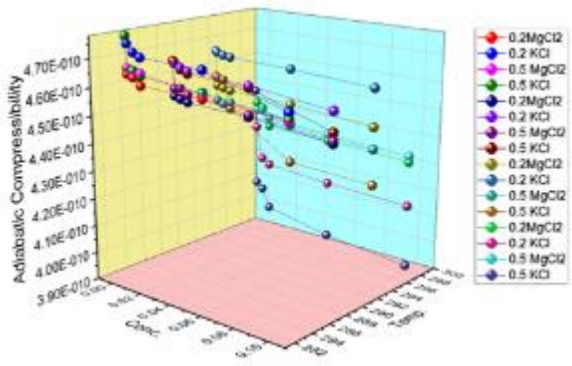


Figure 3 Adiabatic Compressibility v/s Concentration at different temperature

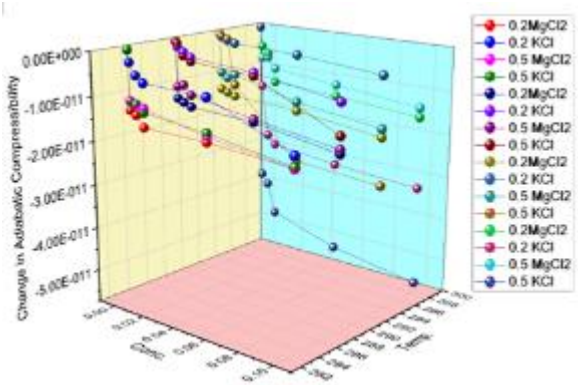


Figure 4 Change in Adiabatic Compressibility v/s Concentration at different temperature

After evaluating and making the graph of change in Adiabatic compressibility versus concentration as expressed in Figure (4), it is observed that the negative values of adiabatic compressibility are because of the solute -solvent interactions. From this negative values it is verify that there is a negative increase in bulk modulus values along concentration which shows that the H-bonding along the unalike constituents in the solution rises.[11]

The relative Change in Adiabatic compressibility was evaluated with the help of adiabatic compressibility value of solute and solvent. From this data, the values are found to be negative which is because of the solute -solvent interconnection. This rise in the relative Change in adiabatic compressibility along the rise of concentration of glucose in water also in both the salt solutions may assign rising of cohesive forces in the solutions.[12] The Specific Heat Ratio was a special physical quantity that depends on the temperature and density of the fluids and its mixtures. Figure (6) convey the variation of specific heat ratio at various concentrations and temperatures. From the graph it is confine that specific heat ratio decreases with concentration and temperature of solution, which gives us idea about the closed bonding of the molecules into the solution through H- bonding.[13]

The Comparative alterations in volume are a measure of Isothermal Compressibility. The general trend of the isothermal compressibility is expressed in Figure (7,8). It had to be decreasing with rising in concentration and temperature. This trend appears to be the outcome of corresponding falling in free volume which confirms the clustering of molecules and hence recommended the increase in interaction among the constituents.[14]

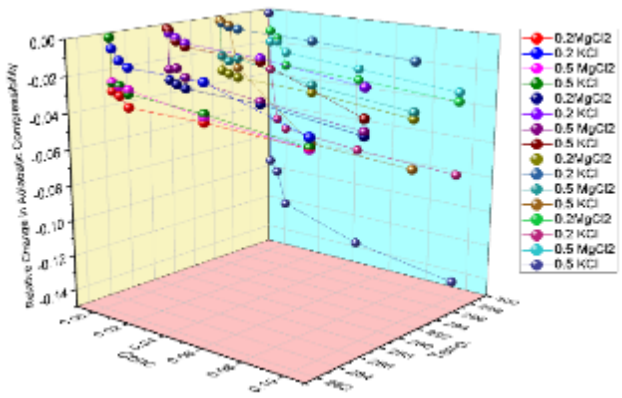


Figure 5 Relative Change in Adiabatic Compressibility v/s Concentration at different temperature

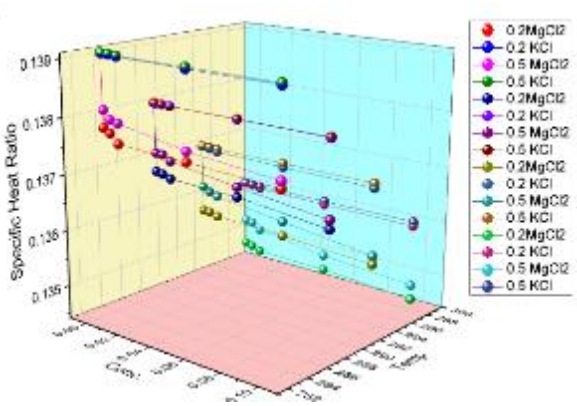


Figure 6 Specific Heat Ratio v/s Concentration at different temperature

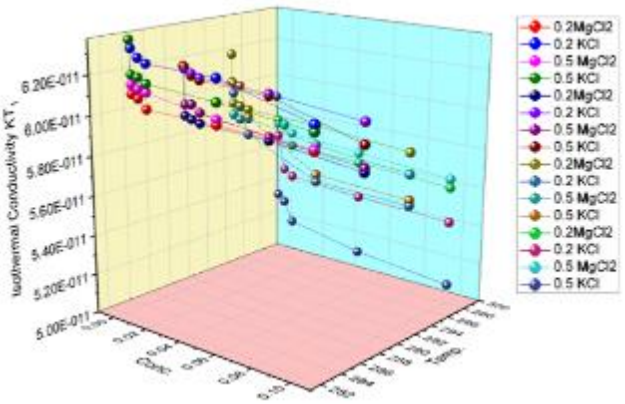


Figure 7 Isothermal Compressibility (KT_1) v/s Concentration at different temperature

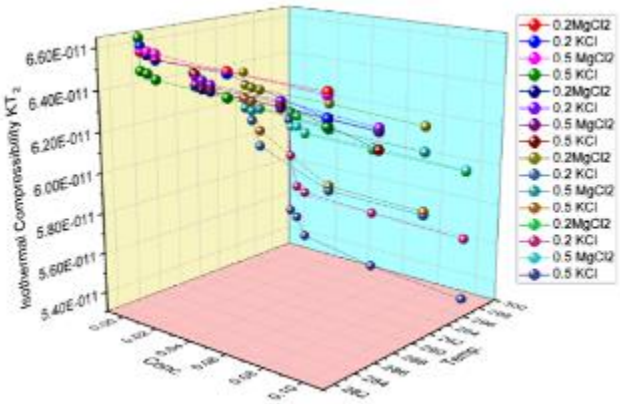


Figure 8 Isothermal Compressibility (KT_2) v/s Concentration at different temperature

Internal pressures relate the thoughtfulness of internal energy with the change in isothermal extension or compression at the isochoric impact of temperature on the Intermolecular interaction's energy. In the present medium the internal pressure rises along with increasing in concentration and temperature of solution. This way of behaving the solution designate that intermolecular spacing fall along with the inclusion of glucose in salt solutions. This increase in

interconnection supports that association will takes place in between the constituents of solute and solvent molecules.[15]

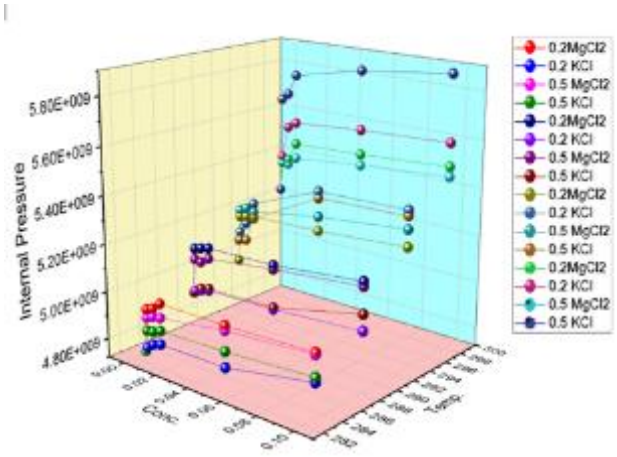


Figure 9 Internal pressure v/s Concentration at different temperature

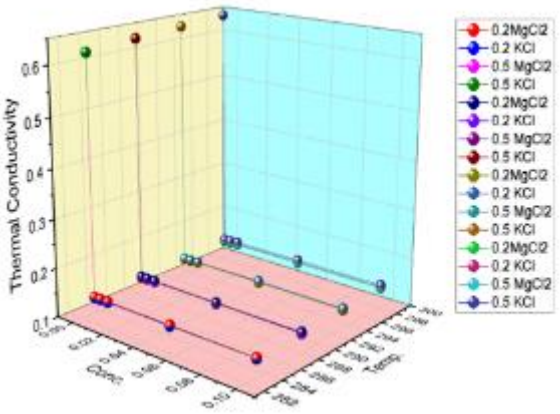


Figure 10 Thermal Conductivity v/s Concentration at different temperature

It is a property that describes a material ability to conduct heat. By understanding the thermal conductivity properties, we may determine how much heat flows in the system. Basic knowledge related to, why salts and water affecting on the thermal conductivity of glucose is also required in adapting water and energy movement in medium consisting salt - affected glucose. The thermal conductivity of glucose at different concentrations and temperature were measured. It is found to be increased with increasing in concentration and temperature. Salts causes a decrement in thermal conductivity, but when glucose are added to salts solution the values of thermal conductivity get increases which confirms that accretion might be strongly affect by the interaction of glucose and salts ions. Thus, verify that Intermolecular interactions taking place in the given system.[16]

The property of the fluids to reduce its surface area is called surface tension. The disparity in the surface tension as a purpose of concentration and temperature is illustrated in Figure (11). The rising trend of surface tension along the concentration and temperature of solute designate the significant association takes place in the solution due to which strong attractive forces occurs in between the solute and solvent molecules.[17]

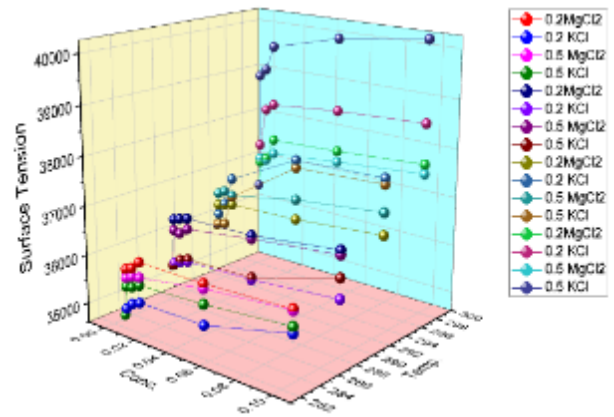


Figure 11 Surface Tension Concentration at different temperature v/s Concentration at different temperature

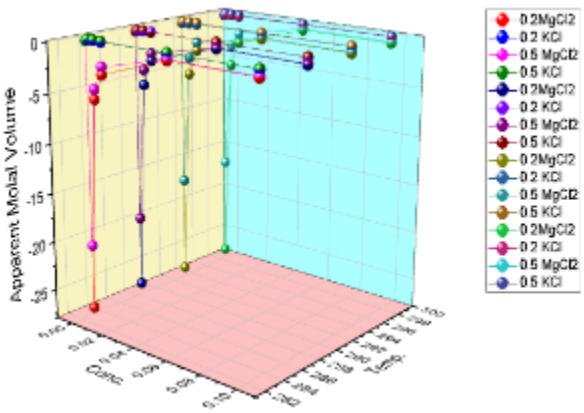


Figure 12 Apparent Molal Volume Concentration at different temperature v/s Concentration at different temperature

The values of apparent molal Volume were depicted with the help of density of water and solvent. It is understandable from the trend shown in Figure (12) that apparent molal volume decreases with rising in concentration and temperature and from this data it is clear that there is a strong ionic interaction assisting in the solution.[18] The Solubility Parameter has been normally useful only for uniform solutions. The solubility parameter was evaluated to find out theoretical glucose salt miscibility. Additionally, the Figure (13) shows the variant of the solubility parameter

with molality at different temperatures. The rising trend of solubility parameter is due to the increase in internal pressure of the solution. Furthermore, an increase in solubility parameter with the rise of temperature values also allotted to a fact the increase of cohesive forces which favors a good association among constituents of a system. A rising tendency of the solubility parameter display that the system has more efficiency to be soluble.[19]

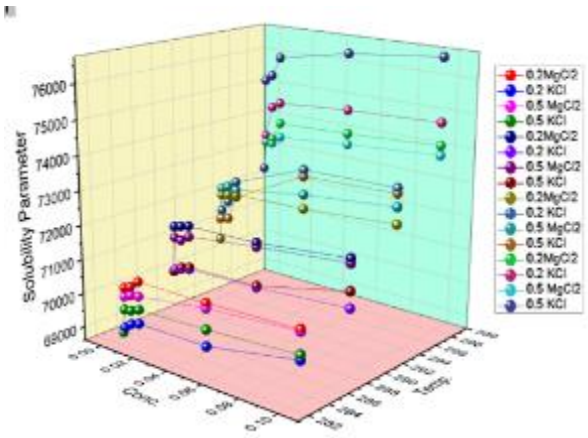


Figure 13 Solubility Parameter v/s Concentration at different temperature

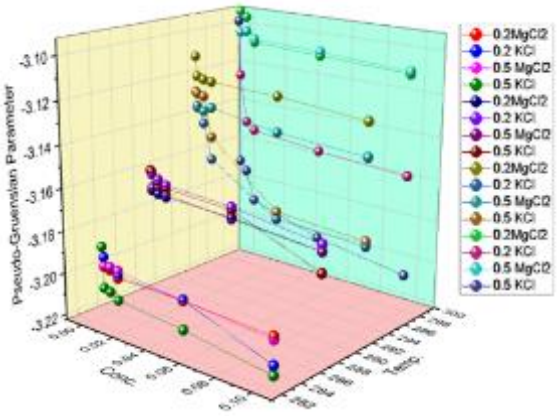


Figure 14 Pseudo-Gruensian Parameter v/s Concentration at different temperature

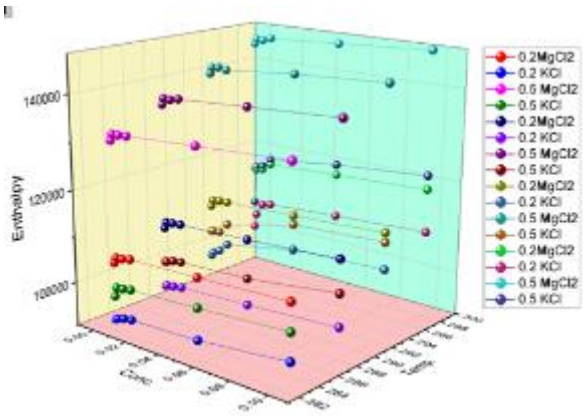


Figure 15 Enthalpy v/s Concentration at different temperature

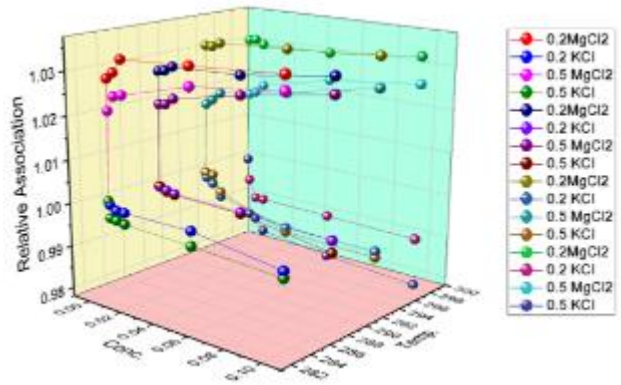


Figure 16 Relative Association v/s Concentration at different temperature

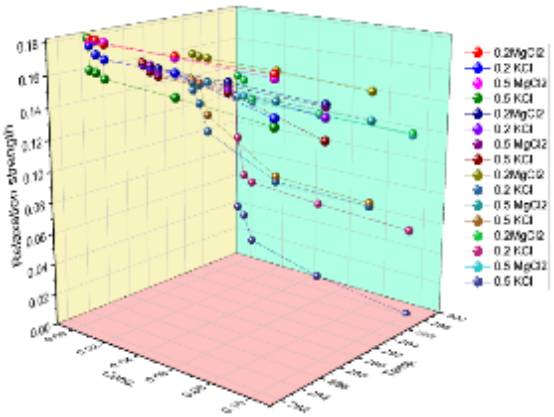


Figure 17 Relaxation Strength v/s Concentration at different temperature

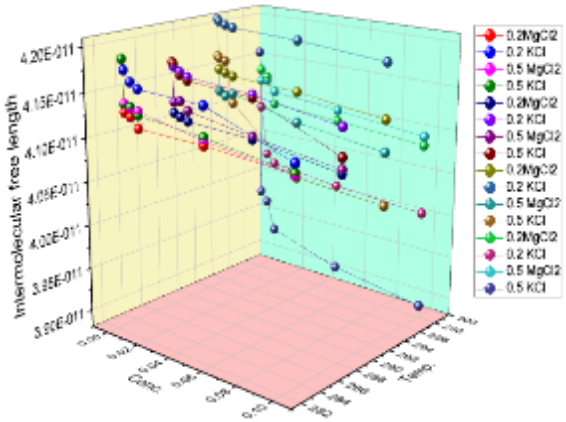


Figure 18 Intermolecular Free length v/s Concentration at different temperature

The Pseudo- Gruensian Parameter (r) is a stage measure the level of molecules or ionic association. The graph is plotted against concentration at different temperatures express in Figure (14). It represented that the (r) values are negative

which shows a falling mode with the combination of glucose in the solvent and these negative values proposed the extension of cluster in the medium and well-fortified intermolecular interaction among solute and solvent.[20] It is the measurement of energy in a thermodynamics system. It is generally the addition of internal energy and the product of internal pressure & volume. The observed reading for enthalpy is observed from the recorded graph as expressed in Figure (15) it is concluded that with rising in concentration and temperature the enthalpy goes on increasing.[21]It is a parameter that has a more significance as it calculates the amount of association that carried out in the components of the mixture. As from the Figure (16), the rising in the value of 'R_A' with concentration concluded that there is a strong association of constituents of molecules which results in an intermolecular interaction. There are fluctuations in the value of 'R_A' with temperature which suggests that there is strong ionic interaction present in the current medium.[22] It is that value which is straightly related to adiabatic compressibility and strongly dependent on term [1-U/U∞]. Here 'U' is considered as the ultrasonic velocity of medium and 'U∞' be the constant having the moral value of 1600 m/ sec. From the graph it is observed that with falling in the values of relaxation strength with a rising in concentration and temperature reveals that in the present medium there is solute- solvent interaction takes place which express in Figure (17). From this it gives the idea about the large association among the glucose and salts.[23]

Intermolecular free length is a mean internal in between the plane of two neighboring ions existing in the fluids. Form the data it is revealed that the values of free length fall with a rising in the concentration of solute as well as solvent which designate that there is remarkable interaction present number of constituents of ions. It also promotes that the system consisting a good association.[24]

4. Conclusion

Ultrasonic inspection of molecules interconnection in different saturated aqueous solution of glucose containing variant concentration of salts ($MgCl_2$ and KCl) had been measured. The demonstrated allied parameters give the valuable details regarding the various interactions in saturated aqueous solutions. Glucose which is used in aqueous system as a solute alter the form of water molecules into more well-arranged structure due to the formation of H-bonding. As per the results, there is strong association in this system which results in the closed packing of molecules. The gradual fall in adiabatic compressibility in present work suggest that the system becomes more and less malleable. It is found that the observed trend is: 0.5M KCl + Glucose + water > 0.2M KCl + Glucose + water > 0.5M$MgCl_2$ +Glucose + water >0.2M$MgCl_2$ +Glucose + water. This data exhibits if we supply glucose with heavy concentration of potassium then the patients suffering from hypoglycemia disorder can be recovered quickly as compared to glucose supplied along with magnesium solution. Meanwhile on a larger scale such a study will be helpful in biological and technical applications in further era.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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