Study of the Effects of Electrolytes on the Carbohydrate Solutions with Volumetric and Viscometric Measurements

by

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Declaration

This is to certify that the thesis work entitled "Study of the effects of electrolytes on the carbohydrate solutions with volumetric and viscometric measurements." has been carried out by Sheikh Ahidul Alam in the department of chemistry, Khulna University of Engineering & Technology Khulna, Bangladesh. The above research work or any part of the work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

In this study, a simple volumetric and viscometric method was used for the analysis of effect of body containing electrolytes such as NaCl and KCl on the carbohydrates (glucose, sucrose and maltose) solution. The densities and viscosities of NaCl and KCl at different concentration in aqueous and aqueous glucose, aqueous sucrose and aqueous maltose (1% (w/v), 5% (w/v) and 10% (w/v)) solutions have been determined at 298.15, 303.15, 308.15, 313.15, 318.15 and 323.15 K respectively. The studied electrolytes are found to be dissolved readily in aqueous and aqueous carbohydrate (upto 10% (w/v)) solutions. The density of glucose, sucrose and maltose in aqueous solution were found to be order of Maltose > Sucrose > Glucose. The value of density of NaCl and KCl increases with the increasing of molarity of the electrolytes. Densities of electrolytes in aqueous carbohydrate solutions are higher than that of electrolytes in aqueous solution. The increase of density with concentration of electrolyte can be attributed to solute-solvent interaction. The apparent molar volumes, ϕ_v were obtained from these densities data. The limiting apparent molar volumes, ϕ_v^o and experimental slope, S_v derived from Masson equation have been interpreted in terms of solute-solute and solute – solvent interactions. The sign of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ i.e. second derivative of limiting apparent molar volume of solutions with respect to temperature at constant pressure which corresponds to structure making or breaking properties of solutes were determined. NaCl in water, 1% (w/v) glucose and 1% (w/v) maltose solution, the value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ were found to be slightly positive suggesting structure making property. In case of sucrose it shows negative value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ for all the electrolytes containing solvent systems indicating structure breaking property. KCl in water and carbohydrate solution, the values of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ were found to be negative suggesting structure breaking tendency.

The viscosity vs molarity plots for all the electrolytes systems are linear in all the solvent systems with some exceptions. The viscosity, η for all the studied electrolytes are greater in aqueous carbohydrate solvent system than those in water system. The viscosities coefficients A and B were determined from viscosities data on the basis of Jones Dole

equation. The coefficient B gives information regarding solute - solvent interaction and shape and size effect on the solvent structure. The coefficient A represents the ion-ion interaction. The B-coefficient for NaCl in aqueous and aqueous glucose, aqueous sucrose and aqueous maltose solutions (1% (w/v)) at all the temperatures are positive. The positive value of the B-coefficient corresponds to the structure making behavior of solutes. The B-coefficient for KCl in water and carbohydrate solutions (1%, 5% and 10% (w/v)) are negative. The negative value of B-coefficient corresponds to the structure breaking behavior of KCl. The sign of $\frac{dB}{dT}$ i.e. first derivative of the viscosity coefficient of B with respect to temperature, which corresponds to structure making or breaking properties of solutes, were determined. For NaCl in aqueous and aqueous carbohydrates (1% (w/v)) solutions, the values of $\frac{dB}{dT}$ are negative which corresponds to structure making behavior. For aqueous and aqueous carbohydrate solution (1%, 5% and 10% (w/v)) of KCl , the values of $\frac{dB}{dT}$ are positive which corresponds to structure breaking behavior.

The free energy of activation, $\Delta G^{\neq}$ for viscous flow was calculated using Nightinagle and Benck equation at the experimental conditions. Activation enthalpy, $\Delta H^{\neq}$ and activation entropy, $\Delta S^{\neq}$ were calculated using the Eyring equation and other thermodynamic relations. The effects of electrolytes on the structure of water and aqueous carbohydrate solutions were interpreted in terms of apparent molar volumes, viscosities and viscosity coefficients (A and B) values and thermodynamic parameters ($\Delta G^{\neq}$, $\Delta H^{\neq}$, $\Delta S^{\neq}$).

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Symbols/Abbreviations	**Explanation**
ρ	Density of solution
φ_v	The apparent molar volume
φ_v^0	The limiting apparent molar volume
v_1	volume of solvent
V_2	Partial molar volume of solute
η	Viscosity
B	B- co-efficient
$\Delta H^\#$	Change of Enthalpy
$\Delta G^\#$	Change of Free energy
$\Delta S^\#$	Change of Entropy
Å	Angstrom
δ	Delta
c	Molarity
n_1	Number of moles of solvent
n_2	Number of moles of solute
a	weight of solute
M_2	Molecular mass of solute
w_e	Weight of empty density bottle
w_0	Wight of the density bottle with solvent
w	Weight of the density bottle with solution
h	Plank's constant
N	Avogadro's number
R	Universal gas constant

CHAPTER I

Introduction

1.1 Properties of solutions

The liquid state, being an intermediate state between gaseous and solid states, retains some characteristics of both the gaseous and solid states. The liquid state, thus, can not be adequately defined as the gaseous and the solid states. The molecular and macroscopic behavior of liquids varies from liquid to liquid due to characteristic intermolecular interactions. The behavior of multi-component mixtures, on account of molecular interactions between dissimilar molecules, becomes still more difficult to interpret. In view of these facts there are serious problems in formulation of any general theory of solution.

It should, in principle, be possible to calculate theoretically, the properties of solution from the properties of individual components. But there are inherent difficulties created by liquid state that is not properly understood. The theoretical treatments, therefore, have to assume some model (e.g., lattice model, cell model etc.) for the structure of the components and their solution. Alternatively, it is considered convenient and useful to determine experimentally the values of certain macroscopic properties of solutions for proper understanding of the structure of the solution. Some of the usually experimentally determined macroscopic properties are: density, viscosity, thermodynamic properties, surface tension, etc., which are readily measurable. Investigations, comprising experimental determination of various thermodynamic properties, viscosity etc on solutions, assume significant importance since it is possible to draw conclusions regarding characteristic molecular interactions between constituent molecules of the components from purely thermodynamic reasoning.

The theoretical treatments need to assume some model for carrying out statistical-mechanical calculations of these properties. The observed discrepancies between theoretically calculated and experimentally determined values are naturally on account of the inadequacies in the theoretical models. Such a comparison often suggests appropriate refinements of the assumed model.

The macroscopic properties of any system have to be interdependent, since these essentially originate from the most probable distribution of energy between the constituent molecules comprising the system. There has, therefore, been interest for seeking interrelations between the macroscopic properties of any system. It should, in principle, be possible to express the value of any macroscopic property in terms of the known values of the other. Since viscosity coefficient is a macroscopic property under non equilibrium condition, there has been a considerable effort for establishing its relationship with thermodynamic properties of a system.

The study of physico-chemical properties of binary and ternary system has drawn early attention from two main points of view. Firstly, it provides the way for accumulating knowledge about the type of interaction or the type of forces acting during the mixing of two different types of species. Secondly it may show the appearance of a new phenomenon which is absent in the pure liquid.

For example due to the mixing of liquids their may be either positive or negative deviation of volume and thus different from additivity rule. The negative volume may be caused by the so-called 'compound formation' through association or decrease in the intermolecular distance between the interacting molecules. The positive volume has been explained by the break down of association of the species formed either by chemical forces such as H-bonding or by physical forces such as dipole-dipole and dipole-induced dipole interaction.

Physical properties like density, viscosity, surface tension, conductivity, dielectric constant, refractive index, group frequency shifts in I.R. spectra etc. give an indication about the molecular structure as well as the molecular interactions that occur when liquids are mixed together. The density and viscosity are two fundamental physico-chemical properties of which are easy, simple, inexpensive and precise tools, by which one can get the valuable information about the molecular interactions in liquids and liquid mixture correlated with equilibrium and transport properties. The thermodynamic data are used subsequently by a variety of physical scientists including chemical kineticists and spectroscopists involved in reaction occurring in solution and by chemical engineers engaged in the operation and design of chemical reactor, distillation columns or other type of separation devices. From the above mentioned properties, quantitative conclusion can hardly be drawn about the molecular interactions even in simple liquids or their mixtures.

Our present investigation is based on the methods of physico-chemical analysis, which is a useful tool in getting sound information about the interaction of some Na, K based electrolytes with carbohydrates (Glucose, Sucrose and Maltose) and in studying the ion-solvent structure in binary and ternary systems.

1.2 Electrolytes

Electrolytes play a crucial role in almost every metabolic reaction in the body. They help the controlling of water balance and fluid distribution in the body. It creates an electrical gradient across cell membranes that are necessary for muscle contraction and nerve transmission. It regulates the acidity (pH) of the blood and help regulating the level of oxygen in the blood. They are involved in moving nutrients into cells and waste products out of cells.

Electrolytes are substances that become ions in solution. It balances our body which is essential for normal function of our cells and our organs [1]. Sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), chloride (Cl^-), biphosphate (HPO_4^{2-}), bicarbonate (HCO_3^-), and Sulfate (SO_4^{2-}) are important electrolytes in human body. In this study, Na^+, K^+ and Cl^- ions were used for the ion-solvent interaction measurements.

Sodium

Sodium is the major positive ion in fluid outside of cells. When it combines with chloride is formed table salt. Sodium is the predominant cation in fluids outside the cells (extracellular fluid). Sodium plays a central role in regulating body fluid balance and distribution of fluid between the extracellular and intracellular compartments. Many processes in the body specially in the brain, nervous system and muscles require electrical signal for communication which are generate from sodium. Too much or too little sodium are causes malfunction of the cell. A normal blood sodium level is 135 - 145 mmol/L[2].

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Potassium

Potassium is the major positive ion in fluid inside of cell. The proper level of potassium is essential for normal cell function. It regulates heartbeat of the body. Potassium is necessary for normal growth and plays an important function in cell metabolism, enzyme reactions, and synthesis of muscle protein. Potassium is involved in maintaining proper acidity (pH) of the blood and in maintaining nerve and muscle functions. A seriously abnormal increase or decrease it affect the nervous system and in the extreme level it can be fatal. The normal blood potassium level is 3.5 – 5.0 mmol/L [2].

Chloride

Chloride is the major anion found in the fluid outside of cells and in the blood. It is produced from sodium chloride with water. It plays a role in helping the body maintain normal balance of fluids. The balance of chloride ion is closely regulated by the body. Significant increases or decreases in chloride can be fatal consequences. The normal serum range for chloride is 98 – 108 mmol/L [2].

1.3 Carbohydrates

Carbohydrates are a common class of simple organic compounds. Carbohydrate is an aldehyde or a ketone that has additional hydroxyl groups. The simplest carbohydrates are called monosaccharide. Monosaccharide link together to form oligosaccharides (disaccharides, trisaccharides, tetrasaccharides) and polysaccharides. Two monosaccharides together to form a disaccharide. Carbohydrates consisting of two to ten simple sugars are called oligosaccharides, and those with a larger number are called polysaccharides [3].

Carbohydrates constitute a major class of naturally occurring organic compounds. They are essential to the maintenance of life in both plants and animals [4]. Carbohydrates are the ultimate source of most of our food. We eat starch-containing grain or feed it to animals to be converted into meat and fat which we then eat. We make clothes with cellulose in the form of cotton and linen, rayon and cellulose acetate. We build houses and furniture from cellulose in the form of wood. Thus carbohydrates quite literally provide us with the necessities of life: food, clothing and shelter. The study of carbohydrates is also one of the most exciting fields of organic chemistry [5].

Functions of Carbohydrates: Carbohydrates have five majors' functions within the body. These are as follows:

1. Carbohydrates catabolism and Glucose: Carbohydrates supply energy for the brain in the form of glucose.
2. Amino acid catabolism: They give energy by avoiding the breakdown of amino acids.
3. Cellular and protein recognition: Its remove glycoprotein, hormones by the liver from the bloodstream.
4. Dietary fiber: It is used as dietary fiber in the human body.
5. Biochemical functions of carbohydrates: Carbohydrates serve several biochemical functions which are:

i. They act as a fuel of cellular metabolism.
ii. It's used in several biosynthesis reactions.
iii. Its source of polysaccharide like glycogen and starch which supply energy to the plant and animal cells.
iv. It is used for function of organism's fertilization, development and immune system [6].

Classification of Carbohydrates:

The Carbohydrates are divided into three major classes depending upon whether or not they undergo hydrolysis and if they do in the number of products formed.

1. Monosaccharides: The monosaccharides are polyhydroxy aldehydes or polyhydroxy ketones which can not be decomposed by hydrolysis to give simpler carbohydrates. Examples are glucose and fructose.

$C_6H_{12}O_6 + H_2O \rightarrow$ no Reaction

Glucose or fructose

2. Oligosaccharides : The oligosaccharides are carbohydrates which yield a definite number (2 -9) of mono saccharide molecules on hydrolysis. They include,

i) Disaccharides , which yield two monosaccharide molecules on hydrolysis. Examples are sucrose and maltose, both of which have molecluar formula, $C_{12}H_{22}O_{11}$.

$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$

Sucrose Glucose Fructose

$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O\ 6$

Maltose Glucose Glucose

ii) Trisaccharides, which yield three monosaccharides on hydrolysis. Example is raffinese which has molecular formula, $C_{18}H_{32}O_{16}$.

3. Polysaccharides: The polysaccharides are carbohydrates of high molecular weight which yield many monosaccharide molecules on hydrolysis. Examples, starch, cellulose etc.

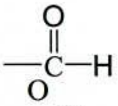
$(C_6H_{10}O_5)_n + n\ H_2O \rightarrow n\ C_6H_{12}O_6$

starch or cellulose. glucose.

In general the monosaccharide and oligosaccharides are crystalline solids, soluble in water and sweet to taste. They are collectively known as sugars. The polysaccharides are insoluble in water and tasteless.

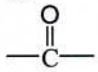
The Carbohydrates may also be classified as either reducing or non reducing sugars. All those carbohydrates which have the ability to reduce Fehling's solution and tollen's reagent are referred to as reducing sugars. All monosaccharide and the disaccharides other than sucrose are reducing sugars. The monosaccharides are the basis of carbohydrate chemistry since all carbohydrates are either monosaccharide or are converted into monosaccharide on hydrolysis. The monosaccharides are polyhydroxy aldhehydes or polyhydroxy ketons. They are divided into two categories, such as:

1) the Aldoses, which contain an aldehyde group,



$-\overset{O}{\overset{\|}{C}}-H$

2) the Ketoses , which contain a ketone group,



$-\overset{O}{\overset{\|}{C}}-$

Glucose and fructose are specific examples of an aldose and a ketose.

The aldoses and ketoses may be represented by the following general formula.

H	CH_2OH
l	l
C=O	C=O
l	l
$(CHOH)_n$	$(CHOH)_n$
l	l
CH_2OH	CH_2OH
Aldoses	Ketoses

Glucose and fructose are specific example of an aldose and a ketose [4].

Glucose ($C_6H_{12}O_6$) :

The most common carbohydrate is glucose. Glucose is a monosaccharide an aldohexose and a reducing sugar [6]. Glucose occurs naturally both in a combined and free state. In the free state, it is present in most sweet fruits and in honey. Small quantities of glucose are also present in human blood and urine, but urine of sufferers from diabetes may contain as much as 8 to 10 percent of glucose. In the combined state, it forms a major component of many disaccharides eg .sucrose, maltose etc. [4].

Disaccharides are carbohydrates which is made of two monosaccharide units. On hydrohysis a molecule of disaccharide yields two molecules of monosaccharide [5]. When a hydroxyl group of one monosaccharide molecule acts as the alcohol to form a glycosidic linkage with the hemiacetal group of a second monosaccharide, the resulting glycoside is called a disaccharide. They are therefore acetals, formed from two monosaccharide by the water in the presence of an acid or by enzymes yields two monosaccharides [4] .

$$\underset{\text{monosaccharide}}{C_6H_{12}O_6 + C_6H_{12}O_6} \rightarrow \underset{\text{disaccharide}}{C_{12}H_{22}O_{11}} + H_2O$$

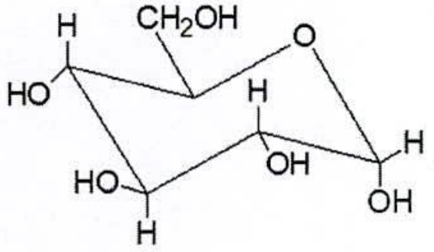
Sucrose:

Sucrose is called saccharose which is ordinary table sugar refined from sugarcane or sugar beets [3]. Sucrose has the molecular formula $C_{12}H_{22}O_{11}$. It does not reduce Tollen's and fehling's reagent. It is a non reducing sugar and in this respect it differs from the other disaccharides [5].

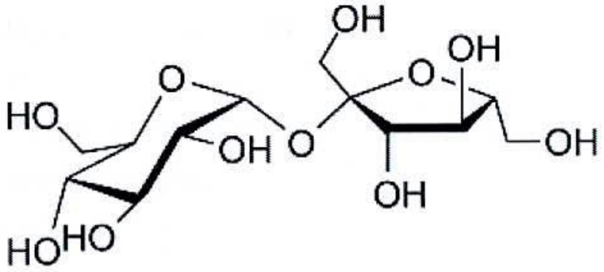
Maltose :

Maltose consists of two α -D- glucose molecules where carbon 1 of one molecule attached to the oxygen at carbon 4 of the second molecule. This is called a 1 α 4 glycosidic linkage [3]. Maltose has the molecular formula $C_{12}H_{22}O_{11}$. It reduces tollen's and fehling's reagent and hence is a reducing sugar [5]. Maltose exists in α and β forms, each of which exhibits mutarotation [4]. It is a colorless, crystalline solid. It is soluble in water but insoluble in alcohol or ether. An aqueous solution of maltose is dextrorotatory and exhibits mutarotation [4]

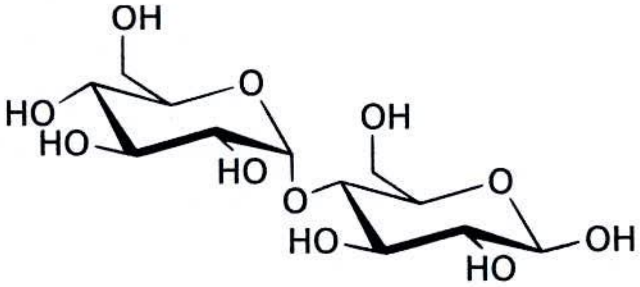
The studied carbohydrates (glucose, sucrose and maltose) cyclic structures are shown in below:



Glucose



Sucrose



Maltose

1.4 Electrolyte-Carbohydrate interaction

Carbohydrate solutions perform an important role in the biological and food industries. Sugars are often used in pharmaceuticals, foods, and biomedical applications to prepare a glassy matrix for long-term storage of biological materials [7-10]. Sucrose and maltose a (disaccharide) is a water-soluble sugar used for immediate energy along with glucose, as it is a basic source for all living organisms. It is also used in a number of biological preparations as a stabilizing agent or osmolality regulator. Maltose plays a vital role in changing the effect by generating a more plasticizing effect than fructose [11]. Therefore, it is very essential to study the interactions between electrolytes and carbohydrates in water.

exists. This molecular polarity causes water to be a powerful solvent and is responsible for its strong surface tension.

When the water molecule makes a physical phase change its molecules arrange themselves in distinctly different patterns. The molecular arrangement taken by ice (the solid form of the water molecule) leads to an increase in volume and a decrease in density. Expansion of the water molecule at freezing allows ice to float on top of liquid water.

Physical properties of water indicate that it is an anomalous liquid. Many properties of it differ essentially from the normal liquids of simpler structure [20]. The notable unique physical properties exhibited by liquid water are [21]: i) negative volume of melting, ii) density maximum in the normal liquid range (at 4°C), iii) isothermal compressibility minimum in the normal liquid range at (46°C), iv) numerous crystalline polymorphs, v) high dielectric constant, vi) abnormally high melting, boiling and critical temperatures for such a low molecular weight substance that is neither ionic nor metallic, vii) increasing liquid fluidity with increasing pressure and vii) high mobility transport for H^+ and OH^- ions.

Liquid water possesses distinctive structural features which are roughly describable by the statement that it retains a certain degree of similarity or analogy to ice i.e., partial retention of the tetrahedrally directed hydrogen bonding involved in the crystalline structure of ice [22]. In other words, liquid water may be treated as a broken down form of the ice lattice, but with the length of the O----H----O bond increased. This view of water structure is supported strongly by the results of X-ray scattering, infrared and Raman absorption spectra. This study indicates that a considerable degree of short range order and the low co-ordination characteristic of the tetrahedrally bonded structure persist in the liquid [22]. The X-ray scattering studies indicate that the average number of nearest neighbors is 4.4 to 4.6 and that the average distance between centers is 2.92 A°. A high concentration of molecules is also found at 4.75A° to 4.90A°, which is roughly the expected distance for the next nearest neighbors if the molecules tend to have a tetrahedral arrangement as in ice [23]. A distinct maximum at 1.1 A° is attributed to the closest O-H distance in the water molecule [23].

Water can be regarded as a particular type of associated liquid in which the association penetrates through the whole volume of the liquid, forming a three dimensional network, several different configurations of which can co-exit simultaneously. Most modern theories of water take this view that water is a mixture of certain three dimensional structure [24].

For a very long time the physicist and the chemists have pondered over the possible structural arrangements responsible for unusual properties displayed by liquid water. To understand the solute water interactions, the most fundamental problem in solution chemistry, the knowledge of water structure is a prerequisite. The physico-chemical properties of aqueous solutions, in most of the cases, are interpreted in terms of the structural changes produced by solute molecules. The structural changes in the solvent may be crucial to the study of the role of water in biological system.

The various structural models, developed to describe the properties of water may generally be grouped into two categories, namely, the continuum models and the mixture models. The continuum models [25-26] treat liquid water as uniform dielectric medium where the environment about particular molecules is considered to be the same as about any other molecules, that is, behavior of all the molecules are equivalent. On the other hand, the mixture models [27-28], treat water as a mixture of short lived clusters consisting of highly hydrogen bonded molecules and non-hydrogen bonded monomers located in various interstices.

Nemethy and Scheraga [25] using statistical methods attempted to build up a molecular description of water, aqueous solutions of a polar solutes and proteins. The development of sophisticated Computing techniques has also widened the scope of this study and attempts have been made to study water-water interactions by ab-initio quantum mechanical methods [25]. Despite numerous endeavours, none of the proposed models on water structure has been unequivocally accepted. Different models although contradictory in some respect [29] can successfully explain several distinctive features of liquid water. Some author prefers continuum models, while other consider mixture models more effective for explaining the behavior of water and aqueous solutions. The mixture models are at present more favored than the continuum models.

Among the mixture models, the 'flickering Cluster" model of Frank and Wen [30], later developed by Nemethy and Schera [25], is commonly adopted in solution chemistry. Properties of dilute aqueous solutions, in terms of structural changes brought about by the solutes, can be explained more satisfactorily using this model than any other model. According to this model, the tetrahedrally hydrogen bonded clusters, referred to as bulky water, $(H_2O)_b$, are in dynamic equilibrium with the monomers, referred to as dense water, $(H_2O)_d$, as represented by [25]:

$$(H_2O)_b \rightleftharpoons (H_2O)_d$$

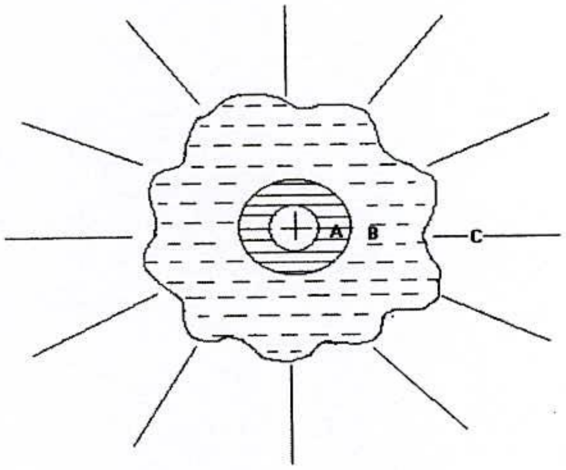


Fig 1.2: Frank and Wen model for the structure modification produce by an ion

It is postulated [30] that the formation of hydrogen bonds in water is a co-operative phenomenon, so that, when one bond forms several other also comes into existence and when one breaks whole cluster will be dissolved. This produces short lived clusters surrounded by non-hydrogen bonded monomers.

The properties of solution can be accounted for in terms of solvent-solvent, solvent-solute and solute-solute interactions. In terms of thermodynamics, the concentration dependence of a given property extrapolated to the limit of infinite dilution provides a measure of solute-solvent interactions. Solute-water interaction or hydration phenomena, can be conveniently classified into three basic types:

(i) **hydrophilic hydration:** Where the solute-solvent interaction occurs via hydrogen bonding such as in the case of aqueous solution of simple sugar (non ionic solute).

(ii) **ionic hydration:** Where the interaction occurs through electrostatic forces such as in the case of polar or ionic solute and

(iii) **hydrophobic hydration**: where there is no direct molecular interactions, rather a restructuring of water molecules around the solute. This is observed in solutions of essentially apolar molecules such as long chain alcohols and long chain fatty acid salts.

The structure of water is profoundly influenced by the presence of solute molecules. The introduction of a solute produces changes in the properties of the liquid water, which are analogous to those brought about by temperature or pressure changes. It is generally agreed that in aqueous solutions of ions not larger than Cs^+ and I^-, the nearest neighbors water molecules are always immobilized by the direct ion-dipole interaction. This idea and related one of electrostriction have been invoked to explain the small or negative values of solute partial molar volumes, heat capacities, compressiblities etc. This idea also explains the influence or Li^+ on the viscosity of water in which it is dissolved. However, the more fluidity of 0.1m solution of CsCl than pure water demonstrates that the idea can't explain all the physico-chemical behavior of aqueous solutions. This phenomenon is interpreted by Bernal and Flower [31] that the ions were somehow breaking the water structure. On the basis of the comparison of results obtained from reanalysis of entropy of hydration by Frank and Evans [32] with the estimated entropy losses arising from (i) restriction of the ions in "free volume" cells in the condensed phases (ii) immobilization of first-layer water and (iii) dielectric polarization of more distant water, Frank and Wen [25] suggested a model, sketched in Figure-1.1 which shows that an ion surrounded by three concentric regions.

The innermost region (A), called the primary solvation sheath, consists of ordered co-ordinate water molecules, is immobilized by the strong ion-dipole interactions. In outermost region (C) water molecules have a normal liquid structure. The water molecules in the intermediate region (B) are more random in organization than normal water due to an approximate balance between the dielectric field of the central ion and the orienting influence of neighboring water molecules.

The solute that shifts the equilibrium to the left and increases the average life of the clusters, is termed as, "structure maker" and one which shifts the equilibrium to the right and increases the numbers of non-bonded dense monomers is called as "structure breaker". The cause of the structure breaking and making is presumably the shift in balance in the region (B) between two competing orienting influences. The low charge density has relatively weak electrostatic fields so that the region (A) is very small thereby causing a net breaks of structure. On the other hand, for the ions with high charge density the region (A) exceeds the region (B), which results in a net structural increase around these ions.

The development of solution chemistry is still far from being adequate to account for the properties of solutions in terms of the properties of the constituent molecules. It is clear that if the solute and the solvent molecules are interacting, as indeed they must, then the chemistry of the solute in a solvent must be different and the presence of a solvent can modify the properties of a solute. There are several experimental procedures, which can in principle be used to obtain information on the solvation of molecules. The experimental result on various macroscopic properties provides useful information for proper understanding of specific interactions between the components and the structure of the spectral band due to the transition of electrons during the ionization of the various solutes solution. The thermodynamic and transport properties are sensitive to the solute-solvent, solute-solute and solvent-solvent interactions. In solution systems these three types of interaction are possible but solute-solute interactions are negligible at dilute solutions. The concentration dependencies of the thermodynamic properties are a measure of solute-solute interaction and in the limit of infinite dilution these parameters serve as a measure of solute-solvent interaction and in the limit of infinite dilution these parameters serve as a measure of solute-solvent interactions. The solute induced changes in water structure also result in a change in solution viscosity. The variation of viscosity of solution with solute concentration is related to the size of the solute as well as on solute-solvent interactions.

Many workers reported and discussed the role of water structure in water electrolyte interactions in aqueous and mixed aqueous solutions. The aqueous solutions of electrolytes contain at least two solute species, a cation and an anion. The degree of ordering of water molecules in the vicinity of an ion depends in the first instance on the ionic surface charge density. This is determined by the charge and the ion radius, so that one might expect highly charged and small ions to posses well ordered hydration spheres, whereas singly charged, large ions would not be able to align the water dipole and to overcome to any marked extent the hydrogen bond interactions that exist in bulk water. Such ions would be classified as structure breakers, whereas the former type would be structure makers. It must, however, be borne in mind that the structure, which such ions enforce, is not the water structure characteristic of the radial distribution function, which reflects the tetrahedral hydrogen bonding pattern in water. Rather, it is a structure imposed on the water by strong ion-dipole forces. The structure in liquid produces spherically symmetric orientations of water molecules, quite incompatible with the tetrahedrally hydrogen bonded network in unperturbed water. Whereas one, two or possible even more water layers will perhaps be so oriented by a structure making ion, that there must also be a region where the magnitudes of the transmitted ion-dipole effect and hydrogen binding between water molecules become equal and this must lead to a structural mismatch where the water molecules are structurally and dynamically highly perturbed.

Structure making or breaking by ions has also been studied by various dynamic methods. In particular, the life times of water molecules in the ionic hydration shell have been examined by nmr and dielectric methods. Thus in pure water at 25°C the life time of the water molecule at a given site is 1 ps [33]. The life time of a water molecule in the hydration shells of Mn^{2+} is 25000 ps, whereas in the hydration shell of an I^- it is only marginally affected (4 ps) [33]. Intermediate values have been estimated for the hydration shells of other ions, for instance Na^+ (10 ps) and Cl^- (5 ps). The diffusion rates of water molecules within the hydration shells are also affected. In the vicinity of an I^-, water rotates more rapidly than it does in bulk water, whereas the opposite effects is observed for structure making ions, where the rotational diffusion is retarded. [33]

From such dynamic data it is also possible to estimate the approximate height of the energy barrier for rotation of water, relative to the energy barrier in pure water [33] such as for

0.54, Cl^- 0.96, F^-, Na^+ and Li^+ 2.0

In the recent past, thermodynamic studies on a number of non-polar or polar solutes with non polar side chains have been undertaken to apprehend the so called "hydrophobic effect". [34-36] Cabani [37] has critically reviewed such studies in aqueous solutions of non-electrolytes. Physico-chemical behavior of amino acids and peptides in aqueous solutions were systematically reviewed by Greenstein and Winitz [38], Lilley [39], Zamyatnim. [40] Wadi and Natarajan [41] and Ahluwalia [42] respectively. They discussed the water structure in water-amino acid and water peptide group interaction in aqueous and mixed aqueous solutions using the results from the investigation of thermodynamic properties.

The foregoing discussions of ions in solution has established that long range (low concentration) properties can be adequately accounted for by electrostatics, taking into account only the magnitude of the ionic charge, the concentration and the dielectric permittivity of the solvent medium. This formalism breaks down at short range properties (high concentration) where specific ion-solvent effects dominate the solution behavior. This distinction is of particular importance in bio-chemistry, where, it is often found that the effects of electrolytes on certain processes are nonspecific up to the concentrations of about 0.1 molal and can be expressed in terms of the ionic strength.

Friedman and Krishnan [43] have suggested a model for ionic solutions based on the concepts of Frank and Evans [32] which enables to interpret the physico-chemical properties of solutions. It is assumed that around an ion there is a cosphere in which the solvent properties are affected by the solutes, characterized by thermodynamics of the process:

$$n[\text{solvent (bulk)}] \longrightarrow n[\text{solvent (cosphere)}]$$

Where, n is the number of solvent molecules in the cosphere. Even though it is necessary to consider the changes affecting the whole of the solvent, it can be assumed that significant effects come only from the solvent molecules directly attached to the solute particles. When two solute particles come close together for their cospheres to overlap some of the solvent molecules from the cospheres get displaced to the bulk. This overlap effect may be described as mutual destruction of the cospheres, if the solute species, namely i and j are different, one cosphere may be disrupted before the other. Conversely, the behavior represented a mutual constructive interaction as the cosphere comes close together. In this the solvent gets transferred to the cospheres from the bulk.

All these critical review of literatures show that a lot of works have been carried one viscometric, volumetric and thermodynamic properties of both aqueous and non-aqueous solution of different substances. But most of these works deal with binary system, either in aqueous or in non-aqueous system. Only a very few work appeared in the literature on ternary system containing both aqueous and non-aqueous substance a mixed solvent. As a result a series of properties of aqueous and non-aqueous solution still remains unknown. As for example, the structure of water which can explain its versatile behavior is still unknown to the scientist. Many models have been proposed but none of these can clearly and completely explain all the properties of water. These above stated facts lead us to carry out this study.

1.6 The phenomena of solute-solvent interaction

Elucidation of the nature of ion-solvent interaction [44] and interpretation of the thermodynamic and transport processes in terms of such parameters as effective size of the solvated ions in solutions have been two of the most difficult problems in the understanding of electrolytic solutions. This is because there is not satisfactory model to represent the various phenomena that occur in solution and the incompleteness in the understanding of the structure of the liquids in general. There is a number of evidence of solvation of ions [44] or solute molecules a number of studies have discussed the effect of solvation on the equilibrium properties of liquids.

The process of solvation and the process of dissolution are known to be close related. When ionic crystal is added to a solvent, the electrostatic force of attraction between the oppositely charged ions in the crystal have to be overcome by interposing solvent layers around each of the ions. The ability of a solvent to dissolve a crystal is reflected by the following properties, its dielectric properties, polarity, degree of self-association and its ability to solvate. Studies on the phenomena of solvation have led to the conclusions that:

(i) The ionic compounds are moderately soluble in dipolar aprotic solvents of relatively high dielectric constant but are much more soluble in water and other hydroxylic solvents like methanol. A number of inorganic salts are dissociated in acetonitrile, which is otherwise known to solvate cations and anions rather poorly. [45-47]

(ii) The dielectric constant alone is not an adequate measure of solvating ability and may even play a major role in determining the solvation of ionic species. Cations should be better solvated in solvents having atoms with an unshared electron pair like nitrogen and oxygen. The cations have been found to be strongly solvated in highly polar solvents with the negative charge localized on an oxygen atom, e.g. in sulphur-di-oxide, dimethylsulphoxide, the phosphorus oxide, pyridine-N-oxides, 2-pryidones, 2-pyrillidones, dimethyl formamides [48] etc. Potassium iodide is less soluble than sodium iodide in methanol or water, [49] but in dimethylsulphoxide or dimethyl formamide the reverse is true, which could be due to differences of cation solvation.

The anions have been found to be solvated in two ways:

(i) Small ions are mostly solvated by hydrogen bonding which is superimposed upon solvation by ion-dipole interactions, and

(ii) large ions are solvated by interaction due to mutual polarizability of the anions and the solvent superimposed upon solvation by dipole interactions. Thus while the anions are more strongly solvated in hydrogen bonding solvents than in dipolar aprotic solvents, the cations are better solvated in the latter type of solvents [49].

The solubility of halides in various solvents generally follow the order:

iodides > bromides > chlorides > fluorides.

The alkaline halides are more soluble in hydroxylic solvents than in the dipolar aprotic solvents like acetionitrile and acetone. These are found to be more soluble in acetonitrile than in acetone [50]. Electrolytes may be divided into two categories: ionophores and ionogens. While the former are ionic in character in the crystalline state as well as in the fused state and in highly dilute solutions, the latter have molecular crystal lattice and ionise in solution only if suitable interaction occurs with the solvent molecules.

The ionophores may exist in solution as an equilibrium mixture containing ion-pairs and free ions. [51]

$$\underset{\text{solvated}}{M^+X^-} \rightleftharpoons \underset{\text{solvated}}{M^+} + \underset{\text{solvated}}{X^-}$$

The ion-pairs are of oppositely charged ions having life terms sufficiently long to be recognized as kinetic entities in solution and in which only electrostatic forces are assumed[44]. Fuoss *et al.* [52] have studied intensely the dependence of the dissociation constant, K_d, on the dielectric constant, the temperature, and the nature of the salt. It was found to be large for solvents having high dielectric constant. It has also been found to be dependent on the distance of closest approach of the ions in the ion pairs. For hydroxylic solvents, large ions have larger K_d values and lower conductance values than smaller ions, which doesn't hold for other solvents.

Interaction of the ions with the solvent molecules causes low conductance. Na^+ ion behaves as a large ion as the K_d of iodides of Bu_4N^+ and Na^+ are found to be of the same order. Small ions like Li^+, F^- have low conductance in acetone [47] but have low K_d values.

H. Remy and others [48] determined the number of moles carried to the cathode in a transport process using the mathematical presentation:

$$S = t^+ n_c - t^- n_a$$

Where, S = the number of moles of solvent carried to the cathode in the transport process; t^+, t^-, are the transport numbers of cations and anions respectively, and n_c, n_a are the number of solvent molecules associated with cations and anions respectively. The number of moles of solvent carried to the cathode in the transport process (S), was determined by the transference methods and the solvation numbers of the ions, n, was then determined. The solvation number for the various ions that they determined are :

$Li^+ = 13$, $Na^+ = 7$, $K^+ = 4$, $Mg^{2+} = 12\text{-}14$, $Ca^{2+} = 8\text{-}12$, $Sr^{2+} = 8\text{-}10$, $Ba^{2+} = 5\text{-}3$.

Limiting ionic conductance of a variety of ions in a number of solvents show that generally the conductance depends on the interaction of the ion with the solvent and not on the size of the ions, Thus, such big ions as Me_4N^+, $E_tNH_3^+$ etc. have much larger conductance values than Li^+, Na^+, K^+. This indicates that several of the cations are solvated or interact strongly with the solvent molecules. For the case of anions, Robinson and Stokes [44], Pure and Sherrington [53] showed that anions and cations of comparable crystallographic size have similar conductance in the hydroxylic solvents, but that of the anions are much more conducting than cations in the dipolar aprotic solvents. A relationship between the values of the limiting equivalent ionic conductance λ_i, and the viscosity value η was advocated and utilized by Walden and others to study the solute-solvent interactions [44]. In one approach which assumes the constancy of the product $\lambda_1\eta$ the effects of variation of temperature, viscosity and variation of the solvent were studied. For large organic ions [44], the temperature co-efficient was found to be nearly constant in water as well as other non-aqueous solvents, while for the other ions it showed variations. For changing solvents, the product was found to vary widely in the case of inorganic ions which has been interpreted to be due to differences in solvation numbers of the ion in the various solvents. In another approach to this study Pure and Sherrington [53] used the relation between viscosity η_t, and limiting ionic conductance λ_1^0, to measure the radii of interaction of solvent and solute, called stoke's law radii, r. They compared the crystallographic radii of some cations and anions with the stoke's law radii in the case of dimethylamide and dimethyl-sulphoxide solvents. They found the degree of solvation to decrease from lithium to cesium and to be less for silver and ammonium ions which have nearly comparable crystallographic radii. They postulated the anions to be unsolvated in dipolar aprotic solvents as the radii obtained are of the same order as that of the crystallographic radii, and that the negative end of the dipole in the solvent molecule is unshielded while the positive end is protected by two methyl groups, so that the cations, but not the anions are solvated by these solvents.

Using the polarographic half-wave reduction potentials ($E_{1/2}$) at the dropping mercury electrode for studying the nature of solvation of the various anions and cations in different solvents, Kolthoff and others [45] found that the cations are reduced at more negative potentials and the anions are depolarised at more positive potentials as they become more solvated. Cations were found to be more solvated in water than in acetonitrile except in case where the cations interact strongly with the solvents, e.g. Cu^+ and Ag^+ ions in acetonitrile. These are in agreement with other data that Ag(1) and Cu(1) salts are more soluble in acetonitrile than in water. Smith, Symon, Kasowers and others [50] used the U.V. and the visible spectral data to study the interactions of solvents with cations and anions. The going into solution, have been postulated to arise from the electron going into a centrosymmotric orbit. This transition has been labelled as Charge Transfer To Solvent (CTTS). Smith and Symons, Buckingham [54, 55] measured the change in the energy wise position of the band maxima in various solvents including ammonia, acetone dioxane and 1,3- dioxalane over a range of temperatures. According to smith and symons, the theory of CTTS would not hold if there is ion-pair formation between cation and anion or complex formation between solute and solvent..

Carbohydrates play an important role in animal and plant life. Understanding of the behaviour of electrolytes in water and in water-carbohydrate solution systems is of utmost importance in biological and pharmaceutical science. The hydration of carbohydrate is reported to depend on the percentage of axial and equatorial hydroxyl groups. It is more favourable when the hydroxyl group is in an equatorial position [56, 57]. Hydrogen bonding plays an important role in the interaction of components in water and in water-electrlyte solution systems. If a carbohydrate molecule is introduced into water and into water-electrolyte solutions, the formation of carbohydrate-water and carbohydrate-aqueous electrolyte hydrogen bonds will depend, to a large extent, on the spacing and orientations of the polar group of the carbohydrate molecules relative to the –OH geometry in water [58]. A large number of researchers [59–64] worked on such properties like apparent molar volumes, adiabatic compressibilities, specific heats etc. for carbohydrates in different concentration ranges. The results obtained by these studies differ for the same carbohydrate and thus the behaviour of carbohydrate molecules in solution systems can not be described conclusively. Although some volumetric and viscometric results on electrolytes in water alone are available, no volumetric and viscometric data are yet available for electrolytes (NaCl, KCl) molecules in water-carbohydrates (glucose, sucrose, maltose) solution systems.

1.7 Objective of this thesis

Carbohydrates are an exceptionally important constituent of biological systems. They play an important role in animal and plant physiology. Carbohydrates are sources of energy for vital metabolic processes. Many functional features of saccharides in living organisms are becoming obvious but are far from being fully understood. In living organisms, interactions of carbohydrates with electrolytes play a key role in a wide range of biochemical process. Therefore, it is very essential to study the interactions between electrolytes and carbohydrates in solutions. This study also gives information in the field of applied and engineering science including flow of fluids, distillation plant etc. The specific aims of this study are:

(i) to examine the volumetric, viscometric and thermodynamic properties of the mixture of carbohydrates, electrolytes and water in different compositions and different temperatures.

(ii) to understand the effect of electrolytes on carbohydrate solutions to generalize the type of interactions among them.

(iii) to enrich the available data on Physico-chemical properties and thermodynamic function of the systems .

CHAPTER II

Theoretical Background

2.1 Physical Properties and chemical constitutions

In interpreting the composition, the structure of molecules and the molecular interaction in the binary and ternary systems, it is inevitable to find out the size and the shape of the molecules and the geometry of the arrangement of their constituent atoms. For this Purpose, the important parameters are bond lengths or interatomic distance and bond angles. The type of atomic and other motions as well as the distribution of electrons around the nuclei must also be ascertained; even for a diatomic molecule a theoretical approach for such information would be complicated. However the chemical analysis and molecular weight determination would reveal the composition of the molecules, and the study of its chemical properties would unable one to ascertain the group or sequence of atoms in a molecule. But this cannot help us to find out the structures of molecules, as bond length, bond angles, internal atomic and molecular motions, polarity etc. cannot be ascertained precisely.

For such information it is indispensable to study the typical physical properties, such as absorption or emission of radiations, refractivity, light scattering, electrical polarization, magnetic susceptibility, optical rotations etc. The measurement of bulk properties like density, surface tension, viscosity etc. are also have gained increased importance during the recent years, because not only of their great usefulness in elucidating the composition and structure of molecules, but also the molecular interaction in binary and ternary systems.

The various physical properties based upon the measurement of density, viscosity, surface tension, refractive index, dielectric constant etc, have been found to fall into the following four categories [65].

(i) **Purely additive properties:** An additive property is one, which for a given system, is the sum of the corresponding properties of the constituents. The only strictly additive property is mass, for the mass of a molecule is exactly equal to the sum of the masses of its constituent atoms, and similarly the mass of a mixture is the sum of the separate masses of the constituent parts. There are other molecular properties like molar volume, radioactivity etc. are large additive in nature.

(ii) **Purely constitutive properties:** The property, which depends entirely upon the arrangement of the atoms in the molecule and not on their number is said to be a purely constitutive property. For example, the optical activity is the property of the asymmetry of the molecule and occurs in all compounds having an overall asymmetry.

(iii) **Constitutive and additive properties:** These are additive properties, but the additive character is modified by the way in which the atom or constituent parts of a system are linked together. Thus, atomic volume of oxygen in hydroxyl group (-OH) is 7.8 while in ketonic group (=CO) it is 12.2. The parachor, molar refraction, molecular viscosity etc. are the other example of this type.

(iv) **Colligative properties:** A colligative property is one which depends primarily on the number of molecules concerned and not on their nature and magnitude. These properties are chiefly encountered in the study of dilute solutions. Lowering of vapor pressure, elevation of boiling point, depression of freezing point and osmotic pressure of dilute solutions on the addition of non-volatile solute molecules are such properties.

2.2 Density

The density of a liquid may be defined as the mass per unit volume of the liquid unit of volume being the cubic centimeter (cm^3) or milliliter (mL). Since the milliliter is defined to be the volume occupied by one gram of water at temperature of maximum density (i.e, at 4^0C), the density of water at this temperature in gmL^{-1} is unity and the density of water at any other temperature is expressed relative to that of water at 4^0C and expressed by ($d^{10}{}_4$).

The relative density of a substance is the ratio of the weight of a given volume of the substance to the weight of an equal volume of water at the same temperature ($d^{10}{}_4$). The absolute density of a certain substance temperature t^0C is equal to the relative density multiplied by the density of water at the temperature. The density of a liquid may be determined either by weighing a known volume of the liquid in a density bottle or picnometer or by buoyancy method based on "Archimedes principle".

In our present investigation, the densities of the pure components and the mixture were determined by weighing a definite volume of the respective liquid in a density bottle.

2.3 Density and temperature

An increase in temperature of a liquid slightly increases the volume of the liquid, thus decreasing its density to some extent. The temperature increase brings about an increase in molecular velocity. These energetic molecules then fly apart causing more holes in the bulk of the liquid. This causes the expansion of the liquid, thereby decreasing the number of molecules per unit volume and hence the density.

2.4 Molarity

Molarity (C), is defined as the number of moles of solute per litre of solution. If n_2 is number of moles of solute and V liters is the volume of the solution then,

$$Molarity(\mathrm{C}) = \frac{\text{Number of moles of solute}}{\text{Volume of solution (L)}}$$

$$\text{or } C = \frac{n_2}{V} \qquad \text{...(2.1)}$$

For one mole of solute dissolved in one liter of solution, C=l i.e. molarity is one. Such a solution is called 1 molar. A solution containing two moles of solute in one liter is 2 molar and so on. As evident from expression (2.1), unit of molarity is $\mathrm{molL^{-1}}$.

2.5 Molar volume of solutions

The volume in mL occupied by one gram of any substance is called its specific volume and the volume occupied by 1 mole is called the molar volume of the substance. Therefore, if ρ is the density and M be the molar mass, we have the molality (m) of a solution is defined as the number of moles of the solute per 1000 g of solvent [66]. Mathematically,

$$Molality(\mathrm{m}) = \frac{\text{Number of moles of solute}}{\text{Weight of solvent in gram}} \times 1000$$

$$\text{or, } \mathrm{m} = \frac{\frac{\mathrm{a}}{\mathrm{M}_2} \times 1000}{\text{Volume of solvent in mL} \times \text{Density of solvent in g cm}^{-3}}$$

$$\text{or, } \mathrm{m} = \frac{\frac{\mathrm{a}}{\mathrm{M}_2} \times 1000}{\mathrm{V}_1 \times \rho_0}$$

$$\text{or, } \mathrm{m} = \frac{\mathrm{a}}{\mathrm{M}_2} \times \frac{1000}{\mathrm{V}_1 \times \rho_0} \quad \text{...(2.2)}$$

Where, a = Weight of solute in gram

M_2 = Molecular weight of solute in gram

V_1 = Volume of solvent in mL

ρ_0 = Density of solvent in g cm^{-3}

$$\text{Specific volume, (V)} = \frac{1}{\rho} mLg^{-1} \quad \text{..(2.3)}$$

$$\text{and Molar volume, (V}_\mathrm{m}\text{)} = \frac{M}{\rho} mLmol^{-1} \text{ ....(2.4)}$$

when two components are mixed together, there may be either a positive or a negative deviation in volume. The positive deviation in volume i.e. volume expansion has been explained by the break down of the mode of association through H-bonding of the associated liquids. The negative deviation in molar volume i.e. volume contraction has been thought of by many observers, as arising from the i) compound formation through association, ii) decrease in the intermolecular distance between the interacting molecules, iii) interstitial accommodation of smaller species in the structural network of the larger species and (iv) change in the bulk structure of either of the substance forming the mixture.

2.6 Apparent/ partial molar volume

The apparent molar volume of a solute in solution, generally denoted by is defined by φ_v the relation [67]

$$\varphi_v = \frac{V - n\overline{V}_1^0}{n_2} \qquad \text{.......(2.5)}$$

where, V is the volume of solution containing n_1 moles of solvent and n_2 moles of solute and $\overline{V}_1^0$ is the molal volume of the pure solvent at specified temperature and pressure. For binary solution, the apparent molar volume (φ_v) of an electrolyte in an aqueous solution is given by [68],

$$\varphi_v = \frac{1}{n_2}\left[\frac{n_1M_1 + n_2M_2}{\rho} - n_1\overline{V}_1^0\right] \qquad \text{.......(2.6)}$$

where, V=$\frac{n_1M_1 + n_2M_2}{\rho}$ and

n_1 and n_2 are the number of moles, M_1 and M_2 are molar masses of the solvent and solute respectively and ρ is the density of the solution. For molal concentration, n_2 = m, the molality and n_1 = 55.51, the number of moles of solvent in 1000g of solvent (water), the equation for apparent molal volume takes the form [68, 69],

$$\varphi_v = \frac{1}{m}\left[\frac{1000 + mM_2}{\rho} - \frac{1000}{\rho_0}\right]$$

$$\text{or, } \varphi_v = \left[\frac{M_2}{\rho} - \frac{1000(\rho - \rho_0)}{m\rho\rho_0}\right] \qquad \text{.......(2.7)}$$

$$\text{or, } \varphi_v = \frac{1}{\rho}\left[M_2 - \frac{1000}{m}\left(\frac{W - W_0}{W_0 - W_e}\right)\right] \qquad \text{.......(2.8)}$$

where, ρ_o and ρ are the densities of the solvent and solution and W_e, W_0 and W are the weight of empty bottle, weight of bottle with solvent and weight of bottle with solution respectively.

If the concentration is expressed in molarity (C), the equation 2.8 takes the form [70]:

$$\varphi_v = \left[\frac{M_2}{\rho_0} - \frac{1000(\rho - \rho_0)}{C\rho_0}\right] \quad \text{.......................................(2.9)}$$

where, the relation, $C = \dfrac{m.\varphi_v.1000}{1000 + \varphi_v.m.\rho_0}$ ....(2.10)

is used for inter conversion of the concentration in the two scales [70].

The partial molal property of a solute is defined as the change in property when one mole of the solute is added to an infinite amount of solvent, at constant temperature and pressure, so that the concentration of the solution remains virtually unaltered. If 'Y' represents partial molal property of a binary solution at constant temperature and pressure, Y will then be a function of two independent variables n_1 and n_2, which represent the number of moles of the two components present. The partial molar property of component one is then defined by the relation:

$$\overline{Y_1} = \left(\frac{\delta Y}{\delta n_1}\right)_{n_2,P,T} \quad \text{.. (2.11)}$$

Similarly for component 2,

$$\overline{Y_2} = \left(\frac{\delta Y}{\delta n_2}\right)_{n_{12},P,T} \quad \text{..(2.12)}$$

The partial molar property is designated by a bar above the letter representing the property and by a subscript, which indicates the components to which the value refers. The usefulness of the concept of partial molar property lies in the fact that it may be shown mathematically as,

$$Y_{(n_1,n_2)} = n_1\overline{Y_1} + n_2\overline{Y_2}, \quad \text{at constant T and P} \quad \text{.........................(2.13)}$$

In respect of the volume of solution, equation 2.5 gives directly

$$V = n_1\overline{V_1} + n_2\overline{V_2}, \quad \text{at constant T and P} \quad \text{.........................(2.14)}$$

The partial molar volumes of solute and solvent can be derived using the equation 2.5 as follows [67]:

$$\overline{V_2} = \left(\frac{\delta V}{\delta n_2}\right)_{P,T,n_1} = \varphi_v + n_2\left(\frac{\delta \varphi_v}{\delta n_2}\right)_{P,T,n_1} = \varphi_v + m\left(\frac{\delta \varphi_v}{\delta m}\right)_{P,T,n_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.15)$$

and,

$$\overline{V_1} = \frac{\left(V - n_2\overline{V_2}\right)}{n_1} = \frac{1}{n_1}\left[n_1\overline{V_1^0} - n_2^2\left(\frac{\delta \varphi_v}{\delta n_2}\right)\right]_{P,T,n_1} = \overline{V_1^0} - \frac{m^2}{55.51}\left(\frac{\delta \varphi_v}{\delta m}\right)_{P,T,n_1} \quad \ldots\ldots\ldots\ldots(2.16)$$

For solutions of simple electrolytes, the apparent molar volume (φ_v) vary linearly with √m, even upto moderate concentrations. This behavior is in agreement with the prediction of the Debye-Huckel theory of dilute solutions as [67] :

$$\frac{\delta \varphi_v}{\delta m} = \frac{\delta \varphi_v}{\delta\sqrt{m}} \cdot \frac{\delta\sqrt{m}}{\delta m} = \frac{1}{2\sqrt{m}} \cdot \frac{\delta \varphi_v}{\delta\sqrt{m}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.17)$$

If φ_v is available as a function of molal concentration, the partial molar volumes of solute and solvent can be obtained from equation 2.15 and 2.16 as:

$$\overline{V_2} = \varphi_v + \frac{\sqrt{m}}{2}\left(\frac{\delta \varphi_v}{\delta\sqrt{m}}\right) = \varphi^0{}_v + \frac{3\sqrt{m}}{2}\left(\frac{\delta \varphi_v}{\delta\sqrt{m}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.18)$$

and

$$\overline{V_1} = \overline{V_1^0} - \frac{m}{55.51}\left(\frac{\sqrt{m}}{2} \cdot \frac{\delta \varphi_v}{\delta\sqrt{m}}\right) = V_1^0 - \frac{M_1 m^{3/2}}{2000}\left(\frac{\delta \varphi_v}{\delta\sqrt{m}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.19)$$

Where, $\varphi^0{}_v$ is the apparent molal volumes at zero concentration.

When molar concentration scale is used to express φ_v as a function of concentration, then

$$\overline{V_2} = \varphi_v + \left[\frac{1000 - C\varphi_v}{2000 + C^{3/2}\left(\frac{\delta \varphi_v}{\delta\sqrt{C}}\right)}\right]\sqrt{C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.20)$$

and

$$\overline{V_1} = \frac{2000\overline{V}_1^0(18.016/\rho_0)}{2000 + C^{3/2}\left(\frac{\delta \varphi_v}{\delta\sqrt{C}}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.21)$$

From equation 2.18 and 2.20, it follows that at infinite dilution, (m or c → 0), the partial molar volume and the apparent molar volume are identical. To obtain reliable φ_v values, it is necessary to measure the density ρ, with great precision because errors in ρ contribute, considerably to the uncertainties in φ_v.

The concentration dependence of the apparent molar volume of electrolytes have been described by the Masson equation [70], the Redlich-Mayer equation [73] and Owen-Brinkley equation [72]. Masson [71] found that the apparent molar volume of the electrolytes vary with the square root of the molar concentration as,

$$\varphi_v = \varphi_v^0 + S_v\sqrt{c} \qquad \text{.........(2.22)}$$

where, S_v is the experimental slope depending on the nature of the electrolyte.

Redlich and Rosenfeld [73] predicated that a constant limiting slope S_v, should be obtained for a given electrolyte charge type if the Debye-Huckel limiting law is obeyed. By differentiating the Debye-Huckel limiting law for activity coefficients with respect to pressure, the theoretical limiting law slope S_v, could be calculated using the equation,

$$S_v = KW^{3/2} \qquad \text{.........(2.23)}$$

where, the terms K and W are given by

$$K = N^2e^3\left(\frac{8\pi}{100D^3RT}\right)^{1/2}\left\{\left(\frac{\delta \ln D}{\delta\rho}\right)-\left(\frac{\beta}{3}\right)\right\} \qquad \text{.........(2.24)}$$

and $$W = 0.5\sum\gamma_i Z_i^2 \qquad \text{.........(2.25)}$$

where, β is the compressibility of the solvent, γ_i is the number of ions of the species i of valency Z_i formed by one molecule of the electrolyte and the other symbols have their usual significance [73]. For dilute solutions the limiting law for the concentration dependence of the apparent molar volume of electrolytes is given by the equation,

$$\varphi_v = \varphi_v^0 + KW^{3/2}\sqrt{C} \qquad \text{.........(2.26)}$$

and for not too low concentrations, the concentration dependence can be represented as,

$$\varphi_v = \varphi_v^0 + S_v\sqrt{C} + b_v C \qquad \text{...(2.27)}$$

where, S_v, is the theoretical limiting law slope and b_v an empirical constant for 1:1 electrolyte, the limiting law slope at 298.15K is 1.868 $\text{cm}^3\text{mol}^{-3/2}.\text{L}^{1/2}$.

2.7 Viscosity

Viscosity means viscous ability. It's more generalized definition is "the internal friction which opposes the relative motion of adjacent layers of a fluid." When a fluid is flowing through a cylindrical tube, layers just touching the sides of the tubes are stationary and velocities of the adjacent layers increases towards the centre of the tube, the layer in the centre of the tube having the maximum velocity. There thus exists a velocity gradient.

In case of liquid, this internal friction arises because of intermolecular friction. Molecules are a slower moving layer try to decrease the velocity of the molecules in a faster moving layer and vice versa, with a result that some tangential force is required to maintain uniform flow. This tangential force will depend upon two factors,

(i) area of contact 'A' between the two layers and

(ii) velocity gradient $\frac{dv}{dx}$

Thus, $f \infty A \frac{dv}{dx}$

or $$f = \eta A \frac{dv}{dx} \qquad \text{..(2.28)}$$

where, η is a proportionality constant, known as the coefficient of viscosity or simply viscosity of the liquid. Thus, the coefficient of viscosity may be defined as the force per unit area required to maintain unit difference in velocity between two parallel layers of liquid unit distance apart.

The reciprocal of viscosity called the fluidity (ϕ) is given by the relation.

$$\phi = \frac{1}{\eta} \qquad \text{.....(2.29)}$$

It is measure of the case with which a liquid can flow.

The C.G.S Unit of viscosity i.e. dynes sec cm^{-2} = g $cm^{-1}sec^{-1}$ is called poise, in honor of J.L.M. Poiseuille who is the pioneer in the study of viscosity. Since viscosity of liquid is usually very small, it is usually expressed in millpoise (mP) or centipoise (cP) or mPa.S.
When a liquid flows through a narrow tube it is probable that the thin layer of liquid in contact with the wall is stationary; as a result of viscosity, therefore, the next layer will be slowed down to some extent, and this effect will continue up to the centre of the tube where the flow rate is maximum.

The rate of flow of the liquid, under a given pressure will obviously be less, the smaller the radius of the tube, and the connection between these quantities was first derived by J.L.M. Poiseuille in 1844, known as the Poiseuille equation (74). If a liquid with a coefficient of viscosity (η) flows with a uniform velocity, at a rate of V cm^3 in t seconds through a narrow tube of radius r cm, and length 1 cm under a driving pressure of p dynes cm^{-2}, then (68):

$$\eta = \frac{\pi \Pr^4 t}{8lV} \qquad \text{.....(2.30)}$$

This equation known as Poiseuille's equation, holds accurately for stream-line flow but not for the turbulent flow which sets as higher velocities. A small error arises in practice, because the liquid emerging from a capillary tube possesses appreciable kinetic energy and since this is not accounted for in Poiseuille's equation, a correction term is introduced. After correction for kinetic energy, the equation becomes,

$$\eta = \frac{\pi \Pr^4 t}{8lv} - \frac{\rho V}{8\pi l t} \qquad \text{.....(2.31)}$$

where, ρ represents the density of the liquid/solution. However, in practical purposes, the correction factor is generally ignored.

The driving pressure P = hρg, where h is the difference in height of the surface of the two reservoirs, since the external pressure is the same at the surface of both reservoirs, g = acceleration due to gravity and ρ = the density of liquid. Thus the equation (2.35) becomes,

$$\eta = \frac{\pi h \rho g r^4 t}{8vl} \qquad \text{..........(2.32)}$$

For a particular viscometer h, l, r and V are fixed, so the equation (2.37) becomes,

$$\eta = A\rho t \qquad \text{..........(2.33)}$$

where $A = \frac{\pi h g r^4}{8vl}$, called the calibration constant of the viscometer used. For flow of water, therefore,

$$\eta_{H_2O} = A\rho_{H_2O} t_{H_2O} \qquad \text{..........(2.34)}$$

$$\text{or, } A = \frac{\eta_{H_2O}}{\rho_{H_2O} t_{H_2O}} \qquad \text{..........(2.35)}$$

knowing the value of η_{H_2O} and ρ_{H_2O} at the experimental temperature and measuring the time of flow for water, the calibration constant A for a particular viscometer can be determined. Putting the value of and of the experimental liquid/solution and the value of viscometer constant A in equation (2.33), the coefficient of viscosity can be obtained for a liquid at a definite temperature.

2.8 Viscosity Coefficients A and B

The viscosity of a solution relative to that of the pure solvent is called relative viscosity which is a measure of the change of the viscosity of the pure solvent due to the addition of solute to the solvent. Attempts had been made to describe the variation of viscosity with solute concentration. Einstein [75] deduced from the classical principles of hydrodynamics that if the solute were composed of spherical incompressible uncharged particles, larger in comparison with the water molecules, then the viscosity of the solution could be expressed as:

$$\eta = \eta_0(1 + 2.5\theta) \text{----------(2.36)}$$

where, θ denotes the volume fraction of the solute particles and η_0 is the viscosity of the solvent. This equation is proved to be valid only at low concentrations. Later, Falkenhagen and Dole [76] attacked the problem of the viscosity of electrolyte solutions and proposed that the electrical forces between ions in the solution tend to establish and maintain a preferred rearrangement and thus to 'stiffen' the solution i.e. increases its viscosity. The mathematical treatment of this effect resulted in the following limiting law for very low concentrations of electrolytes (0.01M) as,

$$\frac{\eta}{\eta_0} = \eta_{rel} = 1 + A\sqrt{C} \text{ --- } (2.37)$$

where, the always positives constant A is a function of solvent properties, ionic charges, mobilities and temperature. The Falkenhagen equation was of little use in calculating viscosities since the square root term is swamped by a much larger linear term expressed in the empirical equation of Jone and Dole [77] as follows,

$$\eta_{rel} = 1 + A\sqrt{C} + BC \text{ --- } (2.38)$$

where, A is again Falkenhagen theoretical coefficient while the empirical parameter B represents ion-solvent interaction.

The concentration dependence of viscosity of electrolytes in aqueous solutions are found to follow the Jones-Dole [77] equation up to 0.1M concentration [78].

In the concentrated solution region (up to 10M), several features of the viscosity of electrolyte solutions have been noted. For some salts a plot of the viscosity vs, the molality at fixed temperature fields a roughly exponentially increasing function. However, for other salts a pronounced minimum occurs. These latter salts fall into the category of structure breakers.

The effect of concentration on the viscosity of salt solutions in the more concentrates region and at fixed temperature, has been approached empirically in various V. J. Vand [79] extended Einstein's limiting theory to higher concentration giving.

$$\ln\eta_{rel} = \frac{2.5\theta}{1-Q\theta} \tag{2.39}$$

where, θ is proposed to be an interaction parameter dealing with the mutual interference between the spheres. Suryanarayna and Venkatesan have observed that equation.

$$\eta_p = A''\exp\left(B''C_p\right) \tag{2.40}$$

adequately describes the variation of electrolyte viscosity throughout the high concentration range. Here η_p represents the ratio of the viscosity of the solution at a given concentration relative to that at saturation at the same temperature and C_p the ratio of the mole fraction of the solute at given concentration to that at saturation at the same temperature, A″ and B″ are experimentally determined constants.

2.9 Viscosity and temperature

The viscosity of a liquid is generally decrease with the increase of temperature, i.e., a liquid becomes more free moving at higer temperatures. This in sharp contrast with the gas behavior, viscosity of gases increases with the increase of temperature. Numerous equations, connecting viscosity and temperature, have been proposed, but those of the exponential type, first derived independently by S. Arrhenius (1912) and J. De Guzmann(1913), are preferred due to their theoretical practical importance.

$$\eta = Ae^{E/RT} \tag{2.41}$$

Where 'A' and 'E' are constants for the given liquid. It follows from equation (2.41) that the plot of log η versus 1/T will be a straight line. By analogy with the Arrhenius theory of reaction rates, 'E' has the dimension of work and can be regarded as the activation energy of viscous flow. It is probably related to the work needed to form 'holes' in the liquid, into which molecules can move, thus permitting relative motion to take place.

It has been suggested that before a molecule can take part in liquid flow, it must acquire sufficient energy 'B' to push aside the molecules which surround it. As the temperature increases, the number of such molecules increases in proportion to the Boltzmann factor $e^{-E/RT}$ as in equation 2.41.

At low temperature the viscosity of a liquid is usually greater because the intermolecular attractive forces simply dominate the disruptive kinetic forces. At elevated temperatures the kinetic energy of the molecules increases at the expense of intermolecular forces which diminish progressively. Therefore, the molecules of a liquid at high temperature offer less resistance to the flow and hence less viscosity.

Viscosity also depends on pressure, molecular weight or mass of the molecule, molecular size and particularly chain length, the magnitude of intermolecular forces, such as association in pure liquids. Non polar liquids e.g., benzene, toluene etc. have low viscosities, whereas liquids in which direct bonding can occur between the molecules, e.g., glycerin, water etc. have high viscosities where H-bonding occurs extensively.

2.10 Viscosity as a rate process

Liquids in a tube are considered as combination of concentric layers and it flows as a rate processes.

To treat the viscosity of a liquid as a rate process it is assumed that

i) The motion of one layer with respect to another is assumed to involve the passes of a molecule from one equilibrium position to another is the same layer.

ii) In order to move a molecule from one equilibrium position to another, a suitable 'hole' or site should be available.

iii) The production of a such site requires the expenditure of energy because work must be done in pushing back the molecules.

iv) The jump of the moving molecules from one equilibrium position to the next may thus be regarded as equivalent to the passage of the system over a plot of energy barrier.

Eyring and his co-workers [80] using absolute reaction rate theory and partition function. Correlated co-efficient of viscosity, η as follows:

$$\eta = \frac{hN}{V_m} e^{\Delta G^{\#}/RT} \quad \text{....(2.42)}$$

Where, $\Delta G^{\#}$ is the free energy of activation per mole for viscous flow, V_m is the molar volume for pure liquids or solutions and h, N, R and T have their meanings. The values of change of free energy of activation ($\Delta G^{\#}$) can be calculated by using the Nightingle and Benck equation [81]:

$$\Delta G^{\#} = RT \ln\left(\frac{\eta V_m}{Nh}\right) \quad \text{....(2.43)}$$

The experimental term in equation 2.48 depends on the temperature and is typical for the processes which require activation energy. The activation process to which $\Delta G^{\#}$ refers can not be precisely described but in general terms, it corresponds to the passes of the system into some relatively favorable configuration, from which it can then easily go to the final state of the molecular process. For example, in normal liquids the activation step may be the creation in the body of the liquid of a vacancy or holes into which an adjacent molecule can move. For associated liquids, it might be the breaking of enough intermolecular bonds to permit a molecule to move into available vacancy.

Enthalpy ($\Delta H^{\#}$) and entropy ($\Delta S^{\#}$) of activation for viscous flow:

Enthalpy of activation ($\Delta H^{\#}$) and entropy of activation ($\Delta S^{\#}$) for viscous flow for the solution can be obtained with the help of Eyring equation [80]:

$$\eta = \left(\frac{hN}{V_m}\right) e^{\Delta G/RT}$$

$$\text{or } \ln\eta + \ln\frac{hN}{V_m} + \frac{\Delta G^{\#}}{RT}$$

$$\text{or, } \ln\frac{\eta V_m}{Nh} = \frac{\Delta G^{\#}}{RT} \quad \text{....(2.44)}$$

Since,

$$\Delta G^{\#} = \Delta H^{\#} - T\Delta S^{\#} \quad \text{....(2.45)}$$

The Eyring equation takes the form,

$$\ln\frac{\eta V_m}{Nh} = \frac{\Delta H^{\#}}{RT} - \frac{\Delta S^{\#}}{R} \qquad \text{(2.46)}$$

Assuming $\Delta H^{\#}$ and $\Delta S^{\#}$ to be almost independent in the temperature range studied, a plot of $\ln \eta V_m / Nh$ against 1/T, will give a straight line with slope $= \frac{\Delta H^{\#}}{R}$ and intercept $= -\frac{\Delta S^{\#}}{R}$

From the slope of this straight line, $\Delta H^{\#}$ can be calculated as,

$$\Delta H^{\#} = \text{slope} \times R \qquad \text{(2.47)}$$

and from of the intercept of this straight line, $\Delta S^{\#}$ can be calculated as

$$\Delta S^{\#} = -\text{ intercept} \times R \qquad \text{(2.48)}$$

$\Delta H^{\#}$ and $\Delta S^{\#}$ respectively the enthalpy of activation per mole for viscous flow and $\Delta S^{\#}$ is the entropy of activation. Since $\Delta S^{\#}$ does not change much within a range of temperature, so when in $\ln\eta V_m / hN$ is plotted against 1/T, will be found. From the slope and intercept, $\Delta H^{\#}$ and $\Delta S^{\#}$ respectively can be calculated.

2.11 Different thermodynamic parameters

2.11.1 Free energy of activation ($\Delta G^{\#}$) for viscous flow

In any liquid, for a molecule to take part in flow, a hole must be available. This hole is not necessarily the full size of a molecule but the additional volume required by the activated state as compared with the initial state. The energy required to make a hole of a molecular size is equal to the energy of activation E_{vap} and so the free energy of activation may be expected to be some fraction of the energy of vaporization.

2.11.2 Enthalpy of activation ($\Delta H^{\#}$) for viscous flow

A plot of $\ln\eta V_m/hN$ VS 1/T [according to Eyring equation] will give a straight line of slope $\Delta H^{\#}/R$ and intercept $-\Delta S^{\#}/R$. Assuming that $\Delta H^{\#}$ and $\Delta S^{\#}$ to be almost independent of temperature. The value of $\Delta H^{\#}$ as found by this procedure are almost constant, for normal liquids over a range of temperature under ordinary condition.

2.11.3 Entropy of activation ($\Delta S^{\#}$) for viscous flow

In view of high activation energy for the flow of associated liquids, it is a striking fact that the free energy of activation shows no such abnormality. The explanation is that, $\Delta G^{\#}$ is equivalent to ($\Delta H^{\#}$ - $T\Delta S^{\#}$) and that the high value of the enthalpy of activation $\Delta H^{\#}$ is compensated by the large positive value of $\Delta S^{\#}$, so that $\Delta G^{\#}$ remains normal. If as suggested above the unit of even in associated liquids is a single molecule and the formation of the activated state involves of a number of hydrogen–bonds, it is evident that the entropy of the activated state will be appreciably greater than that of the initial state. In other words, the entropy of activation $\Delta S^{\#}$ for flow should be relatively large positive, in agreement with the experimental fact that $\Delta G^{\#}$ is normal in spite of the volume of the $\Delta H^{\#}$ for associated liquids.

2.12 Change of chemical potential $((\Delta\mu1^{\neq} - \Delta\mu o^{\neq}))$ for viscous flow:

Although a complete theory of B coefficient is not known, even then it has been used for a long time by workers to interpret the interaction between the ions and solvent molecules [82-84]. The study of B –coefficient is very important for qualitative determination of the effects of ions on the structure of solvents. According to Feakins, Freemantle and Lawrence [85] coefficient B is related to the difference in chemical potential for the flow of one mole of solution having concentration C and that of solvent by the relation,

$$X_2\left(\Delta\mu_1^* - \Delta\mu_0^*\right) = RT\ln\frac{(1+BC)V_m}{V_0} \qquad \text{..............................(2.49)}$$

CHAPTER III

Experimental

3.1 General Techniques

During the course of the present work a number of techniques were involved which were in general standard ones. Constant efforts for attaining the ideal conditions for the experiments were always attempted.

The thoroughly cleaned glass pieces were dried in electric oven. The smaller pieces of apparatus were dried in electric oven and stored in a desiccator, while larger pieces of apparatus were used directly from the oven.

Ostwald viscometer of British standard institution form was used for measurement of viscosity. The inside wall of the viscometer was cleaned thoroughly with warm chromic acid so that there was no obstruction in the capillary and the liquid could run clearly without leaving any drop behind. It was then rinsed thoroughly with distilled water followed by rectified spirit and finally with acetone and dried.

3.2 Materials

The chemicals used for study were - Sodium Chloride , Potassium Chloride, Glucose , Sucrose , Maltose . All chemicals were of analytical reagent (A.R) grade. Specifications and structural formula for all of them are given below:

Chemicals	Molecular formula	Molar mass	Reported purity	Producer
Sodium Chloride	$NaCl$	58.5	99.8%	E. MERCK Germany
Potassium Chloride	KCl	74.55	98.0%	E. MERCK Germany
Glucose	$C_6H_{12}O_6$	180	99.98%	E. MERCK Germany
Sucrose	$C_{12}H_{22}O_{11}$	342.30	99.76%	E. MERCK Germany
Maltose	$C_{12}H_{22}O_{11}$	342.30	99.98%	E. MERCK Germany

3.3 Preparation and Purification of Solvent

Ordinary distilled water was purified by a quick-fit glass made distillation apparatus. About 1.5L water was taken in a round bottom flux of which the capacity was 2L. Then it was distilled in presence of $KMnO_4$. Distilled water was collected at only 100°C. Other liquids of which the temperatures were below and above the mentioned boiling point were discarded. In all the experiments double distilled and deionized water was used. Conductivity of this redistilled water was found to be less than 1×10^{-6} $S.cm^{-1}$. This redistilled water was used for the preparation of Carbohydrates solutions for volumetric and viscometric studies.

3.4 Apparatus

The glass-ware used for the measurement for density of solvents and solutions were of the density bottle (25ml). Viscosities of various liquids were measured using the calibrated ostwald type viscometer. A & D company, (Model ; HR 200, Made in Japan) electronic balance with an accuracy of ± 0.0001g was used for weighting. The flow time of liquids were recorded by a stop-watch capable to read up to 0.01 seconds. The temperature was controlled by water thermostat (Model: Huber CC-E , Made in Germany) with an accuracy of $\pm 0.01^0$C. The experimental temperatures were 298.15, 303.15, 308.15, 313.15, 318.15 and 323.15K respectively. Both the density bottle and viscometer were calibrated with doubly distilled water at the studied temperature. Calibrated volumetric flask, pipette and burette were used for necessary volume measurement.

3.5 Conductance measurements

Conductance of water and aqueous Carbohydrates solution by using a digital conductivity meter (EXTECH INATRUMENTS Model no. 407303). Rinsed the cell with one or more portions of sample and adjust sample temperature about 25^0C. Immerse cell in sample: sample level above vent holes then read and noted conductivity of sample.

3.6 Density measurements

The densities of the solutions were determined by weighing a definite volume of the solution in a density bottle at specified temperature. The volumes were obtained by measuring the weight of water at that temperature and using the density of water from literature. The density of solution was determined from the relation.

$$\rho = \frac{w - w_e}{v_0} \qquad \text{..(3.1)}$$

where, ρ = density of the solution, w = weight of bottle with solution, w_e = weight of empty bottle, v_0 = volume of bottle.

The density bottle was first thoroughly cleaned with warm chromic acid and then with enough distilled water. Then it was rinsed with acetone and finally dried at 85^0C for more than two hours. The weight of the dried empty density bottle was noted after proper cooling. The density bottle was calibrated at experimental temperature with doubly distilled water.

The solution under investigation was taken in a density bottle up to the mark. The density bottle was clamped carefully with stand in the thermostatic water bath maintained at the desired temperature. As the solution started to gain the temperature of the bath excess liquid overflowed through the capillary. Then it was allowed to keep in the bath for about 30 minutes to attain the thermal equilibrium. When no overflowed observed through the capillary the density bottle was taken out from the thermostatic water bath, wiped with tissue-paper, dried and weighed in the analytical balance. The difference between the two weights (weight with solution and without solution) gave the weight of the solution in the density bottle. The density measurement was performed for each of the solutions at the temperature 298, 303, 308, 313, 318 and 323K respectively in this way using equation 3.1.

3.7 Apparent/ Partial molar volume measurements

The apparent molar volumes of the solution for binary and ternary systems were determined from density measurement using the following equation:

$$\varphi_v = \frac{1}{\rho}\left\{M_2 - \frac{1000}{m}\left(\frac{\rho-\rho_0}{\rho_0}\right)\right\}$$

$$\text{or, } \varphi_v = \frac{1000}{m\rho\rho_0}(\rho_0-\rho)+\frac{M_2}{\rho} \quad \text{..(3.2)}$$

where, ρ is the density of the experimental solution, M_2 and m are the molar mass and molality of the electrolyte respectively and ρ_0 is the density of the solvent. The molality 'm' of a solution were calculated from mole fraction of solute and solvent

$$m = \frac{X_2 \times 1000}{X_1 M_1}$$

where, M_1 and M_2 = the molecular weight of solute and solvent

and also from molarity C,

$$m = \frac{1}{\left(\frac{\rho}{C} - \left(\frac{M_2}{1000}\right)\right)} \quad \text{... (3.3)}$$

where, C is the molarity, M_2 is the solute molecular weight and ρ is the density of the solution respectively.

The molarity 'C' of a solution was calculated from the following equation:

$$C = \frac{1}{M_2} \times \frac{a}{\text{vol. of solution in liter}} \quad \text{...(3.4)}$$

where, a = weight of the solute (electrolyte) in gm, M_2 = solute molecular weight.

Molar volume of solvent (pure water) at experimental temperature was calculated using the following equation (34).

$$\overline{V}_1^0 = \frac{\text{Molecular masses of solvent}}{\text{Density of solvent (at expt. temp.)}} \quad \text{...(3.5)}$$

The partial molar volumes of the solute and solvent can be obtained from density measurement using the following equation.

$$\overline{V_2} = \varphi_v + \frac{\sqrt{m}}{2}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) = \varphi^0{}_v + \frac{3\sqrt{m}}{2}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right) \quad \text{...(3.6)}$$

Where, $\varphi^0{}_v$ = apparent molar volumes at zero concentration.

and $\overline{V_1} = V_1^0 - \frac{M_1 m^{3/2}}{2000}\left(\frac{\delta\varphi_v}{\delta\sqrt{m}}\right)$ ....(3.7)

The values of $\frac{\delta\varphi_v}{\delta\sqrt{m}}$ were obtained from the slope of the plot of φ_v against $\sqrt{C}$ by the use of Masson [44] equation and the apparent molar volume of solutes at infinite dilution ($\varphi_v{}^0 \approx \overline{V_2}^0$) were determined from the intercept of the plot, at C equal to zero.

3.8 Viscosity measurements

Viscosity of water, the binary solution of Sodium Chloride-water, Potasium Chloride-Water and ternary solution of Sodium Chloride -Water- Glucose , Sodium Chloride-Water- Sucrose, Sodium Chloride - Water- Maltose, Potasium Chloride -Water-Glucose, Potasium Chloride -Water- Sucrose, , Potasium Chloride -Water- Maltose were measured by using the British standard Ostwald U-type viscometer. The interior of the viscometer was cleaned thoroughly with warm chromic acid and then with distilled water, so that there was no obstruction in the capillary and the liquid could run freely without leaving any drop behind. It was then rinsed with acetone and dried in and oven at about 75^0C. The viscometer was then clamped vertically in the thermostatic water bath such that the upper mark of the top bulb was well below the water level. 10 mL of doubly distilled water was poured into the viscometer. Then it was allowed to keep in the thermostatic bath for about 30 minutes to attain the bath temperature. With the help of a pipette filler attached to the narrower limb of the viscometer, the water was sucked up above the upper mark of the bulb. The water of bulb was then allowed to fall into the capillary and the time of fall between the two marks was noted with the help of stop-watch capable of reading up to 0.01 second. The reading at each temperature was repeated three or four times, in order to check the reproducibility of the flow time, the temperature being maintained at the same value. Since the accurate viscosity and density of water at different temperatures are known (from literature) calibration constant A of the viscometer for different temperature were obtained by using equation,

$$\eta = A\rho t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.8)$$

where, $A = \dfrac{\eta_{H_2O}}{\rho_{H_2O}\, t_{H_2O}}$

Putting the values of the calibration constant, density and time of flow of the experimental solution, the viscosity of that solution was determined by using the equation 3.40.

3.9 Coefficient A and B determinations

The coefficients A and B for the electrolyte solutions were calculated using the empirical equations of Jones-Dole:

$$\eta_r = 1 + A\sqrt{C} + BC$$

$$\text{or, } \frac{\eta_r - 1}{\sqrt{C}} = A + B\sqrt{C} \text{ --(3.9)}$$

where, η_r is the relative viscosity = $\dfrac{\text{Viscosity of solution}}{\text{Viscosity of solvent}}$

and C is the molar concentration.

The values of the coefficients A and B were obtained from the intercept and slope of the plot $\dfrac{\eta_r - 1}{\sqrt{C}}$ against $\sqrt{C}$ respectively.

3.10 Thermodynamic parametes

The change of free energy of activation ($\Delta G^{\#}$) was calculated by the help of Nightingle and Benck equation:

$$\Delta G^{\#} = RT\ \ln\left(\frac{\eta V_m}{Nh}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (3.10)$$

Where η = Viscosity of the liquid in SI unit (Kg $m_l^{-1}S^{-1}$)

V_m = Average molar volume of solution (m_l^{3})

N= Avogadro's constant = 6.023×10^{23} mol^{-1}

h = Plank's constant = 6.626×10^{-34}Js

T = Absolute temperature (K)

R = Universal gas constant = 8.314 JK^{-1} mol^{-1}

Energy of activation ($\Delta H^{\#}$) and entropy of activation ($\Delta S^{\#}$) for viscous flow for the solution were determined y using the Eyring equation:

$$\eta = \left(\frac{Nh}{V_m}\right) e^{\frac{\Delta G^{\#}}{RT}}$$

$$\text{or,} \quad \text{In}\ \frac{\eta V_m}{Nh} = \frac{\Delta G^{\neq}}{RT} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.11)$$

Since, $\Delta G^{\#} = \Delta H^{\#} - T\Delta S^{\#}$

$$\therefore \ln\left(\frac{\eta V_m}{Nh}\right) = \frac{\Delta H^{\#}}{RT} - \frac{\Delta S^{\#}}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.12)$$

Assuming $\Delta H^{\#}$ and $\Delta S^{\#}$ are almost independent of temperature in this range, a plot of ln $\frac{\eta V_m}{Nh}$ against $\frac{1}{T}$ will give a straight line with slope = $\frac{\Delta H^{\#}}{R}$ and intercept = - $\frac{\Delta S^{\#}}{R}$ from which,

$$\Delta H^{\#} = \text{slope} \times R \qquad (3.13)$$

and

$$\Delta S^{\#} = -\text{intercept} \times R \qquad (3.14)$$

Results and Discussion

Electrolytes such as NaCl and KCl are very important for living organisms. Carbohydrates are an exceptionally important constituent of biological systems. Carbohydrates are polyhydroxy aldehydes and ketones. Due to the presence of a large number of –OH groups, they are highly polar and are hydrated easily. The carbohydrates included in this study are glucose as monosaccharides and sucrose and maltose as disaccharides. Our studies included the interaction of NaCl and KCl with glucose, sucrose and maltose in terms of volumetric, viscometric and thermodynamic measurements.

The volumetric, viscometric, thermodynamic and some other related properties of some simple electrolytes such as NaCl and KCl in aqueous and aqueous glucose, aqueous sucrose and aqueous maltose solutions (1% (w/v), 5% (w/v) and 10% (w/v)) have been measured at different temperatures. The properties have been discussed in the light of recent developments of the subject. All the studied electrolytes are found to be dissolved readily in water but aqueous glucose, sucrose and maltose solutions are found to be dissolved properly up to 10% (w/v).

The above mentioned systems were studied precisely at six equidistant temperatures ranging from 298.15K to 323.15K at interval of 5K by volumetric and viscometric methods. The volumetric properties such as apparent molar volume are determined from density. Viscometric properties such as viscosity coefficients A and B parameters and thermodynamic properties like change of enthalpy ($\Delta H^{\#}$), entropy ($\Delta S^{\#}$) and free energy ($\Delta G^{\#}$) of activation for viscous flow are determined from viscosity value. From these studies we obtained various information, which are presented in various sections and discussed in the light of theories mentioned in the earlier chapter.

4.1 Volumetric properties of electrolyte solutions

Densities of glucose, sucrose and maltose in aqueous solutions (1% (w/v), 5% (w/v), and 10% (w/v)) were measured at 298.15 to 323.15 K firstly and then densities of NaCl and KCl at different concentration (0.01-1.0M) in aqueous, aqueous glucose, aqueous sucrose and aqueous maltose solutions (1% (w/v), 5% (w/v) and 10% (w/v)) were measured at 298.15 to 323.15 K respectively. The densities, ρ of the binary carbohydrate systems (water, +glucose,

+sucrose and +maltose) have been shown in Table 4.1-4.3 at different temperatures. The density of carbohydrates increase with the increase of composition (% w/v) of carbohydrates. The density of glucose, sucrose and maltose of 5% (w/v) solution were found to be order of

Maltose > Sucrose > Glucose

The densities of maltose are higher than sucrose and glucose in aqueous solutions may depend on molecular weight, structural formula and the orientation of –OH groups. Although the molecular weight of sucrose and maltose are same, but sucrose is made up of one glucose and one fructose units whereas maltose is made up of two glucose units ascribed that the six membered pyranose ring in maltose being more favorable for interaction with water compared to the five membered furanose ring in glucose or sucrose.

The densities of binary (water +electrolytes) and ternary (water +carbohydrates+electrolytes) systems have been shown in Table 4.4-4.23. The representative curves (density vs molarity) for all the electrolyte systems are linear in all the solvent systems (shown in Figure 4.1-4.20). The values of ρ increase with the increasing molarity of the electrolytes. At 0.4M concentration, the density of the electrolytes in aqueous solution has been found to be in the order of,

KCl > NaCl

Densities of electrolyte + carbohydrate +water are higher than that of electrolyte +water systems (shown in Figure 4.21-4.26). Density value decreases with increase in the temperature. Increase of density with concentration of electrolytes indicate the increase in ion-solvent interactions, whereas the decrease in density indicates the lesser magnitude of ion –solvent interactions. Increase in density with concentration is also due to the shrinkage in the volume which in turn is due to the presence of solute molecules. In other words, an increase in density may be interpreted to the structure-maker of the solvent due to the added solute and the decrease in density with concentration indicates structure breaker of the solvent (86, 87).

Mixing of NaCl or KCl with aqueous or aqueous carbohydrates (glucose, sucrose and maltose) solutions will induce changes in hydrogen bonding and dipolar interactions. On addition of NaCl and KCl to the aqueous or carbohydrate solutions the self association of solvent will be disrupted partly or fully and new dipolar interactions between electrolyte and carbohydrates or water will be formed. At the same time, segmental inclusion of electrolyte into the vacant spaces left in the structural network of water or carbohydrate solutions may also occur. With the increase of concentration of electrolytes in water or aqueous carbohydrate solution, the free volume in the solution decreased gradually and the density increased progressively (Figure 4.1-4.20). But with the increasing temperature densities decreased regularly, this is due to the increase of thermal agitation and hence the weaker the dipole-dipole interaction or dissociation of H-bonding are occurred. The values of densities of electrolyte + aqueous carbohydrate systems at a fixed electrolyte concentration has been found to be in the order of,

Electrolyte +10% (w/v) carbohydrate > Electrolyte +5% (w/v) carbohydrate> Electrolyte +1% (w/v) carbohydrate

From the sequence, it is seen that the density increase with the increasing of carbohydrate concentration at a fixed electrolyte concentration. The increase of density with concentration of carbohydrate can be attributed to solute- solvent interaction and weight of carbohydrate in solution.

The density order of carbohydrate in electrolyte solution was similar as carbohydrate in pure water solution. The density of maltose is higher than sucrose and glucose in electrolyte solution, although the difference in sucrose and maltose is not large (shown in Figure 4.27-4.29) as the molecular weight of sucrose and maltose are same.

The apparent molar volume (ϕ_v) of different electrolytes in aqueous and aqueous glucose, aqueous sucrose and aqueous maltose solutions (1% (w/v), 5% (w/v) and 10% (w/v)) have been determined by equation 3.2. The apparent molar volume (ϕ_v) data of different electrolytes at 0.4-1.0M were tabulated in tables 4.24-4.43, respectively. In the very low concentration region small error in density and molarity brings large uncertainty in ϕ_v values (88). So, we have avoided the ϕ_v data at lower concentration. The concentration dependence of ϕ_v of the chosen electrolytes in aqueous, aqueous glucose, aqueous sucrose and aqueous maltose solutions (1% (w/v), 5% (w/v) and 10% (w/v)) at different temperatures were shown in Figure 4.30-4.49, respectively. It appears from the figure that apparent molar volume is dependent upon the electrolyte concentration as well as on the temperature.

The apparent molar volume (ϕ_v) were found to be positive for NaCl and KCl in aqueous solution and dilute carbohydrate (1%) solution whereas it is negative in concentrated (5% and 10% (w/v)) carbohydrate solution. Plots of ϕ_v vs. square root of molarity of the NaCl show linear relationship in water system. The value of ϕ_v increases linearly with the increase of molarity of NaCl. No significant change of ϕ_v observed for KCl with the increase of concentration in aqueous solution. But the plots of ϕ_v vs square root of molarity of the NaCl and KCl show slightly curvature relationship in water + carbohydrate solvent systems (shown in Figure 4.30-4.49). This is ascribed that the nature of interaction of same electrolyte with water and water + carbohydrate systems are not similar. This relation also holds at higher temperature, the value of ϕ_v increases with the increase of temperature. The value of ϕ_v increases with the increase in concentration of the electrolyte suggesting that solute-solvent interactions increase with the increase in molarity of the electrolyte in solution. At a fixed carbohydrate concentration and temperature, the increase of ϕ_v with the concentration of added electrolytes in the studied molarity range may be due to the cluster formation or aggregation. In the case of NaCl in water, ϕ_v values are increased with concentration but for KCl, the ϕ_v values are almost unchanged (aqueous solution) with the increase of molarity. The decrease may be attributed to the destruction of the tetrahedrally bonded water cluster.

Comparatively lower apparent molar volume, ϕ_v of electrolytes in aqueous glucose, aqueous sucrose and aqueous maltose solutions than aqueous solution was found. This indicates that the electrolytes are penetrated into the vacant space of carbohydrate-water solvent system easily than aqueous solution.

The values of ϕ_v for the electrolytes in carbohydrates (5% and 10% (w/v)) solutions are negative over the entire range of composition. The negative values of ϕ_v indicate strong hydrophilic interactions occurring in these systems. As more number of water molecules is available at lower concentration of metal halides, the chances for the penetration of solute molecules in the solvent mixtures are highly favored. The negative values of ϕ_v were reported (89).

The increase of ϕ_v with temperature and decreased with the increase of carbohydrate concentration may be: (i) due to the increase in thermal energy at higher temperature, the relaxation to the bulk of the electrostricted water molecules from the interaction regions of ion -dipole or dipole- dipole interaction with –OH and –CH_2OH results in a positive volume change; (ii) that an increase in temperature renders the ion–ion interactions relatively weaker giving rise to a small negative volume change and (iii) the carbohydrate –carbohydrate or carbohydrate-water or water–water interactions decreases with the increase in temperature leading to a small negative change in volume. The predominance of the positive contributions from (i) may overcome the small positive contribution from (ii) and (iii) thus a net positive change in volume arises at higher temperature.

The apparent molar volume at infinite dilution (ϕ_v^o) was calculated using least square fit to the plots of experimental values of ϕ_v versus square root of molar concentration using the equation (2.22). The limiting apparent molar volume ϕ_v^o and S_v values are given in table 4.44-4.63. The limiting apparent molar volume ϕ_v^o which is taken to be the partial molar volume of the electrolytes in water and in water +carbohydrate solutions at infinite dilution reflects the true volume of the electrolyte and the volume change arising from the solute-solvent interactions (90-91).

It is evident from the tables that the values of S_v are positive for NaCl and KCl in aqueous and aqueous carbohydrate solution systems. Since S_v is a measure of solute-solute or ion-ion interactions, the result indicates the presence of very strong ion-ion interactions. For the different electrolytes in aqueous, aqueous glucose, aqueous sucrose and aqueous maltose, the value of S_v are positive in all the solutions but the value of S_v are larger in glucose, sucrose and maltose solutions than water solution. This indicates that the ion-ion interactions are very strong for electrolytes in glucose, sucrose and maltose solutions.

Most of the S_v values are positive and decrease with an increase of temperature (with few exception) in the aqueous and aqueous carbohydrate systems suggesting that less solute is accommodated in the void space left in the packing of the large associated solvent molecules. The results also indicate the presence of strong solute-solute interactions, and these interactions decrease with the increase in temperature. The values of S_v increase with the increase in percent composition of carbohydrates showing strong solute-solute interactions. It can be said that the solvation of ions decrease with the increase of carbohydrate content in water.

The ϕ_v^o values of the electrolytes reflect the true volume of the solute and the volume change arising from the solute-solvent interactions. The volumetric behavior of a solute at infinite dilution is satisfactorily represented by ϕ_v^o, which is independent of the solute-solute interaction and provides information concerning solute-solvent interactions. It was observed that ϕ_v^o values of NaCl and KCl are positive in aqueous solution. But the ϕ_v^o values are negative (with few exception) for all the percent compositions of carbohydrates at all temperatures suggesting the presence of weak solute-solvent interactions (92, 93).

The change in the limiting apparent molar volume, ϕ_v^o of the electrolytes can also be explained by considering of the charge and size of the cations and anions of the electrolytes in aqueous and in aqueous carbohydrate solutions. The salts NaCl and KCl contain mono-valent dissimilar cations with same anion. The ionic radius of of Na^+, K^+ and Cl^- are 0.97, 1.38 A°, 1.67 A°, respectively (88). The contribution of Cl^- to ϕ_v^o is the same in both the cases. The variation of ϕ_v^o in these cases, therefore, may be due to the difference in ionic radii, charge density and ion-solvent interactions respectively.

According to Vaslows concept (88) of hydration small cations normally enhance hydrogen bonded structural grouping in liquid water. As the radius of Na^+ is smaller than K^+, it occupies the smallest space in the hydration sheath. For the larger radius of K^+ it occupies larger space in the hydration sheath than Na^+. Besides, the high charge to radius ratio in case of Na^+ renders electrostriction of water structure causing the limiting ϕ_v^o of NaCl and KCl in aqueous solution follow the order $\phi_v^o{}_{\mathrm{NaCl}} > \phi_v^o{}_{\mathrm{KCl}}$.

The values of ϕ_v^o (shown in Table 4.44-4.63) increased with an increase in temperature in the aqueous and aqueous carbohydrate systems which indicate that the solvent molecules are loosely attached to solutes which expand with the increase of temperature, thus resulting in higher values of ϕ_v^o at higher temperatures. The following contributions of ϕ_v^o (ion) are instructive:

(1) The ion has a definite intrinsic size, V_{int}, for which a cavity in the solvent must be provided. (2) The ion has a large electric field that exerts a strong inductive effect on the surrounding solvent, referred to as electrostriction, V_{el}. (3) Short-range interactions take place, in particular, where multivalent cations (donor-acceptor interactions) and anions (hydrogen bonding) are concerned that are manifested by a volume effect V_{cov}. (4) The volume of the solvent, V_{str}, changes due to its rearrangement around the ion as a result of the size, shape, electric field (beyond the effects of electrostriction), and short-range interactions of the ion and the size, shape, and structure of the solvent molecules. If these volume effects are chosen to be independent of each other, then the partial molar volume of the ion can be considered as their sum (94):

$$\phi_v^o{}_{(\text{ion})} = V_{\text{int}} + V_{\text{el}} + V_{\text{cov}} + V_{\text{str}} \quad (1)$$

A somewhat different expression was presented by Millero on the basis of the Frank and Wen model for aqueous ions (95):

$$\phi_v^o{}_{(\text{ion})} = V_{\text{int}} + V_{\text{el}} + V_{\text{dis}} + V_{\text{cag}} \quad (2)$$

where, V_{dis} describes the volume effect of the broken (disordered) solvent structure around structure-breaking ions and V_{cag} describes the volume effect of "caged" solvent around hydrophobic ions.

The limiting apparent molar volume ϕ_v^o for all the electrolytes studied show higher values in aqueous solution than those in aqueous carbohydrate solution. The variation of ϕ_v^o with molarity of carbohydrate can be rationalized in terms of cosphere overlap model. According to this model, the overlap of the cospheres of two similar ions or polar groups and an ion with that of a hydrophilic group, always produces positive volume change. On the other hand, the overlap of the cospheres overlapping of hydrophilic-hydrophobic and hydrophobic-hydrophobic groups led to a decrease in volume result in a negative change of volume i.e. the effect of overlap of two cospheres is destructive. In the present ternary systems, the overlap of cospheres of hydrophilic – hydrophilic or hydrophobic groups of interactions take place. The overlap of cospheres of carbohydrate gives negative change in volume due to the relaxation of the electrostricted water molecules from its cosphere to the bulk. The overlap of the cospheres of hydrophilic group with those of hydrophobic groups of carbohydrate results negative changes in volume.

The water-water interactions are assumed to be the same and do not produce considerable change in volume. An increase in the carbohydrate concentration increases the ion-hydrphobic and also hydrophilic-hydrophilic or hydrophobic interaction giving rise to an overall decreased of ϕ_v^o value. This account for the decrease in ϕ_v^o value with the increase in carbohydrate concentration (data are shown in table 4.44-4.63).

The transfer volume $\phi_v^o{}_{(\text{tr})}$ from aqueous to aqueous carbohydrate solution is given by the equation

$$\phi_{v,tr}{}^o = V_{CE} + V_{EW} - V_{CC} - V_{CW} \quad (3)$$

Where V_{CE}, V_{EW}, V_{CC}, and V_{CW} are the contribution from Carbohydrate-Electrolyte, Electrolyte-water, Carbohydrate- Carbohydrate, Carbohydrate –Water interactions respectively. Addition of carboydrate decrease contribution due to V_{CE} and $V_{EW,}$ but increase V_{CC} and $V_{CW,}$ thereby overall decreasing $\phi_v^o{}_{(tr)}$ with the addition of carbohydrate (96-98).

The thermodynamic transfer functions may also be interpreted in terms of water structure forming or breaking ability of the solute, as has been postulated by Frank and Evans (99). Thus, the transfer volume $\phi_v^o{}_{(tr)}$ from aqueous to aqueous carbohydrate solution was calculated using the relation

$$\phi_v^o{}_{(tr)} = \phi_v^o{}_{(aq.\ carbohydrate)} - \phi_v^o{}_{(aq)} \ldots\ldots\ldots\ldots \quad (4)$$

As shown in Table 4.44-4.63, it is found that the $\phi_v^o{}_{(aq.\ carbohydrate)}$ values are lower than $\phi_v^o{}_{(aq)}$, resulting in negative transfer of volumes. The temperature dependence of limiting apparent molar volume ϕ_v^o for binary and ternary solution can be expressed as:

$$\phi_v^o = a + bT + CT^2 \ldots\ldots\ldots\ldots (5)$$

over the temperature range under investigation.

The partial molar expansibilites

$$\varphi_E{}^\circ = (\partial\varphi_v{}^\circ/\partial T)_P = \alpha_2 + 2\alpha_3 T \ldots\ldots\ldots\ldots (6)$$

can be obtained by differentiating eq 6 with respect to temperature. It is evident that $\varphi_E{}^\circ$ increased in magnitude with the increase in temperature for NaCl and KCl in the aqueous and aqueous carbohydrate systems, showing the presence of caging or packing effects.

During the past few years it has been emphasized by different workers (96-100) that S_v and ϕ_v^o is not the sole criterion for determining the structure-making or structure-breaking nature of any solute. Hepler (100) developed a technique of examining the sign of $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]_p$ for various solutes in terms of long-range structure-making and structure-breaking capacity of solutes using the general thermodynamic expression

$$(\partial C_P/\partial P)_T = (-\partial^2\varphi_v{}^\circ/\partial T^2)_P = -2\alpha_3 T \ldots\ldots\ldots\ldots (7)$$

The sign of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ i.e. second derivative of limiting apparent molar volume of solution with respect to temperature at constant pressure which corresponds to structure making or breaking properties of solution were determined. NaCl in aqueous solution show positive value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ which is represented in Tables 4.44. The positive values indicate that NaCl act as structure maker for water, whereas KCl in aqueous solution shows negative values indicate that KCl act as structure breaker for water (101,102). For NaCl in 1% glucose, 1% sucrose and 1% maltose solution the value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ were found to be positive (few exception) suggesting structure making property. But NaCl in higher carbohydrate content solution (5% and 10%), the value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ were found to be negative suggesting structure breaking tendency. In the case of NaCl in Sucrose, it shows negative value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ for all the carbohydrate content (1%, 5% and 10%) systems. This indicates that NaCl in all compostion of sucrose solution act as structure breaker. i.e. the structure making tendency of NaCl is overcome by the structure breaking tendency of sucrose in carbohydrate solution. Slightly positive value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ maltose and glucose in electrolyte solution than sucrose can be ascribed to the six membered pyranose ring in glucose and maltose being more favorable for interaction with ion compared to the five membered furanose rings in sucrose. Sucrose has a higher percentage of axial –OH groups than glucose and maltose, probably for that reason exhibits a negative value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$. For KCl in glucose, sucrose and maltose solution, the value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ were found to be negative suggesting structure breaking tendency.

Several authors (100, 103-104) have also reported KCl as a structure breaker in aqueous systems. On the other hand, water structure making property of NaCl has also been reported (88).

For all the studied electrolyte systems, it is seen that the ϕ_v versus $\sqrt{c}$ plots are linear in aqueous solution but in water + carbohydrate system they are non linear. So the electrolyte in carbohydrate system does not obey the Masson equation (2.22) properly. In the very low concentration region small error in density and molarity brings large uncertainty in ϕ_v values. The scattered ϕ_v values in low concentration may be attributed to these uncertainties. Therefore, the values of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_p$ are not enough for the explaining the structure making and breaking properties of studied salts.

4.2 Viscometric properties of electrolyte solutions

The viscosities of the binary (carbohydrates +water) systems have been shown in Table 4.64-4.66 at different temperatures. The viscosities of carbohydrates increase with the increase of composition (%w/v) of carbohydrates. Viscosity of glucose, sucrose and maltose of 5% (w/v) solution were found to be order of

Maltose>Sucrose> Glucose

Viscosities of NaCl and KCl in aqueous and aqueous glucose, aqueous sucrose and aqueous maltose solutions (1% (w/v), 5% (w/v), and 10% (w/v)) have been determined at 298.15, 303.15, 308.15, 313.15, 318.15 and 323.15 K respectively. The relevant data were shown in table 4.64-4.66 and the results were represented graphically in figures 4.50-4.69 respectively. At a fixed carbohydrate composition, the viscosities of electrolytes has been found to be in the order of

Electrolytes (higher concentration)> Electrolytes (lower concentration)

The representative curves (viscosity vs. molarity) for all the electrolytes systems are linear in aqueous and aqueous carbohydrate solvent systems with some exception. The value of η increases with the increase in molarity of the NaCl and decrease with temperature. KCl in aqueous and aqueous carbohydrate solution (1% and 5%) systems are showed some different features of viscosity curve. No significant changes of η observed for KCl with the increase in molarity in aqueous and aqueous carbohydrate solution.

The following characteristic features of viscosity are observed:

a) For NaCl in aqueous solution, 1% (w/v), 5% (w/v) and 10% (w/v) glucose solution, the viscosities increase slowly with concentration.

b) For NaCl in (1% (w/v), 5% (w/v) and 10% (w/v)) sucrose solution, the viscosities increase slowly with concentration. No significant change is appeared with the change of sucrose composition.

c) For NaCl in 1% (w/v) maltose solution, the viscosities increase slowly with concentration but in 5% (w/v) and 10% (w/v) maltose solution, the viscosities decrease firstly and then increase slowly with concentration.

d) For KCl in aqueous solution, the viscosities are almost unchanged with concentration. In 5% (w/v) glucose solution the viscosities increase up to 0.1 M solution and then this concentration, the viscosity is unchanged with concentration. For 10% (w/v) glucose solution, the viscosities increase up to 0.1M rapidly and then increase slowly.

e) For KCl in (1% (w/v) , 5% (w/v) and 10% (w/v)) sucrose solution, the viscosities are almost unchanged with concentration although very slight modification are appeared at 10% sucrose solution.

f) For KCl in 1% (w/v) and 5% (w/v) maltose solution, the viscosities increases very slowly but in 10%(w/v) maltose solution, the viscosity is unchanged with concentration up to 0.2M and beyond this concentration the viscosity increases slowly.

g) Viscosities decrease with rise of temperature.

Viscosity of the studying electrolytes in different solvent systems for 0.2M concentration and at a particular temperature (303.15K) in the following order:

NaCl (Water) > KCl (Water)

NaCl (10% Glucose) > NaCl (5% Glucose) > NaCl (1% Glucose) > NaCl (water)

KCl (10% Glucose) > KCl (5% Glucose) > KCl (1% Glucose) > KCl (water)

NaCl (10% Sucrose) > NaCl (5% Sucrose) > NaCl (1% Sucrose) ~ NaCl (water)

KCl (10% Sucrose) > KCl (5% Sucrose) > KCl (1% Sucrose) > KCl (water)

NaCl (10% Maltose) > NaCl (5% Maltose) > NaCl (1% Maltose) > NaCl (water)

KCl (10% Maltose) > KCl (5% Maltose) > KCl (1% Maltose) > KCl (water)

The viscosity, η for all the studied electrolytes are higher in aqueous carbohydrate solvent system than those in pure water system (shown in Figure 4.70-4.75). i.e. the solution resistance of carbohydrate solution are higher than water. This may be due to the size and structural effects of carbohydrates in electrolytic solution. At a fixed temperature (303.15K), the viscosities of NaCl or KCl are greater in higher composition of carbohydrate (10% carbohydrate) than lower composition of carbohydrate (1% carbohydrate) or water (shown in Figure 4.70-4.75). And also at a fixed temperature and composition of different carbohydrates, the viscosities of electrolytes are greater in maltose solution than sucrose or glucose with few exception (shown in Figure 4.76-4.81). Sucrose has a higher percentage of axial –OH group than maltose and glucose, this indicate that the six membered pyranose ring in maltose being more favorable for interaction compared to the five membered furanose ring in sucrose or glucose. In the maltose systems at lower concentration of NaCl the viscosities are decreases with concentration but at higher concentration the viscosities are increases with concentration indicating that aqueous maltose systems at low concentration of electrolyte are less structural but at higher concentration the structure denaturation tendency of carbohydrate is overcome by the structure making tendency of electrolyte.

There is a significant decrease in the viscosity with the increase of temperature for all studied electrolytes in water and carbohydrate solution systems (shown in Figure 4.82-4.87). By using a empirical equation of the form,

$$\ln\eta = A + B/\mathrm{T}$$

the linear dependence of $\ln\eta$ against 1/T shows that at 0.2M concentration of electrolytes (shown in Figure 4.88-4.93). From the Figures, it is seen that both KCl and NaCl in aqueous or carbohydrate systems show linear relationship. NaCl or KCl in aqueous and 1% carbohydrate systems, no significant change of viscosity with temperature is appeared. But the electrolytes in 5% and 10% carbohydrate systems, there is a marked change of viscosity showed. This is ascribed that electrolytes in carbohydrates solution are less structural than aqueous solution.

The above sequence can be explained by the viscosity B-coefficient data (106). According to the 'flickering cluster' model [105] of water, there are large void spaces within the hydrogen bonded framework of water structure. The linear increase of relative viscosity, η_r with concentration may be interpreted by the fact that molecules may have penetrated in the void spaces and may have a positive interaction with water.

To calculate the B-coefficient values, the viscosity data were analyzed in terms of the semi-empirical Jones-Dole equation [106].

The B-coefficient represents information regarding solute-solvent interaction and shape and size effect on the solvent structure. The viscosity coefficient B for the chosen electrolytes in aqueous and in aqueous carbohydrate solutions at different temperature are shown in table 4.87-4.106. From the table it is seen that the B-coefficient for NaCl in water and 1% carbohydrate system at all the temperatures are positive. The B-coefficient values for KCl in water and carbohydrate systems at all the temperatures (few exceptions) are negative. Usually the positive value of the B-coefficient corresponds to the structure making behavior of solutes. As the molecular mass of the salt is relatively large, it may show an obstructive effect, which causes bending of the streamlines around a large solute particle. In such case B coefficient will always positive irrespective of how it interact with the solvent. The negative value of the B- coefficient corresponds to the structure breaking behavior of solutes. Most of the cases the B-coefficient for NaCl and KCl at higher carbohydrate composition (5% and 10% carbohydrate) solution system at all the temperatures are negative. The B- coefficient values of the above electrolytes in aqueous solutions are based on the fact that there exists around an ion, a region of modified solvent differing from the bulk in structure and in properties. Gurney's [107] cosphere, Frank and Wens [105] A, B and C zones (shown in the introduction chapter) and Nightinagle's (107) hydrated radius are recent reflection of this idea. From the above approaches Kaminsky (105) indicated that the observed viscosity changes result from competition between various effects occurring in the neighborhood ion. The viscosity of a dilute electrolyte solutions to that of the solvent plus the contributions from four other sources can be equated in the following manner:

$$\eta-\eta_o=\eta^*+\eta^E+\eta^A+\eta^D \qquad (8)$$

where, η^* is the positive increment in the viscosity caused by coulombic interactions ,η^E is the viscosity increment arising from the size and shape of an ion which is closely related to the Einstein effect. It is always positive and normally increases with the increasing ion size, η^A is the increment due to the alignment or orientation of polar molecules by the ionic field. Since the freedom of movement of these molecules is restricted this generally results in stiffening of the solution and the increment will again be positive, η^D is the viscosity change associated with distortion of the solvent structure leading to greater fluidity. This distortion can be thought of as due to competing forces from the solvent structure in the bulk and from the ionic field and /or the oriented molecules associated with the ion. In mixed solvents the η^D is of considerable magnitude due to significant distortion in the solvent molecules present in the vicinity of ionic field.

Substituting equation (8) into the following Jones-Dole equation one obtains,

$$\eta-\eta_o = \eta_o (A\sqrt{C}+BC)$$

Or $$\eta^*+\eta^E+\eta^A+\eta^D = \eta_o (A\sqrt{C}+BC) \text{---}(9)$$

Eliminating the contributions due to the ionic interaction from both sides we have,

$$\eta^E+\eta^A+\eta^D = \eta_o BC \text{ ---}(10)$$

Thus at a given concentration (C), the coefficient B can be interpreted in terms of a competition between these specialized viscosity effects.

Very small and highly charged cations, Na^+ strongly orient water molecules and in fact are believed to have a primary sheath of firmly attached molecules which moves with them as a kinetic entity, η^E will therefore be large because the ion plus its primary sheath can be visualized as a single particle. It is also probable that at room temperature water molecules beyond this inner layer are oriented to some extent, giving positive η^A. The sum of $\eta^E + \eta^A$ will far outweigh the decrement due to η^D because it is thought to be small for these ions as the fixed outward pointing hydrogen atoms fit reasonably well into the tetrahedral water structure. Thus in this class of ions the $\eta^E + \eta^A >> \eta^D$ and the coefficient B is fairly large and positive.

The crystallographic radius of Na^+ and K^+ are 0.97 and 1.38 A° respectively (88). For KCl, the viscosity coefficient B is negative in a water and carbohydrate solutions. This indicates that KCl salt behaves as a water structure breaker in aqueous and carbohydrate solution. The structure breaking tendency of KCl can be explained by the consideration of large size and low charge density of K^+ ion. Because of the dipole –dipole repulsion between solvation shell molecules, the relatively weak electrostatic field about such ions can cause polarization, immobilization and electrostriction of water or carbohydrate molecules only in the first layer. Beyond this layer a strong structure breaking effect persists i.e. a shift in the structure equilibrium in the direction of smaller degree of ice-likeness. Non nearest neighbour water or carbohydrate molecules in the vicinity of these ions probably become more mobile than those in pure water or carbohydrate. For the interaction of such ions with water the term negative hydration has been employed. In the view of Gurney (107) there is a critical radius above which the electric field of the ion is too weak to produce order in the aqueous solution. For an ion to fit into a cavity formerly occupied by a water molecule, its radius must be less than that of water molecule (1.37 A°). This type of ions should fit into such cavity without disruption of the water structure (the primary and secondary hydration layers about this cavity). K^+ whose radius is 1.38A° would be expected to disrupt the primary hydration layer slightly. Furthermore this would also result in a disruption of the secondary hydration layer. This disruption should lead to a weakening of the bonds holding this water molecule together in the hydration layer. This disruption is always accompanied by structure breaking effects in aqueous or aqueous carbohydrate solution.

The decrease of B coefficient of NaCl and KCl with the increase in carbohydrate concentration reveals that these electrolytes must be in a progressively less structured environment as carbohydrate concentration is increased. In the ternary (H_2O+carbohydrate+electrolyte) solution, on addition of carbohydrates to the aqueous electrolyte solution, the ion-solvation atmosphere (structured) will be disrupted partly around them and then competing influences between water and carbohydrate with electrolytes are appeared. As a result the overall effect for NaCl and KCl in aqueous carbohydrate solution systems is thus structure breaking tendency i.e at higher composition of carbohydrate solution, the structure making tendency of NaCl is overcome by the structure breaking tendency of carbohydrates.

The sign of $\frac{dB}{dT}$ i.e. first derivative of the viscosity coefficient of B with respect to temperature, which corresponds to structure making or breaking properties of solutes were determined. The value of $\frac{dB}{dT}$ were tabulated in table 4.87-4.106. For water and 1% carbohydrate systems of NaCl showed that the values of $\frac{dB}{dT}$ are negative which corresponds to structure making behavior. For other studied systems NaCl in 5% and 10% carbohydrates and KCl in water, 1%, 5% and 10% carbohydrate solutions showed that the values of $\frac{dB}{dT}$ are positive (with few exception) which corresponds to structure breaking behavior.

The coefficient A represents the solute-solute interactions coupled with size and shape effect of the solute and to some extent solute-solvent interactions. In this study an irregular variation in values of A-coefficient is found (shown in table 4.87-4.106). This irregular variation in the values of A-coefficient may be due to:

i) an incomplete dissociation and ion association of electrolyte in aqueous and aqueous carbohydrate solvation and

ii) the size of the ions which differs in the degree of hydration or solvation.

The values of '*A*' have been found to decrease with the rise of temperature. This is probably due to the greater thermal agitation and reduction of attractive forces between the ions. The increase in A value can be explained by the inter-penetration effect, which brings the ions closer together. Most of the cases the higher positive A values for aqueous and carbohydrate solution of NaCl were observed than KCl. This is may be due to the higher charge to radius for Na^+ ion.

4.3 Thermodynamic properties of binary and ternary solutions

Table 4.107-4.126 show the free energy of activation $\Delta G^{\neq}$, enthalpy of activation, $\Delta H^{\neq}$ and entropy of activation, $\Delta S^{\neq}$ for the viscous flow of NaCl and KCl in aqueous, and aqueous carbohydrate solutions at the studied temperatures. The free energy vs concentration plots are shown in figure 4.94-4.113. The $\Delta G^{\neq}$ value is positive for all the studied systems. The positive free energy of activation for viscous flow can be interpreted with the help of Furth model [108], which states that the kinetic species involved in forming cavities or holes in the liquid medium is given by the work required in forming the hole against surface tension of the solution. The solute-solvent interaction, interstitial incorporation, hydrophilic hydration interaction renders the binary and ternary systems. This is reflected by the positive $\Delta G^{\neq}$ value. This implies that the species formed in the solutions have to surmount a large additional energy barrier in order to flow.

It is seen that $\Delta G^{\neq}$ of these studied electrolytes in aqueous and aqueous carbohydrate solutions increases with increase of solute concentration and decrease with the increase in temperature. The systems having bulky skeleton show steric hindrance and hence the species experience enhanced resistance to flow with the increase of solute concentration. Similar increasing property of $\Delta G^{\neq}$ have been reported by other authors as well [109].

It is seen that the $\Delta G^{\neq}$ of NaCl or KCl in maltose solutions increase with the concentration of electrolytes at the studied temperature. The $\Delta G^{\neq}$ shows little change until a concentration of about 0.2M is reached. Beyond this concentration, there is a large increase of $\Delta G^{\neq}$ with electrolyte concentration. Although the increase does not seem to very linear in the figure, it clearly indicates that the flow process is not favored energetically beyond 0.2M electrolyte concentration. The change may be attributed to the fact that $\Delta G^{\neq}$ is essentially constant or increase very little until electrolyte clustering begins at about 0.2M electrolyte concentration i.e. above 0.2M electrolyte concentration cluster formation occurs. Since $\Delta G^{\neq}$ controls the rate of flow, which is governed by the slowest step in the fluid process, the data suggests the below 0.2M electrolyte there is essentially no effect on the fluid process of water or carbohydrate. The slowest step in the fluid motion is dependent on the ease with which translation of the principle kinetic entity occurs. The data suggests that this entity may likely to be water or carbohydrate itself below 0.2M electrolyte and above 0.2M electrolyte, the principle kinetic entity for fluid flow is an aggregate of electrolyte with water or carbohydrate.

The variation of entropy of activation, $\Delta S^{\neq}$ with the concentration of binary and ternary systems in noted in tables 4.107-4.126. The $\Delta S^{\neq}$ values for the flow process are negative in all cases but do not follow any specific pattern. It is also found that the $\Delta S^{\neq}$ values of flow process for all the studied electrolytes are very close to each other in aqueous and aqueous carbohydrate solution. But some cases the $\Delta S^{\neq}$ values of NaCl and KCl in carbohydrate solutions are slightly higher (with few exception) than those of water system. This indicates that the studied salts in carbohydrate solutions are more random than in the water system.

Tables 4.107-4.126 show that positive values of $\Delta H^{\neq}$ indicate that the positive work has to be done to overcome the energy barrier for the flow process. That is, the viscous flow is not thermodynamically favored for the systems studied.

Table 4.1: Density, ρ (gm.cm^{-3}) of Glucose in aqueous Solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Composition (%w/v)	**298.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**	**323.15K**
1% - Glucose	0.997352	0.999873	0.997761	0.995486	0.992551	0.989669
5% - Glucose	1.016528	1.015506	1.012754	1.010335	1.005881	1.005641
10% - Glucose	1.035331	1.033084	1.031383	1.029830	1.026177	1.023962

Table 4.2: Density, ρ (gm.cm^{-3}) of Sucrose in aqueous Solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Composition(%w/v)	**298.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**	**323.15K**
1% - Sucrose	0.999241	0.998258	0.997585	0.996821	0.995581	0.992974
5% - Sucrose	1.017150	1.015775	1.014818	1.013688	1.011074	1.009130
10% - Sucrose	1.036487	1.035209	1.033889	1.033273	1.030849	1.028142

Table 4.3: Density, ρ (gm.cm^{-3}) of Maltose in aqueous Solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Composition(% w/v)	**298.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**	**323.15K**
1% - Maltose	1.001914	1.000011	0.998001	0.996996	0.995793	0.993073
5% - Maltose	1.018810	1.016198	1.015906	1.014385	1.012056	1.010903
10% - Maltose	1.037315	1.036803	1.034377	1.034418	1.031569	1.029052

Table 4.4: Density, ρ (gm.cm^{-3}) of NaCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0100	0.997639	0.996199	0.994551	0.992694	0.990638	0.988411
0.0504	0.999569	0.998062	0.996325	0.994393	0.992236	0.989922
0.1000	1.001835	1.000205	0.998401	0.996347	0.994085	0.991645
0.2010	1.006139	1.004296	1.002323	1.000164	0.997699	0.995005
0.4000	1.014005	1.011681	1.009514	1.007149	1.004189	1.001108
0.6013	1.021199	1.018561	1.016294	1.013369	1.010061	1.006596
0.8000	1.027398	1.024716	1.021930	1.018871	1.015463	1.011103
1.0000	1.033319	1.030208	1.027134	1.023569	1.020123	1.015327

Table 4.5: Density, ρ (gm.cm^{-3}) of KCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.0100	0.997812	0.996381	0.994740	0.992899	0.990860	0.988651
0.0500	1.000532	0.999057	0.997367	0.995482	0.993408	0.991164
0.1000	1.003935	1.002399	1.000649	0.998711	0.996599	0.994303
0.1970	1.010505	1.008847	1.006989	1.004935	1.002727	1.000369
0.4009	1.024329	1.022354	1.020242	1.017981	1.015604	1.013052
0.5992	1.037781	1.035566	1.033114	1.030670	1.028116	1.025373
0.8012	1.051432	1.048902	1.046135	1.043501	1.040814	1.037823
0.9980	1.064711	1.061808	1.058780	1.056054	1.053082	1.049941

Table 4.6: Density, ρ (gm.cm^{-3}) of NaCl in 1% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.0106	1.002200	1.000931	0.999200	0.996800	0.994400	0.991900
0.0505	1.004260	1.003051	1.000917	0.998579	0.996200	0.993600
0.1022	1.006570	1.005189	1.002900	1.000700	0.998500	0.995900
0.2016	1.010400	1.009200	1.006900	1.004600	1.002500	0.999757
0.4024	1.018260	1.017123	1.014900	1.012300	1.010100	1.007673
0.6009	1.026350	1.025064	1.022708	1.019851	1.017773	1.015300
0.8000	1.034100	1.032527	1.030400	1.027700	1.025400	1.023000
1.0000	1.041515	1.040291	1.037977	1.035251	1.032800	1.030697

Table 4.7: Density, ρ (gm.cm^{-3}) of NaCl in 5% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.0106	1.018842	1.017000	1.014700	1.012400	1.010000	1.008088
0.0505	1.020120	1.018380	1.016160	1.013835	1.011390	1.009387
0.1022	1.022030	1.020250	1.018030	1.015800	1.013200	1.011220
0.2016	1.025640	1.023800	1.021590	1.019300	1.016870	1.014690
0.4024	1.033512	1.031802	1.029016	1.026400	1.024100	1.021973
0.6009	1.041200	1.039000	1.036320	1.033740	1.031400	1.029100
0.8000	1.048392	1.046300	1.043490	1.040800	1.038300	1.035865
1.0000	1.055000	1.052791	1.050200	1.047682	1.044808	1.042231

Table 4.8: Density, ρ (gm cm^{-3}) of NaCl in 10% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0106	1.018842	1.017220	1.015026	1.012878	1.010553	1.008270
0.0505	1.019570	1.018150	1.016000	1.013835	1.011540	1.009387
0.1022	1.020860	1.019432	1.017410	1.015190	1.013150	1.010860
0.2016	1.024630	1.022857	1.020602	1.018700	1.016600	1.014345
0.4024	1.033512	1.031802	1.029016	1.027133	1.024380	1.021973
0.6009	1.041790	1.039440	1.036910	1.034940	1.032350	1.029630
0.8000	1.048392	1.046110	1.043580	1.041411	1.039010	1.036420
1.0000	1.054328	1.052220	1.049950	1.047682	1.044808	1.042231

Table 4.9: Density, ρ (gm.cm^{-3}) of KCl in 1% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0097	1.002421	1.000788	0.998113	0.996278	0.994027	0.991950
0.0504	1.004100	1.002200	0.999900	0.997600	0.995500	0.993200
0.1007	1.006300	1.004300	1.002400	0.999900	0.997500	0.995100
0.2009	1.011170	1.009200	1.007167	1.005066	1.002406	0.999700
0.4006	1.021525	1.019515	1.016811	1.014804	1.012363	1.009092
0.5998	1.031600	1.029800	1.027300	1.024600	1.021800	1.018200
0.8000	1.040800	1.038900	1.036600	1.033800	1.030800	1.027460
0.9998	1.048900	1.046813	1.044600	1.042100	1.039700	1.037071

Table 4.10: Density, ρ (gm.cm^{-3}) of KCl in 5% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0097	1.018500	1.015600	1.012700	1.011100	1.009300	1.008000
0.0504	1.021100	1.018900	1.016000	1.014400	1.012700	1.010800
0.1007	1.024800	1.022100	1.019200	1.017500	1.015600	1.013800
0.2009	1.030300	1.027600	1.025200	1.023400	1.021500	1.019600
0.4006	1.040800	1.039000	1.036300	1.034400	1.032400	1.030000
0.5998	1.052000	1.049272	1.046458	1.044500	1.042100	1.039374
0.8000	1.063100	1.059700	1.056800	1.054400	1.052100	1.049600
0.9998	1.073700	1.071000	1.067000	1.064200	1.061700	1.059400

Table 4.11: Density, ρ (gm.cm^{-3}) of KCl in 10% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0097	1.029100	1.027100	1.024100	1.021500	1.019700	1.017600
0.0504	1.032800	1.030800	1.027600	1.025400	1.022800	1.020600
0.1007	1.036400	1.034467	1.031540	1.029375	1.026500	1.024100
0.2009	1.042900	1.041000	1.038600	1.036605	1.033200	1.030200
0.4006	1.054241	1.052176	1.050100	1.047700	1.044900	1.041115
0.5998	1.064000	1.061600	1.059400	1.056800	1.054400	1.051200
0.8000	1.072700	1.070202	1.068000	1.065700	1.063100	1.059700
0.9998	1.081026	1.079471	1.076617	1.073980	1.071164	1.068334

Table 4.12: Density, ρ (gm.cm^{-3}) of NaCl in 1% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0096	1.001600	1.000300	0.999100	0.997330	0.995900	0.994500
0.0498	1.003300	1.001900	1.000700	0.998850	0.997400	0.996000
0.1002	1.005300	1.003800	1.002700	1.000970	0.999320	0.997860
0.2000	1.009900	1.008300	1.006900	1.004930	1.003410	1.002000
0.4001	1.018700	1.017300	1.015700	1.013660	1.011900	1.010400
0.6008	1.028190	1.026600	1.024690	1.022510	1.020800	1.019300
0.8009	1.037510	1.035600	1.033905	1.032200	1.030200	1.028506
1.0003	1.046999	1.045611	1.044510	1.042508	1.040500	1.038311

Table 4.13: Density, ρ (gm.cm^{-3}) of NaCl in 5% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0090	1.016260	1.014488	1.013434	1.012329	1.010241	1.008150
0.0501	1.018111	1.016702	1.015461	1.014140	1.012141	1.009979
0.1004	1.020150	1.018821	1.017670	1.016244	1.014143	1.012037
0.1995	1.024480	1.022945	1.021688	1.020241	1.017962	1.015731
0.3995	1.032252	1.030570	1.029244	1.027750	1.025630	1.023150
0.5998	1.040112	1.038760	1.037211	1.035522	1.033412	1.030833
0.7995	1.047360	1.045951	1.044809	1.042861	1.040741	1.038229
1.0001	1.054675	1.053610	1.052706	1.050720	1.048708	1.046243

Table 4.14: Density, ρ (gm.cm^{-3}) of NaCl in 10% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0090	1.034496	1.033749	1.032611	1.031010	1.029309	1.027738
0.0501	1.036303	1.035406	1.034302	1.032801	1.031102	1.029305
0.1004	1.038605	1.037607	1.036505	1.035012	1.033110	1.031211
0.1995	1.042919	1.041957	1.040403	1.038606	1.036904	1.035048
0.3995	1.051509	1.050210	1.048257	1.046307	1.044306	1.042510
0.5998	1.059234	1.057608	1.055812	1.053862	1.051803	1.050109
0.7995	1.066509	1.064893	1.063515	1.061409	1.059300	1.057608
1.0001	1.073998	1.072361	1.070610	1.069107	1.067163	1.064663

Table 4.15: Density, ρ (gm.cm^{-3}) of KCl in 1% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0103	1.000503	0.999265	0.998004	0.996446	0.995410	0.994207
0.0509	1.002710	1.001547	1.000167	0.998402	0.997203	0.996010
0.0999	1.004838	1.003935	1.002825	1.000791	0.999509	0.998304
0.1994	1.010091	1.008738	1.007416	1.005541	1.004111	1.002709
0.4002	1.019581	1.018369	1.016881	1.014944	1.013575	1.012411
0.5980	1.029120	1.027783	1.026371	1.024447	1.022701	1.021205
0.7992	1.038206	1.036543	1.035236	1.033352	1.032193	1.030801
0.9980	1.047694	1.046085	1.044201	1.042391	1.040800	1.039557

Table 4.16: Density, ρ (gm.cm^{-3}) of KCl in 5% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0099	1.015537	1.014359	1.013357	1.011713	1.010769	1.009610
0.0506	1.017402	1.016248	1.015011	1.013737	1.012504	1.011266
0.1015	1.020100	1.018899	1.017602	1.016063	1.015012	1.013703
0.1989	1.024749	1.023555	1.022108	1.020493	1.019304	1.018105
0.4015	1.034311	1.032961	1.031704	1.029939	1.028644	1.027406
0.6007	1.043459	1.042356	1.040910	1.039402	1.037803	1.036610
0.8003	1.052510	1.051380	1.049941	1.048606	1.047102	1.045701
0.9997	1.061105	1.060159	1.058701	1.057011	1.055707	1.054411

Table 4.17: Density, ρ (gm.cm^{-3}) of KCl in 10% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0106	1.035449	1.034190	1.032602	1.030928	1.029649	1.028010
0.0494	1.037454	1.035764	1.034398	1.032812	1.031410	1.029803
0.1017	1.040211	1.038502	1.036858	1.035203	1.033590	1.032019
0.2021	1.045201	1.043511	1.041610	1.039910	1.038203	1.036309
0.3998	1.055209	1.053510	1.051106	1.049411	1.047220	1.045413
0.5962	1.064010	1.062109	1.059811	1.057701	1.055808	1.054008
0.8002	1.073304	1.071011	1.069010	1.066913	1.064715	1.062806
1.0024	1.082706	1.079704	1.078306	1.076014	1.074012	1.071709

Table 4.18: Density, ρ (gm.cm^{-3}) of NaCl in 1% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0106	1.001202	0.999867	0.998093	0.996457	0.994212	0.992011
0.0505	1.003304	1.001600	1.000105	0.998101	0.995934	0.993601
0.1022	1.005299	1.003699	1.002099	1.000142	0.997840	0.995556
0.2016	1.009203	1.007901	1.006210	1.003902	1.001593	0.999067
0.4024	1.016801	1.015363	1.013802	1.011603	1.009275	1.006805
0.6009	1.024581	1.023202	1.021398	1.019003	1.016602	1.013804
0.8000	1.032591	1.030950	1.029201	1.027004	1.024501	1.021738
1.0000	1.040575	1.039105	1.037082	1.034816	1.031696	1.029043

Table 4.19: Density, ρ (gm.cm^{-3}) of NaCl in 5% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0099	1.014380	1.013010	1.011380	1.009590	1.007870	1.005480
0.0499	1.016520	1.015060	1.013870	1.012011	1.010003	1.007620
0.1023	1.018962	1.017973	1.016399	1.014380	1.012330	1.009844
0.1986	1.022815	1.022106	1.020686	1.018517	1.016312	1.013816
0.4022	1.030834	1.029744	1.028420	1.026082	1.024140	1.021400
0.6013	1.038858	1.037830	1.036021	1.033927	1.031580	1.029100
0.8028	1.046591	1.045101	1.043570	1.041304	1.038906	1.036702
1.0014	1.054469	1.053506	1.051227	1.049105	1.046730	1.044003

Table 4.20: Density, ρ (gm.cm^{-3}) of NaCl in 10% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0098	1.033627	1.032449	1.030391	1.028587	1.026598	1.024184
0.0493	1.035430	1.034302	1.032304	1.030298	1.028083	1.025600
0.1006	1.037569	1.036311	1.034309	1.032300	1.030009	1.027551
0.2014	1.041526	1.040012	1.038099	1.036109	1.033842	1.031402
0.4025	1.049401	1.047803	1.045801	1.043636	1.041352	1.039030
0.6001	1.056999	1.055563	1.053500	1.051403	1.048939	1.046700
0.8002	1.064706	1.063101	1.061004	1.058649	1.056690	1.053994
0.9993	1.072500	1.071135	1.068518	1.066270	1.063746	1.061324

Table 4.21: Density, ρ (gm.cm^{-3}) of KCl in 1% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0099	1.000455	0.998806	0.997398	0.995246	0.993494	0.991141
0.0500	1.002605	1.000458	0.998799	0.996313	0.993783	0.991100
0.0998	1.005504	1.003500	1.001800	0.999140	0.996503	0.993531
0.2004	1.010499	1.008899	1.006901	1.004501	1.001800	0.998900
0.4005	1.020503	1.018151	1.016367	1.014604	1.011946	1.009205
0.5992	1.029708	1.027702	1.025998	1.023796	1.021288	1.018582
0.8003	1.038698	1.036503	1.034801	1.032403	1.030000	1.027092
1.0004	1.048200	1.045970	1.043516	1.041005	1.038809	1.035688

Table 4.22: Density, ρ (gm.cm^{-3}) of KCl in 5% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0097	1.015579	1.014461	1.012564	1.010868	1.008603	1.006880
0.0504	1.017483	1.016403	1.014499	1.012599	1.010087	1.008400
0.1007	1.020003	1.018689	1.016921	1.015001	1.012600	1.010702
0.2009	1.025120	1.023201	1.021989	1.019604	1.017356	1.015415
0.4006	1.034299	1.032403	1.030500	1.028400	1.026100	1.023800
0.5998	1.043601	1.041399	1.039503	1.037698	1.035090	1.033099
0.8000	1.052990	1.050901	1.048905	1.046801	1.044300	1.041839
0.9998	1.062394	1.060763	1.058543	1.056407	1.053804	1.051593

Table 4.23: Density, ρ (gm.cm^{-3}) of KCl in 10% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0101	1.016125	1.014801	1.012789	1.011315	1.008867	1.006422
0.0494	1.018597	1.017309	1.015066	1.013302	1.011168	1.008504
0.1010	1.022402	1.020903	1.018990	1.017005	1.014906	1.012109
0.1981	1.030303	1.028001	1.026002	1.023700	1.022000	1.018500
0.4026	1.046298	1.043402	1.041103	1.038904	1.036808	1.033502
0.6002	1.058301	1.055503	1.054000	1.051702	1.049400	1.046500
0.7999	1.069900	1.067815	1.065781	1.063300	1.061009	1.058099
1.0003	1.079999	1.077070	1.074740	1.072801	1.070699	1.067704

Table 4.24: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of NaCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

C(mol.L^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.4038	16.36	18.56	19.86	21.16	23.47	25.67
0.6099	18.53	20.49	21.51	23.29	25.39	27.49
0.8158	20.72	22.24	23.64	25.14	26.84	29.53
1.0258	22.38	24.00	25.40	27.09	28.49	31.08

Table 4.25: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of KCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

C(mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.4032	6.73	8.00	9.09	10.05	10.80	11.56
0.6034	6.73	7.93	9.17	10.07	10.82	11.60
0.8079	6.80	8.04	9.31	10.18	10.87	11.72
1.0078	6.85	8.17	9.41	10.17	10.97	11.77

Table 4.26: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of NaCl in 1% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

C(mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.4045	6.01	5.25	6.63	8.45	8.78	9.26
0.6062	9.90	9.63	10.75	12.37	12.38	12.76
0.8103	12.32	12.46	13.01	14.02	14.29	14.47
1.0173	14.16	13.93	14.54	15.36	15.71	15.56

Table 4.27: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of NaCl in 5% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

C(mol.L^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.3980	-32.01	-31.48	-28.87	-27.17	-26.73	-27.16
0.5972	-14.89	-13.76	-12.20	-11.14	-10.79	-10.80
0.7987	-5.59	-4.88	-3.57	-2.65	-2.21	-2.05
1.0035	0.63	1.30	2.14	2.70	3.41	3.67

Table 4.28: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of NaCl in 10% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.3984	-32.01	-31.48	-28.87	-28.95	-27.42	-27.16
0.5969	-15.87	-14.51	-13.20	-13.12	-12.38	-11.71
0.7987	-5.59	-4.66	-3.68	-3.39	-3.07	-2.73
1.0042	1.31	1.88	2.41	2.74	3.45	3.70

Table 4.29: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of KCl in 1% (w/v) Glucose solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.4040	-2.02	-0.67	1.86	2.20	3.11	5.65
0.6078	1.57	2.11	3.42	4.74	5.90	8.09
0.8154	4.60	5.10	5.83	6.91	7.99	9.29
1.0261	7.53	8.10	8.59	9.15	9.43	9.75

Table 4.30: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of KCl in 5% (w/v) Glucose solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.3963	-49.98	-49.30	-46.98	-47.08	-47.46	-47.31
0.5955	-32.23	-30.34	-28.65	-28.66	-28.29	-27.70
0.7973	-23.03	-20.86	-19.53	-19.03	-18.90	-18.75
1.0006	-16.99	-15.94	-13.88	-13.13	-12.85	-12.93

Table 4.31: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of KCl in 10% (w/v) Glucose solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.3911	-83.44	-82.23	-81.52	-80.56	-79.15	-75.80
0.5885	-52.13	-50.82	-50.18	-49.25	-48.98	-47.72
0.7897	-34.93	-33.86	-33.39	-33.06	-32.64	-31.49
0.9933	-24.24	-24.26	-23.30	-22.74	-22.21	-21.84

Table 4.32: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of NaCl in 1% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.4020	4.60	4.48	4.33	4.76	3.99	2.13
0.6050	6.82	7.04	7.42	7.92	7.30	6.05
0.8085	8.10	8.64	8.65	8.43	8.31	7.60
1.0120	8.67	8.58	8.01	8.10	8.00	7.90

Table 4.33: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of NaCl in 5% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.3960	-29.50	-29.03	-29.96	-30.99	-31.01	-30.58
0.5968	-13.20	-13.42	-13.69	-14.07	-14.12	-13.68
0.7990	-4.34	-4.44	-5.14	-5.12	-5.14	-4.91
1.0039	0.96	0.55	-0.23	-0.19	-0.32	-0.19

Table 4.34: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of NaCl in 10% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.3886	-77.84	-78.43	-77.99	-78.09	-78.59	-80.03
0.5857	-45.17	-45.05	-45.02	-45.09	-45.34	-46.47
0.7840	-28.36	-28.29	-28.76	-28.64	-28.77	-29.63
0.9848	-18.41	-18.34	-18.37	-18.85	-19.12	-19.03

Table 4.35: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of KCl in 1% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.4044	2.77	2.19	1.75	1.91	0.17	-2.52
0.6073	5.52	5.32	4.89	4.95	4.39	3.13
0.8167	7.76	7.99	7.54	7.53	6.39	5.32
1.0254	8.63	8.76	8.93	8.84	8.34	7.34

Table 4.36: Apparent molar volume, ϕ_v (cm^3.mol^{-1}) of KCl in 5% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m(mol.Kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
0.3997	-33.63	-33.97	-35.07	-35.46	-37.50	-40.13
0.6015	-17.97	-18.60	-19.04	-19.73	-20.61	-22.44
0.8060	-9.89	-10.33	-10.68	-11.41	-12.19	-13.32
1.0133	-4.54	-5.07	-5.34	-5.59	-6.41	-7.41

Table 4.37: Apparent molar volume, ϕ_v ($cm^3.mol^{-1}$) of KCl in 10% (w/v) Sucrose in aqueous solutions at 298.15, 303.15, 308.15, 313.15, 318.15 and 323.15 K respectively.

m($mol.Kg^{-1}$)	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.3899	-86.13	-85.79	-84.32	-85.04	-85.11	-86.55
0.5847	-52.82	-52.29	-51.50	-51.34	-51.88	-52.86
0.7894	-35.66	-34.83	-34.60	-34.51	-34.57	-35.18
0.9945	-25.67	-24.38	-24.76	-24.52	-24.76	-24.89

Table 4.38: Apparent molar volume, ϕ_v ($cm^3.mol^{-1}$) of NaCl in 1% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m($mol.Kg^{-1}$)	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.4051	9.64	9.63	9.40	10.24	10.90	11.49
0.6073	12.85	12.74	12.97	13.84	14.39	15.31
0.8115	14.22	14.44	14.54	14.94	15.46	16.10
1.0183	15.10	15.11	15.44	15.82	16.83	17.22

Table 4.39: Apparent molar volume, ϕ_v ($cm^3.mol^{-1}$) of NaCl in 5% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

m($mol.Kg^{-1}$)	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.3993	-25.37	-26.32	-27.24	-26.21	-26.64	-25.56
0.5991	-10.93	-11.67	-11.51	-11.23	-10.88	-10.60
0.8031	-3.12	-3.12	-3.34	-2.94	-2.62	-2.75
1.0055	1.24	0.73	1.26	1.44	1.67	2.06

Table 4.40: Apparent molar volume, ϕ_v ($cm^3.mol^{-1}$) of NaCl in 10% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m($mol.Kg^{-1}$)	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.3924	-71.56	-71.42	-70.85	-70.41	-70.20	-70.33
0.5873	-41.38	-41.55	-41.08	-40.91	-40.49	-40.73
0.7862	-26.02	-25.95	-25.57	-25.14	-25.44	-25.08
0.9855	-16.97	-17.15	-16.36	-16.13	-15.84	-15.82

Table 41: Apparent molar volume, ϕ_v ($cm^3.mol^{-1}$) of KCl in 1% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

m($mol.Kg^{-1}$)	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.4043	0.51	2.71	3.00	2.74	4.18	5.42
0.6083	4.65	5.53	5.57	6.09	6.77	7.51
0.8175	7.23	8.09	8.11	8.72	9.09	9.86
1.0275	8.26	8.96	9.68	10.26	10.34	11.15

Table 4.46: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S_v and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of NaCl in 1% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	**ϕ_v^o (cm^3.mol^{-1})**	S_v	**$\delta^2\phi_v^o/\delta T^2$**
NaCl in 1% Glucose solution	298.15	-7.78	22.25	0.0007
	303.15	-5.10	39.73	
	308.15	-6.61	21.60	
	313.15	-2.86	18.65	
	318.15	-2.78	18.86	
	323.15	-1.18	17.18	

Table 4.47: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S_v and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of NaCl in 5% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	**ϕ_v^o (cm^3.mol^{-1})**	S_v	**$\delta^2\phi_v^o/\delta T^2$**
NaCl in 5% Glucose solution	298.15	-86.55	89.09	-0.0237
	303.15	-85.87	89.18	
	308.15	-80.47	84.55	
	313.15	-76.96	81.60	
	318.15	-77.07	82.32	
	323.15	-78.60	84.16	

Table 4.48: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S_v and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of NaCl in 10% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	**ϕ_v^o (cm^3.mol^{-1}**	S_v	**$\delta^2\phi_v^o/\delta T^2$**
NaCl in 10% Glucose solution	298.15	-88.49	91.34	-0.0098
	303.15	-87.57	91.26	
	308.15	-81.68	85.77	
	313.15	-82.51	86.97	
	318.15	-79.62	84.46	
	323.15	-79.05	84.24	

Table 4.49: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of KCl in 1% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	**ϕ_v^o (cm^3.mol^{-1})**	**S$_v$**	**$\delta^2\phi_v^o/\delta T^2$**
KCl in 1% Glucose solution	298.15	-18.47	25.92	-0.004
	303.15	-16.05	23.88	
	308.15	-10.15	18.27	
	313.15	-9.78	18.82	
	318.15	-7.70	17.34	
	323.15	-1.09	11.25	

Table 4.50: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of KCl in 5% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	**ϕ_v^o (cm^3.mol^{-1})**	**S$_v$**	**$\delta^2\phi_v^o/\delta T^2$**
KCl in 5% Glucose solution	298.15	-104.57	89.66	-0.0089
	303.15	-104.27	91.06	
	308.15	-101.52	89.97	
	313.15	-103.29	92.46	
	318.15	-104.42	93.95	
	323.15	-103.51	93.09	

Table 4.51: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of KCl in 10% (w/v) Glucose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	**ϕ_v^o (cm^3.mol^{-1})**	**S$_v$**	**$\delta^2\phi_v^o/\delta T^2$**
KCl in 10% Glucose solution	298.15	-181.89	161.38	-0.0215
	303.15	-178.47	158.31	
	308.15	-178.12	158.73	
	313.15	-176.19	157.23	
	318.15	-173.73	155.05	
	323.15	-165.97	147.50	

Table 4.52: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of NaCl in 1% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	Temp(K)	ϕ_v^o (cm^3.mol^{-1})	S_v	$\delta^2\phi_v^o/\delta T^2$
NaCl in 1% Sucrose solution	298.15	-13.62	24.25	-0.0357
	303.15	-12.69	23.37	
	308.15	-14.07	24.78	
	313.15	-12.92	23.61	
	318.15	-17.14	28.09	
	323.15	-23.94	35.01	

Table 4.53: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of NaCl in 5% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	Temp(K)	ϕ_v^o (cm^3.mol^{-1})	S_v	$\delta^2\phi_v^o/\delta T^2$
NaCl in 5% Sucrose solution	298.15	-79.94	82.92	-0.0003
	303.15	-78.26	80.79	
	308.15	-79.02	80.91	
	313.15	-81.87	83.95	
	318.15	-81.72	83.70	
	323.15	-80.69	82.82	

Table 4.54: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]$ of NaCl in 10% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	Temp(K)	ϕ_v^o (cm^3.mol^{-1})	S_v	$\delta^2\phi_v^o/\delta T^2$
NaCl in 10% Sucrose solution	298.15	-175.74	161.53	-0.0155
	303.15	-177.19	163.19	
	308.15	-175.84	161.55	
	313.15	-175.40	160.85	
	318.15	-176.26	161.55	
	323.15	-180.30	165.43	

Table 4.55: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S_v and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of KCl in 1% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	ϕ_v^o **(cm^3.mol^{-1})**	S_v	$\delta^2\phi_v^o/\delta T^2$
KCl in 1% Sucrose solution	298.15	-7.38	26.43	-0.0167
	303.15	-9.24	18.55	
	308.15	-10.68	19.96	
	313.15	-10.09	19.28	
	318.15	-13.25	21.92	
	323.15	-18.42	26.36	

Table 4.56: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S_v and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of KCl in 5% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	ϕ_v^o **(cm^3.mol^{-1})**	S_v	$\delta^2\phi_v^o/\delta T^2$
KCl in 5% Sucrose solution	298.15	-81.91	79.20	-0.0229
	303.15	-82.11	78.86	
	308.15	-84.46	81.05	
	313.15	-85.15	81.26	
	318.15	-88.95	84.49	
	323.15	-94.42	89.12	

Table 4.57: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S_v and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of KCl in 10% (w/v) Sucrose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp(K)**	ϕ_v^o **(cm^3.mol^{-1})**	S_v	$\delta^2\phi_v^o/\delta T^2$
KCl in 1% Sucrose solution	298.15	-184.96	163.50	-0.022
	303.15	-186.30	166.03	
	308.15	-181.68	161.07	
	313.15	-183.70	163.43	
	318.15	-183.88	163.39	
	323.15	-187.54	166.86	

Table 4.58: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of NaCl in 1% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

System	**Temp**(K)	ϕ_v^o **(cm^3.mol^{-1})**	S_v	$\delta^2\phi_v^o/\delta T^2$
NaCl in 1% Maltose solution	298.15	0.73	14.80	0.008
	303.15	0.48	15.14	
	308.15	-0.51	16.46	
	313.15	1.36	14.95	
	318.15	1.42	15.71	
	323.15	2.59	15.06	

Table 4.59: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of NaCl in 5% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	**Temp***(K)*	ϕ_v^o **(cm^3.mol^{-1})**	S_v	$\delta^2\phi_v^o/\delta T^2$
NaCl in 5% Maltose solution	298.15	-69.68	72.75	0.0195
	303.15	-71.69	74.51	
	308.15	-74.52	77.80	
	313.15	-72.35	75.76	
	318.15	-73.64	77.46	
	323.15	-71.43	75.27	

Table 4.60: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of NaCl in 10% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

System	**Temp**(K)	ϕ_v^o **(cm^3.mol^{-1})**	S_v	$\delta^2\phi_v^o/\delta T^2$
NaCl in 10% Maltosesolution	298.15	-162.27	149.29	-0.0034
	303.15	-161.81	148.69	
	308.15	-161.59	149.09	
	313.15	-161.01	148.78	
	318.15	-160.50	148.35	
	323.15	-161.24	149.24	

Table 4.61: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of KCl in 1% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	Temp(K)	ϕ_v^o (cm^3.mol^{-1})	S_v	$\delta^2 \phi_v^o / \delta T^2$
KCl in 1% Maltose solution	298.15	-12.49	21.38	-0.0029
	303.15	-8.20	17.60	
	308.15	-8.69	18.51	
	313.15	-10.16	20.73	
	318.15	-6.51	17.09	
	323.15	-4.73	16.01	

Table 4.62: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of KCl in 5% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	Temp(K)	ϕ_v^o (cm^3.mol^{-1})	S_v	$\delta^2 \phi_v^o / \delta T^2$
KCl in 5% Maltose solution	298.15	-80.00	76.19	-0.01
	303.15	-77.31	73.80	
	308.15	-76.89	73.74	
	313.15	-76.40	73.33	
	318.15	-75.71	73.08	
	323.15	-76.04	73.33	

Table 4.63: Limiting apparent molar volume, ϕ_v^o (cm^3.mol^{-1}) , S$_v$ and second derivative of limiting value, $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]$ of KCl in 10% (w/v) Maltose in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

System	Temp(K)	ϕ_v^o (cm^3.mol^{-1})	S_v	$\delta^2 \phi_v^o / \delta T^2$
KCl in 10% Maltose solution	298.15	-129.67	108.47	-0.0126
	303.15	-122.76	102.24	
	308.15	-120.95	100.55	
	313.15	-119.35	99.08	
	318.15	-119.50	99.23	
	323.15	-114.56	94.53	

Table 4.64: Viscosity, η of Glucose in aqueous Solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Composition(% w/v)	**298.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**	**323.15K**
1% - Glucose	0.9116	0.8013	0.7229	0.6551	0.5979	0.5424
5% - Glucose	1.0245	0.9038	0.8142	0.7470	0.6750	0.6154
10% - Glucose	1.0819	0.9665	0.8479	0.7717	0.7159	0.6385

Table 4.655: Viscosity, η of Sucrose in aqueous Solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Composition(% w/v)	**298.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**	**323.15K**
1% - Sucrose	0.9273	0.8251	0.7437	0.6734	0.6140	0.5587
5% - Sucrose	1.0265	0.9139	0.8212	0.7507	0.6752	0.6163
10% - Sucrose	1.1866	1.0518	0.9436	0.8457	0.7691	0.6925

Table 4.66: Viscosity, η of Maltose in aqueous Solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K, respectively.

Composition(% w/v)	**298.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**	**323.15K**
1% - Maltose	0.9351	0.8395	0.7529	0.6790	0.6206	0.5594
5% - Maltose	1.0274	0.9154	0.8302	0.7515	0.6777	0.6221
10% - Maltose	1.1964	1.0556	0.9539	0.8461	0.7738	0.6950

Table 4.67: Viscosity, η (mPa.S) of NaCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0100	0.9022	0.8053	0.7262	0.6594	0.6021	0.5521
0.0504	0.9066	0.8110	0.7323	0.6621	0.6063	0.5564
0.1000	0.9111	0.8156	0.7368	0.6664	0.6094	0.5603
0.2010	0.9202	0.8258	0.7446	0.6762	0.6172	0.5649
0.4000	0.9403	0.8440	0.7644	0.6933	0.6334	0.5781
0.6013	0.9632	0.8644	0.7816	0.7084	0.6455	0.5885
0.8000	0.9846	0.8845	0.8009	0.7222	0.6623	0.6046
1.0000	1.0071	0.9071	0.8173	0.7405	0.6792	0.6214

Table 4.68: Viscosity, η (mPa.S) of KCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0100	0.9108	0.8012	0.7283	0.6572	0.5996	0.5477
0.0500	0.9096	0.8032	0.7291	0.6601	0.6031	0.5479
0.1000	0.9087	0.8072	0.7302	0.6630	0.6033	0.5510
0.1970	0.9100	0.8111	0.7361	0.6690	0.6090	0.5540
0.4009	0.9140	0.8110	0.7400	0.6700	0.6090	0.5580
0.5992	0.9170	0.8150	0.7430	0.6720	0.6120	0.5600
0.8012	0.9160	0.8180	0.7470	0.6730	0.6120	0.5640
0.9980	0.9200	0.8230	0.7470	0.6730	0.6150	0.5670

Table 4.69: Viscosity, η (mPa.S) of NaCl in 1% Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0106	0.9207	0.8178	0.7378	0.6660	0.6090	0.5608
0.0505	0.9209	0.8242	0.7405	0.6695	0.6123	0.5611
0.1022	0.9250	0.8276	0.7424	0.6752	0.6136	0.5650
0.2016	0.9331	0.8339	0.7485	0.6792	0.6182	0.5704
0.4024	0.9535	0.8502	0.7639	0.6933	0.6320	0.5843
0.6009	0.9705	0.8652	0.7808	0.7063	0.6462	0.5981
0.8000	0.9900	0.8865	0.7986	0.7249	0.6606	0.6106
1.0000	1.0057	0.9090	0.8186	0.7480	0.6733	0.6220

Table 4.70: Viscosity, η (mPa.S) of NaCl in 5% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0106	0.9989	0.9136	0.8181	0.7388	0.6729	0.6155
0.0505	1.0000	0.9107	0.8120	0.7372	0.6662	0.6059
0.1022	1.0030	0.9108	0.8141	0.7365	0.6683	0.6090
0.2016	1.0150	0.9197	0.8199	0.7411	0.6770	0.6136
0.4024	1.0430	0.9411	0.8490	0.7668	0.6987	0.6350
0.6009	1.0680	0.9689	0.8702	0.7863	0.7138	0.6517
0.8000	1.0870	0.9880	0.8820	0.7960	0.7253	0.6655
1.0000	1.1069	1.0013	0.8931	0.8110	0.7403	0.6779

Table 4.71: Viscosity, η (mPa.S) of NaCl in 10% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0106	1.1791	1.0292	0.9244	0.8310	0.7543	0.6872
0.0505	1.1804	1.0415	0.9330	0.8399	0.7608	0.6900
0.1022	1.1887	1.0403	0.9308	0.8419	0.7616	0.6979
0.2016	1.1881	1.0544	0.9418	0.8509	0.7692	0.6964
0.4024	1.2315	1.0778	0.9620	0.8687	0.7913	0.7235
0.6009	1.2609	1.1235	1.0007	0.9041	0.8211	0.7439
0.8000	1.2890	1.1510	1.0300	0.9340	0.8530	0.7750
1.0000	1.3250	1.1840	1.0640	0.9640	0.8890	0.8000

Table 4.72: Viscosity, η (mPa.S) of KCl in 1% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0097	0.9268	0.8239	0.7389	0.6684	0.6127	0.5633
0.0504	0.9250	0.8220	0.7410	0.6720	0.6140	0.5660
0.1007	0.9238	0.8230	0.7447	0.6730	0.6160	0.5671
0.2009	0.9260	0.8290	0.7497	0.6788	0.6210	0.5700
0.4006	0.9370	0.8380	0.7570	0.6873	0.6289	0.5793
0.5998	0.9460	0.8500	0.7650	0.6940	0.6340	0.5890
0.8000	0.9577	0.8630	0.7750	0.7040	0.6460	0.5943
0.9998	0.9684	0.8713	0.7833	0.7152	0.6572	0.6048

Table 4.73: Viscosity, η (mPa.S) of KCl in 5% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0097	1.0140	0.9040	0.8000	0.7180	0.6510	0.5930
0.0504	1.0456	0.9267	0.8287	0.7490	0.6833	0.6207
0.1007	1.0681	0.9418	0.8451	0.7620	0.6946	0.6374
0.2009	1.0707	0.9545	0.8526	0.7724	0.7023	0.6460
0.4006	1.0700	0.9610	0.8650	0.7860	0.7130	0.6580
0.5998	1.0770	0.9690	0.8803	0.7931	0.7200	0.6642
0.8000	1.0750	0.9671	0.8713	0.7943	0.7203	0.6605
0.9998	1.0678	0.9508	0.8535	0.7798	0.7077	0.6513

Table 4.74: Viscosity, η (mPa.S) of KCl in 10% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0097	1.0733	0.9478	0.8599	0.7744	0.7027	0.6447
0.0504	1.1060	0.9820	0.8880	0.7980	0.7210	0.6600
0.1007	1.1270	1.0046	0.9075	0.8138	0.7403	0.6781
0.2009	1.1584	1.0347	0.9293	0.8349	0.7582	0.6890
0.4006	1.1750	1.0540	0.9463	0.8498	0.7721	0.7056
0.5998	1.1933	1.0692	0.9611	0.8648	0.7860	0.7200
0.8000	1.2151	1.0840	0.9796	0.8881	0.8051	0.7370
0.9998	1.2394	1.1070	0.9982	0.9081	0.8242	0.7558

Table 4.75: Viscosity, η (mPa.S) of NaCl in 1% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0096	0.9005	0.8081	0.7377	0.6682	0.6049	0.5554
0.0498	0.9041	0.8152	0.7420	0.6691	0.6081	0.5601
0.1002	0.9083	0.8184	0.7455	0.6726	0.6124	0.5602
0.2000	0.9152	0.8232	0.7471	0.6761	0.6150	0.5670
0.4001	0.9350	0.8415	0.7625	0.6934	0.6293	0.5784
0.6008	0.9612	0.8675	0.7836	0.7105	0.6486	0.5956
0.8009	0.9791	0.8850	0.8040	0.7282	0.6642	0.6092
1.0003	0.9961	0.8988	0.8196	0.7395	0.6734	0.6180

Table 4.76: Viscosity, η (mPa.S) of NaCl in 5% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0090	1.0313	0.9221	0.8368	0.7526	0.6820	0.6238
0.0501	1.0330	0.9217	0.8351	0.7501	0.6791	0.6215
0.1004	1.0321	0.9232	0.8341	0.7506	0.6809	0.6205
0.1995	1.0382	0.9281	0.8356	0.7542	0.6871	0.6260
0.3995	1.0466	0.9427	0.8480	0.7672	0.6988	0.6376
0.5998	1.0628	0.9610	0.8662	0.7810	0.7103	0.6502
0.7995	1.0907	0.9793	0.8851	0.8009	0.7290	0.6641
1.0001	1.1133	1.0015	0.9006	0.8170	0.7452	0.6828

Table 4.77: Viscosity, η (mPa.S) of NaCl in 10% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0090	1.1432	1.0212	0.9197	0.8232	0.7442	0.6841
0.0501	1.1490	1.0281	0.9256	0.8281	0.7451	0.6876
0.1004	1.1601	1.0360	0.9331	0.8326	0.7530	0.6883
0.1995	1.1804	1.0516	0.9444	0.8465	0.7662	0.6980
0.3995	1.2120	1.0831	0.9720	0.8671	0.7921	0.7211
0.5998	1.2373	1.1067	0.9931	0.8931	0.8111	0.7390
0.7995	1.2671	1.1350	1.0158	0.9156	0.8330	0.7581
1.0001	1.2921	1.1751	1.0353	0.9334	0.8526	0.7756

Table 4.78: Viscosity, η (mPa.S) of KCl in 1% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0103	0.9262	0.8294	0.7453	0.6674	0.6084	0.5668
0.0509	0.9245	0.8303	0.7419	0.6672	0.6130	0.5641
0.0999	0.9202	0.8293	0.7422	0.6709	0.6145	0.5662
0.1994	0.9293	0.8290	0.7493	0.6768	0.6214	0.5691
0.4002	0.9351	0.8341	0.7523	0.6840	0.6271	0.5710
0.5980	0.9403	0.8484	0.7634	0.6947	0.6372	0.5815
0.7992	0.9577	0.8570	0.7780	0.7070	0.6482	0.5871
0.9980	0.9675	0.8617	0.7817	0.7204	0.6596	0.6065

Table 4.79: Viscosity, η (mPa.S) of KCl in 5% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0099	1.0053	0.9042	0.8122	0.7313	0.6661	0.6112
0.0506	1.0257	0.9165	0.8224	0.7445	0.6754	0.6171
0.1015	1.0278	0.9187	0.8313	0.7483	0.6797	0.6212
0.1989	1.0261	0.9209	0.8353	0.7484	0.6852	0.6234
0.4015	1.0310	0.9320	0.8450	0.7594	0.6975	0.6343
0.6007	1.0391	0.9404	0.8541	0.7657	0.7034	0.6415
0.8003	1.0522	0.9512	0.8624	0.7735	0.7141	0.6481
0.9997	1.0630	0.9583	0.8710	0.7860	0.7179	0.6564

Table 4.80: Viscosity, η (mPa.S) of KCl in 10% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0106	1.1719	1.0396	0.9264	0.8392	0.7613	0.6962
0.0494	1.1781	1.0451	0.9342	0.8491	0.7668	0.7008
0.1017	1.1934	1.0595	0.9472	0.8575	0.7727	0.7141
0.2021	1.1872	1.0567	0.9481	0.8584	0.7705	0.7094
0.3998	1.1877	1.0562	0.9494	0.8642	0.7836	0.7156
0.5962	1.1934	1.0675	0.9554	0.8698	0.7953	0.7292
0.8002	1.2093	1.0832	0.9733	0.8856	0.8166	0.7421
1.0024	1.2366	1.1260	1.0030	0.9073	0.8382	0.7632

Table 4.81: Viscosity, η (mPa.S) of NaCl in 1% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0106	0.9204	0.8307	0.7303	0.6651	0.6033	0.5547
0.0505	0.9253	0.8386	0.7380	0.6679	0.6125	0.5605
0.1022	0.9280	0.8454	0.7450	0.6727	0.6190	0.5654
0.2016	0.9367	0.8536	0.7543	0.6826	0.6236	0.5714
0.4024	0.9530	0.8652	0.7685	0.6993	0.6354	0.5844
0.6009	0.9679	0.8805	0.7822	0.7122	0.6476	0.5965
0.8000	0.9854	0.8990	0.7959	0.7275	0.6600	0.6057
1.0000	0.9976	0.9140	0.8116	0.7357	0.6769	0.6201

Table 4.82: Viscosity, η (mPa.S) of NaCl in 5% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0099	1.1840	1.1340	1.0373	0.9570	0.8980	0.8207
0.0499	1.1470	1.0600	0.9562	0.8800	0.8012	0.7577
0.1023	1.1340	1.0400	0.9330	0.8520	0.7860	0.7201
0.1986	1.1340	1.0340	0.9340	0.8400	0.7740	0.7050
0.4022	1.1470	1.0400	0.9280	0.8360	0.7730	0.6960
0.6013	1.1710	1.0470	0.9330	0.8440	0.7730	0.6960
0.8028	1.2000	1.0630	0.9490	0.8470	0.7890	0.7120
1.0014	1.2180	1.0800	0.9650	0.8650	0.8020	0.7300

Table 4.83: Viscosity, η (mPa.S) of NaCl in 10% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0098	1.2814	1.1439	1.0179	0.9439	0.8593	0.7514
0.0493	1.1600	1.0560	0.9300	0.8280	0.7570	0.7110
0.1006	1.1637	1.0566	0.9279	0.8312	0.7555	0.7000
0.2014	1.1720	1.0653	0.9326	0.8402	0.7649	0.7013
0.4025	1.1950	1.0830	0.9490	0.8560	0.7760	0.7120
0.6001	1.2130	1.1049	0.9692	0.8780	0.7993	0.7311
0.8002	1.2400	1.1306	0.9960	0.8984	0.8140	0.7460
0.9993	1.2724	1.1535	1.0163	0.9176	0.8406	0.7657

Table 4.84: Viscosity, η (mPa.S) of KCl in 1% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0099	0.9325	0.8309	0.7524	0.6750	0.6175	0.5658
0.0500	0.9228	0.8206	0.7383	0.6662	0.6093	0.5580
0.0998	0.9243	0.8303	0.7456	0.6757	0.6170	0.5660
0.2004	0.9290	0.8380	0.7540	0.6830	0.6240	0.5699
0.4005	0.9299	0.8494	0.7657	0.6940	0.6377	0.5810
0.5992	0.9390	0.8600	0.7720	0.7010	0.6420	0.5890
0.8003	0.9533	0.8718	0.7802	0.7051	0.6501	0.5979
1.0004	0.9680	0.8903	0.7961	0.7143	0.6647	0.6115

Table 4.85: Viscosity, η (mPa.S) of KCl in 5% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0097	1.0207	0.9182	0.8113	0.7340	0.6671	0.6070
0.0504	1.0280	0.9240	0.8120	0.7401	0.6710	0.6151
0.1007	1.0330	0.9283	0.8172	0.7450	0.6730	0.6201
0.2009	1.0390	0.9360	0.8221	0.7550	0.6809	0.6290
0.4006	1.0450	0.9460	0.8350	0.7636	0.6870	0.6360
0.5998	1.0590	0.9610	0.8517	0.7720	0.6970	0.6460
0.8000	1.0650	0.9730	0.8671	0.7840	0.7129	0.6600
0.9998	1.0750	0.9940	0.8814	0.8011	0.7348	0.6739

Table 4.86: Viscosity, η (mPa.S) of KCl in 10% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
0.0101	1.0274	0.9278	0.8230	0.7458	0.6739	0.6212
0.0494	1.0306	0.9250	0.8240	0.7418	0.6770	0.6233
0.1010	1.0375	0.9279	0.8260	0.7445	0.6840	0.6253
0.1981	1.0590	0.9430	0.8399	0.7600	0.6970	0.6350
0.4026	1.1140	1.0020	0.9010	0.8180	0.7490	0.6850
0.6002	1.1760	1.0570	0.9450	0.8530	0.7850	0.7190
0.7999	1.2137	1.1012	0.9723	0.8791	0.7999	0.7407
1.0003	1.2356	1.1184	0.9896	0.8987	0.8205	0.7561

Table 4.87: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of NaCl in aqueous solution.

System	Temp.(K)	*A*-coefficient	*B*-coefficient	δB/δT
NaCl in aqueous solution	298.15	0.0239	0.1048	-7.53703E-05
	303.15	0.0268	0.1067	
	308.15	0.0286	0.1071	
	313.15	0.0364	0.0951	
	318.15	0.0307	0.1056	
	323.15	0.0199	0.1105	

Table 4.88: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in aqueous solution.

System	Temp.(K)	*A*-coefficient	*B*-coefficient	δB/δT
KCl in aqueous solution	298.15	0.0605	-0.0300	0.0007
	303.15	0.0364	-0.0087	
	308.15	0.0584	-0.0205	
	313.15	0.0712	-0.0419	
	318.15	0.0586	-0.0302	
	323.15	0.0227	-0.0131	

Table 4.89: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of NaCl in 1% (w/v) Glucose in aqueous solutions.

System	Temp.(K)	*A*-coefficient	*B*-coefficient	δB/δT
NaCl in 1% Glucose solution	298.15	0.0767	0.0520	-0.0009
	303.15	0.0363	0.0998	
	308.15	0.0245	0.1108	
	313.15	0.0094	0.1312	
	318.15	0.0348	0.0955	
	323.15	0.0567	0.0812	

Table 4.90: Viscosity coefficients ***A*** and ***B*** parameters and δ*B*/δT of NaCl in 5% (w/v) Glucose in aqueous solutions.

System	Temp. (K).	*A*-coefficient	*B*-coefficient	δB/δT
NaCl in 5% Glucose solution	298.15	0.3551	-0.1204	0.0024
	303.15	0.3905	-0.1420	
	308.15	0.3634	-0.1238	
	313.15	0.3470	-0.1092	
	318.15	0.3480	-0.1135	
	323.15	0.2933	-0.0568	

Table 4.91: Viscosity coefficients ***A*** and *B* parameters and δB/δT of NaCl in 10% (w/v) Glucose in aqueous solutions.

System	Temp.(K)	*A*-coefficient	*B*-coefficient	δB/δT
NaCl in 10% Glucose solution	298.15	0.9229	-0.4656	0.0082
	303.15	0.8555	-0.4009	
	308.15	0.8062	-0.3605	
	313.15	0.7851	-0.3401	
	318.15	0.7299	-0.2730	
	323.15	0.6968	-0.2596	

Table 4.92: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in 1% (w/v) Glucose in aqueous solutions.

System	Temp(K).	*A*-coefficient	*B*-coefficient	δB/δT
KCl in 1% Glucose solution	298.15	0.0849	-0.0013	0.0007
	303.15	0.0757	-0.0145	
	308.15	0.0894	-0.0053	
	313.15	0.0787	-0.0111	
	318.15	0.0809	0.0147	
	323.15	0.0835	-0.0189	

Table 4.93: Viscosity coefficients *A* and ***B*** parameters and δB/δT of KCl in 5%(w/v) Glucose in aqueous solutions.

System	Temp(K).	*A*-coefficient	*B*-coefficient	δB/δT
KCl in 5% Glucose solution	298.15	0.6248	-0.4420	0.0030
	303.15	0.6149	-0.4291	
	308.15	0.5812	-0.3918	
	313.15	0.5689	-0.3737	
	318.15	0.5549	-0.3672	
	323.15	0.5687	-0.3787	

Table 4.94: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in 10% (w/v) Glucose in aqueous solutions.

System	Temp(K).	*A*-coefficient	*B*-coefficient	δB/δT
KCl in 10% Glucose solution	298.15	0.8547	-0.4972	0.0061
	303.15	0.8513	-0.4963	
	308.15	0.8251	-0.4689	
	313.15	0.7690	-0.4095	
	318.15	0.7521	-0.3999	
	323.15	0.7091	-0.3546	

Table 4.95: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of NaCl in 1% (w/v) Sucrose in aqueous solutions.

System	**Temp.(K)**	***A*-coefficient**	***B*-coefficient**	**δB/δT**
NaCl in 1% Sucrose solution	298.15	0.0127	0.1081	-0.0002
	303.15	0.0222	0.1084	
	308.15	0.0334	0.1049	
	313.15	0.0344	0.1012	
	318.15	0.0196	0.1156	
	323.15	0.0363	0.0967	

Table 4.96: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of NaCl in 5% (w/v) Sucrose in aqueous solutions.

System	**Temp.(*K*)**	***A*-coefficient**	***B*-coefficient**	**δB/δT**
NaCl in 5% Sucrose solution	298.15	0.4349	-0.2079	0.0027
	303.15	0.4309	-0.1947	
	308.15	0.4216	-0.1863	
	313.15	0.4013	-0.1669	
	318.15	0.3937	-0.1617	
	323.15	0.3649	-0.1355	

Table 4.97: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of NaCl in 10% (w/v) Sucrose in aqueous solutions.

System	**Temp.(*K*)**	***A*-coefficient**	***B*-coefficient**	**δB/δT**
NaCl in 10% Sucrose solution	298.15	0.9134	-0.4925	0.0052
	303.15	0.8704	-0.4352	
	308.15	0.8748	-0.4631	
	313.15	0.8125	-0.4073	
	318.15	0.7800	-0.3733	
	323.15	0.7527	-0.3573	

Table 4.98: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in 1% (w/v) Sucrose in aqueous solutions.

System	**Temp.(*K*)**	***A*-coefficient**	***B*-coefficient**	**δB/δT**
KCl in 1% Sucrose solution	298.15	0.0945	-0.0152	0.0020
	303.15	0.0834	-0.0037	
	308.15	0.0810	-0.0028	
	313.15	0.0560	-0.0414	
	318.15	0.0765	-0.0240	
	323.15	0.0640	-0.0300	

Table 4.99: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in 5% (w/v) Sucrose in aqueous solutions.

System	Temp.(*K*)	*A*-coefficient	*B*-coefficient	δB/δT
KCl in 5% Sucrose solution	298.15	0.4337	-0.2589	0.0022
	303.15	0.4433	-0.2561	
	308.15	0.4599	-0.2655	
	313.15	0.4131	-0.2262	
	318.15	0.4267	-0.2322	
	323.15	0.3926	-0.2049	

Table 4.100: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in 10% (w/v) Sucrose in aqueous solutions.

System	Temp.(*K*)	*A*-coefficient	*B*-coefficient	δB/δT
KCl in 10% Sucrose solution	298.15	0.9726	-0.6322	0.0067
	303.15	0.9182	-0.5629	
	308.15	0.9053	-0.5623	
	313.15	0.9051	-0.5593	
	318.15	0.8093	-0.4387	
	323.15	0.8296	-0.4734	

Table 4.101: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of NaCl in 1% (w/v) Maltose in aqueous solutions.

System	Temp.(*K*)	*A*-coefficient	*B*-coefficient	δB/δT
NaCl in 1% Maltose solution	298.15	0.1052	0.0126	-0.0026
	303.15	0.1509	0.0124	
	308.15	0.0854	0.0378	
	313.15	0.0794	0.0499	
	318.15	0.0723	0.0568	
	323.15	0.0715	0.0586	

Table 4.102: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of NaCl in 5% (w/v) Maltose in aqueous solutions.

System	Temp.(*K*)	*A*-coefficient	*B*-coefficient	δB/δT
NaCl in 5% Maltose solution	298.15	0.7626	-0.4235	-0.0041
	303.15	0.8679	-0.5521	
	308.15	0.8716	-0.5754	
	313.15	0.8491	-0.5672	
	318.15	0.8781	-0.5763	
	323.15	0.8365	-0.5551	

Table 4.103: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of NaCl in 10% (w/v) Maltose in aqueous solutions.

System	**Temp.(*K*)**	***A*-coefficient**	***B*-coefficient**	**δB/δT**
NaCl in 10% Maltose solution	298.15	0.8869	-0.4961	0.0052
	303.15	0.9436	-0.5332	
	308.15	0.8145	-0.4334	
	313.15	0.7880	-0.4107	
	318.15	0.7677	-0.3922	
	323.15	0.7722	-0.4039	

Table 4.104: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in 1% (w/v) Maltose in aqueous solutions.

System	**Temp.(*K*)**	***A*-coefficient**	***B*-coefficient**	**δB/δT**
KCl in 1% Maltose solution	298.15	0.0886	-0.0118	0.0014
	303.15	0.1042	0.0033	
	308.15	0.1052	-0.0074	
	313.15	0.1114	-0.0206	
	318.15	0.1012	0.0069	
	323.15	0.0741	0.0380	

Table 4.105: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in 5% (w/v) Maltose in aqueous solutions.

System	**Temp.(*K*)**	***A*-coefficient**	***B*-coefficient**	**δB/δT**
KCl in 5% Maltose solution	298.15	0.4798	-0.2899	0.0045
	303.15	0.4754	-0.2516	
	308.15	0.3716	-0.1601	
	313.15	0.4260	-0.2207	
	318.15	0.3608	-0.1531	
	323.15	0.3924	-0.1797	

Table 4.106: Viscosity coefficients ***A*** and ***B*** parameters and δB/δT of KCl in 10% (w/v) Maltose in aqueous solutions.

System	**Temp.(*K*)**	***A*-coefficient**	***B*-coefficient**	**δB/δT**
KCl in 10% Maltose solution	298.15	0.4393	-0.0464	0.0020
	303.15	0.4050	-0.0084	
	308.15	0.3847	-0.0043	
	313.15	0.3772	-0.0104	
	318.15	0.4017	-0.0146	
	323.15	0.3605	-0.0374	

Table 4.107: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0100	12.11	12.03	11.97	11.92	11.88	11.84	15.39	-27.24
0.0504	12.12	12.05	11.99	11.93	11.89	11.85	15.33	-27.46
0.1000	12.13	12.06	12.00	11.94	11.90	11.87	15.28	-27.68
0.2010	12.14	12.08	12.02	11.97	11.92	11.88	15.27	-27.78
0.4000	12.18	12.11	12.07	12.01	11.97	11.93	15.13	-28.37
0.6013	12.22	12.16	12.11	12.05	12.01	11.96	15.29	-27.97
0.8000	12.26	12.20	12.15	12.09	12.06	12.02	15.11	-28.69
1.0000	12.30	12.25	12.19	12.14	12.12	12.08	14.94	-29.42

Table 4.108: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0100	12.74	12.63	12.60	12.54	12.51	12.47	15.81	-27.89
0.0500	12.73	12.63	12.60	12.55	12.51	12.46	15.70	-28.23
0.1000	12.72	12.64	12.59	12.55	12.51	12.47	15.59	-28.58
0.1970	12.71	12.63	12.60	12.56	12.52	12.46	15.42	-29.16
0.4009	12.68	12.60	12.58	12.53	12.48	12.45	15.34	-29.32
0.5992	12.66	12.58	12.56	12.50	12.46	12.43	15.31	-29.35
0.8012	12.62	12.56	12.54	12.48	12.43	12.41	15.16	-29.76
0.9980	12.60	12.54	12.51	12.44	12.41	12.40	15.13	-29.79

Table 4.109: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 1% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0106	12.15	12.06	12.00	11.94	11.90	11.87	15.55	-26.83
0.0505	12.15	12.08	12.01	11.94	11.91	11.87	15.55	-26.84
0.1022	12.15	12.08	12.01	11.96	11.91	11.88	15.50	-27.03
0.2016	12.17	12.09	12.02	11.97	11.91	11.89	15.49	-27.07
0.4024	12.20	12.12	12.05	12.00	11.95	11.94	15.40	-27.49
0.6009	12.23	12.14	12.09	12.03	11.99	11.98	15.21	-28.21
0.8000	12.26	12.19	12.13	12.08	12.03	12.01	15.21	-28.34
1.0000	12.28	12.23	12.17	12.14	12.06	12.04	15.19	-28.52

Table 4.110: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 5% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0106	12.31	12.30	12.23	12.17	12.12	12.07	15.40	-27.98
0.0505	12.31	12.29	12.20	12.16	12.09	12.03	15.86	-26.45
0.1022	12.32	12.29	12.21	12.15	12.09	12.04	15.78	-26.69
0.2016	12.34	12.30	12.21	12.16	12.12	12.05	15.85	-26.54
0.4024	12.39	12.34	12.29	12.23	12.18	12.12	15.55	-27.70
0.6009	12.43	12.40	12.33	12.27	12.22	12.17	15.59	-27.71
0.8000	12.45	12.43	12.35	12.29	12.24	12.21	15.56	-27.89
1.0000	12.48	12.44	12.36	12.32	12.28	12.24	15.43	-28.40

Table 4.111: Activation parameters for free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 10% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0106	12.73	12.60	12.54	12.47	12.42	12.37	16.79	-24.53
0.0505	12.73	12.63	12.56	12.50	12.44	12.38	16.77	-24.67
0.1022	12.74	12.62	12.55	12.50	12.44	12.41	16.63	-25.12
0.2016	12.73	12.65	12.57	12.52	12.46	12.39	16.71	-24.91
0.4024	12.80	12.68	12.61	12.55	12.51	12.47	16.55	-25.60
0.6009	12.84	12.77	12.69	12.63	12.59	12.53	16.49	-26.01
0.8000	12.88	12.81	12.74	12.70	12.67	12.62	15.85	-28.26
1.0000	12.93	12.87	12.81	12.77	12.77	12.69	15.57	-29.38

Table 4.112: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 1% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0097	12.77	12.69	12.63	12.58	12.55	12.53	15.60	-28.71
0.0504	12.76	12.68	12.63	12.59	12.56	12.54	15.36	-29.48
0.1007	12.75	12.68	12.64	12.59	12.56	12.54	15.27	-29.79
0.2009	12.75	12.69	12.64	12.60	12.57	12.54	15.18	-30.09
0.4006	12.75	12.69	12.64	12.60	12.58	12.56	15.02	-30.62
0.5998	12.75	12.70	12.64	12.60	12.57	12.58	14.92	-30.96
0.8000	12.76	12.71	12.65	12.62	12.60	12.58	14.94	-30.93
0.9998	12.77	12.72	12.66	12.64	12.62	12.60	14.72	-31.70

Table 4.113: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 5% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc.	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ /	$\Delta S^{\neq}$ /
(mol.L^{-1})	298.15 K			313.15 K	318.15 K	323.15 K	kJ mol^{-1}	J mol^{-1}
0.0097	12.95	12.89	12.80	12.73	12.67	12.63	16.97	-24.80
0.0504	13.02	12.94	12.88	12.83	12.79	12.74	16.28	-27.32
0.1007	13.07	12.98	12.92	12.86	12.83	12.81	16.15	-27.86
0.2009	13.06	13.00	12.93	12.88	12.84	12.83	15.92	-28.64
0.4006	13.03	12.99	12.94	12.90	12.86	12.85	15.34	-30.51
0.5998	13.02	12.98	12.96	12.90	12.86	12.85	15.25	-30.82
0.8000	12.99	12.95	12.91	12.88	12.83	12.81	15.22	-30.79
0.9998	12.95	12.88	12.83	12.81	12.76	12.74	15.36	-30.14

Table 4.114: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 10% (w/v) Glucose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc.	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ /	$\Delta S^{\neq}$ /
(mol.L^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K	kJ mol^{-1}	J mol^{-1}
0.0097	13.07	12.98	12.95	12.90	12.85	12.83	15.90	-28.72
0.0504	13.13	13.06	13.03	12.96	12.91	12.88	16.17	-28.07
0.1007	13.17	13.11	13.07	13.01	12.97	12.94	15.94	-28.96
0.2009	13.23	13.17	13.11	13.05	13.02	12.97	16.27	-28.06
0.4006	13.23	13.19	13.13	13.07	13.03	13.01	16.06	-28.81
0.5998	13.25	13.20	13.15	13.09	13.06	13.04	15.90	-29.37
0.8000	13.27	13.21	13.18	13.14	13.10	13.08	15.61	-30.42
0.9998	13.30	13.25	13.21	13.18	13.14	13.12	15.43	-31.11

Table 4.115: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 1% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc.	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ /	$\Delta S^{\neq}$ /
(mol.L^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K	kJ mol^{-1}	J mol^{-1}
0.0096	12.10	12.03	12.00	11.94	11.87	11.83	15.27	-27.66
0.0498	12.11	12.05	12.01	11.94	11.89	11.86	15.23	-27.82
0.1002	12.12	12.06	12.03	11.96	11.90	11.86	15.28	-27.67
0.2000	12.13	12.07	12.02	11.96	11.91	11.88	15.17	-28.03
0.4001	12.16	12.10	12.05	12.01	11.95	11.91	15.15	-28.20
0.6008	12.20	12.15	12.09	12.04	12.00	11.96	15.12	-28.47
0.8009	12.22	12.18	12.13	12.08	12.03	11.99	14.98	-29.03
1.0003	12.24	12.19	12.16	12.09	12.04	12.01	15.10	-28.70

Table 4.116: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 5% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0090	12.40	12.33	12.29	12.21	12.15	12.11	15.90	-26.55
0.0501	12.40	12.32	12.28	12.20	12.14	12.10	16.07	-25.95
0.1004	12.39	12.32	12.27	12.20	12.14	12.09	16.07	-25.96
0.1995	12.40	12.33	12.26	12.20	12.15	12.10	15.92	-26.45
0.3995	12.40	12.35	12.28	12.22	12.18	12.13	15.65	-27.38
0.5998	12.42	12.37	12.32	12.25	12.20	12.16	15.59	-27.65
0.7995	12.46	12.41	12.35	12.30	12.25	12.20	15.60	-27.77
1.0001	12.50	12.44	12.38	12.33	12.29	12.25	15.45	-28.36

Table 4.117: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 10% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0090	12.61	12.54	12.48	12.40	12.34	12.31	16.40	-25.55
0.0501	12.62	12.55	12.49	12.41	12.33	12.32	16.47	-25.35
0.1004	12.64	12.57	12.51	12.42	12.36	12.31	16.63	-24.89
0.1995	12.67	12.59	12.53	12.45	12.39	12.34	16.64	-24.97
0.3995	12.72	12.65	12.58	12.50	12.46	12.41	16.43	-25.80
0.5998	12.75	12.69	12.62	12.55	12.51	12.46	16.28	-26.44
0.7995	12.79	12.73	12.66	12.60	12.56	12.51	16.22	-26.78
1.0001	12.82	12.80	12.69	12.63	12.60	12.55	16.30	-26.64

Table 4.118: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 1% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0090	12.77	12.71	12.65	12.57	12.53	12.54	15.82	-28.04
0.0501	12.76	12.71	12.63	12.57	12.55	12.52	15.76	-28.21
0.1004	12.75	12.70	12.63	12.58	12.55	12.53	15.49	-29.05
0.1995	12.76	12.69	12.64	12.59	12.57	12.53	15.42	-29.29
0.3995	12.75	12.68	12.63	12.59	12.56	12.51	15.42	-29.28
0.5998	12.74	12.70	12.64	12.61	12.58	12.54	15.12	-30.30
0.7995	12.76	12.70	12.67	12.63	12.60	12.54	15.25	-29.93
1.0001	12.77	12.69	12.66	12.65	12.63	12.60	14.49	-32.41

Table 4.119: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 5% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0099	12.94	12.89	12.83	12.77	12.73	12.70	15.89	-28.39
0.0506	12.98	12.92	12.86	12.81	12.76	12.72	16.09	-27.83
0.1015	12.98	12.92	12.88	12.82	12.77	12.74	15.95	-28.33
0.1989	12.97	12.92	12.88	12.81	12.78	12.73	15.76	-28.91
0.4015	12.96	12.92	12.89	12.82	12.81	12.76	15.37	-30.20
0.6007	12.95	12.92	12.89	12.82	12.81	12.76	15.31	-30.40
0.8003	12.96	12.93	12.90	12.82	12.82	12.77	15.32	-30.39
0.9997	12.97	12.93	12.90	12.85	12.81	12.78	15.27	-30.59

Table 4.120: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 10% (w/v) Sucrose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0106	13.27	13.20	13.12	13.08	13.04	13.00	16.44	-27.61
0.0494	13.28	13.20	13.14	13.11	13.05	13.02	16.36	-27.91
0.1017	13.31	13.23	13.17	13.13	13.06	13.06	16.31	-28.15
0.2021	13.28	13.21	13.16	13.12	13.05	13.03	16.32	-28.06
0.3998	13.26	13.19	13.14	13.11	13.07	13.03	15.84	-29.59
0.5962	13.25	13.19	13.13	13.11	13.09	13.06	15.46	-30.83
0.8002	13.26	13.21	13.16	13.13	13.13	13.09	15.19	-31.78
1.0024	13.29	13.29	13.21	13.17	13.18	13.14	15.25	-31.73

Table 4.121: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 1% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0106	12.16	12.10	11.98	11.93	11.87	11.84	16.13	-24.92
0.0505	12.16	12.12	12.00	11.94	11.91	11.86	15.95	-25.56
0.1022	12.17	12.14	12.02	11.95	11.93	11.88	15.79	-26.13
0.2016	12.18	12.15	12.04	11.98	11.94	11.90	15.77	-26.26
0.4024	12.20	12.17	12.07	12.02	11.97	11.94	15.56	-27.04
0.6009	12.22	12.19	12.09	12.05	12.00	11.98	15.39	-27.65
0.8000	12.25	12.23	12.12	12.09	12.03	12.00	15.47	-27.51
1.0000	12.26	12.25	12.15	12.10	12.08	12.04	15.10	-28.77

Table 4.122: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 5% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0099	12.75	12.86	12.84	12.85	12.89	12.86	11.67	-42.07
0.0499	12.66	12.68	12.63	12.62	12.58	12.63	13.45	-35.67
0.1023	12.63	12.63	12.56	12.53	12.52	12.49	14.37	-32.45
0.1986	12.62	12.60	12.55	12.48	12.47	12.42	15.06	-30.14
0.4022	12.63	12.60	12.52	12.45	12.45	12.37	15.70	-28.00
0.6013	12.66	12.59	12.51	12.46	12.43	12.35	16.24	-26.26
0.8028	12.70	12.61	12.54	12.45	12.47	12.39	16.28	-26.22
1.0014	12.72	12.63	12.56	12.48	12.49	12.44	16.00	-27.19

Table 4.123: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of NaCl in 10% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0098	12.90	12.83	12.75	12.76	12.72	12.57	16.19	-27.23
0.0493	12.65	12.62	12.51	12.42	12.38	12.42	16.02	-26.95
0.1006	12.65	12.62	12.50	12.42	12.37	12.37	16.45	-25.54
0.2014	12.66	12.63	12.50	12.44	12.40	12.36	16.48	-25.46
0.4025	12.69	12.65	12.53	12.47	12.42	12.38	16.60	-25.18
0.6001	12.71	12.69	12.56	12.52	12.47	12.44	16.18	-26.65
0.8002	12.74	12.73	12.62	12.56	12.50	12.47	16.30	-26.39
0.9993	12.79	12.76	12.65	12.59	12.57	12.52	16.11	-27.16

Table 4.124: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 1% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0099	12.79	12.72	12.68	12.61	12.58	12.55	15.73	-28.39
0.0500	12.76	12.68	12.63	12.57	12.54	12.51	15.72	-28.28
0.0998	12.76	12.70	12.64	12.60	12.57	12.54	15.38	-29.44
0.2004	12.76	12.71	12.66	12.61	12.58	12.54	15.32	-29.67
0.4005	12.73	12.73	12.67	12.63	12.61	12.57	14.81	-31.36
0.5992	12.74	12.73	12.67	12.63	12.61	12.58	14.79	-31.42
0.8003	12.75	12.75	12.68	12.62	12.62	12.60	14.83	-31.34
1.0004	12.77	12.78	12.71	12.64	12.65	12.64	14.65	-31.99

Table 4.125: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 5% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0097	12.98	12.93	12.83	12.78	12.74	12.69	16.47	-26.57
0.0504	12.99	12.94	12.83	12.80	12.75	12.72	16.29	-27.17
0.1007	13.00	12.95	12.84	12.81	12.75	12.74	16.24	-27.38
0.2009	13.00	12.96	12.84	12.83	12.77	12.77	15.96	-28.32
0.4006	12.99	12.96	12.86	12.84	12.77	12.77	15.86	-28.67
0.5998	13.00	12.98	12.89	12.85	12.79	12.79	15.86	-28.69
0.8000	12.99	12.99	12.91	12.86	12.82	12.83	15.36	-30.39
0.9998	12.99	13.02	12.93	12.90	12.88	12.86	14.95	-31.80

Table 4.126: Activation parameters for change of free energy ($\Delta G^{\neq}$), enthalpy ($\Delta H^{\neq}$) and entropy ($\Delta S^{\neq}$) of KCl in 10% (w/v) Maltose in aqueous solutions at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	Free energy $\Delta G^{\neq}$ (kJ mol^{-1}) of NaCl in aqueous solution						$\Delta H^{\neq}$ / kJ mol^{-1}	$\Delta S^{\neq}$ / J mol^{-1}
	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K		
0.0101	12.99	12.96	12.87	12.82	12.77	12.76	16.06	-27.98
0.0494	12.99	12.94	12.87	12.80	12.77	12.76	15.98	-28.24
0.1010	13.00	12.94	12.86	12.81	12.79	12.76	15.95	-28.35
0.1981	13.03	12.96	12.89	12.84	12.82	12.78	15.98	-28.34
0.4026	13.12	13.08	13.03	12.99	12.97	12.95	15.20	-31.28
0.6002	13.23	13.19	13.12	13.07	13.07	13.04	15.49	-30.67
0.7999	13.28	13.26	13.16	13.12	13.09	13.09	15.82	-29.75
1.0003	13.30	13.28	13.19	13.16	13.13	13.12	15.60	-30.55

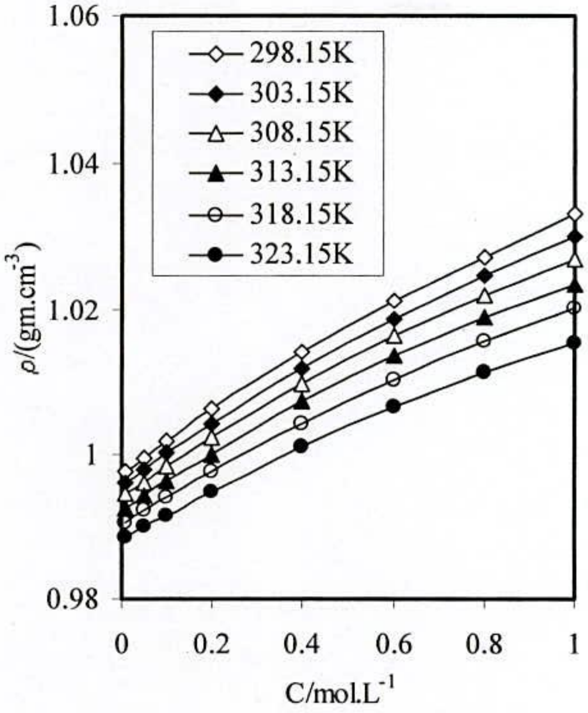


Figure 4.1: Plots of density (ρ) vs concentration (c) of NaCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

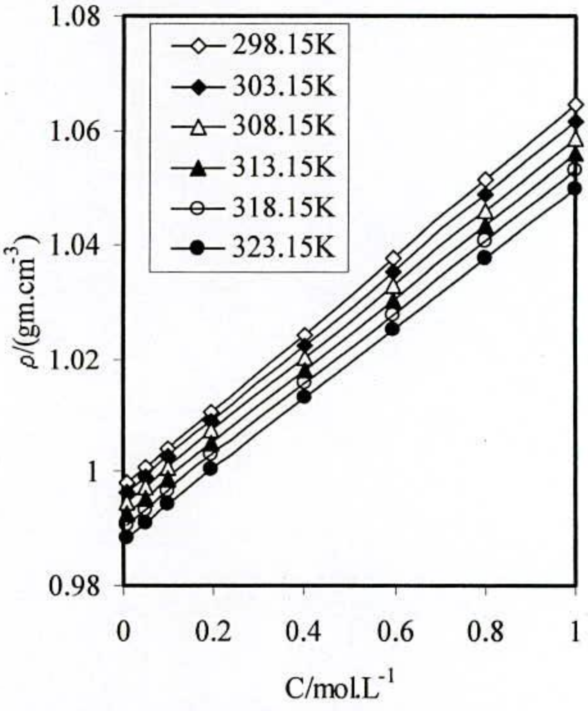


Figure 4.2: Plots of density (ρ) vs concentration (c) of KCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

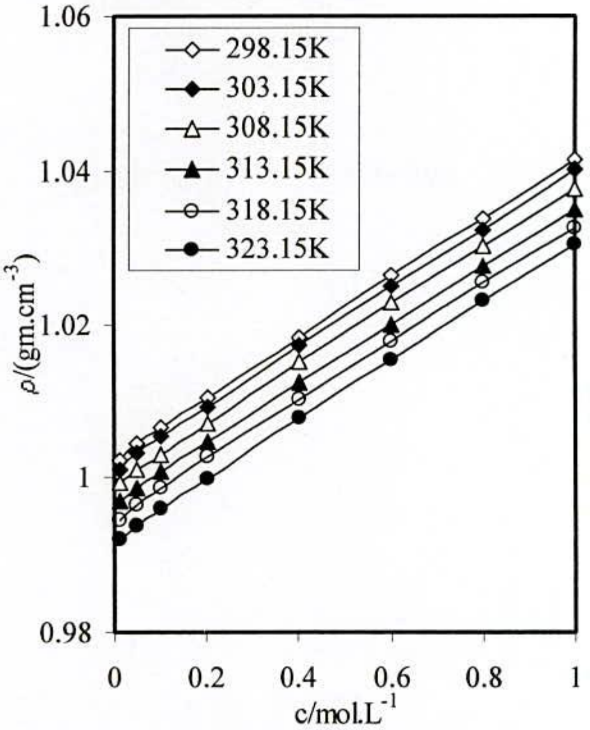


Figure 4.3: Plots of density (ρ) vs concentration (c) of NaCl in 1% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

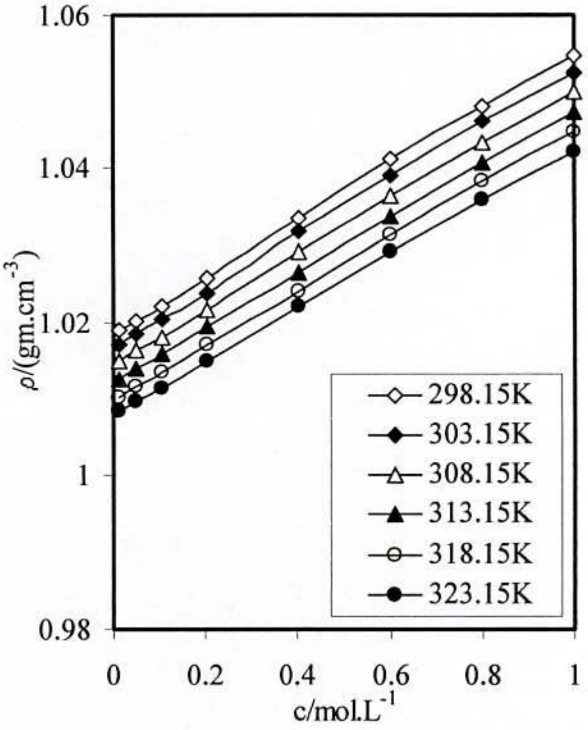


Figure 4.4: Plots of density (ρ) vs concentration (c) of NaCl in 5% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

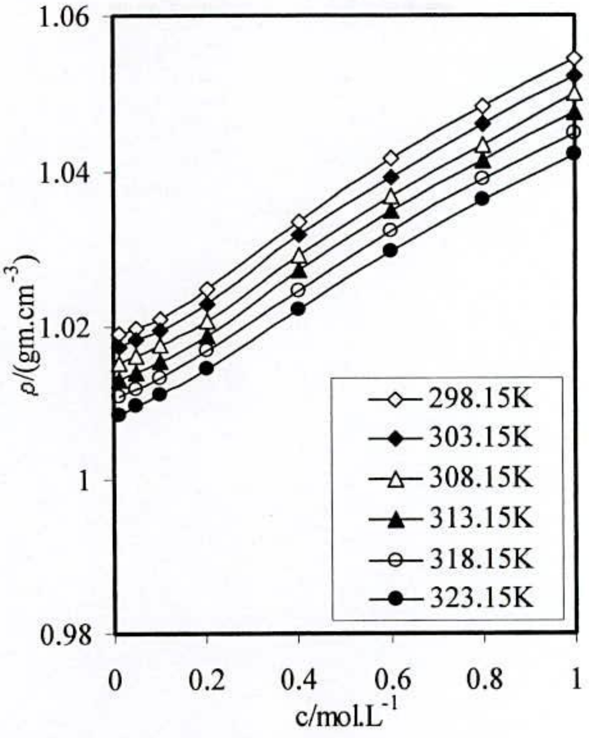


Figure 4.5: Plots of density (ρ) vs concentration (c) of NaCl in 10% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

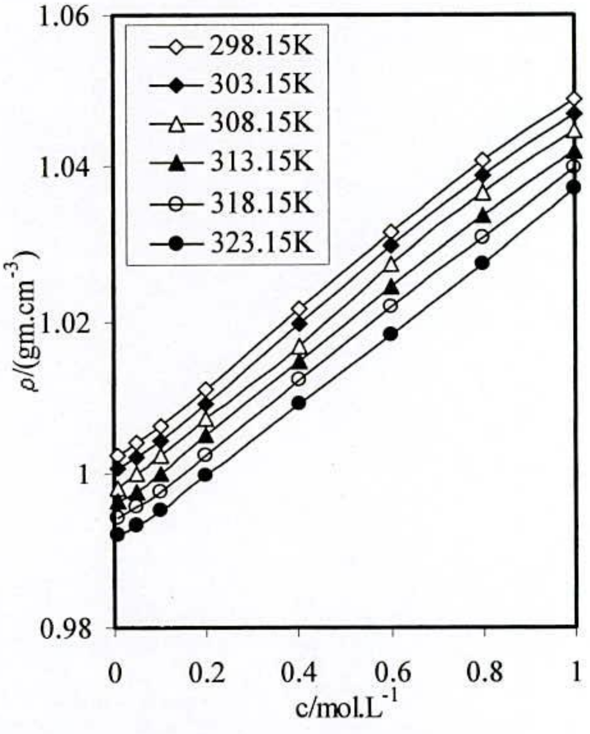


Figure 4.6: Plots of density (ρ) vs concentration (c) of KCl in 1% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

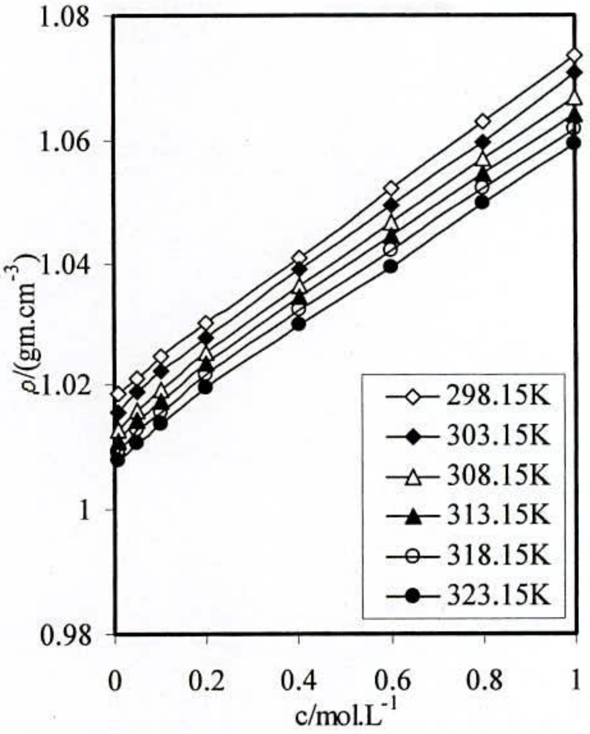


Figure 4.7: Plots of density (ρ) vs concentration (c) of KCl in 5% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

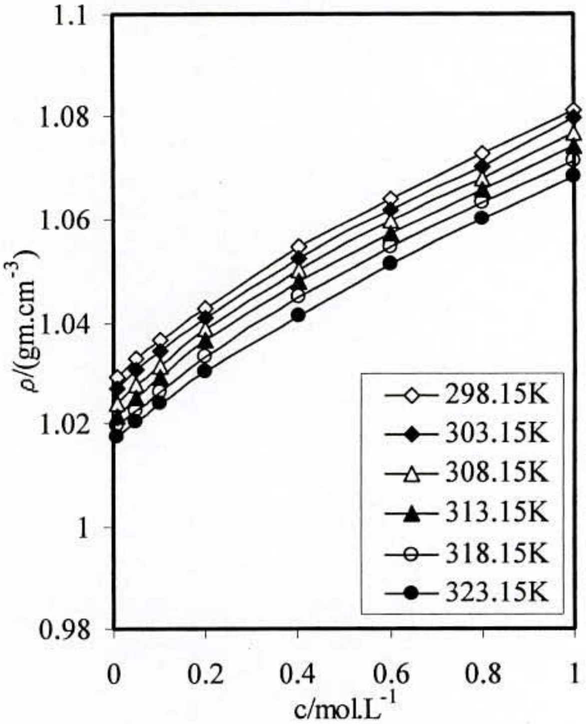


Figure 4.8: Plots of density (ρ) vs concentration (c) of KCl in 10% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

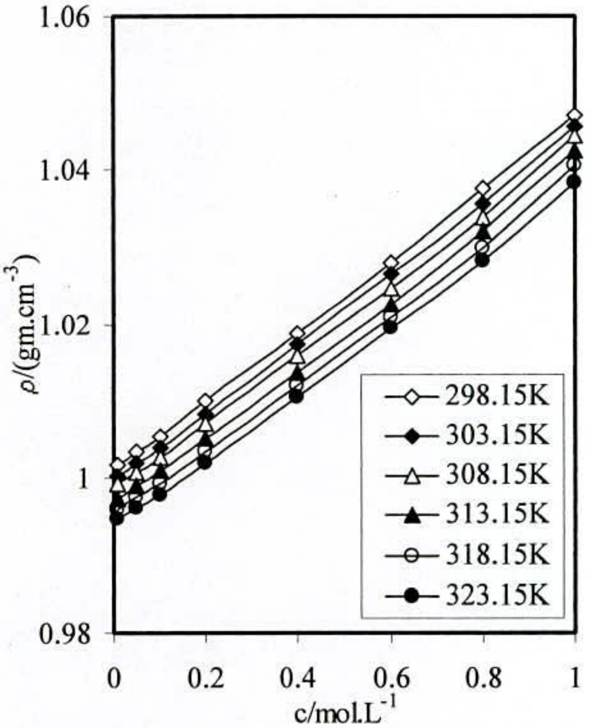


Figure 4.9: Plots of density (ρ) vs concentration (c) of NaCl in 1% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

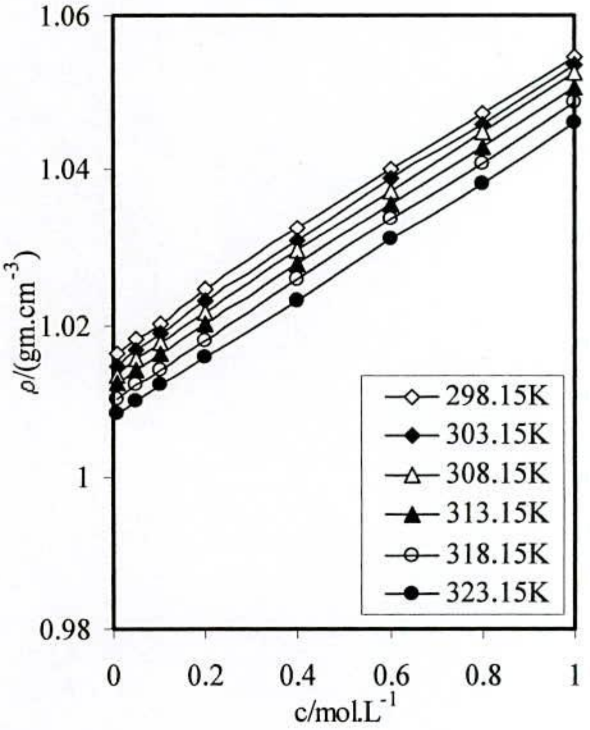


Figure 4.10: Plots of density (ρ) vs concentration (c)of NaCl in 5% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

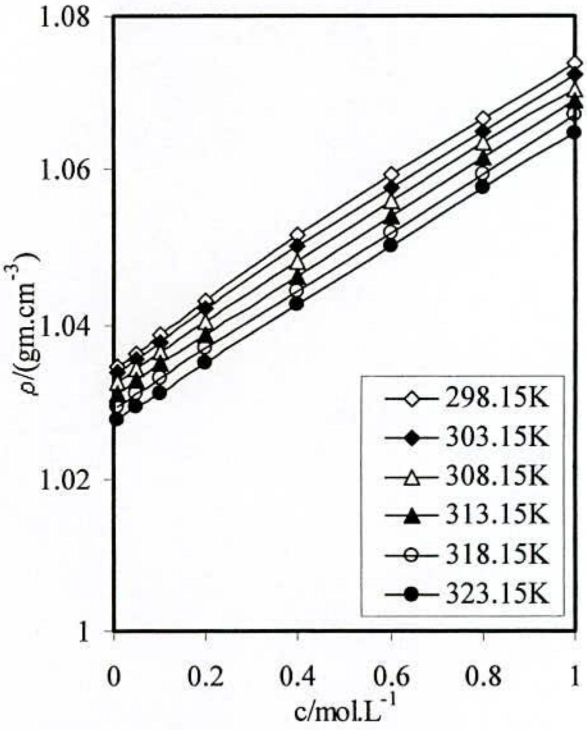


Figure 4.11: Plots of density (ρ) vs concentration (c)of NaCl in 10% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

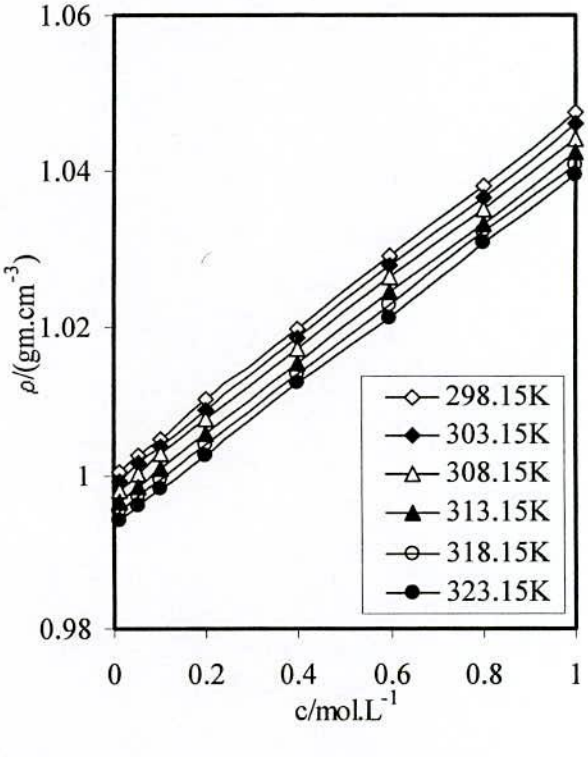


Figure 4.12: Plots of density (ρ) vs concentration (c)of KCl in 1% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

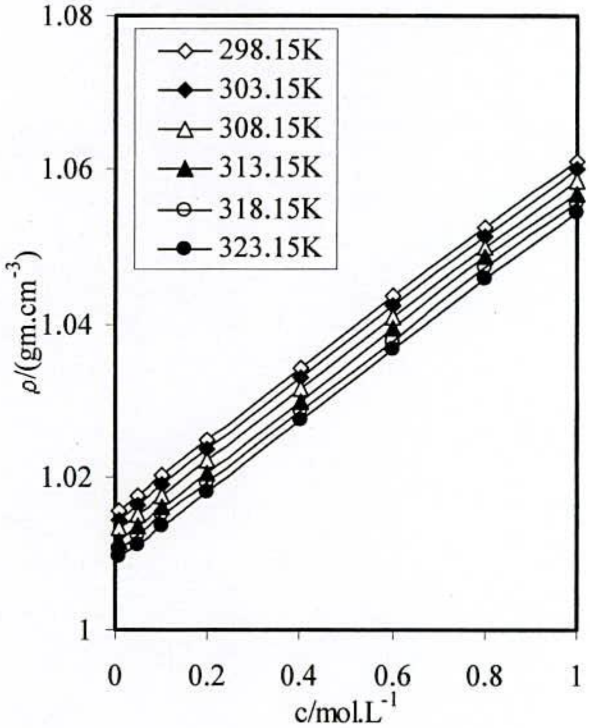


Figure 4.13: Plots of density (ρ) vs concentration (c)of KCl in 5% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

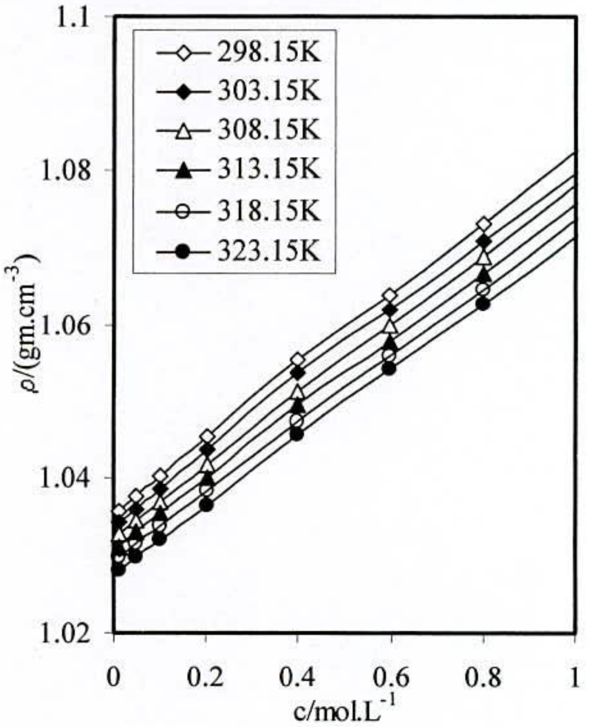


Figure 4.14: Plots of density (ρ) vs concentration (c)of KCl in 10% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

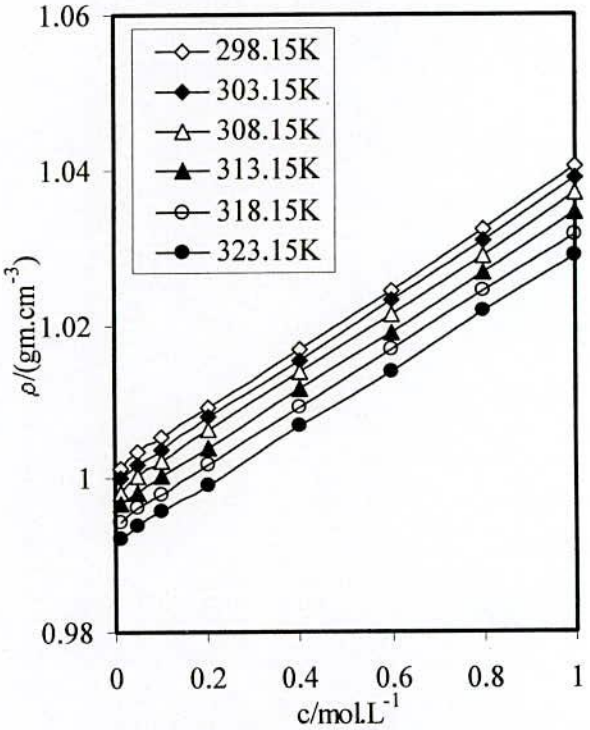


Figure 4.15: Plots of density (ρ) vs concentration (c)of NaCl in 1% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

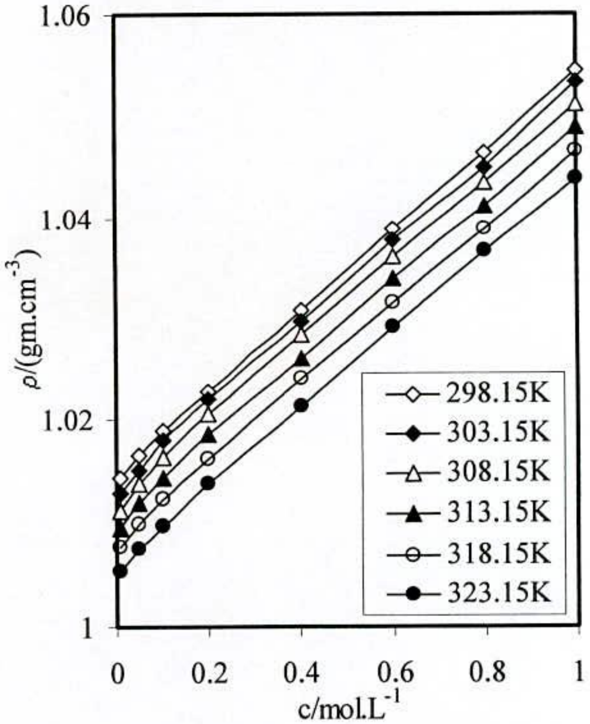


Figure 4.16: Plots of density (ρ) vs concentration (c)of NaCl in 5% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

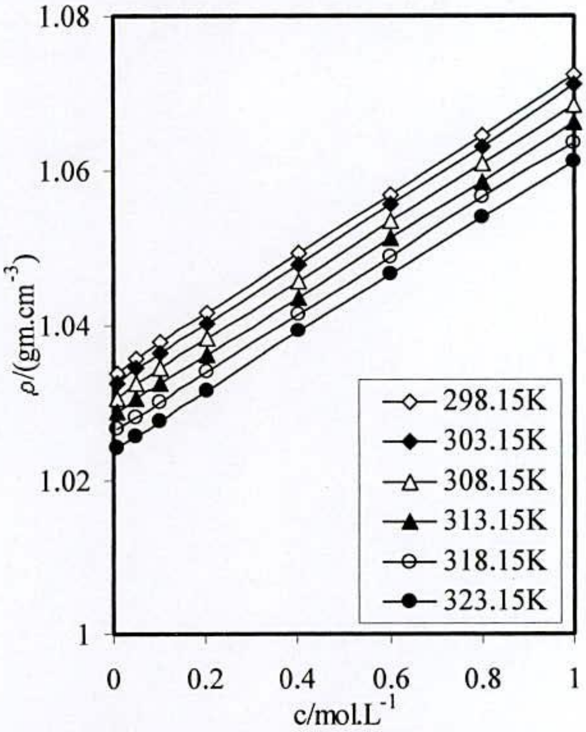


Figure 4.17: Plots of density (ρ) vs concentration (c)of NaCl in 10% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

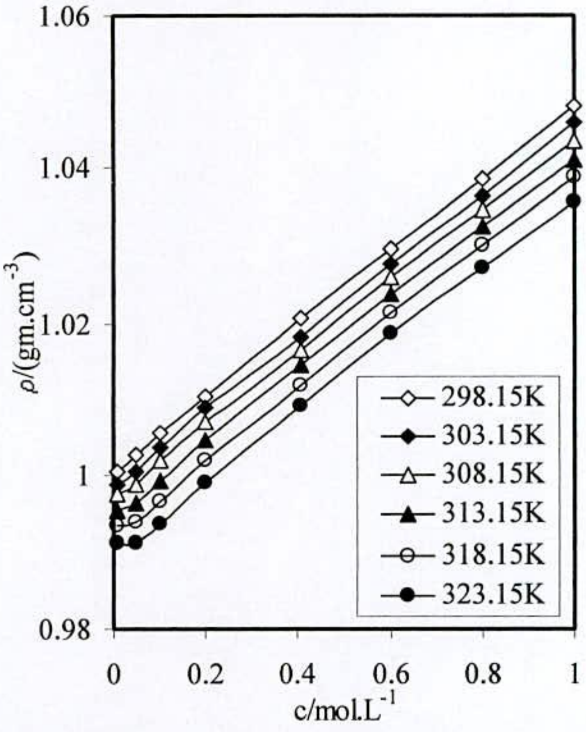


Figure 4.18: Plots of density (ρ) vs concentration (c)of KCl in 1% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

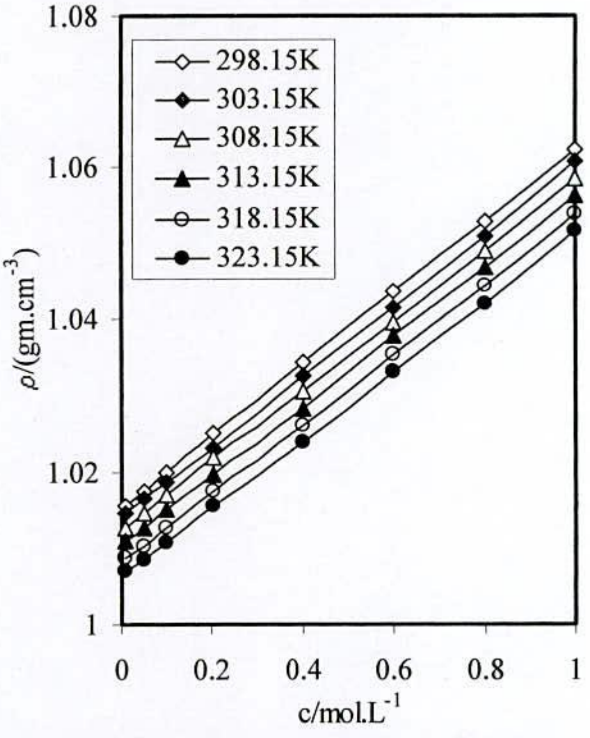


Figure 4.19: Plots of density (ρ) vs concentration (c)of KCl in 5% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

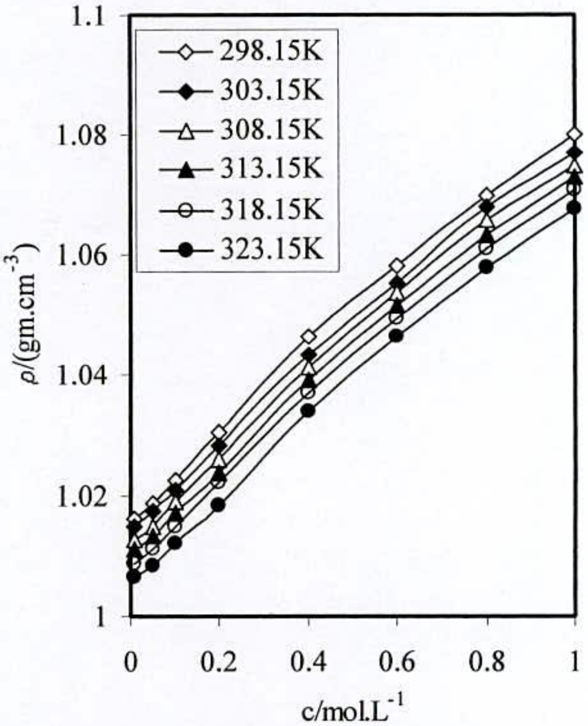


Figure 4.20: Plots of density (ρ) vs concentration (c)of KCl in 10% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

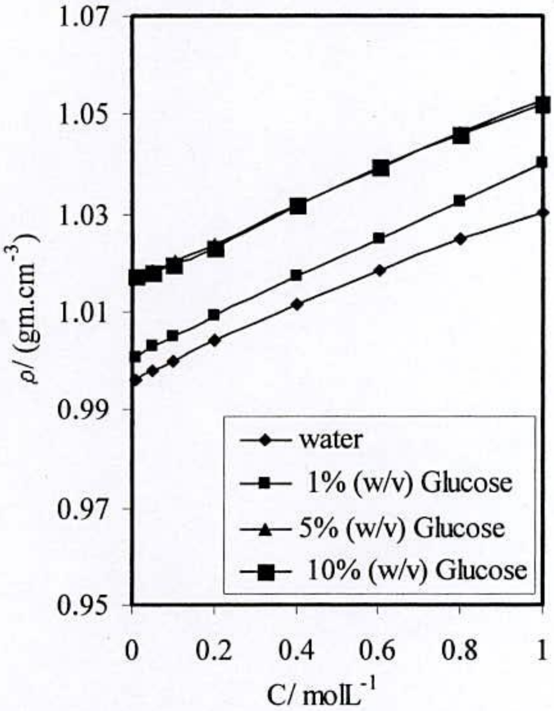


Figure 4.21: Comparison of density (ρ) vs concentration (c) of NaCl in water, 1% (w/v), 5%(w/v) and 10% (w/v) Glucose solution at 303.15K.

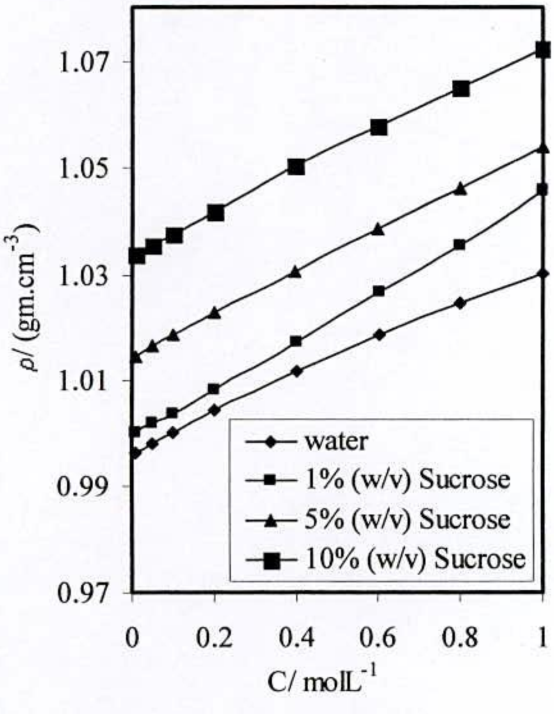


Figure 4.22: Comparison of density (ρ) vs concentration (c) of NaCl in water, 1% (w/v), 5% (w/v) and 10% (w/v) Sucrose solution at 303.15K.

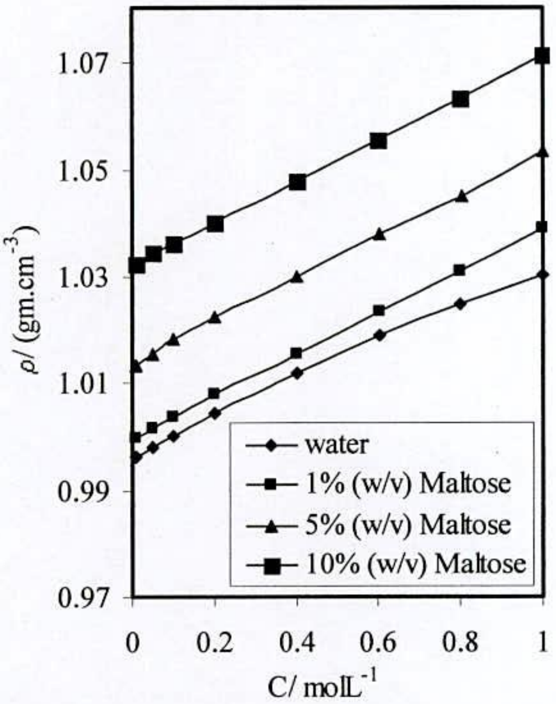


Figure 4.23: Comparison of density (ρ) vs concentration (c) of NaCl in water, 1% (w/v), 5%(w/v) and 10% (w/v) Maltose solution at 303.15K.

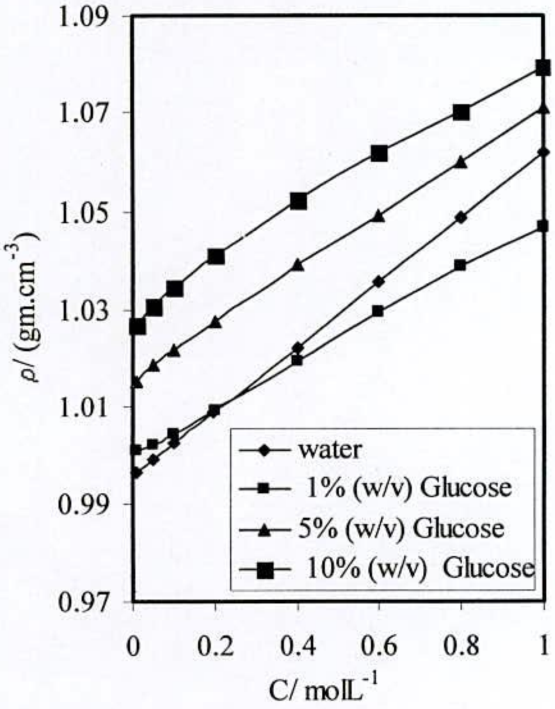


Figure 4.24: Comparison of density (ρ) vs concentration (c) of KCl in water, 1%(w/v), 5%(w/v) and 10%(w/v) Glucose solution at 303.15K.

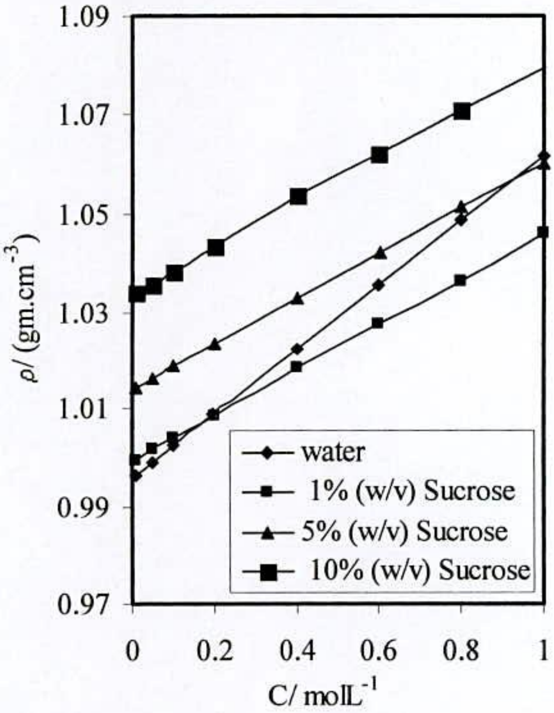


Figure 4.25: Comparison of density (ρ) vs concentration (c) of KCl in water, 1%(w/v), 5%(w/v) and 10% (w/v) Sucrose solution at 303.15K.

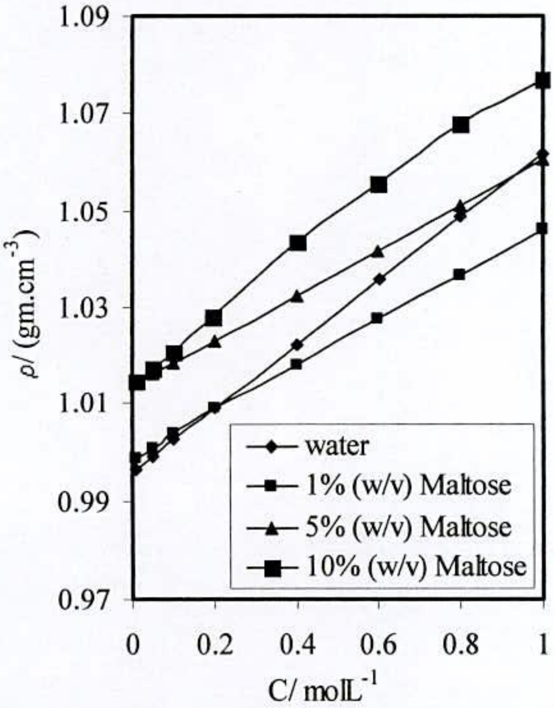


Figure 4.26: Comparison of density (ρ) vs concentration (c) of KCl in water, 1%(w/v), 5%(w/v) and 10%(w/v) Maltose solution at 303.15K.

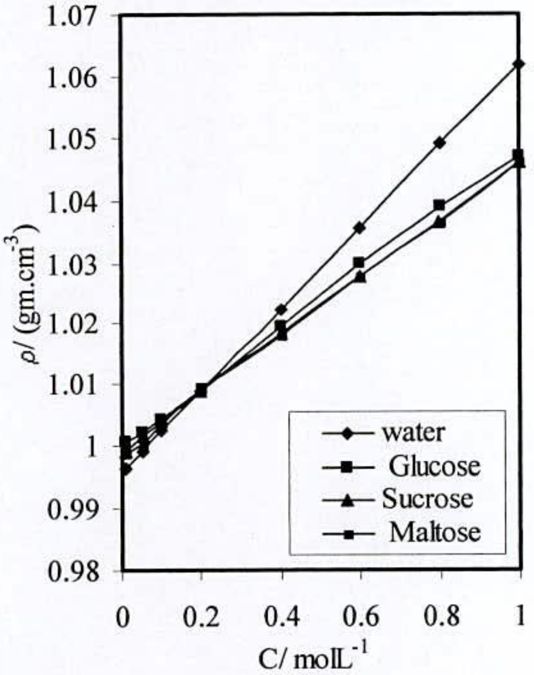


Figure 4.27: Comparison of density (ρ) vs concentration (c) of KCl in water, 1% (w/v) Glucose, 1% (w/v) Sucrose, 1% (w/v) Maltose solution at 303.15K.

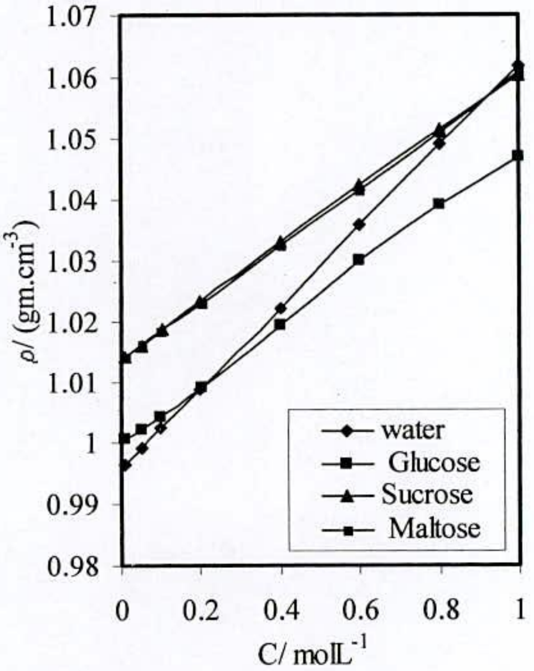


Figure 4.28: Comparison of density (ρ) vs concentration (c) of KCl in water, 5% (w/v) Glucose, 5% (w/v) Sucrose, 5% (w/v) Maltose solution at 303.15K.

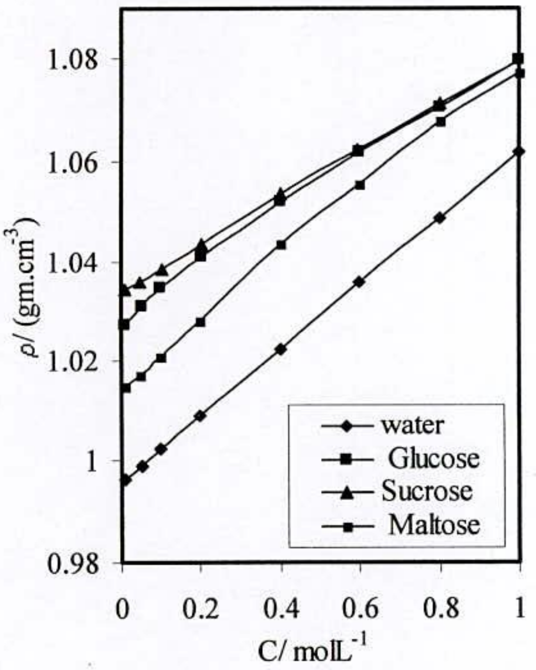


Figure 4.29: Comparison of density (ρ) vs concentration (c) of KCl in water, 10% (w/v) Glucose, 10% (w/v) Sucrose, 10% (w/v) Maltose solution at 303.15K.

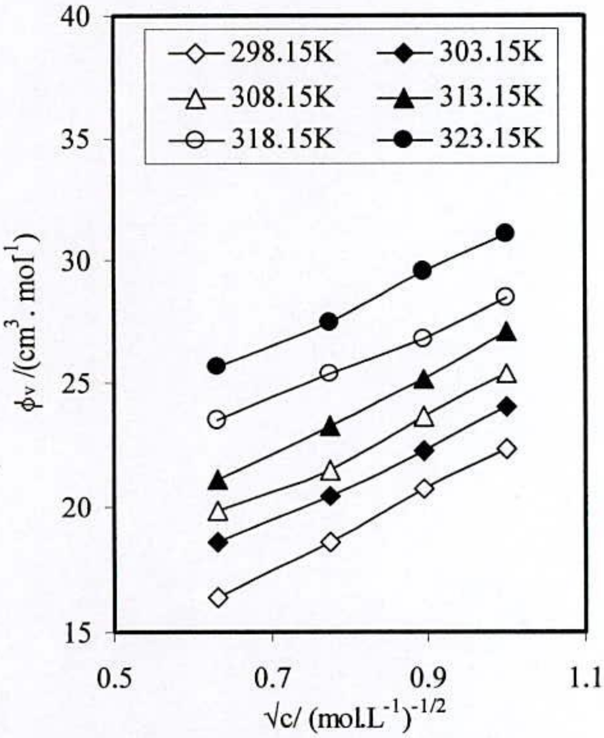


Figure 4.30: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

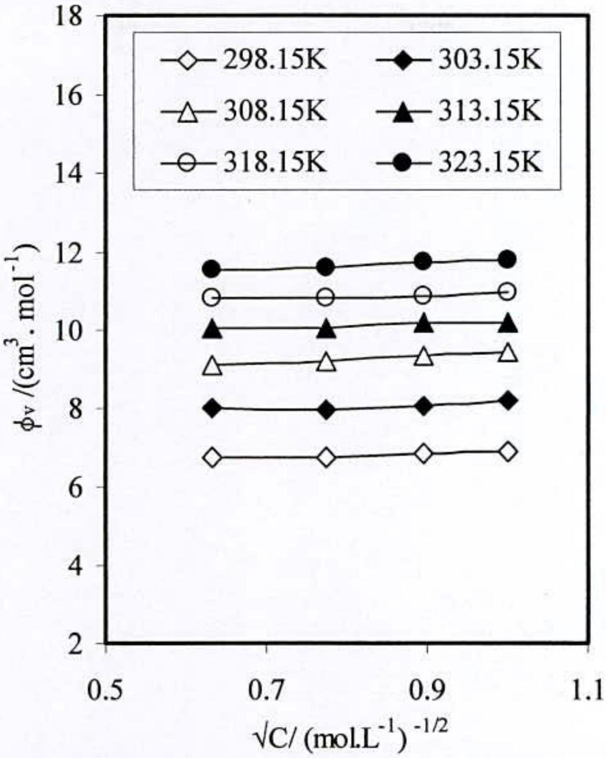


Figure 4.31: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

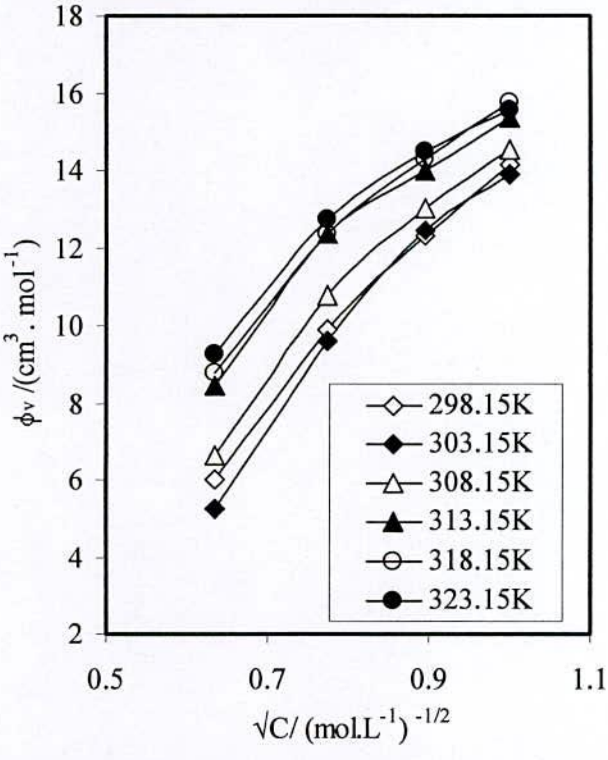


Figure 4.32: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 1% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

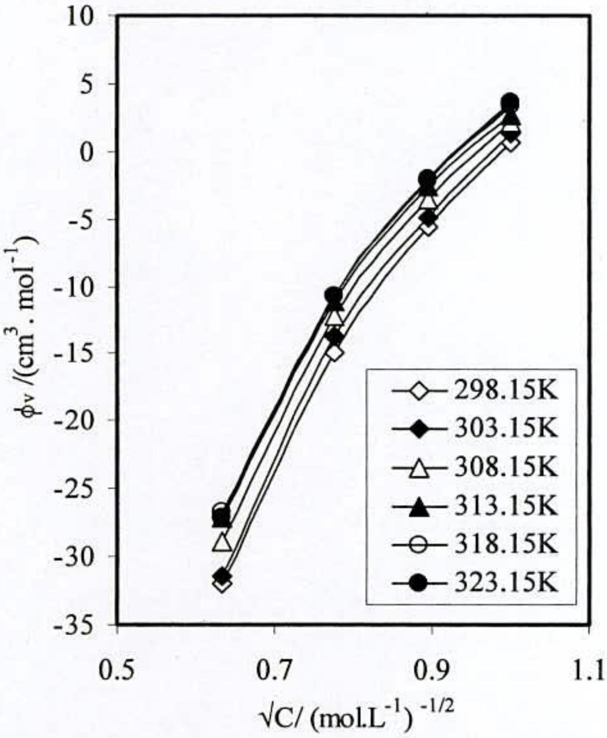


Figure 4.33: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 5% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

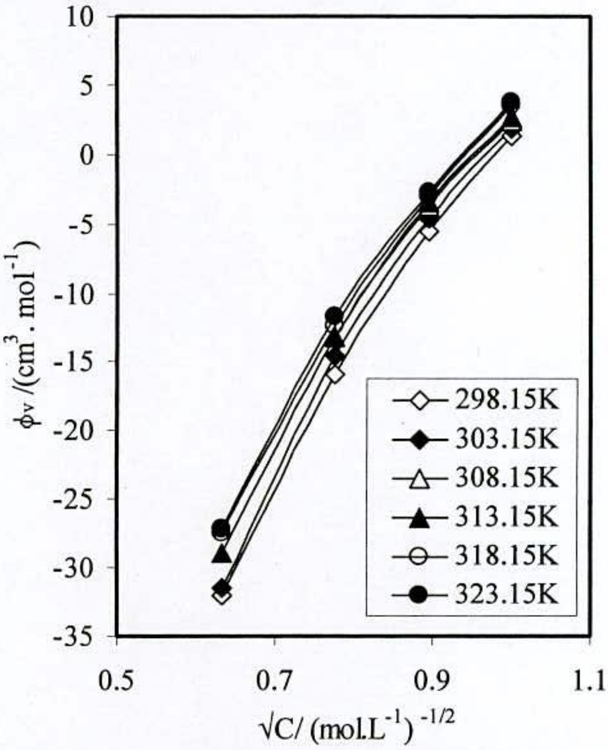


Figure 4.34: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 10% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

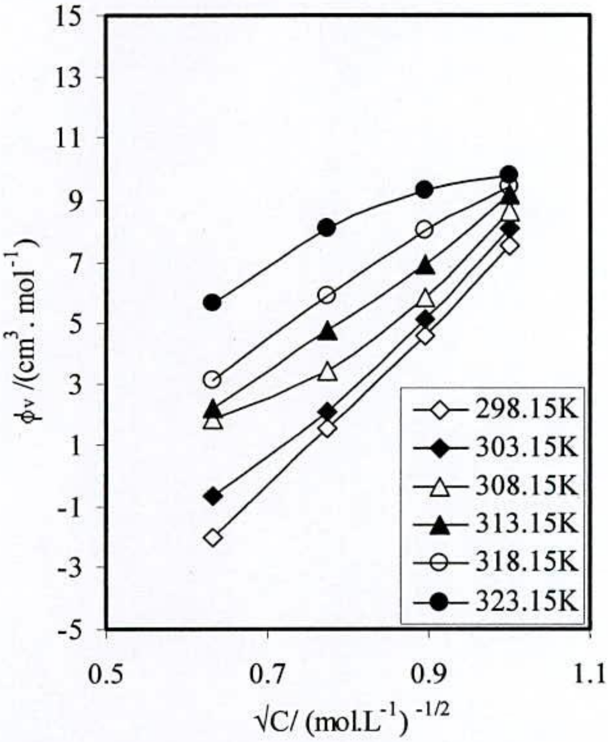


Figure 4.35: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 1% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

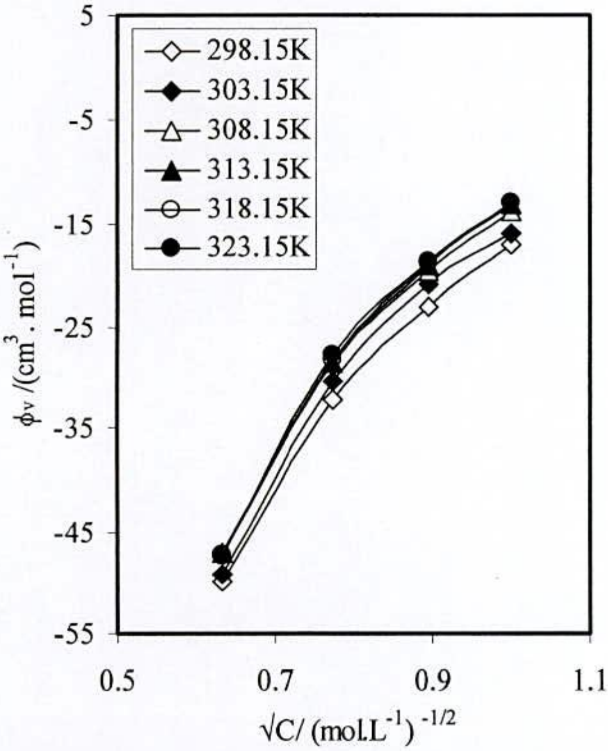


Figure 4.36: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 5% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

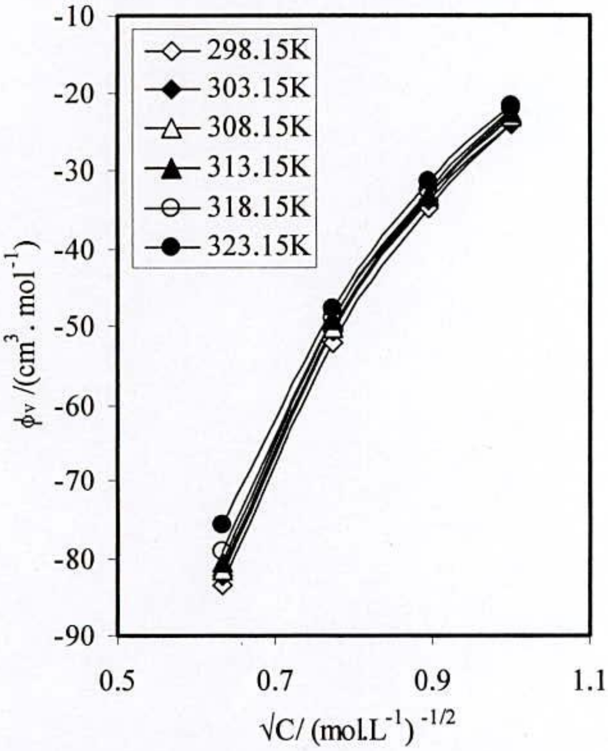


Figure 4.37: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 10% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

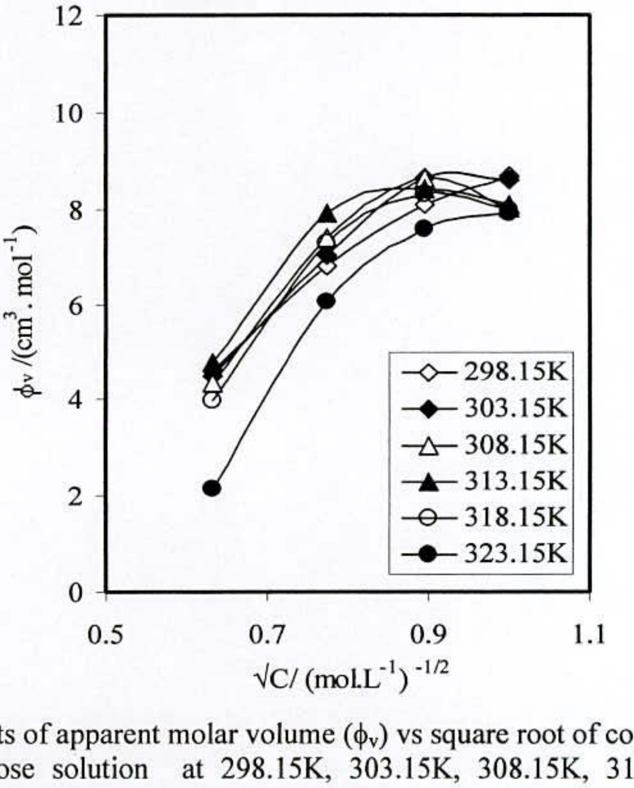


Figure 4.38: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 1% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

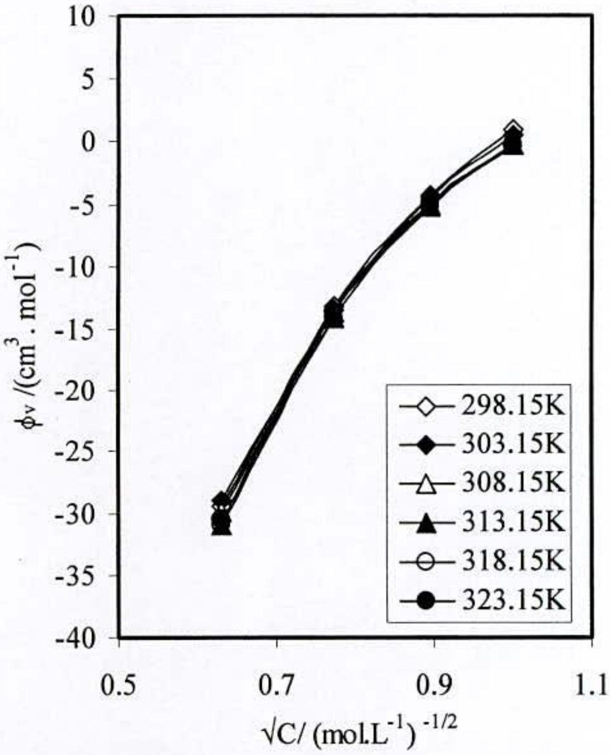


Figure 4.39: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 5% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

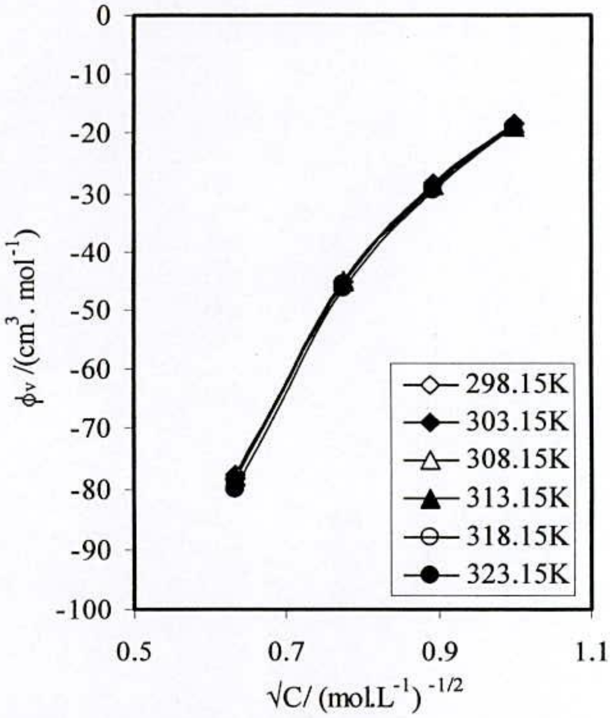


Figure 4.40: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 10% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

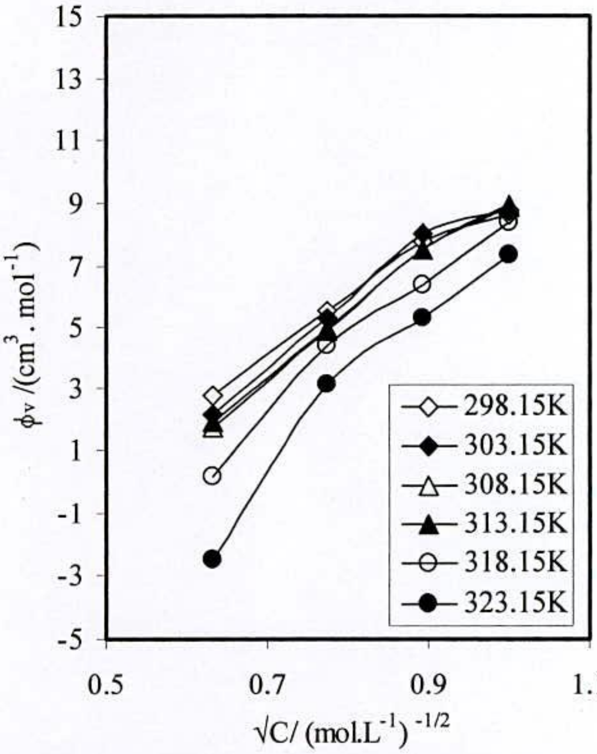


Figure 4.41: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 1% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

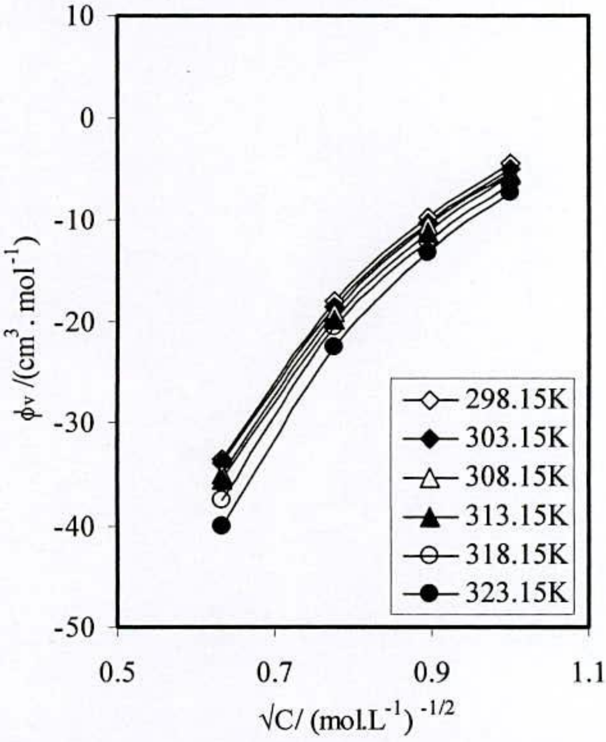


Figure 4.42: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 5%**(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

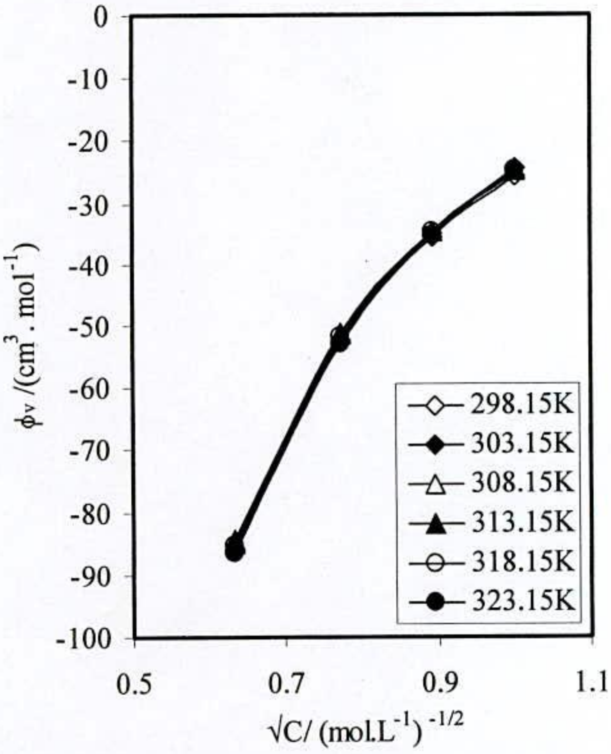


Figure 4.43: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 10% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

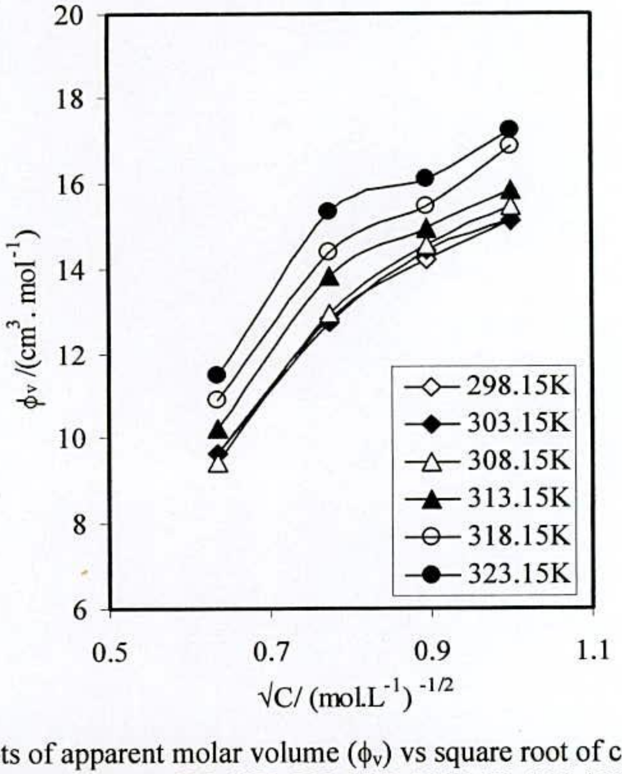


Figure 4.44: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 1% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

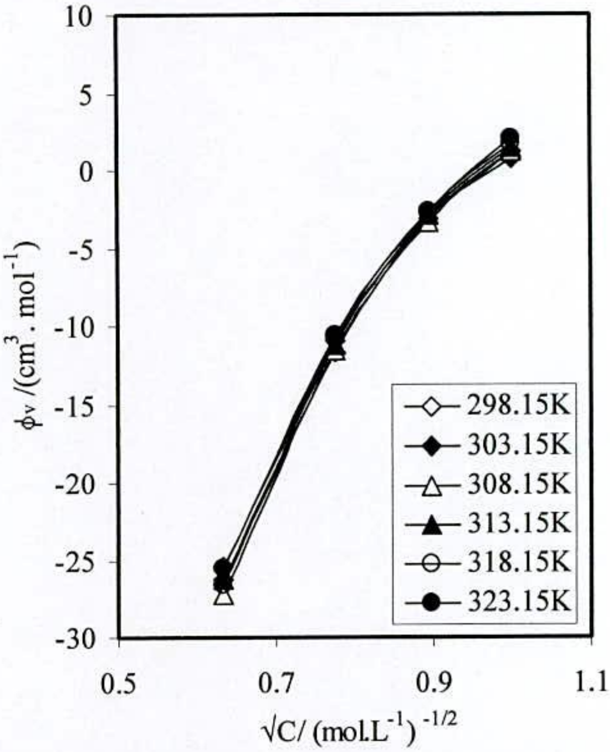


Figure 4.45: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 5% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

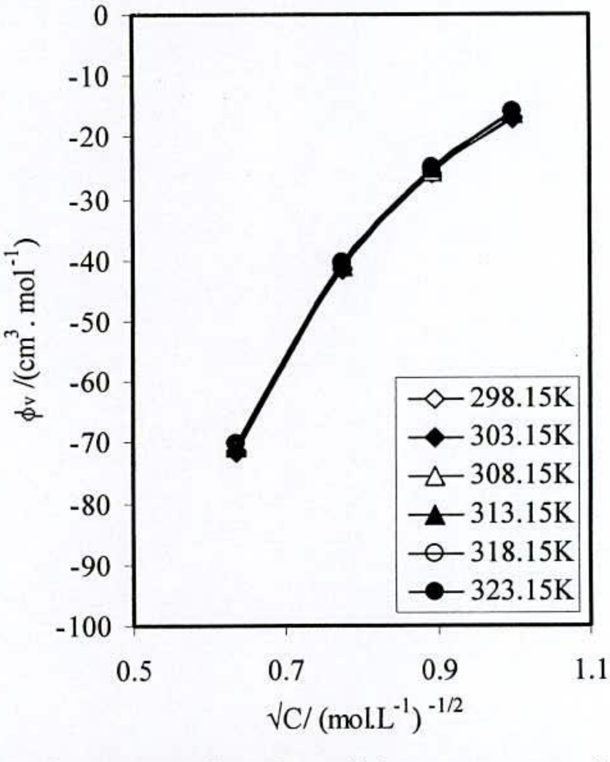


Figure 4.46: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of NaCl in 10% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

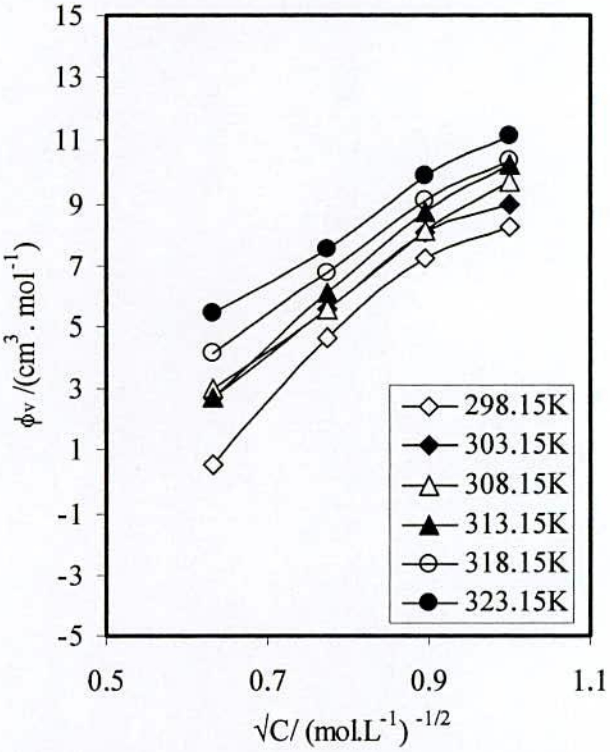


Figure 4.47: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 1% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

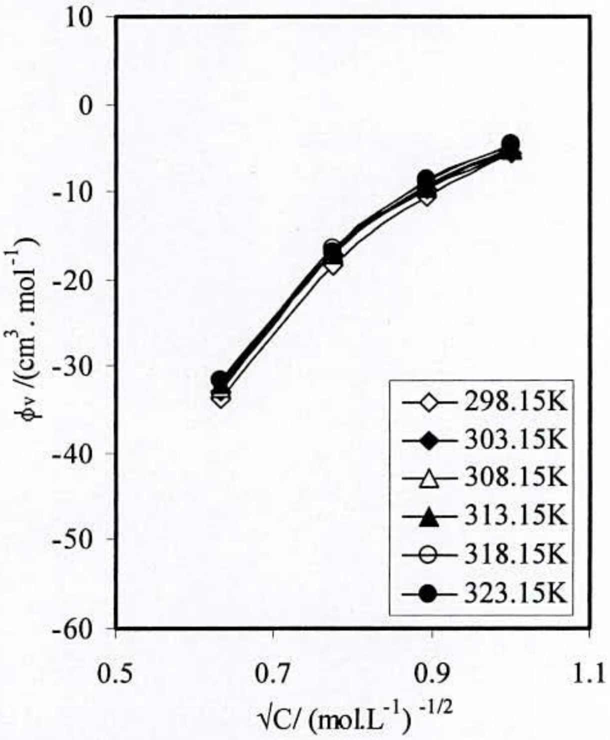


Figure 4.48: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 5% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

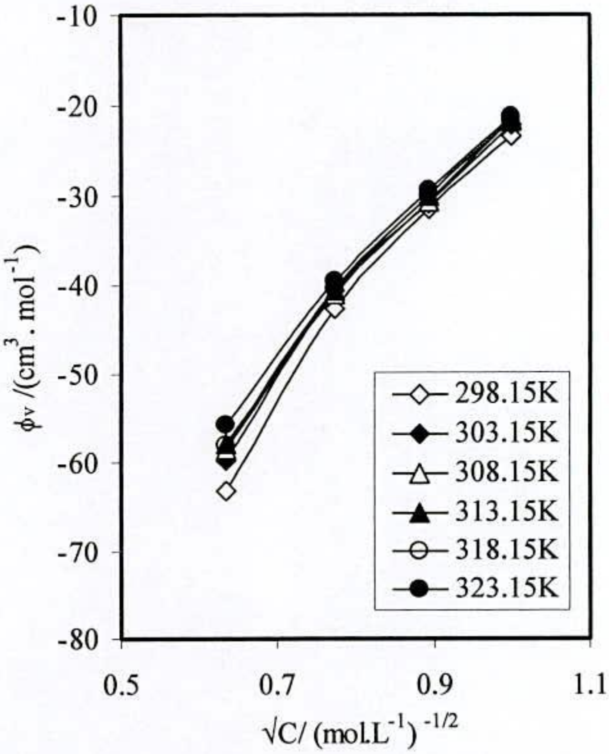


Figure 4.49: Plots of apparent molar volume (ϕ_v) vs square root of concentration (√c) of KCl in 10% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

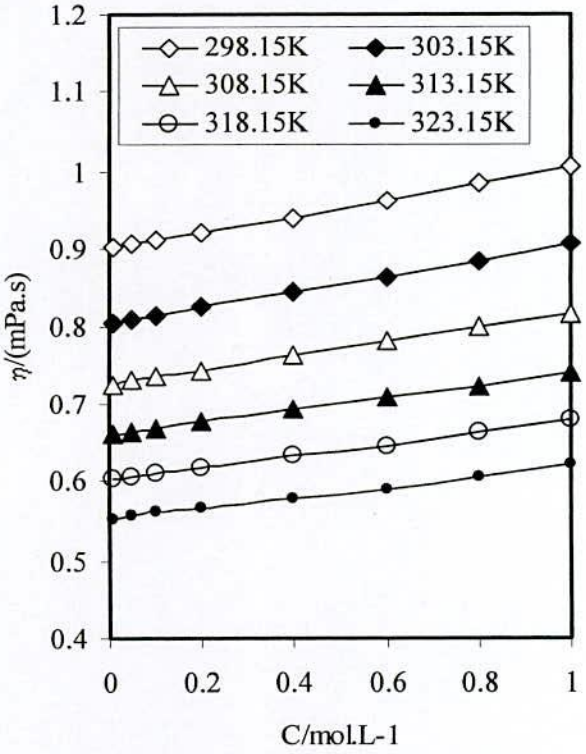


Figure 4.50: Plots of viscosity (η) vs concentration (c) of NaCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

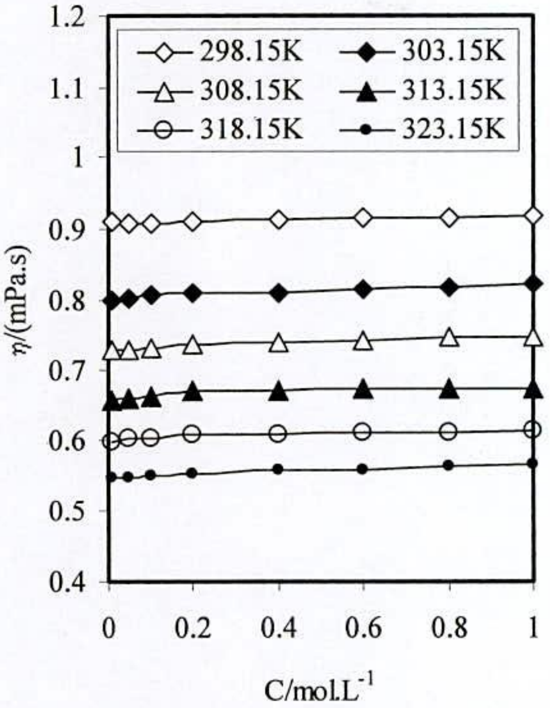


Figure 4.51: Plots of viscosity (η) vs concentration (c) of KCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

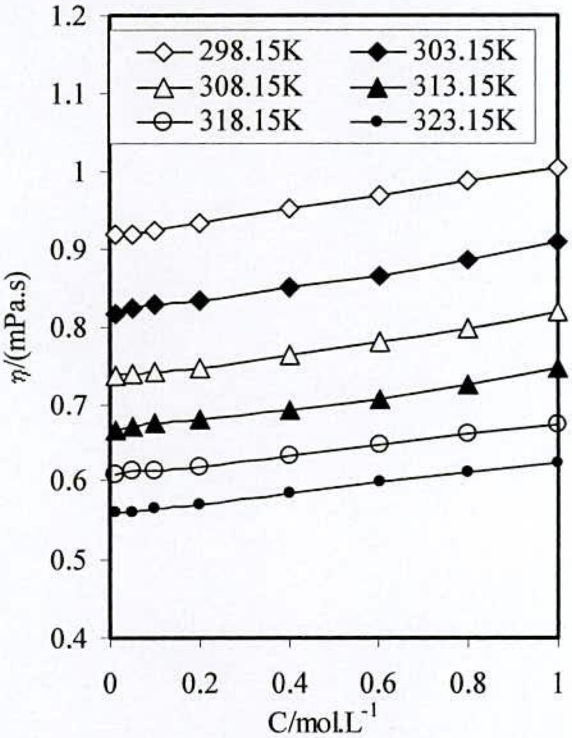


Figure 4.52: Plots of viscosity (η) vs concentration (c) of NaCl in 1% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

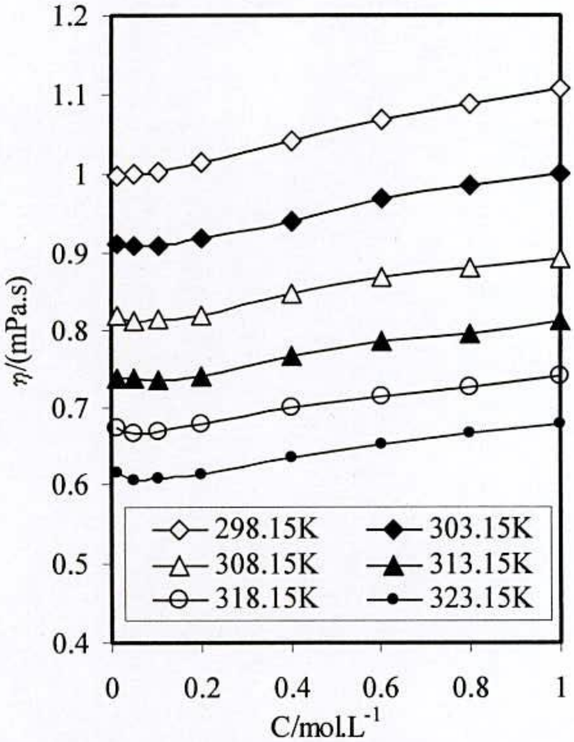


Figure 4.53: Plots of viscosity (η) vs concentration (c) of NaCl in 5% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

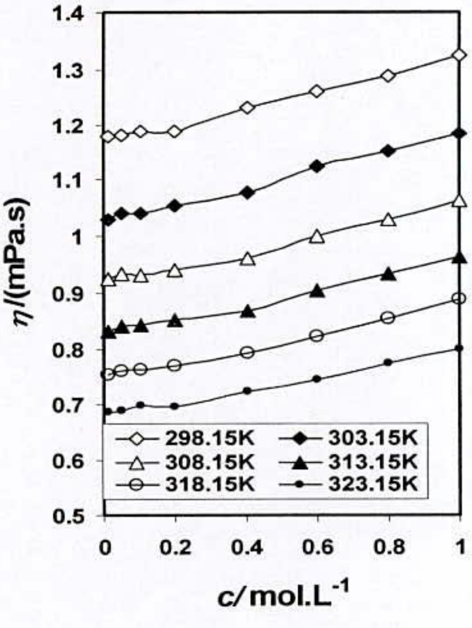


Figure 4.54: Plots of viscosity (η) vs concentration (c) of NaCl in 10% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

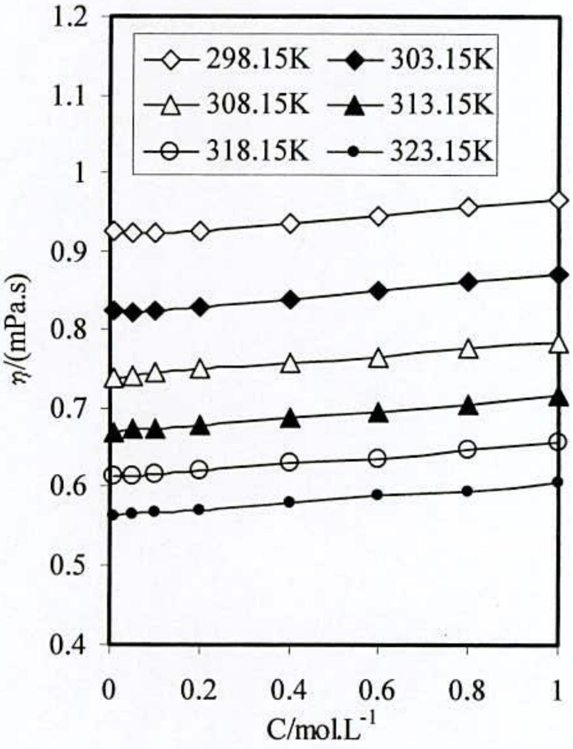


Figure 4.55: Plots of viscosity (η) vs concentration (c) of KCl in 1% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

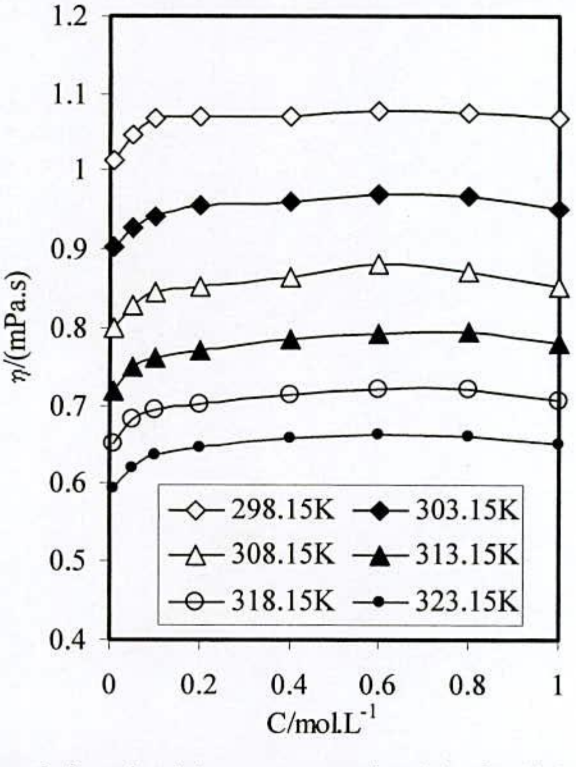


Figure 4.56: Plots of viscosity (η) vs concentration (c) of KCl in 5% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

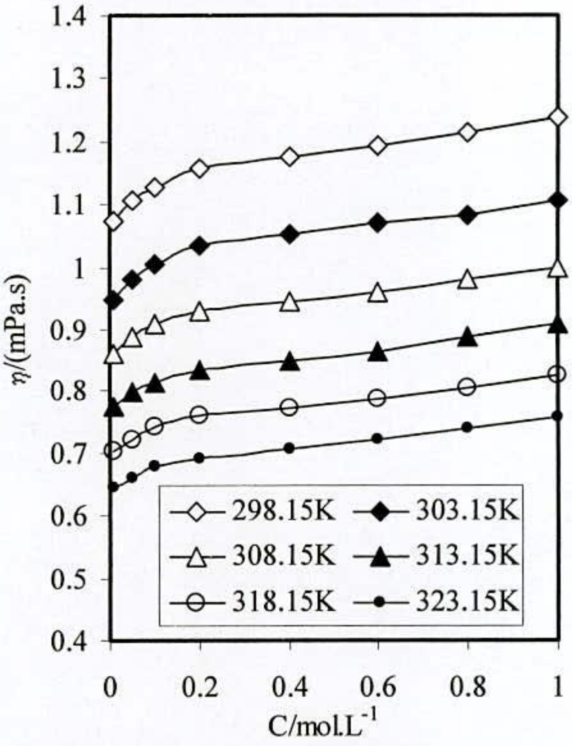


Figure 4.57: Plots of viscosity (η) vs concentration (c) of KCl in 10% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

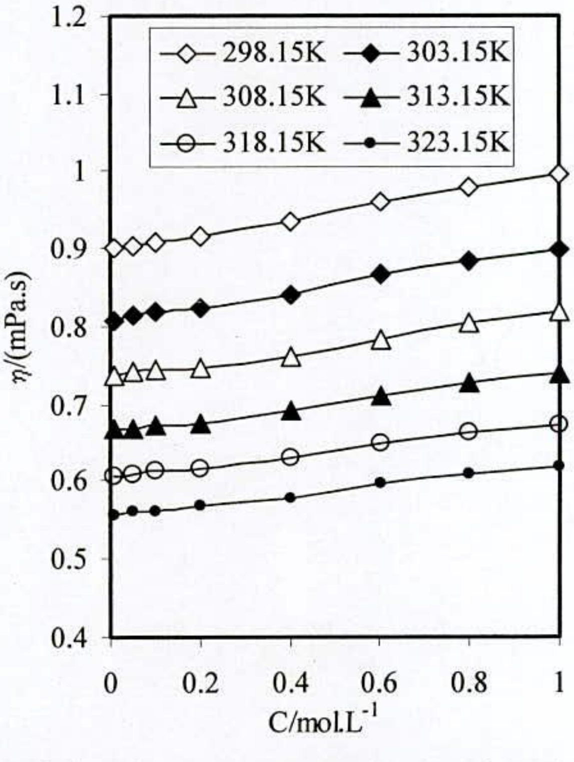


Figure 4.58: Plots of viscosity (η) vs concentration (c) of NaCl in 1% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

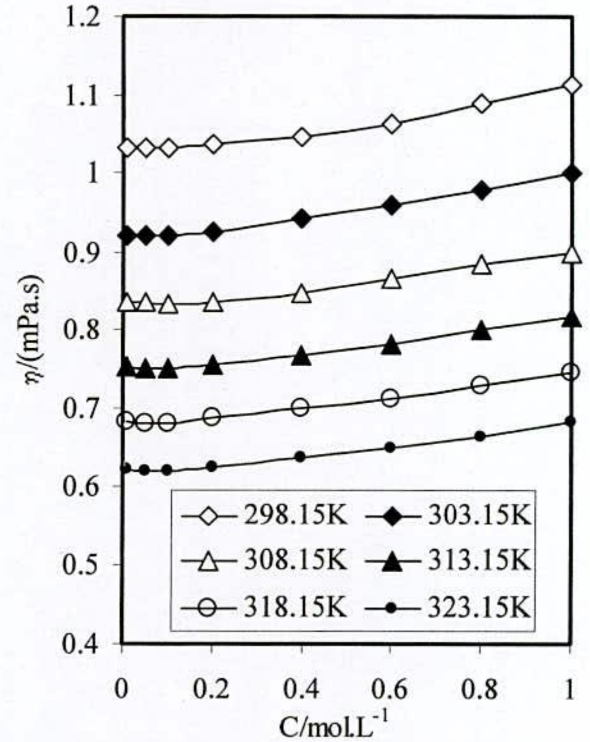


Figure 4.59: Plots of viscosity (η) vs concentration (c) of NaCl in 5% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

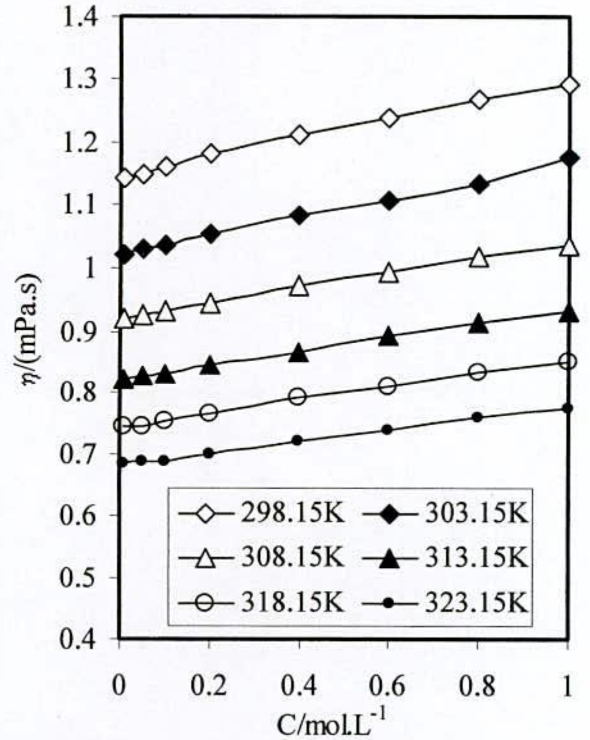


Figure 4.60: Plots of viscosity (η) vs concentration (c) of NaCl in 10% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

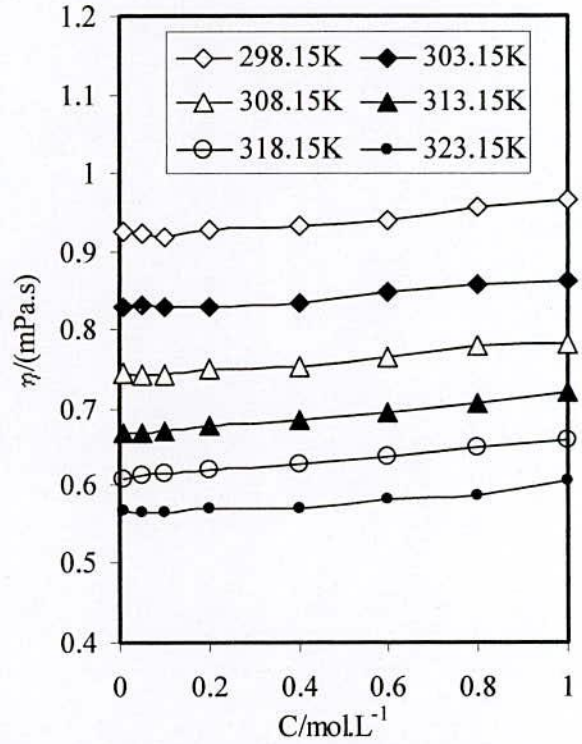


Figure 4.61: Plots of viscosity (η) vs concentration (c) of KCl in 1% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

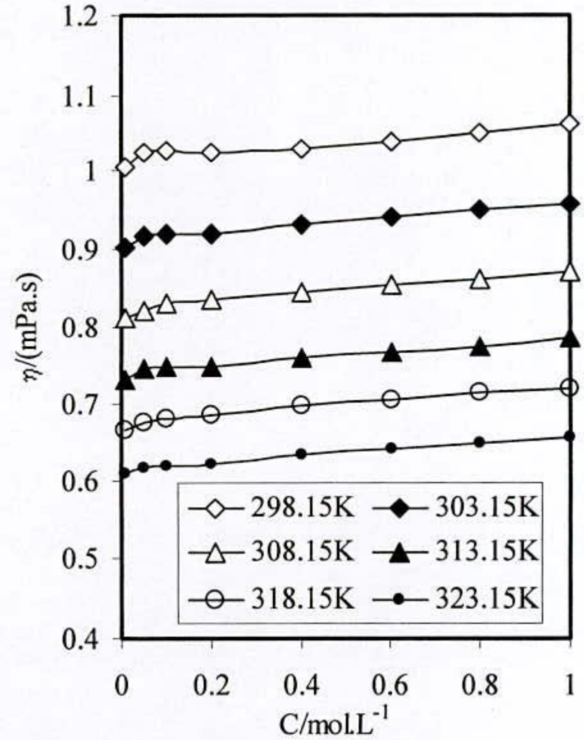


Figure 4.62: Plots of viscosity (η) vs concentration (c) of KCl in 5% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

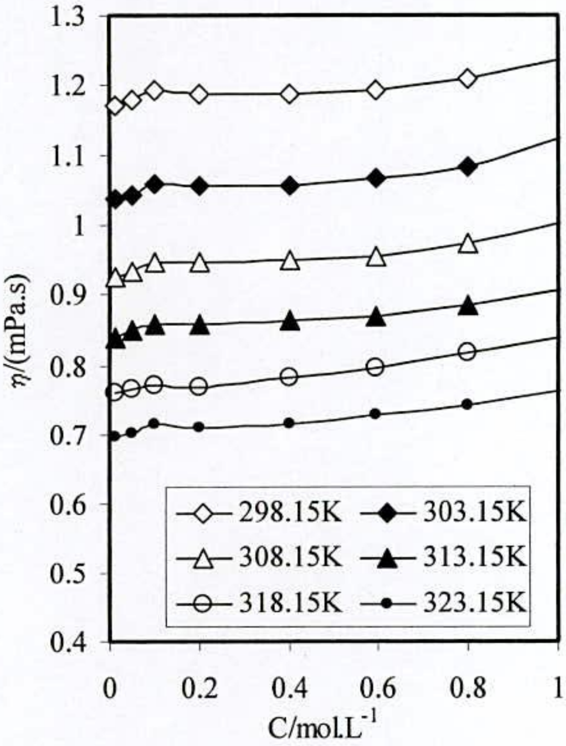


Figure 4.63: Plots of viscosity (η) vs concentration (c) of KCl in 10% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

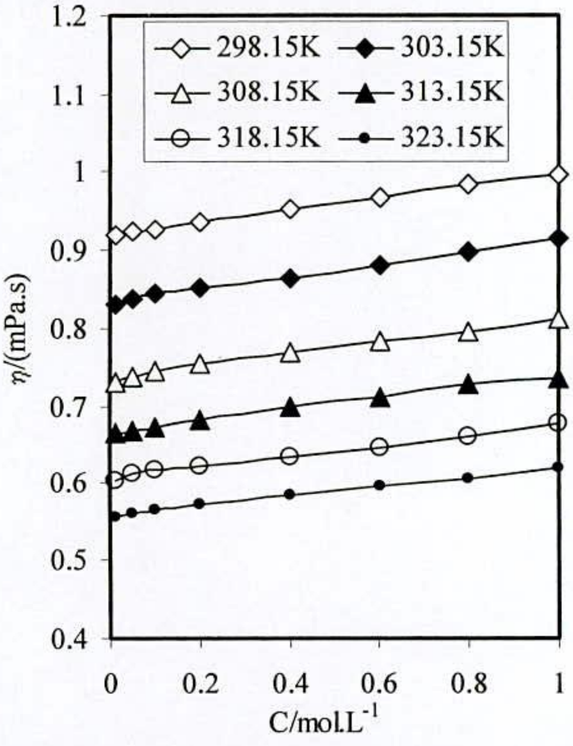


Figure 4.64: Plots of viscosity (η) vs concentration (c) of NaCl in 1% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

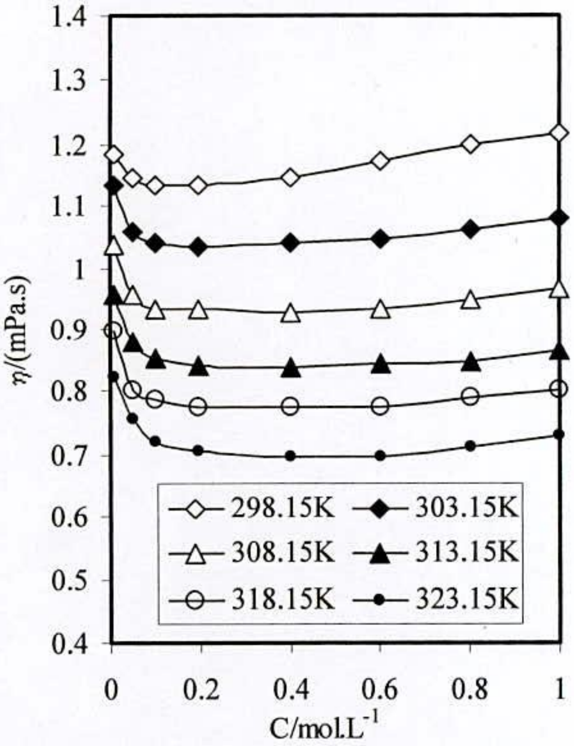


Figure 4.65: Plots of viscosity (η) vs concentration (c) of NaCl in 5% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

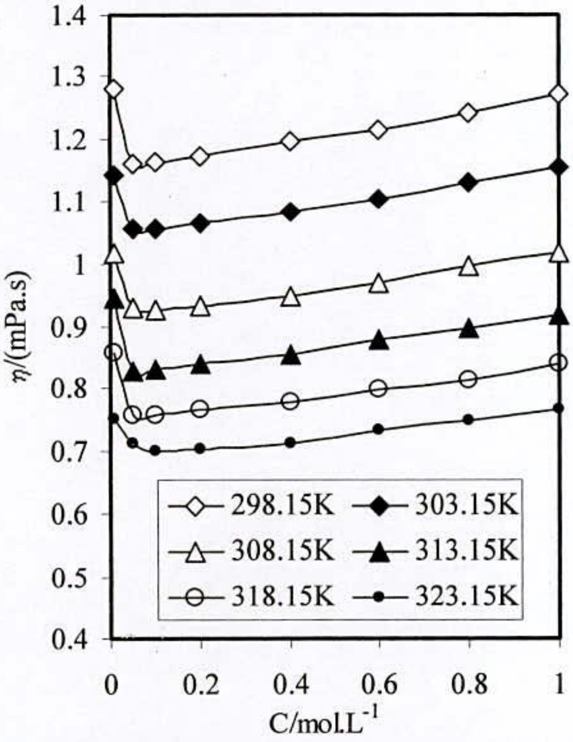


Figure 4.66: Plots of viscosity (η) vs concentration (c) of NaCl in 10% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

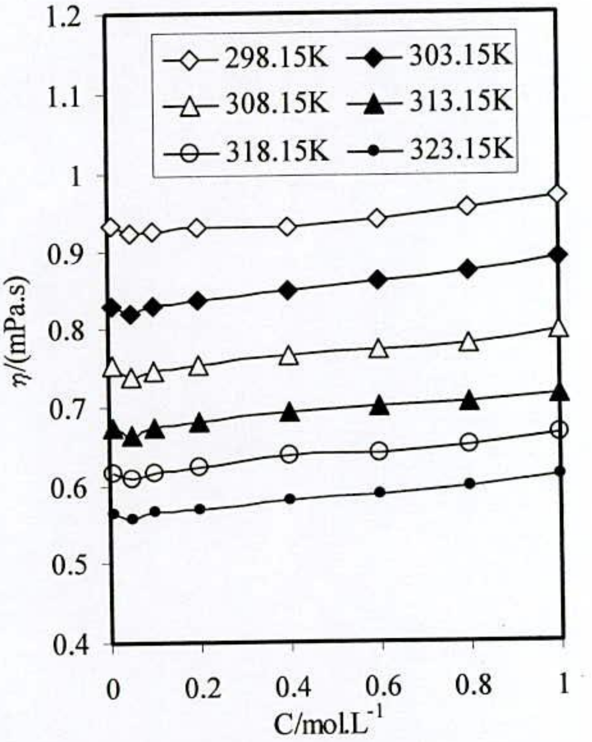


Figure 4.67: Plots of viscosity (η) vs concentration (c) of KCl in 1% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

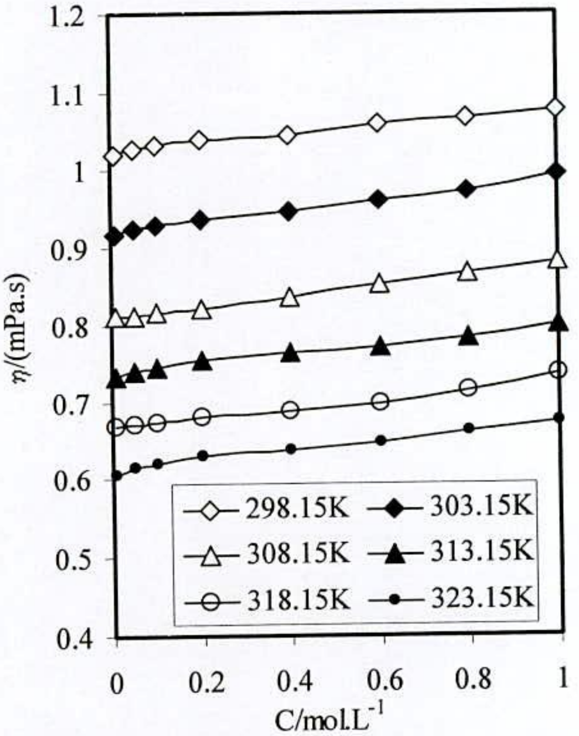


Figure 4.68: Plots of viscosity (η) vs concentration (c) of KCl in 5% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

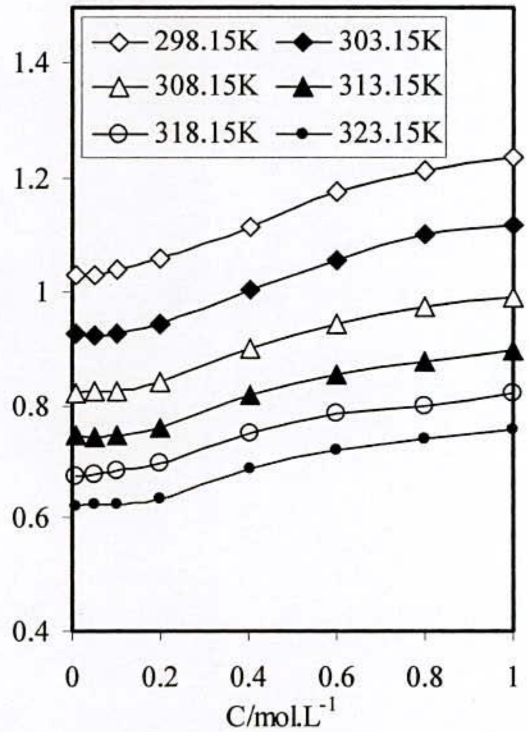


Figure 4.69: Plots of viscosity (η) vs concentration (c) of KCl in 10% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

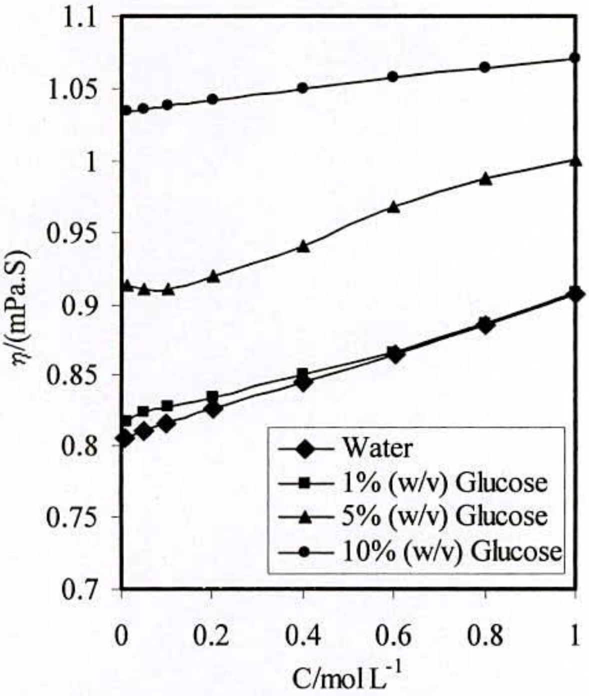


Figure 4.70: Comparison of viscosity (η) vs concentration (c) of NaCl in water, 1% (w/v), 5%(w/v) and 10% (w/v) Glucose solution at 303.15K.

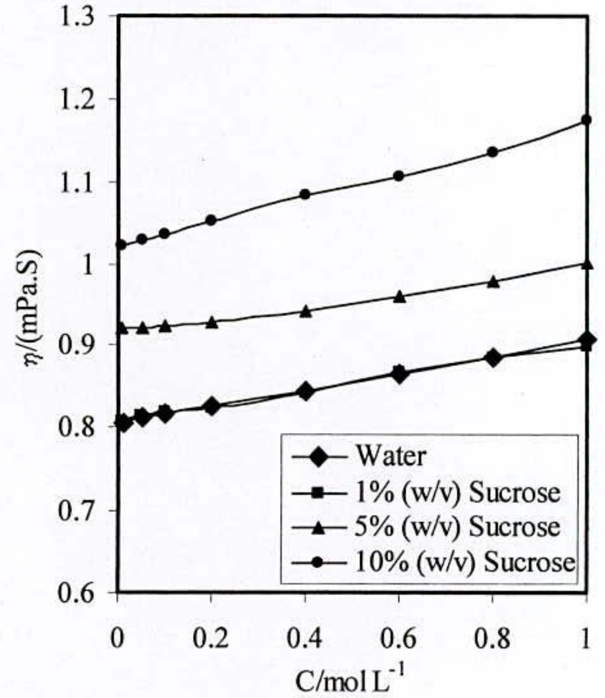


Figure 4.71: Comparison of viscosity (η) vs concentration (c) of NaCl in water, 1%(w/v), 5%(w/v) and 10% (w/v) Sucrose solution at 303.15K.

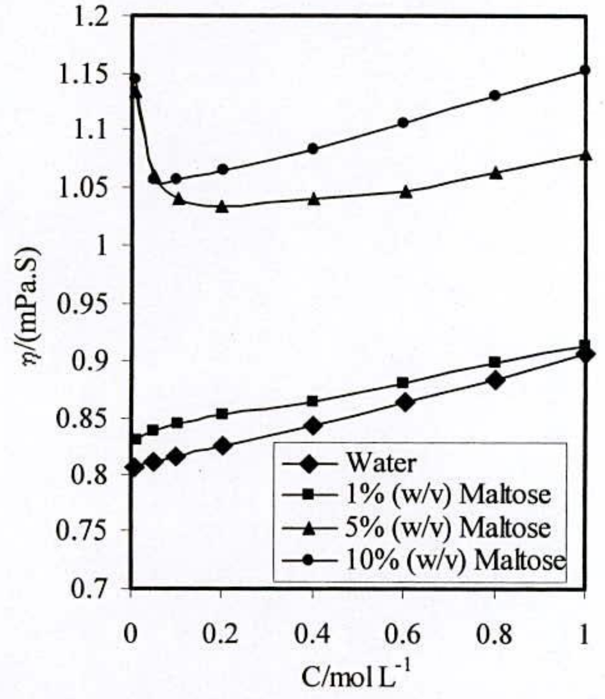


Figure 4.72: Comparison of viscosity (η) vs concentration (c) of NaCl in water, 1% (w/v), 5%(w/v) and 10%(w/v) Maltose solution at 303.15K.

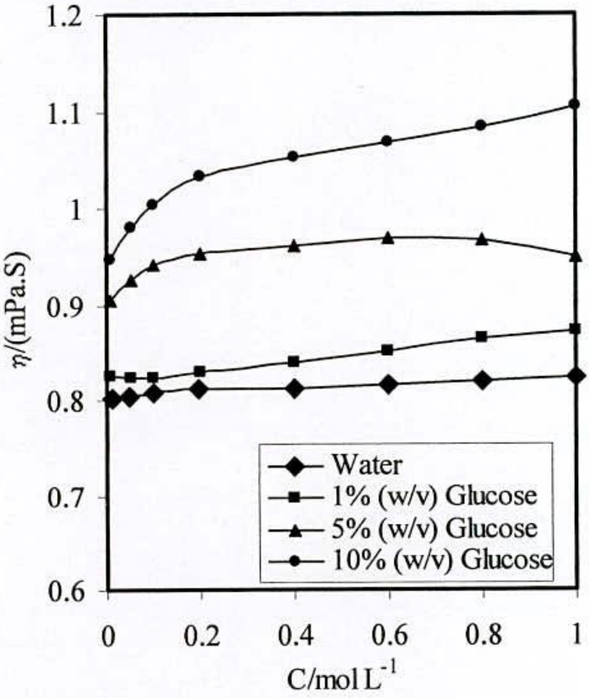


Figure 4.73: Comparison of viscosity (η) vs concentration (c) of KCl in water, 1%(w/v), 5%(w/v) and 10%(w/v) Glucose solution at 303.15K.

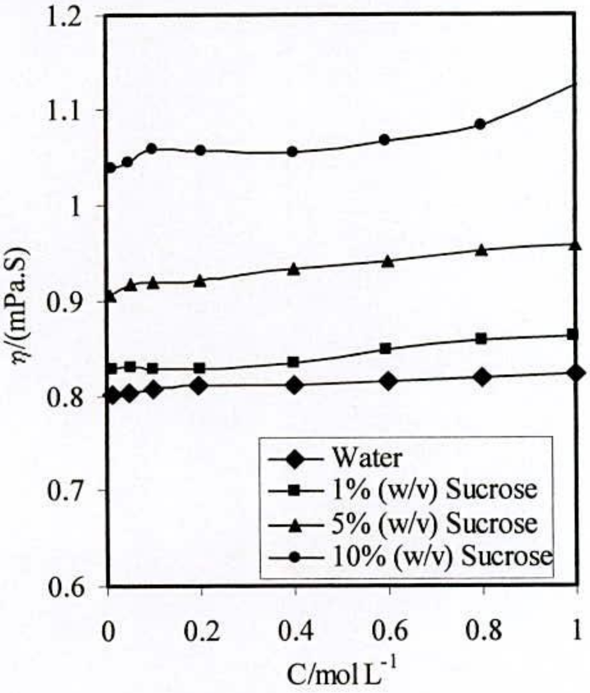


Figure 4.74: Comparison of viscosity (η) vs concentration (c) of KCl in water, 1%(w/v), 5%(w/v) and 10% (w/v) Sucrose solution at 303.15K.

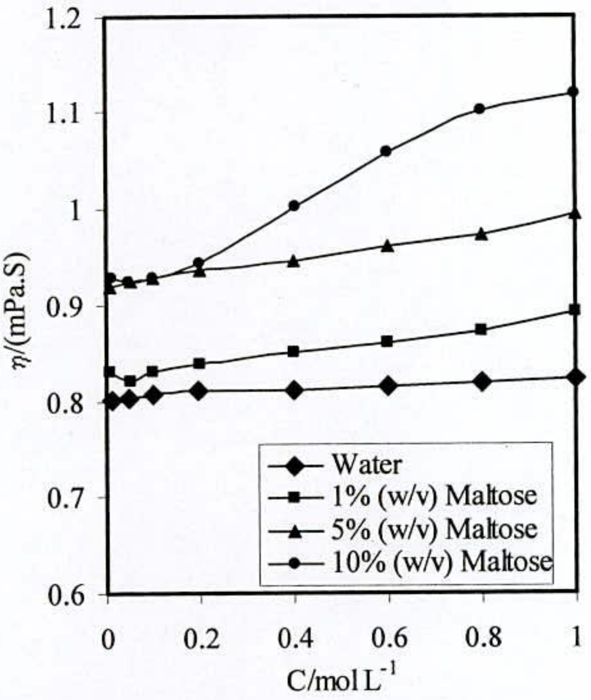


Figure 4.75: Comparison of viscosity (η) vs concentration (c) of KCl in water, 1%(w/v), 5%(w/v) and 10% (w/v) Maltose solution at 303.15K.

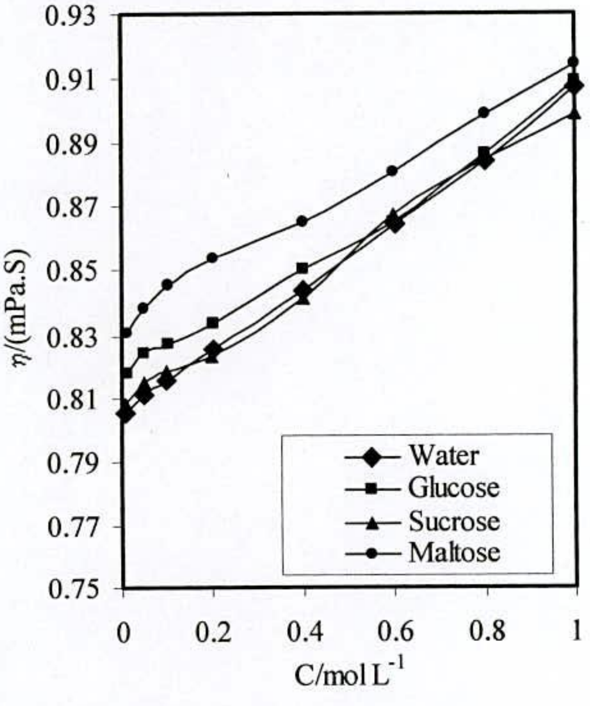


Figure4.76: Comparison of viscosity (η) vs concentration (c) of NaCl in water, 1% (w/v) Glucose, 1% (w/v) Sucrose and 1% (w/v) Maltose solution at 303.15K.

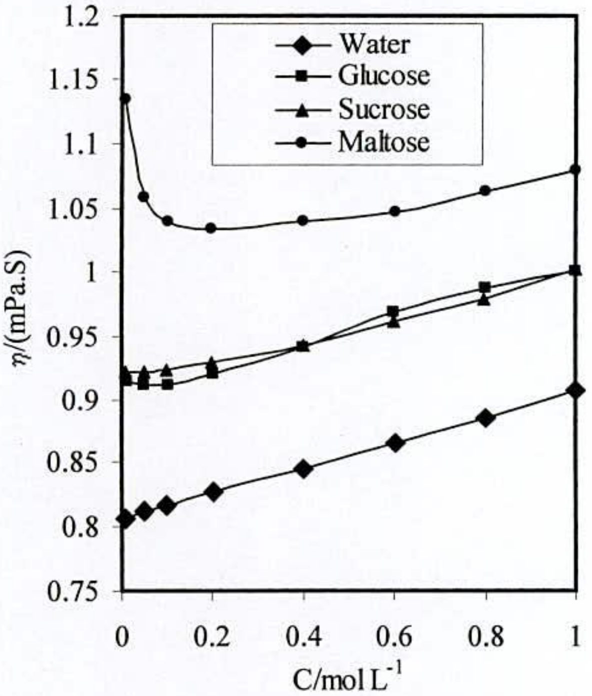


Figure 4.77: Comparison of viscosity (η) vs concentration (c) of NaCl in water, 5% (w/v) Glucose, 5% (w/v) Sucrose and 5% (w/v) Maltose solution at 303.15K.

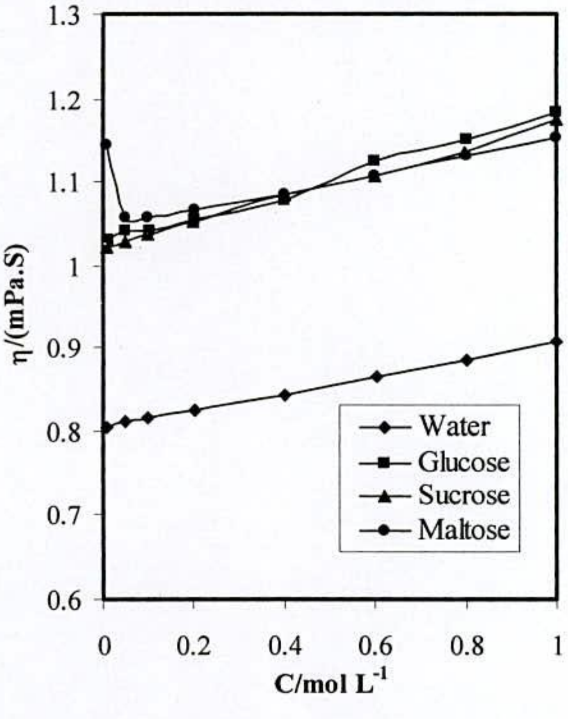


Figure 4.78: Comparison of viscosity (η) vs concentration (c) of NaCl in water, 10% (w/v) Glucose, 10% (w/v) Sucrose and 10% (w/v) Maltose solution at 303.15K.

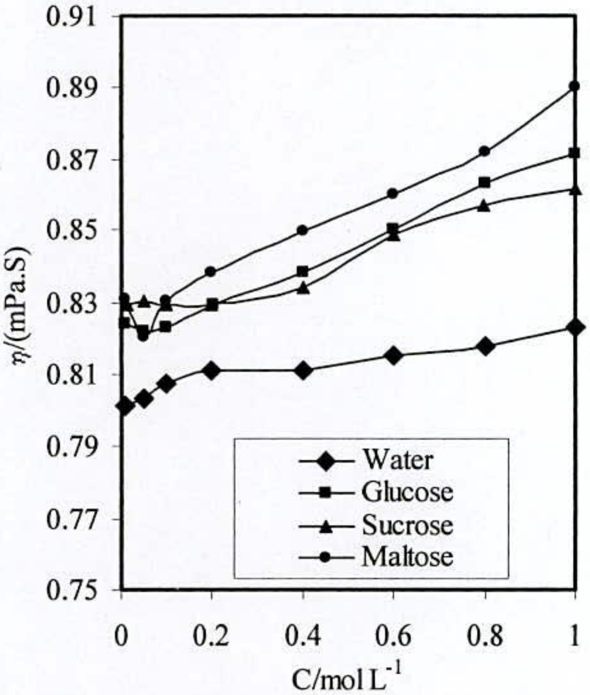


Figure 4.79: Comparison of viscosity (η) vs concentration (c) of KCl in water, 1% (w/v) Glucose, 1% (w/v) Sucrose and 1% (w/v) Maltose solution at 303.15K.

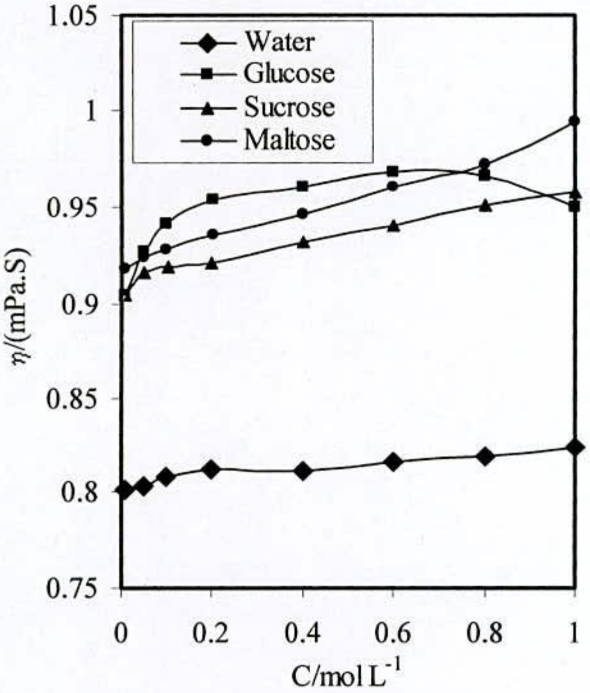


Figure 4.80: Comparison of viscosity (η) vs concentration (c) of KCl in water, 5% (w/v) Glucose, 5% (w/v) Sucrose and 5% (w/v) Maltose solution at 303.15K.

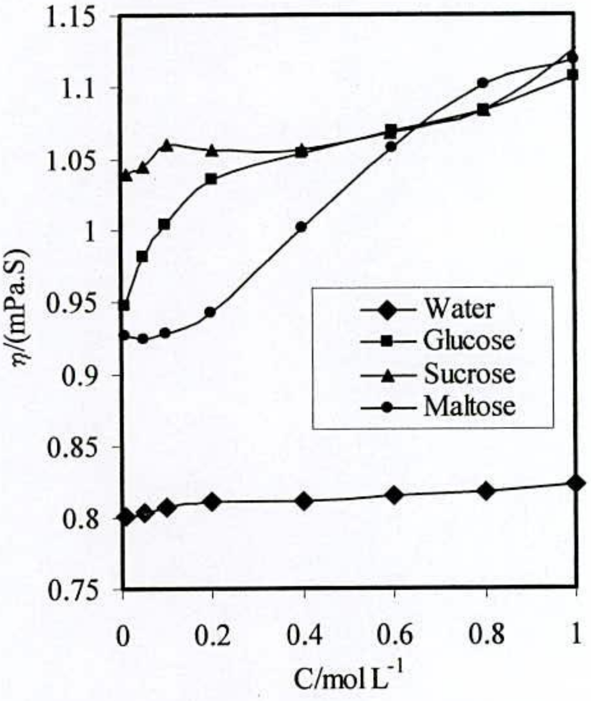


Figure 4.81: Comparison of viscosity (η) vs concentration (c) of KCl in water, 10% (w/v) Glucose, 10% (w/v) Sucrose and 10% (w/v) Maltose solution at 303.15K.

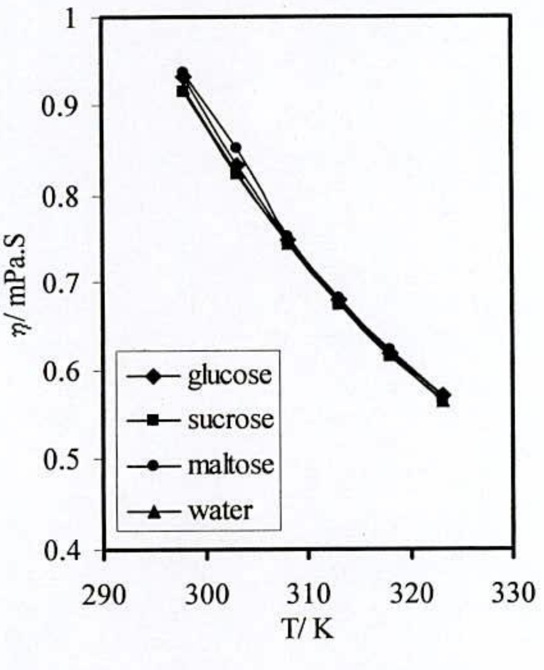


Figure 4.82: Comparison of viscosity (η) vs temperature (T) of NaCl in water, 1%(w/v) Glucose, 1%(w/v) Sucrose and 1%(w/v) Maltose solution at 0.2M concentration.

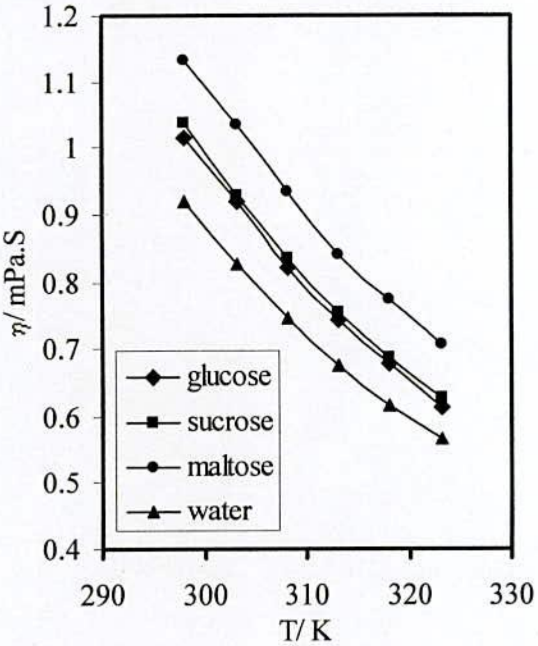


Figure 4.83: Comparison of viscosity (η) vs temperature (T) of NaCl in water, 5% (w/v) Glucose, 5% (w/v) Sucrose and 5% (w/v) Maltose solution at 0.2M concentration.

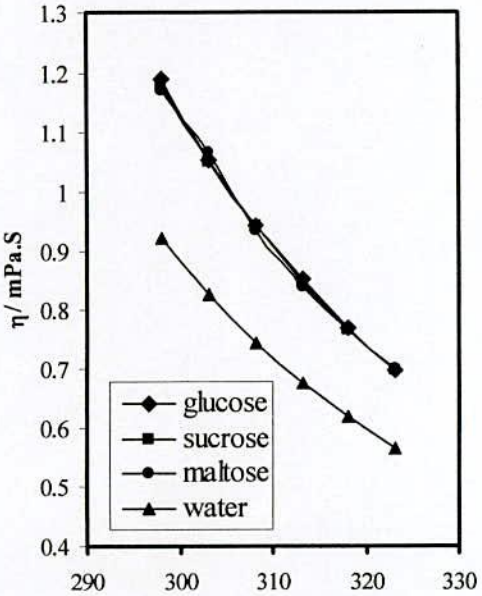


Figure 4.84: Comparison of viscosity (η) vs temperature (T) of NaCl in water, 10%(w/v) Glucose, 10%(w/v) Sucrose and 10%(w/v) Maltose solution at 0.2M concentration.

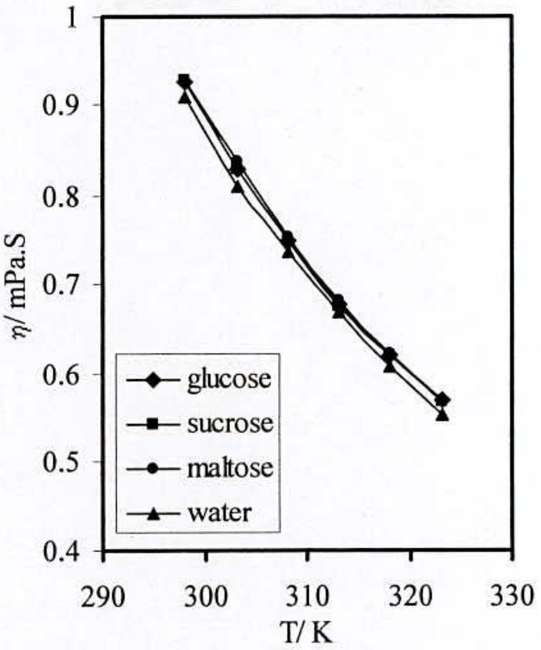


Figure 4.85: Comparison of viscosity (η) vs temperature (T) of KCl in water, 1%(w/v) Glucose, 1%(w/v) Sucrose and 1%(w/v) Maltose solution at 0.2M concentration.

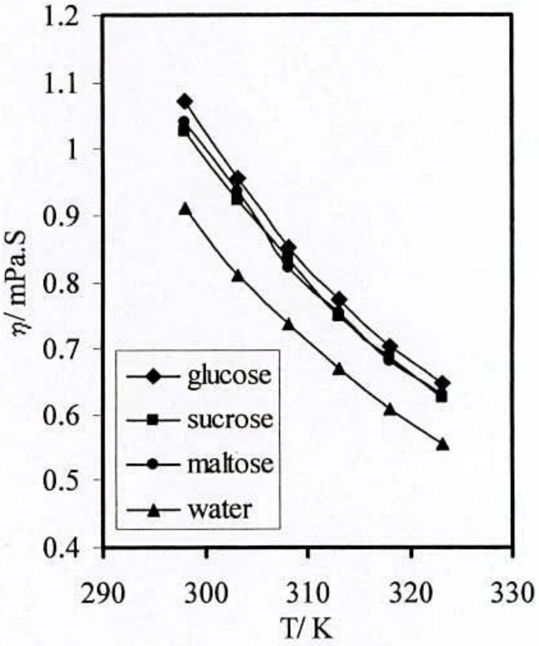


Figure 4.86: Comparison of viscosity (η) vs temperature (T) of KCl in water, 5% (w/v) Glucose, 5% (w/v Sucrose and 5% (w/v) Maltose solution at 0.2M concentration.

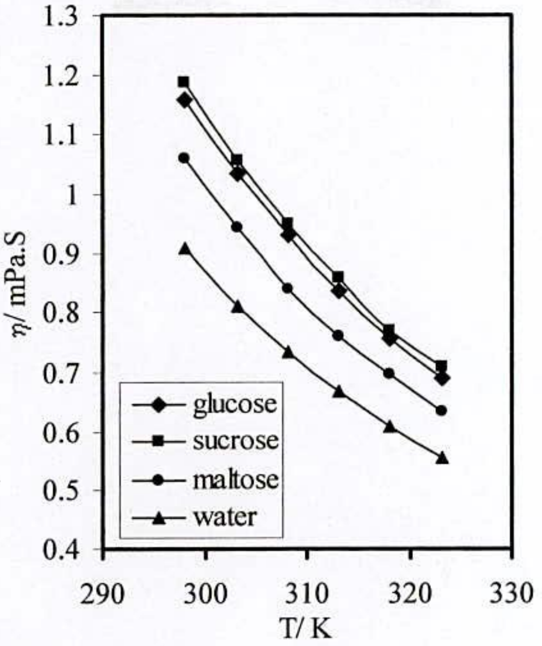


Figure 4.87: Comparison of viscosity (η) vs temperature (T) of KCl in water, 10% (w/v) Glucose, 10% (w/v) Sucrose and 10% (w/v) Maltose solution at 0.2M concentration.

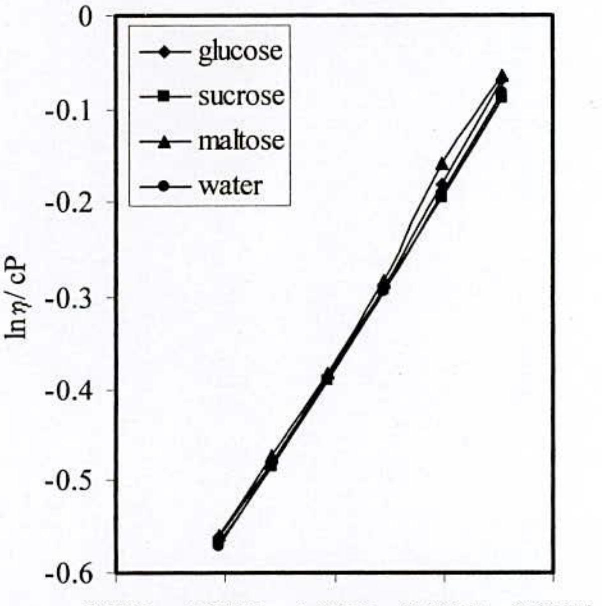


Figure 4.88: Comparison of ln η vs 1/T of NaCl in water, 1% (w/v) Glucose, 1% (w/v) Sucrose and 1% (w/v) Maltose solution at 0.2M concentration.

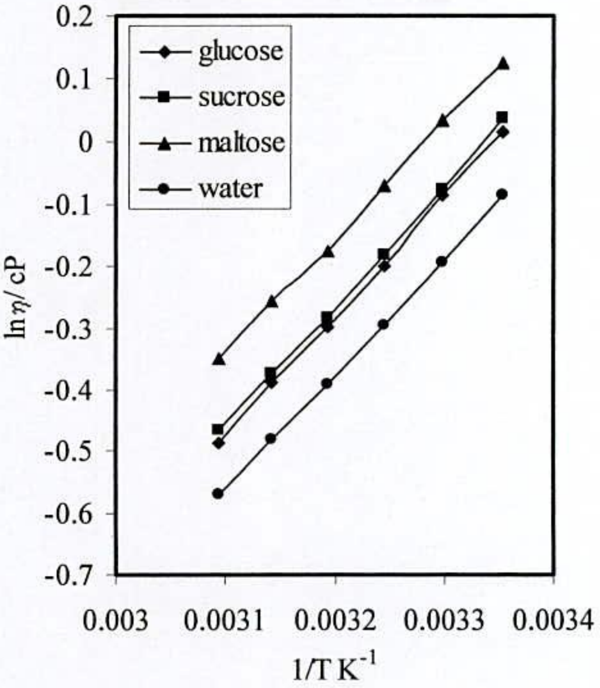


Figure 4.89: Comparison of ln η vs 1/T of NaCl in water, 5% (w/v) Glucose, 5% (w/v) Sucrose and 5% (w/v) Maltose solution at 0.2M concentration.

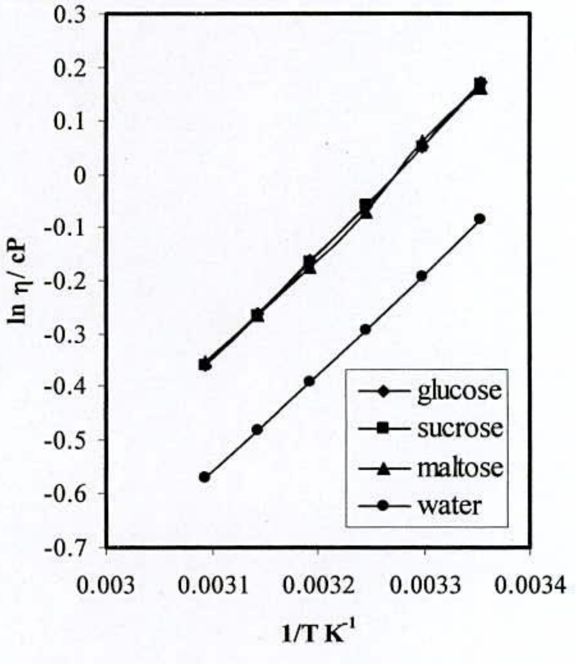


Figure 4.90: Comparison of ln η vs 1/T of NaCl in water, 10% (w/v) Glucose, 10% (w/v) Sucrose and 10% (w/v) Maltose solution at 0.2M concentration.

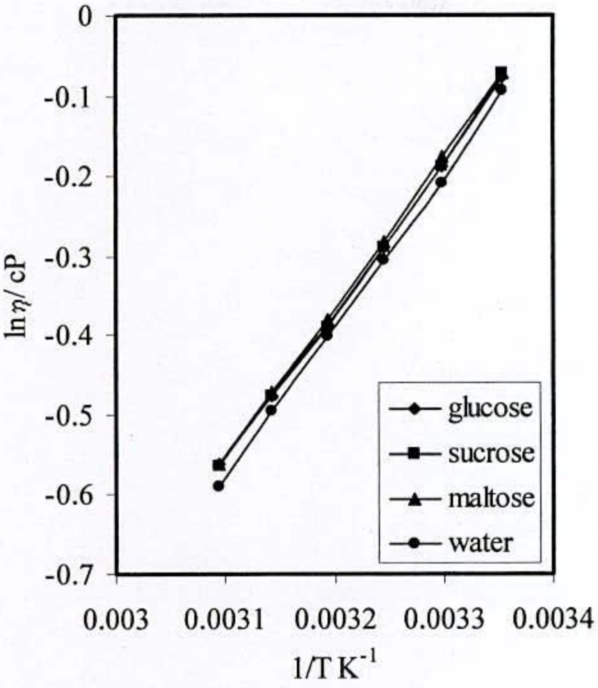


Figure 4.91: Comparison of ln η vs 1/T of KCl in water, 1% (w/v) Glucose, 1% (w/v) Sucrose and 1% (w/v) Maltose solution at 0.2M concentration.

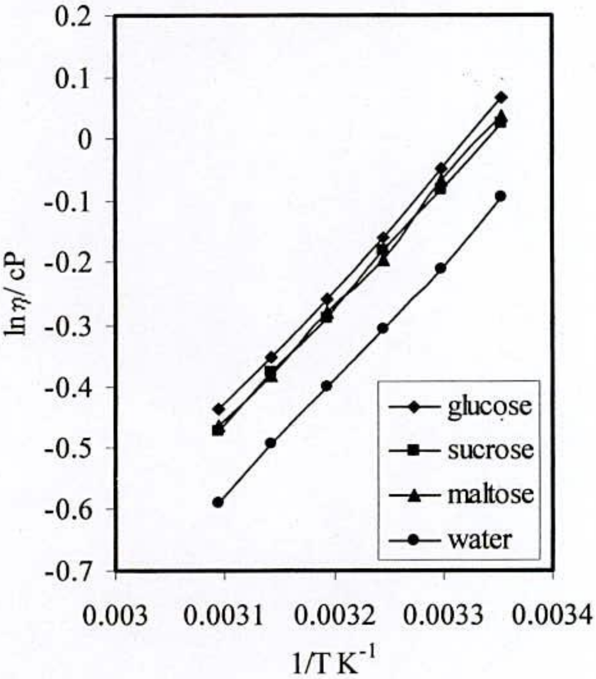


Figure 4.92: Comparison of ln η vs 1/T of KCl in water, 5% (w/v) Glucose, 5% (w/v) Sucrose and 5% (w/v) Maltose solution at 0.2M concentration.

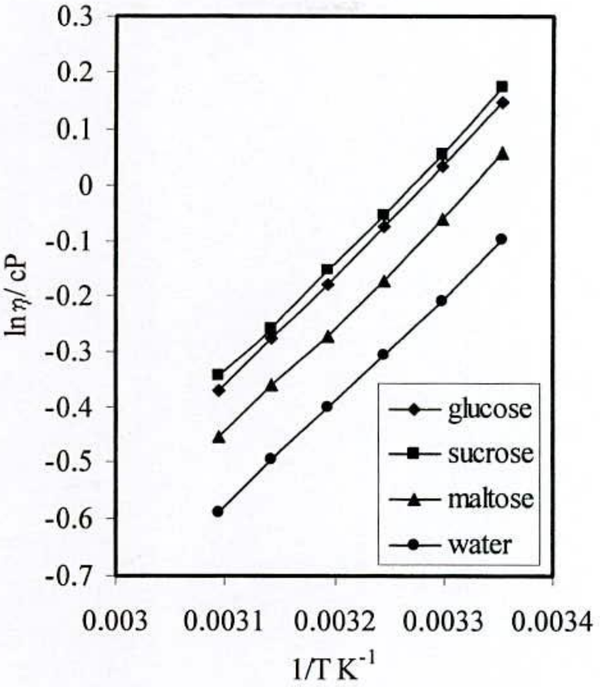


Figure 4.93: Comparison of ln η vs 1/T of KCl in water, 10% (w/v) Glucose, 10% (w/v) Sucrose and 10% (w/v) Maltose solution at 0.2M concentration.

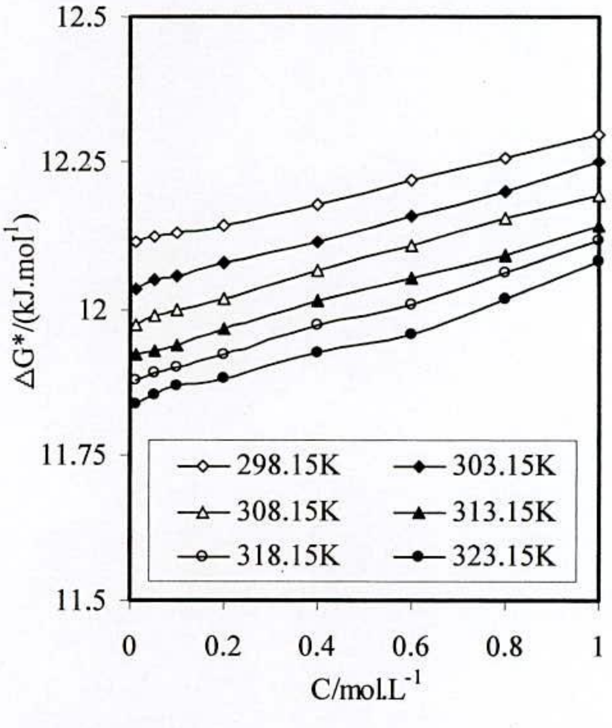


Figure 4.94: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

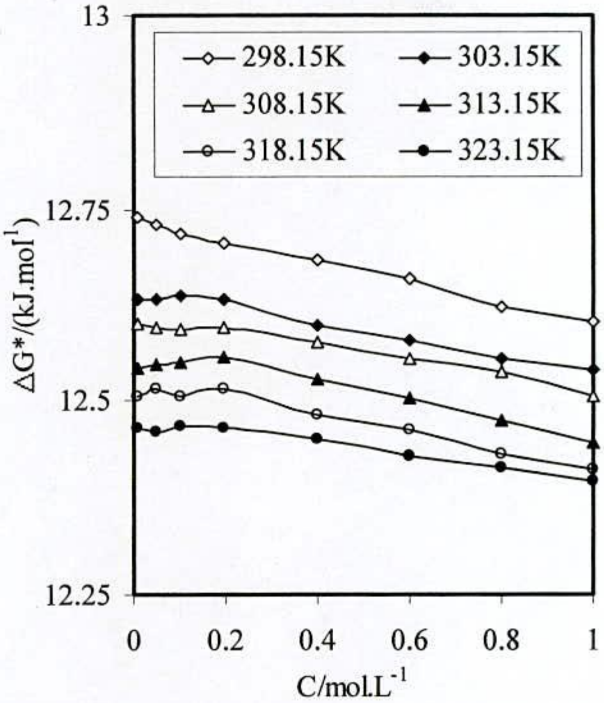


Figure 4.95: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in aqueous solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

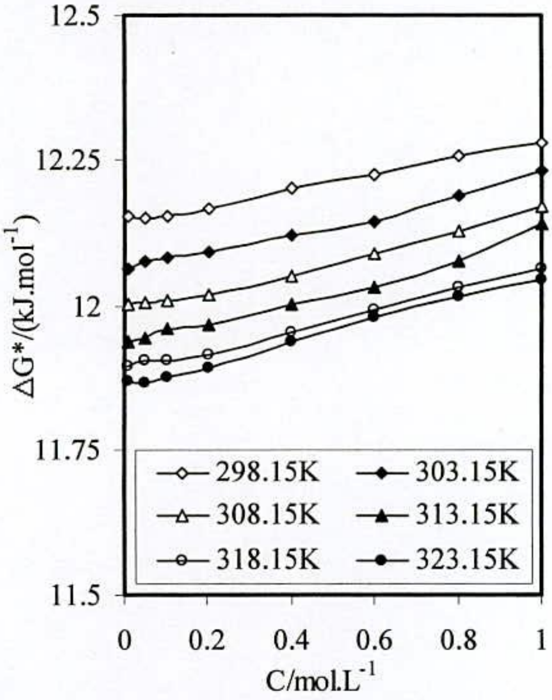


Figure 4.96: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 1% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

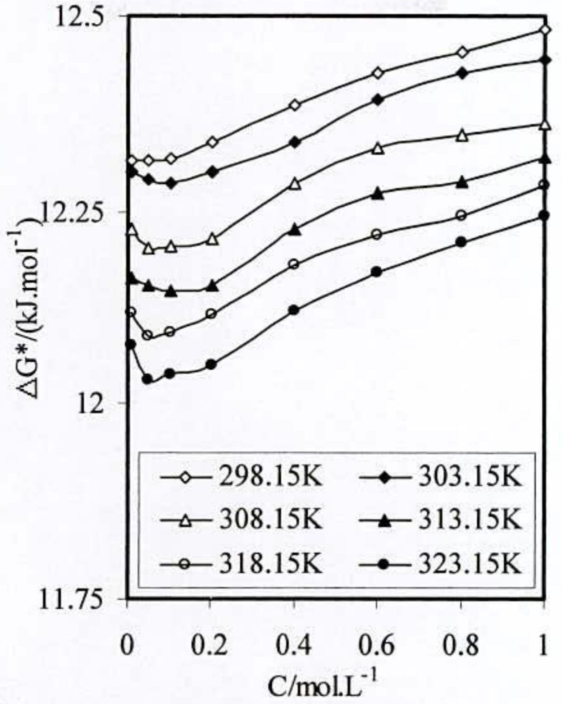


Figure 4.97: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 5% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

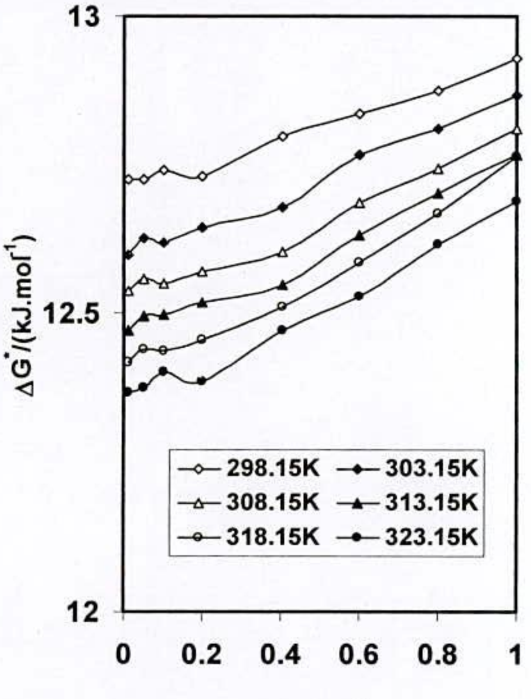


Figure 4.98: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 10% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

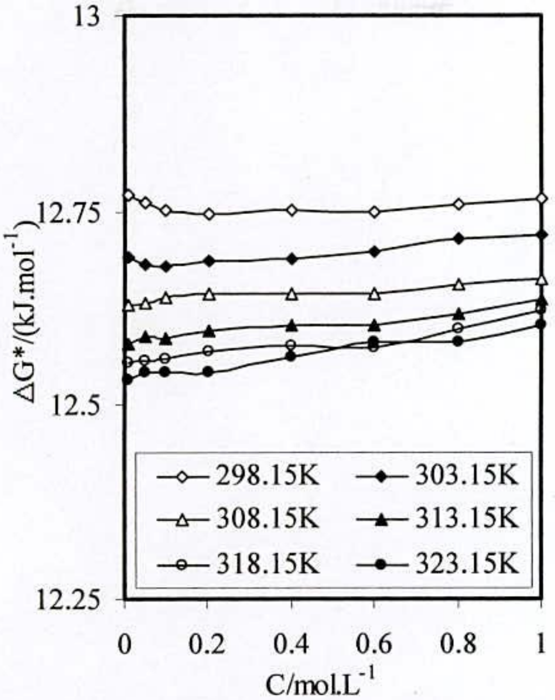


Figure 4.99: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 1% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

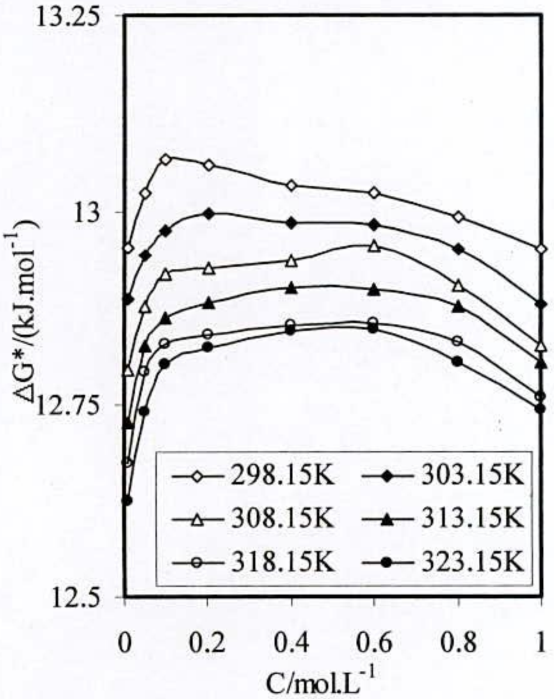


Figure 4.100: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 5% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

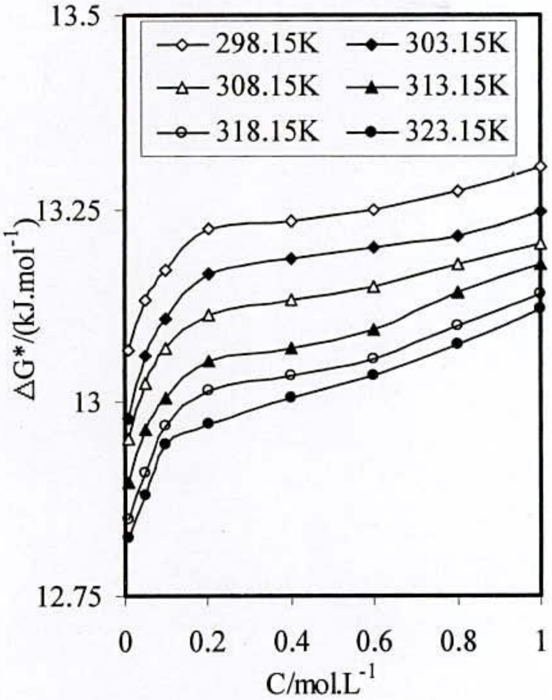


Figure 4.101: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 10% **(w/v)** Glucose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

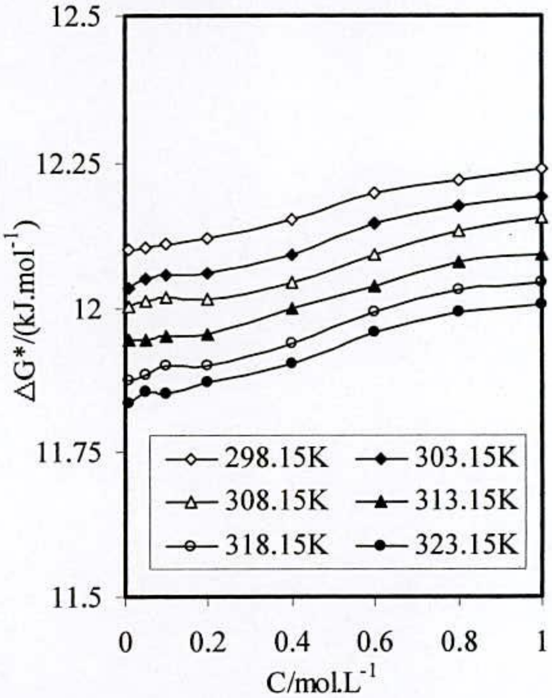


Figure 4.102: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 1% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

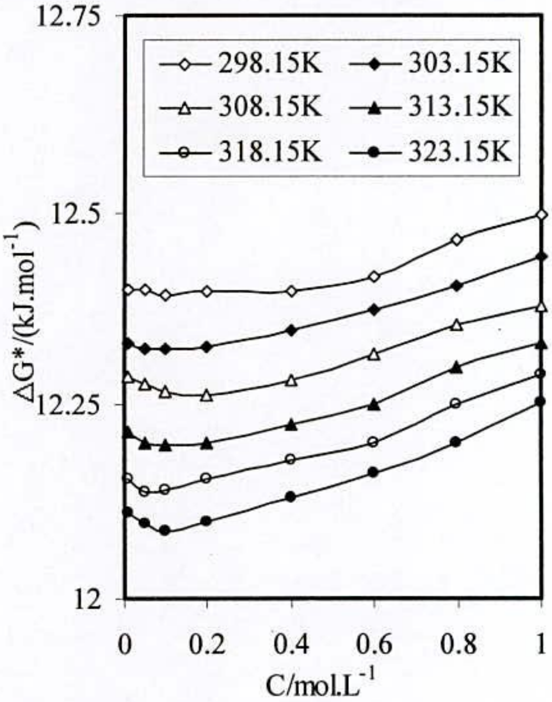


Figure 4.103: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 5% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

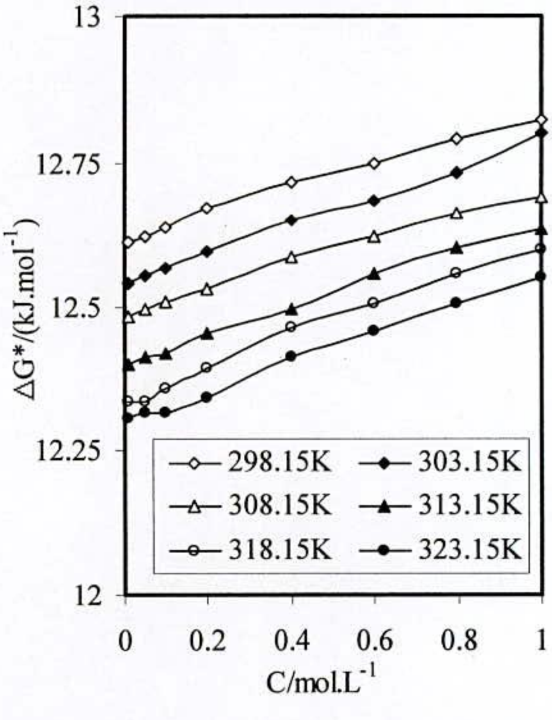


Figure 4.104: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 10% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

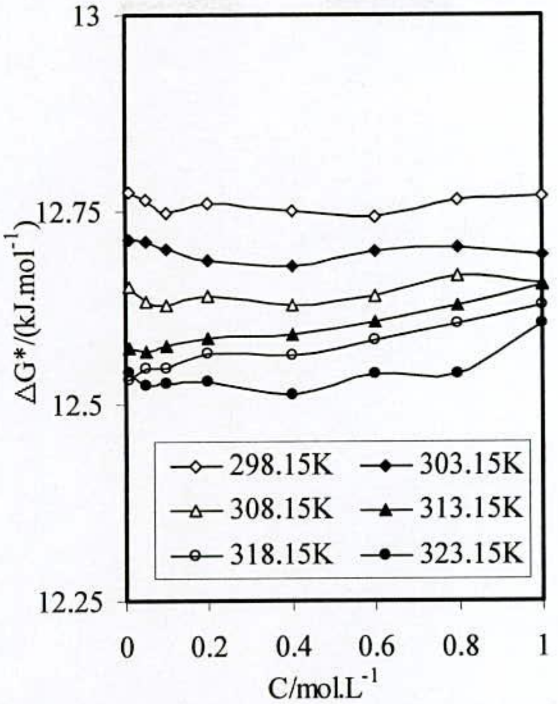


Figure 4.105: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 1% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

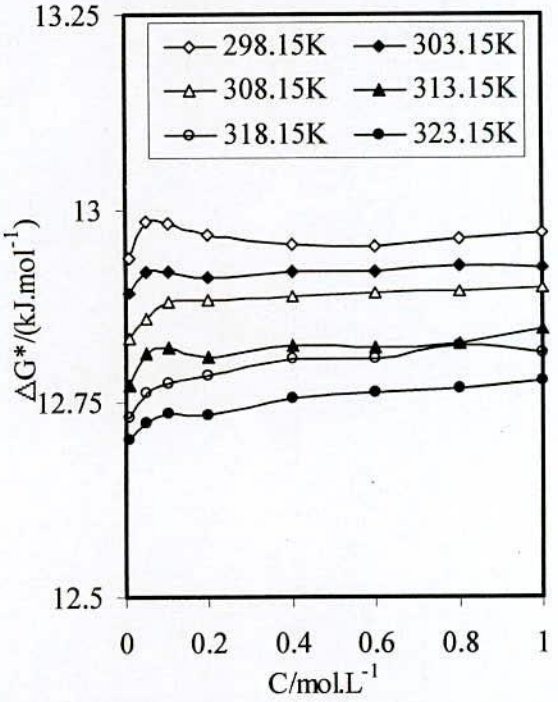


Figure 4.106: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 5% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

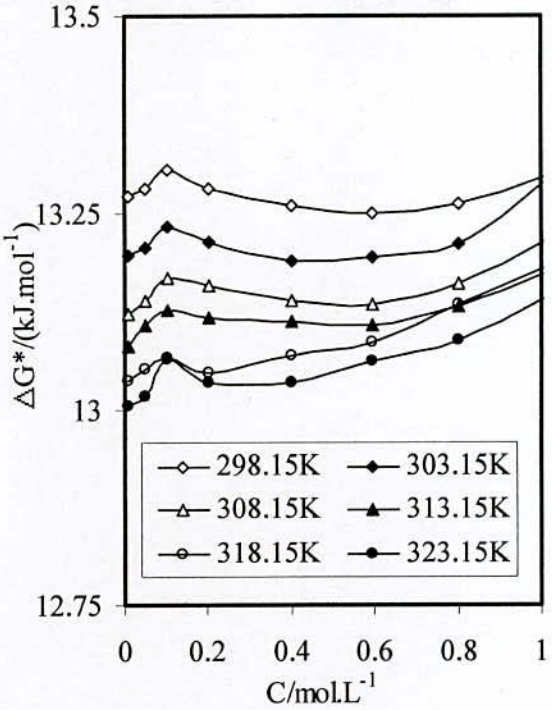


Figure 4.107: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 10% **(w/v)** Sucrose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

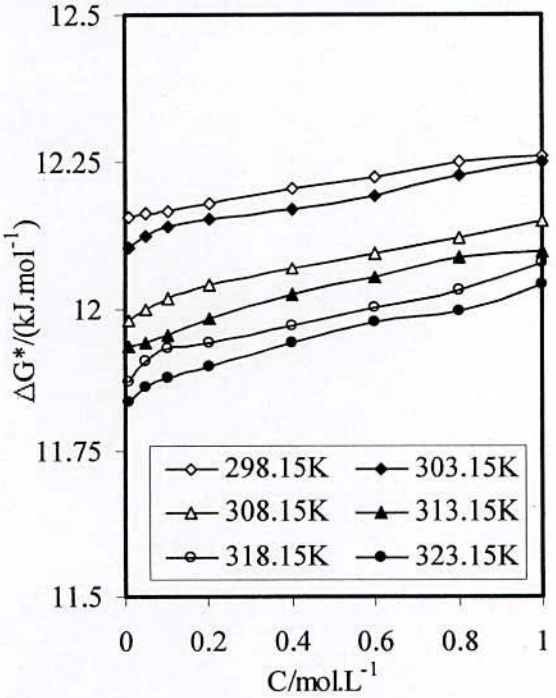


Figure 4.108: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 1% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

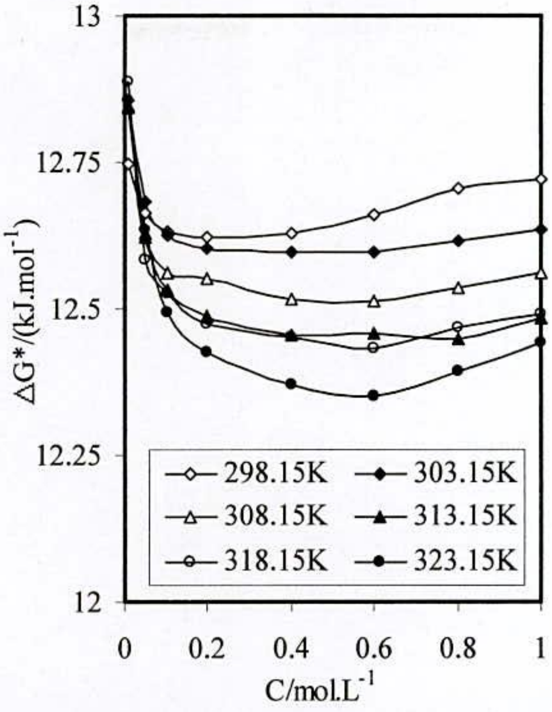


Figure 4.109: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 5% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

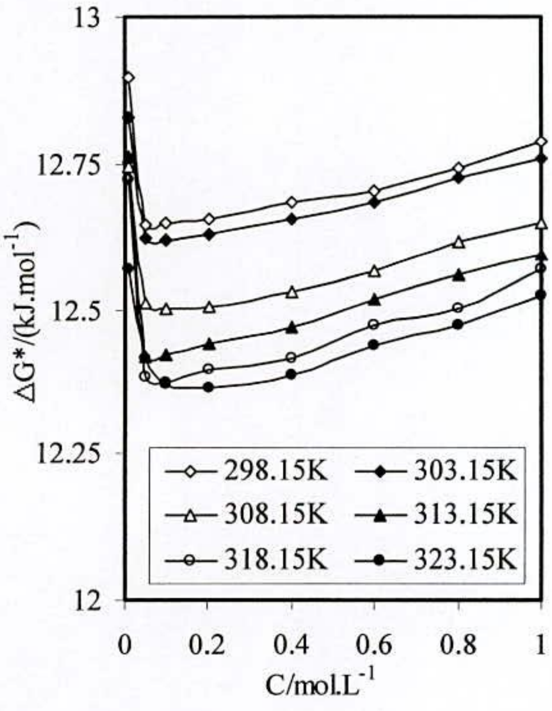


Figure 4.110: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of NaCl in 10% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

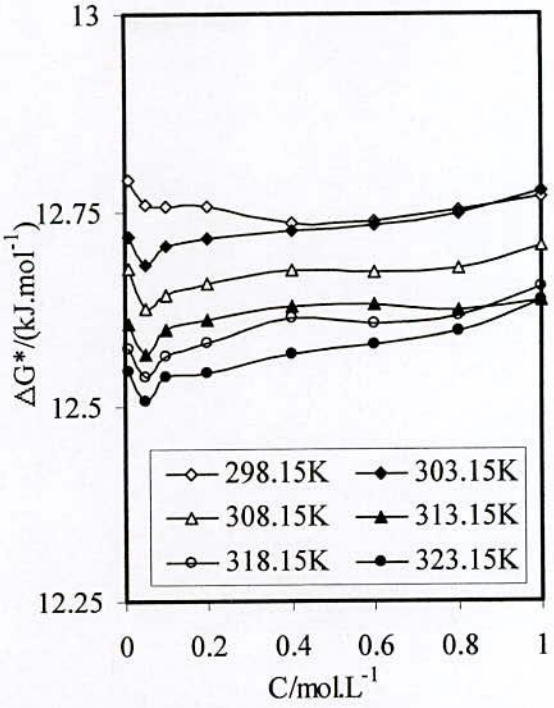


Figure 4.111: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 1% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

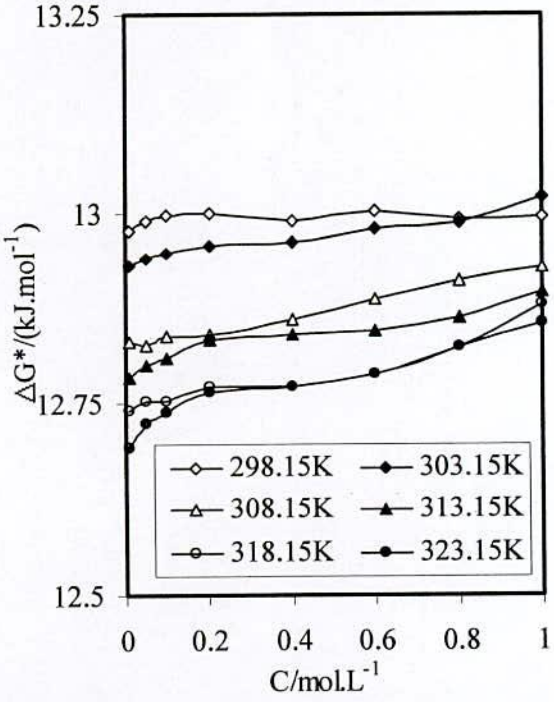


Figure 4.112: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 5% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

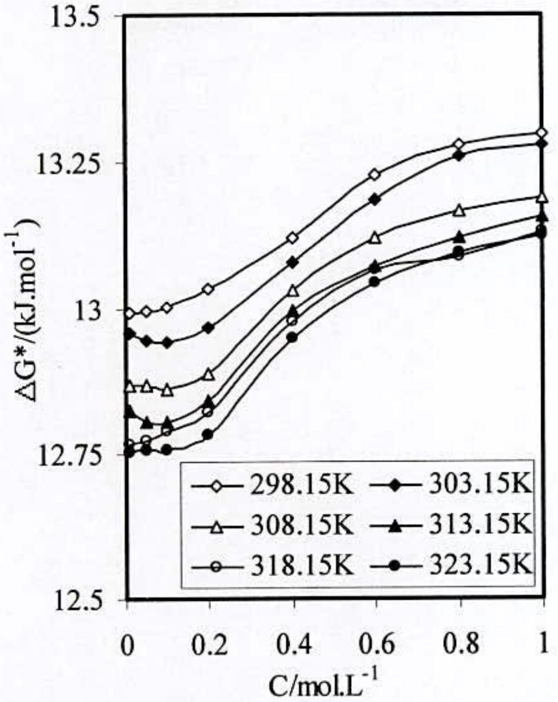


Figure 4.113: Plots of Free energy ($\Delta G^{\#}$) vs concentration (c) of KCl in 10% **(w/v)** Maltose solution at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K, 323.15K respectively.

4.4 Conclusion

In the present investigation, density and viscosity data have been measured for NaCl and KCl in aqueous and aqueous carbohydrates solution at different temperatures and their derived parameters have been applied to explore the possible molecular interaction existing in the present system of mixtures. All the studied electrolytes are found to be dissolved in water and carbohydrate solutions. The binary (electrolytes + water) and ternary (electrolytes + water + carbohydrates) systems show strong solute-solvent interactions in solutions.

Some interesting solution properties of these electrolytes in aqueous and carbohydrate solutins were observed as follows:

i) The values of density, ρ increase with the increasing molarity of the electrolytes. At 0.4M concentration the density of the electrolytes in aqueous solution has been found to be in the order of

KCl > NaCl

The values of densities of electrolyte + aqueous carbohydrate systems has been found to be in the order of,

Electrolyte +10 (w/v) %) carbohydrate > Electrolyte +5 (w/v) %) carbohydrate> Electrolyte +1 (w/v) %) carbohydrate

ii) The apparent molar volume, ϕ_v is dependent upon the electrolyte concentration as well as on the temperature. The apparent molar volumes (ϕ_v) were found to be positive for NaCl and KCl in aqueous solution whereas it is negative in 5% and 10% carbohydrate solution. The value of ϕ_v of NaCl increases with the increase in concentration of the electrolyte, suggesting that solute-solvent interactions increase with the increase in molarity of the electrolyte in solution. For KCl, the value of ϕ_v almost unchanged with the increase in concentration of electrolyte.

iii) Comparatively lower apparent molar volume, ϕ_v of electrolytes in aqueous glucose, aqueous sucrose and aqueous maltose solutions than aqueous solution was found.

iv) For NaCl in water, 1% (w/v) Glucose and 1% (w/v) Maltose solution, the value of $\left[\frac{\partial^2 \phi_v^o}{\partial T^2}\right]_P$ were found to be slightly positive suggesting structure making property. In the case of Sucrose, it shows negative value of $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]_p$ for all the electrolytes containing solvent systems either water or carbohydrates. This indicates that Sucrose act as structure breaker for all there studied electrolyte systems. KCl in water, glucose, sucrose and maltose solution, the values of $\left[\frac{\partial^2\phi_v^o}{\partial T^2}\right]_p$ were found to be negative suggesting structure breaking tendency.

v) The viscosities of carbohydrates increase with the increase of composition % (w/v) of carbohydrates. Viscosities of carbohydrate solutions are found to be

Maltose> Sucrsoe> Glucose

The viscosity vs molarity plots for all the electrolytes systems are linear in all the solvent systems with some exceptions. The value of η increases with the increase in molarity of the electrolytes and decrease with temperature. KCl in aqueous solution systems, the viscosities are almost unchanged with concentration. The values of viscosities of electrolyte + aqueous carbohydrate systems for 0.2M concentration and at a particular temperature (303.15K) has been found to be in the order of,

NaCl (Water) > KCl (Water)

NaCl (10% Carbohydrate) > NaCl (5% carbohydrate) > NaCl (1% Carbohydrate) > NaCl (water)

vi) The B-coefficient for NaCl in water and 1% (w/v) carbohydrate solutions at all the temperatures are positive. The positive value of the B- coefficient corresponds to the structure making behavior of solutes. The B- coefficients of KCl in water and carbohydrate solution (1%, 5% and10%) are negative. The negative value of B- coefficient corresponds to structure breaking behavior of solute.

vii) For NaCl in aqueous and aqueous carbohydrate (1% (w/v)) solution, the values of $\frac{dB}{dT}$ are negative which corresponds to structure making behavior. For KCl in water and carbohydrate solutions, the values of $\frac{dB}{dT}$ are positive which corresponds to structure breaking behavior.

viii) The $\Delta G^{\neq}$ value is positive for all the studied systems. The positive free energy of activation for viscous flow states that the kinetic species involved in forming cavities or holes in the liquid medium is given by the work required in forming the hole against surface tension of the solution. The increase in property of $\Delta G^{\neq}$ for aqueous and aqueous carbohydrate solutions indicates the structure promoting property is increased with increase of solute concentration. The $\Delta H^{\neq}$ is positive for all the studied systems indicate that positive work has to be done to overcome the energy barrier for the flow process. The $\Delta S^{\neq}$ is found to be negative for all the studied electrolyte systems.

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