

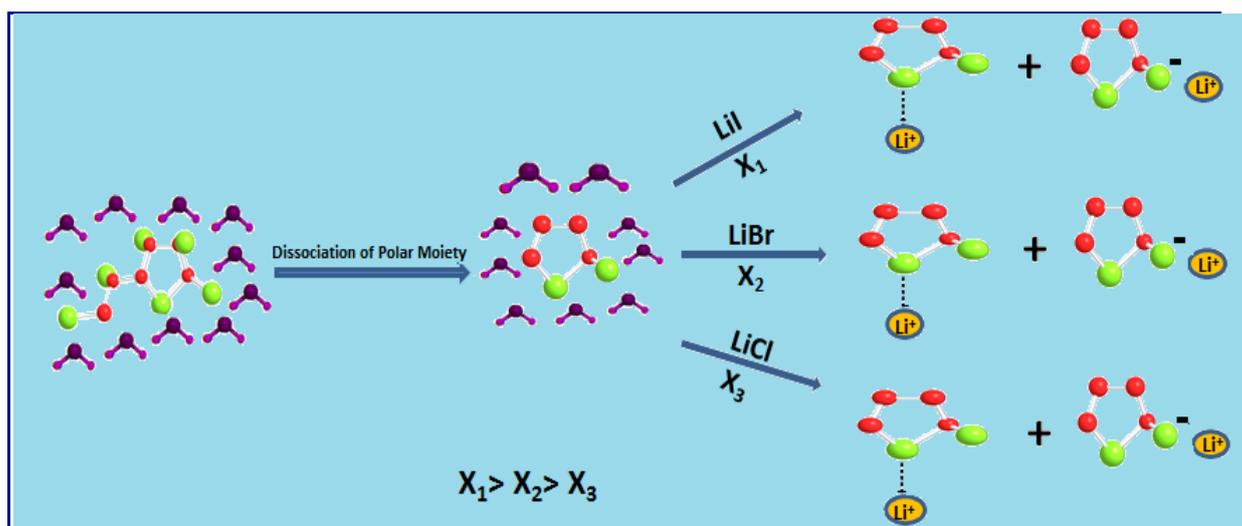
CHAPTER-V

Conjoint beneficial impacts of lithium-ion along with aqueous vitamin in driven rechargeable batteries and also in neurotransmitter drugs

Abstract ⇒

Lithium ions are “energy capsules”. The electrochemical calculations of the aqueous rechargeable lithium-ion battery has been widely investigated in efforts to design a green and safe technology that can provide a highly explicit capacity, high efficiency and long life for high power applications such as the smart grid and electric vehicle. It is assumed that the advantages of this battery will overcome the limitations of the rechargeable lithium-ion battery with organic electrolytes that encompass safety and create high production cost issues. This assessment focuses on the opportunities of the aqueous rechargeable lithium-ion battery compared to the conventional rechargeable lithium-ion battery with organic-based electrolytes.

Graphical Abstract ⇒



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1. Introduction

Since years the specific biochemical mechanism of lithium deed in stabilizing mood is known. Previously reported studies are briefly summarized, together with the presentation of new findings based on the conductivity, morphology, electrochemical performance and cycling stability consequences. The factors that influence the electrochemical performance, the challenges and potential of the aqueous rechargeable lithium-ion battery are highlighted with emphasis on maintaining the excellent battery performance. Moreover current studies, tip to the possibility that long-term treatment with ascorbic acid based lithium drug might prove useful for reducing brain damage and motivating new neural growth in neurodegenerative diseases.

Presently, the majority of Lithium ions utilized in aqueous rechargeable designs of batteries can be widely used in various kinds of portable electric devices because of their high performance with much more power, high output voltage and also can find applications in the development of electrolyte solutions [1, 2] . Moreover the interconnection of Lithium salts with vitamin increases diverse impacts in biological systems [3, 4].

In the present work molecular dynamics calculations from the experimental determination of solvation phenomena for the ions of lithium halides in water-ascorbic acid solvents have been discussed. The results have been interpreted in terms of ion-solvent interactions and structural modifications in the solvent media [5, 6]. The electrical conductivity of electrolytes in mixed solvent solutions mainly depends upon the concentration of the electrolyte and also upon the viscosity of the solvent. The use of mixed solvents in high energy batteries has also extended the area in the field of mixed solvent systems [7, 8]. Hence, in studying the behavior of lithium salts in different solvent systems will help in the production of more useful and “cost-effective batteries” [9].

Vitamin is very suitable due to the excellent solubility characteristics.

Vitamin plays an important role for the synthesis of several important neurotransmitters. So, in our recent work due to incorporation of Lithium ion in aqueous ascorbic acid solution, enhancement of neurotransmission property occurs. The new battery is similar to many commercially-available lithium-ion batteries with one important difference – it has the probability to use butenolide (2-Furanone) from vitamin C (ascorbic acid) as the cathode, the part that stores the electricity that is released when connected to a device. While bio-derived battery parts have been created previously, this is the one that uses bio-derived long-chain molecules – for one of the electrodes, essentially allowing battery energy to be stored,

instead of expensive, harder to process, and more environmentally-harmful metals such as cobalt. Modern batteries contain a positive terminal, a negative terminal, and an electrolyte solution. When a battery is connected to any electronic device that requires power, electrons flow from the anode— the negatively charged electrode of the device supplying current – to the device, then into the cathode. The ions also migrate through the electrolyte solution to balance the charge. When the device is connected to a charger, this process happens in reverse. The reaction in the anode creates electrons and the reaction in the cathode absorbs them when discharging. The result of this is electricity. The battery will continue to produce electricity until one or both of the electrodes run out of the substances necessary for these reactions to take place.

It is clear from the above discussion that Electrochemical cells of Lithium can be used to provide power, in which case they are called batteries; moreover Lithium ions can use the reactants supplied continuously and thus can be called as fuel cells.

2. Experimental section

2.1. Materials

All the lithium halides were purchased from Merck Company, Ascorbic acid used for this study were of analytical grade supplied by Sisco Research Laboratories (SRL). All these chemicals were used as supplied without any further purification. Lithium chloride (LiCl), lithium bromide (LiBr), and lithium iodide (LiI) with minimum mass fraction purities of (> 0.99) were dried in the electrical oven at about 110°C for 24 h prior to use. Double distilled water was used for preparation of the solutions. Water has been used as the primary solvent obtained from series of distillations till its specific conductance attains the range of ($0.1 \cdot 10^{-6}$ to $1.0 \cdot 10^{-6} \Omega^{-1} \cdot \text{cm}^{-1}$). The purity of water was further checked by measuring its density. Before use the chemicals were kept in a vacuum oven to eliminate any moisture.

2.2 . Preparation of Solutions

All the solutions were prepared by weight and conversions of molality to molarity were done by using the standard expression of an analytical balance (precision $1 \cdot 10^{-5}$ g). All these solutions were prepared in 0.001 m, 0.003m, 0.005m ascorbic acid in water as solvent in the

various temperatures of 298.15K, 303.15K, and 308.15K [scheme 1]. Six concentrations ranging from 0.005 mol·kg⁻¹ to 0.08 mol·kg⁻¹ of LiCl, LiBr, and LiI were prepared by taking different compositions of ascorbic acid in water as solvent for all studies.

2.3. Instrumentation

Density was measured by vibrating-tube digital Anton Paar Density-Meter (DMA 4500M) with a precision of ±0.00005 g cm⁻³, was calibrated by double-distilled water and dry air. The temperature was automatically kept constant within ±0.01 K. It was calibrated by triply-distilled water and passing dry air. The viscosities were measured using a Brookfield DV-III Ultra Programmable Rheometer with fitted spindle size-42 fitted to a Brookfield digital bath TC-500. The viscosities were obtained using the following equation

$$\eta = (100 / RPM) \times TK \times \text{torque} \times SMC$$

Where *RPM*, *TK* (0.09373) and *SMC* (0.327) are the speed, viscometer torque constant and spindle multiplier constant, respectively. The instrument was calibrated against the standard viscosity samples supplied with the instrument, water and aqueous CaCl₂ solutions. Temperature of the solution was maintained to within ± 0.01 K using Brookfield Digital TC-500 temperature thermostat bath. The viscosities were measured with an accuracy of ±1 %. Each measurement reported herein is an average of triplicate reading with a precision of 0.3 %.

Refractive index was measured with the help of a digital refractometer Mettler Toledo. The light source was light emitting diode (LED), λ=589.3 nm. The refractometer was calibrated twice using distilled water and calibration was checked after every few measurements. The uncertainty of refractive index measurement was ±0.0002 units.

The conductance measurements were carried out in a Systronics-308 conductivity bridge of accuracy ±0.01%, using a dip-type immersion conductivity cell, CD-10 having a cell constant of approximately (0.1± 0.001) cm⁻¹ [10,11]. Measurements were made in a thermostat water bath maintained at T = (298.15 ±0.01) K. The cell was calibrated by the method proposed by Lind et al. and cell constant was measured based on 0.01 M aqueous KCl solution. During the conductance measurements, cell constant was maintained within the range 1.10–1.12 cm⁻¹. The conductance data were reported at a frequency of 1 kHz and the accuracy was ±0.3%. During all the measurements, uncertainty of temperatures was ±0.01K [12].

3. Results and discussion

3.1. Density calculation

The measured value of densities (ρ) of lithium halide in solvent mixtures of different mass fraction of Ascorbic acid in water, as a function of concentration at 298.15 K, 303.15K, 308.15K are reported. The measured values of density for binary (ascorbic acid + H₂O) system and ternary (ascorbic acid + LiCl + H₂O), (ascorbic acid + LiBr + H₂O), and (ascorbic acid + LiI + H₂O) mixtures at different concentrations of ascorbic acid and (LiCl, LiBr and LiI), at different temperatures are given. Figure 1 shows the comparison of measured densities for (ascorbic acid + H₂O) binary system in this work and literature at T = 298.15 K, 303.15K, 308.15K. Both data show linear dependence to molality of ionic liquid with almost same intercepts but different slopes [13]. This discrepancy in slopes may come from differences in purities of used ascorbic acid and also little differences in densities due to pressures (Figure 1).

3.2. Apparent Molar volume Studies

The apparent molar volume of LiCl, LiBr and LiI in (0.001, 0.003, 0.005) m aqueous ascorbic acid solution have been calculated from density data (Figure 2(a), (b), (c)) by using Eq.(1)

$$\phi_v = \frac{M_2}{d - (d - d^0) / m} \quad (1)$$

Where d^0 is the density of solvent, d is the density of solution, m the molality of solution and M_2 the molecular weight of electrolyte.

The densities of various solutions of lithium chloride, lithium bromide and lithium iodide in (0.001, 0.003, 0.005) m aqueous ascorbic acid obey Root's equation and justify the use of Masson's Eq. (2) for the estimation of the limiting apparent molar volume

$$\phi_v = \phi_v^0 + S_v^* \sqrt{C} \quad (2)$$

Where ϕ_v^0 and S_v^* are calculated from the intercept and slope from the extrapolation of the plots of ϕ_v versus \sqrt{C} shown. The values of limiting apparent molar volume and slopes S_v^* are recorded in Figure 3(a), (b), (c). The slope S_v^* in Masson's equation may be attributed to be as a measure of ion-ion or solute-solute interactions. Low and positive values of S_v^* for LiCl, LiBr and LiI accounts for weak ion-ion interactions [14, 15]. There is a decrease in inter ionic interactions with increase in temperature for lithium chloride, lithium bromide, lithium iodide

in (0.001, 0.003, 0.005) m aqueous ascorbic acid solutions which may be due to more solvation of electrolytic ions with rise in temperature [16].

The ϕ_v^0 is a measure of ion–solvent interactions [scheme 2] .The positive values of ϕ_v^0 for LiCl, LiBr and LiI shows positive ion–solvent interactions [17, 18]. The ϕ_v^0 values for LiCl, LiBr and LiI increases with increase in temperature and it may be due to more solvation of electrolytic ions as a result of decrease in hydrogen bonding between solvent molecules with rise in temperature, thus making more free solvent molecules available for solvation of electrolytic ions shown in (Scheme 3), where $I_1 > I_2 > I_3$ [19, 20].

3.3. Temperature dependent limiting apparent molar volume

The variation of ϕ_v^0 with the temperature of the Lithium halides in different solvents with the temperature can be expressed by the general polynomial equation as follows,

$$\phi_v^0 = a_0 + a_1T + a_2T^2 \quad (3)$$

Where a_0, a_1, a_2 are the empirical coefficients depending on the solute, mass fraction (w_1) of the co-solute, and T is the temperature range under study in Kelvin. The values of these coefficients of the above equation for the Lithium salts in Vitamin C and water are reported at 298.15 K, 303.15K and 308.15K are shown in Table 1.

The temperature dependence of ϕ_v^0 for LiCl, LiBr and LiI can be expressed as:

$$\phi_v^0 = 265.7 + 0.648T - 0.005T^2 \quad (4)$$

for: (LiCl in 0.001 m aqueous ascorbic acid system)

$$\phi_v^0 = 290.6 - 0.633T - 0.002T^2 \quad (5)$$

for : (LiCl in 0.003 m aqueous ascorbic acid system)

$$\phi_v^0 = 529.6 - 0.503T - 0.001T^2 \quad (6)$$

for : (LiCl in 0.005 m aqueous ascorbic acid system)

$$\phi_v^0 = 251.6 + 0.854T - 0.006T^2 \quad (7)$$

for : (LiBr in 0.001 m aqueous ascorbic acid system)

$$\phi_v^0 = 282.4 + 0.852T - 0.004T^2 \quad (8)$$

for: (LiBr in 0.003 m aqueous ascorbic acid system)

$$\phi_v^0 = 319.4 + 0.755T - 0.002T^2 \quad (9)$$

for: (LiBr in 0.005 m aqueous ascorbic acid system)

$$\phi_v^0 = 178.0 + 2.008T - 0.007T^2 \quad (10)$$

for: (Lil in 0.001 m aqueous ascorbic acid system)

$$\phi_v^0 = 256.2 + 0.912T - 0.004T^2$$

(11)

for: (Lil in 0.003 m aqueous ascorbic acid system)

$$\phi_v^0 = 397.4 + 0.380T - 0.001T^2$$

(12)

for: (Lil in 0.005 m aqueous ascorbic acid system)

The limiting apparent molar expansibilities, ϕ_E^0 can be obtained by the following equation,

$$\left(\frac{\partial \phi_v^0}{\partial T} \right)_p = a_1 + 2a_2T \quad (13)$$

The limiting apparent molar expansibilities, ϕ_E^0 , change in magnitude with the change of temperature. The values of ϕ_E^0 for different solutions of the studied sample at (298.15, 303.15, and 308.15) K are reported in Table 2. The table reveals that ϕ_E^0 is positive for Lithium

halides in all the concentrations of studied solvents and studied temperatures [21, 22]. This fact can be ascribed to the absence of “caging or packing effect” for the Lithium salts in solutions and their behavior is just like common electrolytes [23, 24].

During the past few years it has been emphasized by different workers that S_v^* is not the sole criterion for determining the structure-making or -breaking nature of any solute.

The structure making/ breaking capacity of LiCl, LiBr and LiI may be interpreted with the help of Hepler's reasoning shown in Table 2. Hepler developed a technique of examining the sign of $(\delta\phi_E^0/\delta T)_p$ for the solute in terms of long-range structure-making and -breaking capacity of the solute in the solvent systems using the general thermodynamic expression,

$$(\delta\phi_E^0/\delta T)_p = (\delta^2\phi_v^0/\delta T^2)_p = 2a_2 \quad (14)$$

$$\text{Eq 14 can also be represented as } (\partial\bar{C}_p^0/\partial P)_T = -T(\partial^2\phi_v^0/\partial T^2)_p \quad (15)$$

Where \bar{C}_p^0 is the partial molar heat capacity at infinite dilution. From Eq. (15), it is clear that structure making electrolytes should have a positive value of $(\partial^2\phi_v^0/\partial T^2)_p$ and structure breaking electrolytes should have negative value of $(\partial^2\phi_v^0/\partial T^2)_p$. For LiCl, LiBr and LiI the sign of $(\partial^2\phi_v^0/\partial T^2)_p$ has been found to be negative which suggests that LiCl, LiBr and LiI acts as structure-breaker in 0.001, 0.003, 0.005 m aqueous ascorbic acid solution.

4. Viscosity Studies

Another transport property of Solution is viscosity has been studied for comparison and conformation of the solvation of the electrolyte in the chosen solvents. The viscosity data has been analyzed using Jones-Dole equation.

$$(\eta_r - 1) / \sqrt{c} = A + B\sqrt{c} \quad (16)$$

Where $(\eta/\eta_0) = \eta_r$, η and η_0 are relative viscosities, viscosities of solution and solvent respectively, c is the molar concentration and A and B are constants. The values of η , $(\eta_r - 1) / \sqrt{c}$ are shown. The values of A and B have been determined from the intercept and slope of linear plots of $(\eta_r - 1) / \sqrt{c}$ versus \sqrt{c} . The values of A and B of different solutions are recorded. Parameter A of Jones–Dole equation represents the contribution from ion–ion interactions. The values of A , shows that ion–ion interactions for LiCl, LiBr and LiI decreases with increase in temperature, which may be due to more solvation of ions.

The B parameter which measures the structure making/breaking capacity of an electrolyte in a solution also contain a contribution from structural effects and is responsible for solute–solvent interactions in a solvent. It has been emphasized by a number of workers that dB/dT is more important criteria for determining solute–solvent interactions .Viscosity study of a number of electrolytes has shown that structure-maker will have negative dB/dT and structure breaker will have positive dB/dT. The temperature effect on B coefficient for LiCl, LiBr and LiI shows a positive sign of dB/dT, showing thereby that LiCl, LiBr and LiI behaves as structure-breaker in (0.001, 0.003, 0.005) m aqueous ascorbic acid solution. The effect of temperature on the viscosity is given where A and B are viscosity coefficient indicates the ion–ion and ion–solvent interaction, respectively.

As the electrolytes investigated here are found to be somewhat associated from conductivity measurements, the viscosity data have been analyzed by the following equation

$$\eta_r = 1 + A(\alpha c) + B\alpha c + B'(1-\alpha) \quad (17)$$

Where A, B, and B' are the characteristic constants and α is the degree of dissociation of the ion pair. Equation (2) can be rearranged to give

$$[\eta_r - 1 - A(\alpha c)^{1/2}] / \alpha c = B + B'(1-\alpha / \alpha) \quad (18)$$

For the evaluation of B from Eq. (3), a method suggested earlier by us (in equation 1) was followed. The viscosity data have also been analyzed on the basis of the transition state treatment of the relative viscosity of electrolyte solutions [25, 26]. Relative viscosity (η_r) (a synonym of "viscosity ratio") is the ratio of the viscosity of a solution (η) to the viscosity of the solvent used (η_0), shown.

5. Refractive index calculation

The molar refraction, R_M can be evaluated from the Lorentz-Lorenz relation,

$$R_M = \{(n_D^2 - 1) / (n_D^2 + 2)\}(M / \rho) \quad (19)$$

Where R_M , n_D , M and ρ are the molar refraction, the refractive index, the molar mass and the density of solution respectively. The Limiting molar refraction (R_M^0) estimated from the following equation,

$$R_M = R_M^0 + R_S \sqrt{m} \quad (20)$$

The refractive index measurement is also a convenient method for investigating the interaction occurring in the electrolytic solution. Stated more briefly, by Deetlefs et al. that the refractive index of a compound describes its ability to refract light as it moves from one medium to another and thus, the higher the refractive index of a compound, the more the light is refracted. The values of refractive index n_D , molar refraction R_M , limiting molar refraction R_M^0 are reported in Table 3 respectively and figure 4. The refractive index of a substance is higher when its molecules are more tightly packed or in general when the compound is denser. The refractive index is directly proportional to molecular polarizability, scrutiny of Table 3 reveals the n_D and R_M values increases with an increasing concentration of mass fraction LiI into the solution of the used solvents, suggesting that in the ascorbic acid and water medium it is more tightly packed and more solvated. This is also in best agreement with the results obtained from apparent molar volume and viscosity B -coefficient and viscosity parameters discussed above [27, 28].

6. Challenges of ionic conductivity and Conductance studies

The concentrations and molar conductance's (Λ) of Lithium halides in ascorbic acid and water at 298.15 K, 303.15K, 308.15K temperatures are given. The molar conductance (Λ) has been obtained from the specific conductance (κ) value using the following equation.

$$\Lambda = (1000 \kappa) / c \quad (21)$$

Linear conductance curve (Λ versus \sqrt{c}) were obtained for the electrolyte in aqueous ascorbic acid solution by extrapolation of \sqrt{c} to zero concentration, evaluated the starting limiting molar conductance for the electrolyte. Figure 5(a), (b), (c) concludes at a particular concentration as the temperature is raised in the solute-solvent system then the conductance also rises steeply. (i.e. the transport of the ions also rises steeply). The limiting molar conductance Λ_m^0 for LiCl, LiBr and LiI in (0.001, 0.003, 0.005) m aqueous ascorbic acid solutions were recorded, shows that limiting molar conductance increases with increase in temperature, it may be due to increase in ionic mobility with rise in temperature (Figure 6). Since in the state of infinite dilution, the motion of an ion is limited solely by its interaction with surrounding solvent molecules, there are no other ions within a finite distance [29, 30]. Therefore evaluation of Λ_m^0 should give equally reliable information regarding ion-solvent interactions shown in figure 6. Greater value of Λ_m^0 may therefore be interpreted as a measure of greater ion-solvent interactions. The probable interaction is shown in Scheme 4 .

The order of Solute–Solvent interactions for LiCl, LiBr, LiI in (0.001, 0.003, 0.005) m aqueous ascorbic acid solutions follow as:



We know that hydration is inversely related with charge to radius ratio. Among all halide ions iodide has the largest ionic size than that of the other two concerned ions. That is why hydration is lowest in case of iodide ion and highest in case of chloride ion. Again ion – solvent interaction is inversely related to the extent of hydration. So, ion – solvent interaction is highest in case of iodide ion and is lowest in case of chloride ion (Scheme 5).

This may be explained on the basis of dissociation order of different metal halides as below:



The Walden product data ($\Lambda_m^0 \eta^0$) have been recorded. The structure making/breaking nature of electrolyte has been determined from temperature coefficient of Walden product i.e. $[d(\Lambda_m^0 \eta^0)/dT]$. The negative temperature coefficient of Walden product for LiCl, LiBr, LiI in (0.001, 0.003, 0.005) m aqueous ascorbic acid suggests that LiCl, LiBr, LiI behaves as structure-breaker in (0.001, 0.003, 0.005) m aqueous ascorbic acid which is depicted in (Figure 7).

7. Novelty and characterization following this paper

In this review discussion of a wide range of the representative cathode as 2-furanone and anode as Lithium materials, starting from commercially available and currently used materials to promising novel materials that may be commercialized in the future. Fundamental properties, opportunities, challenges, and latest progress of anode and cathode material research have been discussed. It should be noted that even though flexible batteries have recently been of high interest, we will not cover this topic in this review, and as a substitute refer to other literature. An intercalation cathode is a solid host network, which can store guest ions. The guest ions can be inserted into and be removed from the host network reversibly. In a Li-ion battery, Li^+ is the guest ion and the host network compounds are aqueous ascorbic acid solution which may dissociate in solution and organize to form 2-

furanone molecules. As new supplies and strategies are found, Li-ion batteries will no doubt have an ever greater impact on our lives in the years to come [31-33].

8. Conclusion

The Li-ion battery has essential advantages and decades of research which have developed it into the high energy density, high cycle life, high efficiency battery that it is today. So far research continues on new electrode materials to push the boundaries of cost, energy density, power density, cycle life, and safety. Various promising anode and cathode materials exist, but many suffer from limited electrical conductivity, slow Li transport, dissolution or other unfavorable interactions with electrolyte, low thermal stability, high volume expansion, mechanical brittleness. But these batteries would prove to be useful.

Studies of the transportation properties of different electrolytes in solvent media are of importance to obtain information on the behavior of ions in solution. Molecular interactions can be studied in the solution phase by studying its thermodynamic and transport properties. These properties provide important information about the nature and strength of intermolecular forces operating among the components. The ion-ion interactions for LiCl, LiBr and LiI decreases with increase in temperature, which may be due to more solvation of ions [scheme 3, 4, 5]. The temperature effect on B coefficient for LiCl, LiBr and LiI shows a positive sign of dB/dT , showing thereby that LiCl, LiBr and LiI behaves a structure-breaker in (0.001, 0.003, 0.005) m aqueous ascorbic acid solution. This allows usage for a green battery with high capacity and high voltage. It also paves the way for cheaper consumer electronics.

Keywords: Lithium-ion based battery, Lithium-ion based drugs, Ion-solvent interaction, Ion-ion interaction, Ascorbic acid

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TABLES

TABLE 1: Values of empirical coefficients (a_0 , a_1 , and a_2) of Equation 8 for Lithium Halides in co-solute (ascorbic acid, water) at 298.15 K, 303.15K, 308.15K.

Concentration	Electrolyte	$a_0 \cdot 10^6$ /m ³ · mol ⁻¹	$a_1 \cdot 10^6$ /m ³ · mol ⁻¹ · K ⁻¹	$a_2 \cdot 10^6$ /m ³ · mol ⁻¹ · K ⁻²
0.001	LiCl	265.7	0.648	-0.005
0.003		290.6	-0.633	-0.002
0.005		529.6	-0.503	-0.001
0.001	LiBr	251.6	0.854	-0.006
0.003		282.4	0.852	-0.004
0.005		319.4	0.755	-0.002
0.001	LiI	178.0	2.008	-0.007
0.003		256.2	0.912	-0.004
0.005		397.4	0.380	-0.001

TABLE 2. Limiting apparent molal expansibilities (ϕ_E) for Lithium salts in co-solute (ascorbic acid and water) at 298.15 K to 308.15 K respectively.

Electr	Temperature(T)(K)	$\phi_E^\circ \cdot 10^6 /$	$2a_2$

		(m ³ mol ⁻¹ K ⁻¹)	
LiCl	298.15 K	2.432	-0.014
	303.15K	2.382	
	308.15K	2.333	
LiCl	298.15 K	1.865	-0.004
	303.15K	1.845	
	308.15K	1.825	
LiCl	298.15 K	1.119	-0.016
	303.15K	1.109	
	308.15K	1.099	
LiBr(0.	298.15 K	2.843	-0.028
	303.15K	2.783	
	308.15K	2.723	
LiBr(0.	298.15 K	1.613	-0.036
	303.15K	1.573	
	308.15K	1.533	
LiBr(0.	298.15 K	0.477	-0.04
	303.15K	0.457	
	308.15K	0.437	
LiI	298.15 K	2.306	-0.054
	303.15K	2.230	
	308.15K	2.166	
LiI	298.15 K	1.553	-0.036
	303.15K	1.513	
	308.15K	1.473	
LiI	298.15 K	0.236	-0.016
	303.15K	0.226	
	308.15K	0.216	

TABLE 3: Refractive index (n_D), Molar refraction (R_M), Limiting molar refraction (R_M^0) of LiCl, LiBr, LiI in aqueous solution of ascorbic acid .

Solute	Solvent medium	n_D	R_M	R_M^0
LiCl	Ascorbic Acid + Water	1.3769	9.705	9.685
		1.3776	9.715	
		1.3781	9.723	
		1.3787	9.733	
		1.3792	9.744	
		1.3797	9.754	
LiBr	Ascorbic Acid + Water	1.3775	19.824	19.98
		1.3781	19.801	
		1.3786	19.728	
		1.3791	19.623	
		1.3796	19.550	
		1.3801	19.502	
LiI	Ascorbic Acid + Water	1.3779	30.705	30.65
		1.3785	30.722	
		1.3791	30.751	
		1.3796	30.774	
		1.3802	30.804	
		1.3807	30.828	

FIGURES

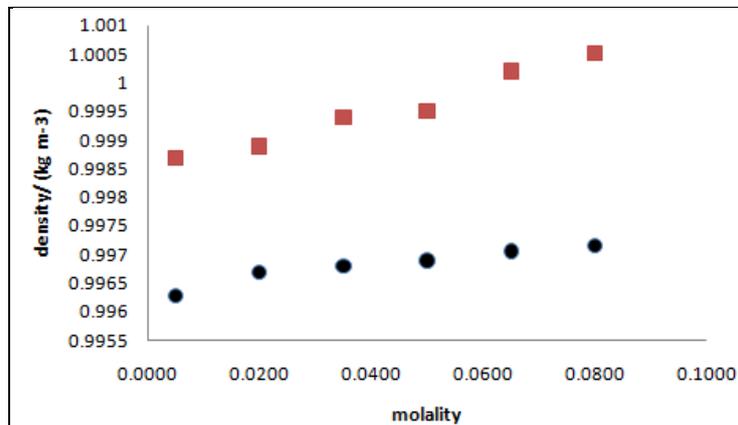
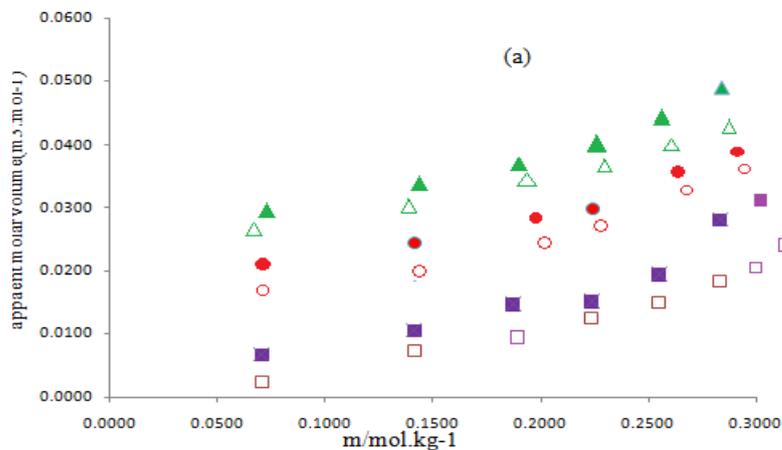


Fig1. Comparison of measured densities for (ascorbic acid+ H₂O) binary system with literature at T = 298.15 K, this work; ● with reference to the introduction of the salt ■ in the above mixture.



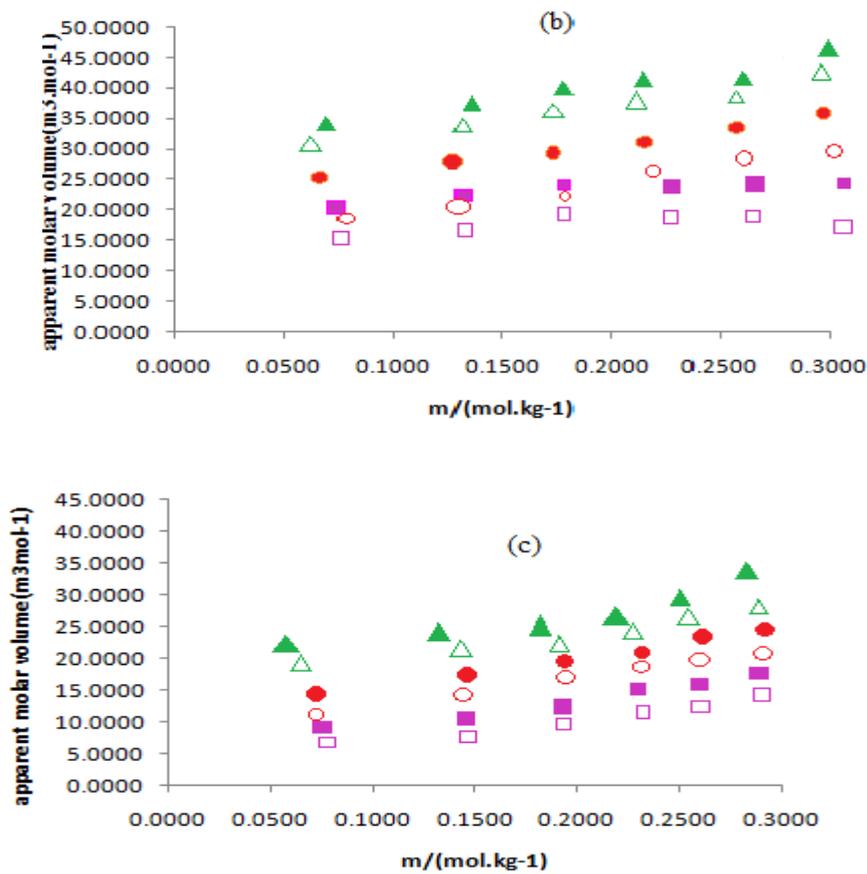


Fig 2. Variation tendency of apparent molar volumes, of Ascorbic acid in aqueous LiCl, LiBr and LiI solutions.

- (a) $w_{\text{salt}} = 0.001(\text{m})$ At $T = 298.15 \text{ K}$: green Δ , LiCl; red \circ , LiBr; purple \square , LiI. At $T = 318.15 \text{ K}$: green \blacktriangle , LiCl; red \bullet , LiBr; purple \blacksquare , LiI.
- (b) $w_{\text{salt}} = 0.003(\text{m})$ at $T = 298.15 \text{ K}$: green Δ , LiCl; red \circ , LiBr; purple \square , LiI. At $T = 318.15 \text{ K}$: green \blacktriangle , LiCl; red \bullet , LiBr; purple \blacksquare , LiI.
- (c) $w_{\text{salt}} = 0.005(\text{m})$ at $T = 298.15 \text{ K}$: green Δ , LiCl; red \circ , LiBr; purple \square , LiI. At $T = 318.15 \text{ K}$: green \blacktriangle , LiCl; red \bullet , LiBr; purple \blacksquare , LiI.

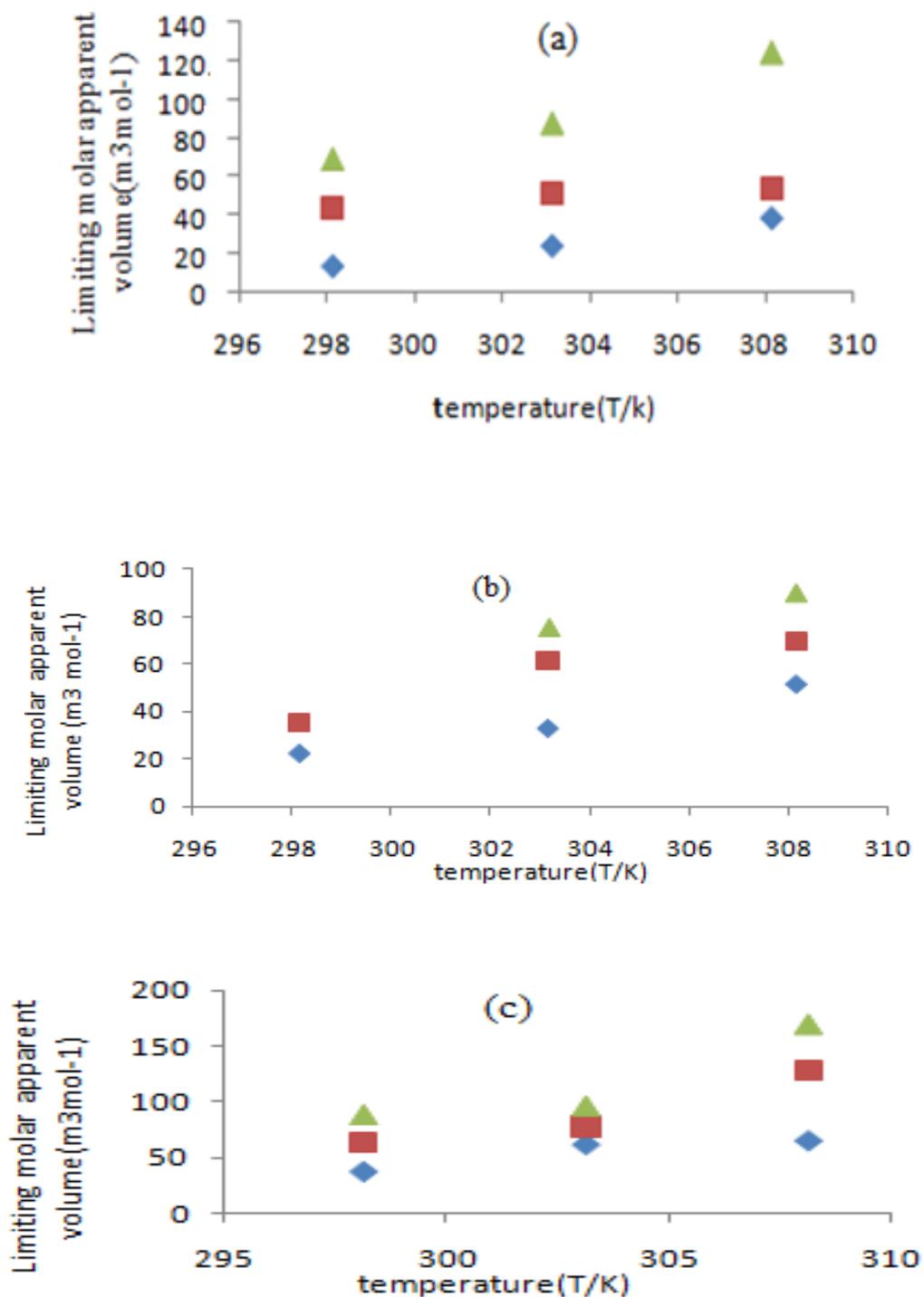


Fig 3. Variation tendency of apparent molar volumes at infinite dilution for ternary [(LiX + Ascorbic acid + H₂O) where X = Cl, Br, I] system at different temperature obtained from the plots: **(a)** LiCl shows φ_v^0 for 0.001(m) concentration as green ; 0.003(m) concentration as brown ; 0.005(m) concentration as blue . **(b)** LiBr shows φ_v^0 for 0.001(m) concentration as green ; 0.003(m) concentration as brown ; 0.005(m) concentration as blue . **(c)** LiI shows φ_v^0 for 0.001(m) concentration as green ; 0.003(m) concentration as brown ; 0.005(m) concentration as blue .

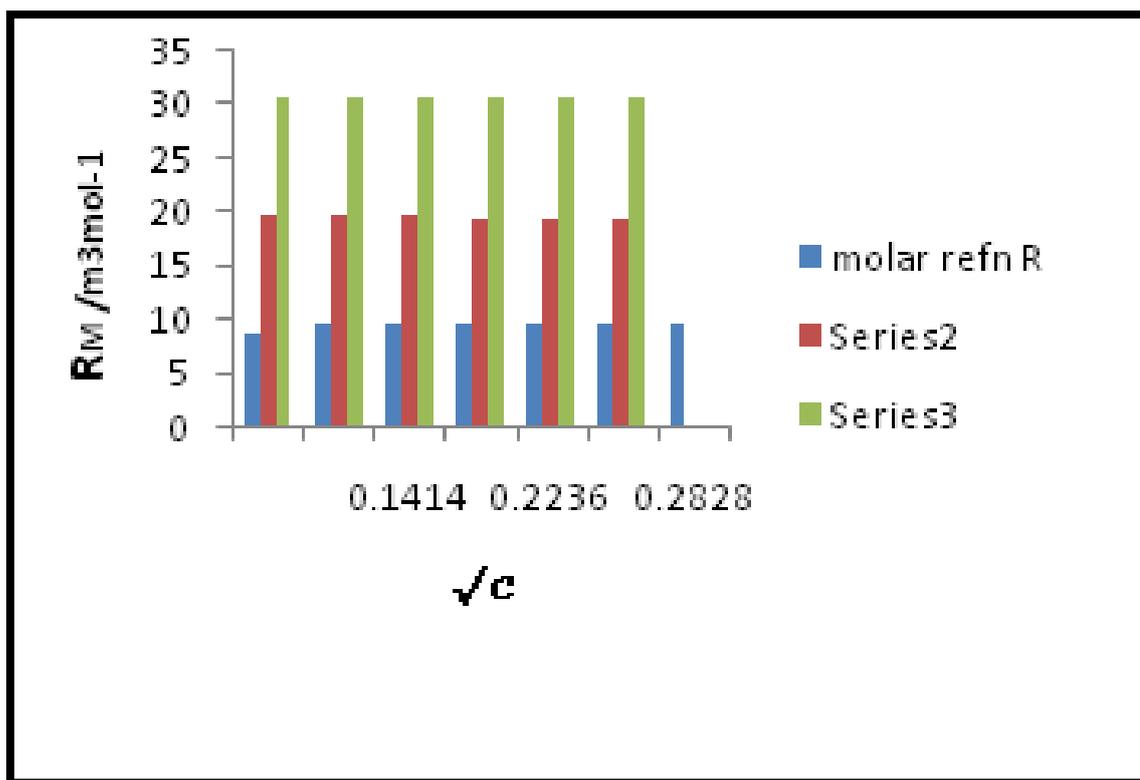


Fig 4:Plot of R_M versus \sqrt{c} for alkali salt formers in ascorbic acid solutions: for LiCl (blue), LiBr (brown), LiI (green)

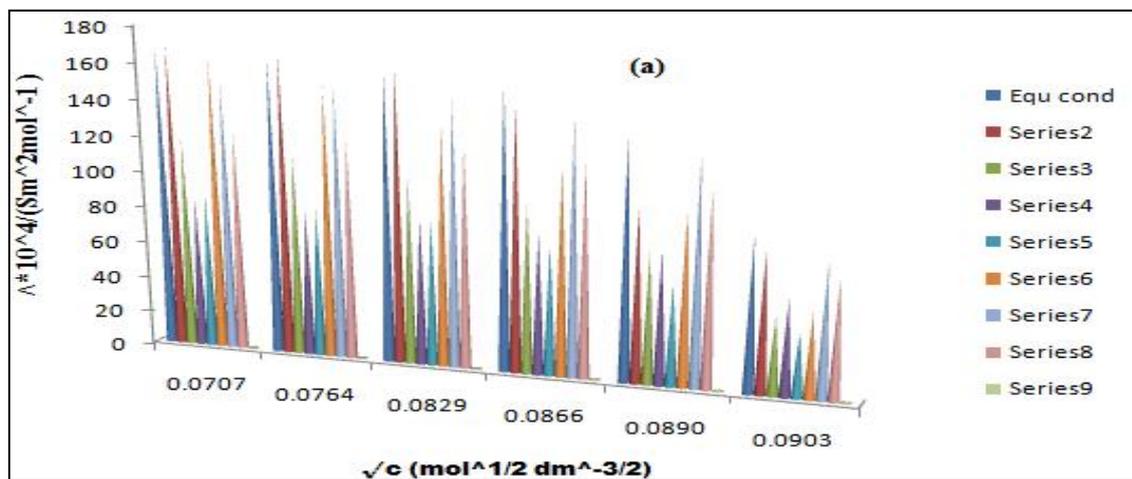


Fig5(a)Plot of molar conductance (Λ) and the square root of concentration (\sqrt{c}) of LiCl in $w_1 = 0.003(m)$ shows series 1 (■) at 308.15K, series 2 (■) at 303.15K, series 3 (■) at 298.15K, similar trends are also shown when $w_1 = 0.001(m)$, $w_1 = 0.005(m)$ of ascorbic acid in water medium.

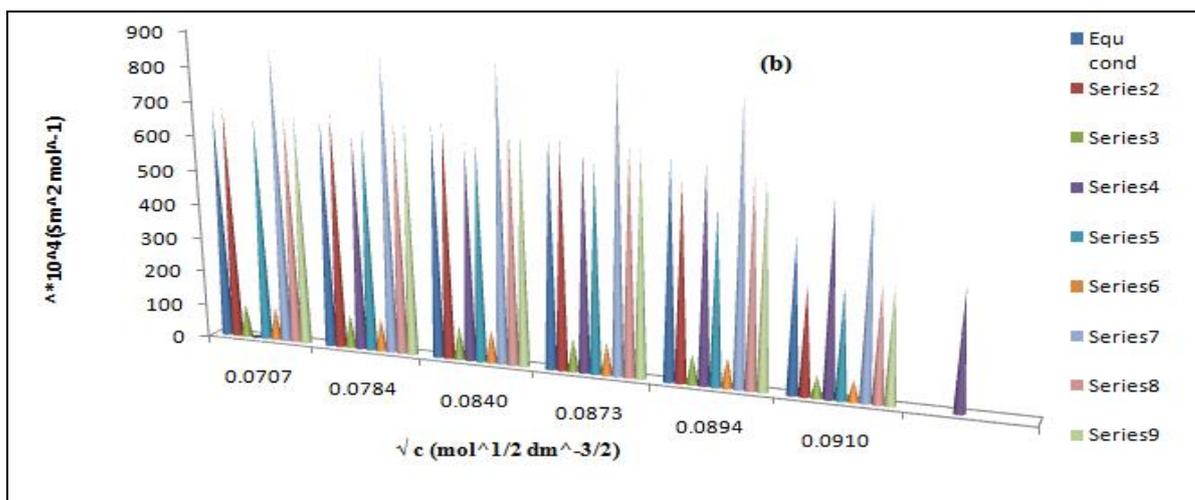


Fig 5(b) Plot of molar conductance (Λ) and the square root of concentration (\sqrt{c}) of **LiBr** in $w_1 = 0.005(m)$ shows series 1 (■) at 308.15K, series 2 (■) at 303.15K, series 3 (■) at 298.15K, similar trends are also shown when $w_1 = 0.001(m)$, $w_1 = 0.003 (m)$ of ascorbic acid in water medium.

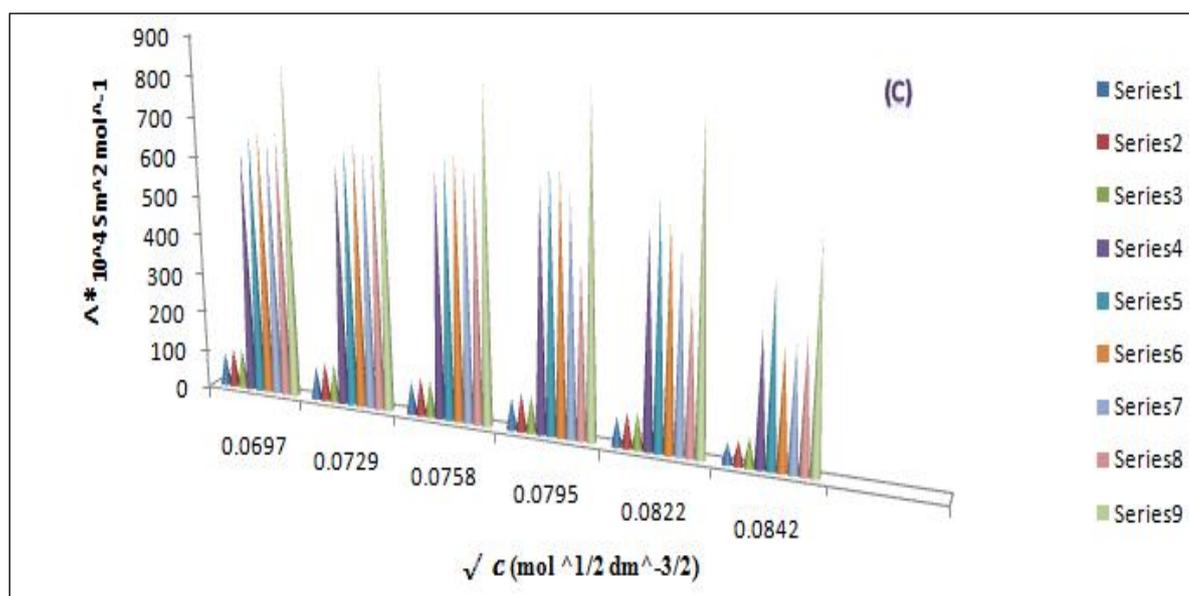


Fig 5(C) Plot of molar conductance (Λ) and the square root of concentration (\sqrt{c}) of **LiI** in $w_1 = 0.001(m)$ shows series 1 (■) at 308.15K, series 2 (■) at 303.15K, series 3 (■) at 298.15K, similar trends are also shown when $w_1 = 0.003(m)$, $w_1 = 0.005 (m)$ of ascorbic acid in water medium.

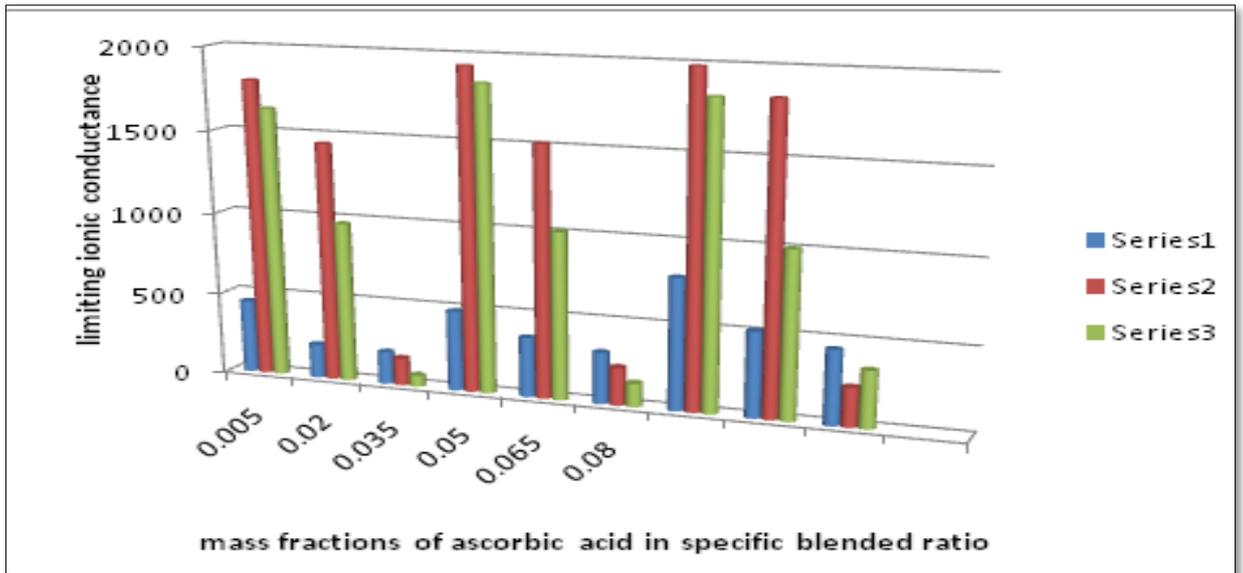


Fig 6. Plot of limiting molar conductance (λ_0) vs mass fraction (w) for LiCl, LiBr, LiI in definite 0.001(m) , 0.003(m), 0.005(m) fractions at the variable ranges of temperatures of 298.15K, 303.15K, 308.15K. Series1 (■) denotes LiCl, Series2 (■) denotes LiBr, Series3 (■) denotes LiI in increasing trends of mass fractions from the left hand side of the graph.

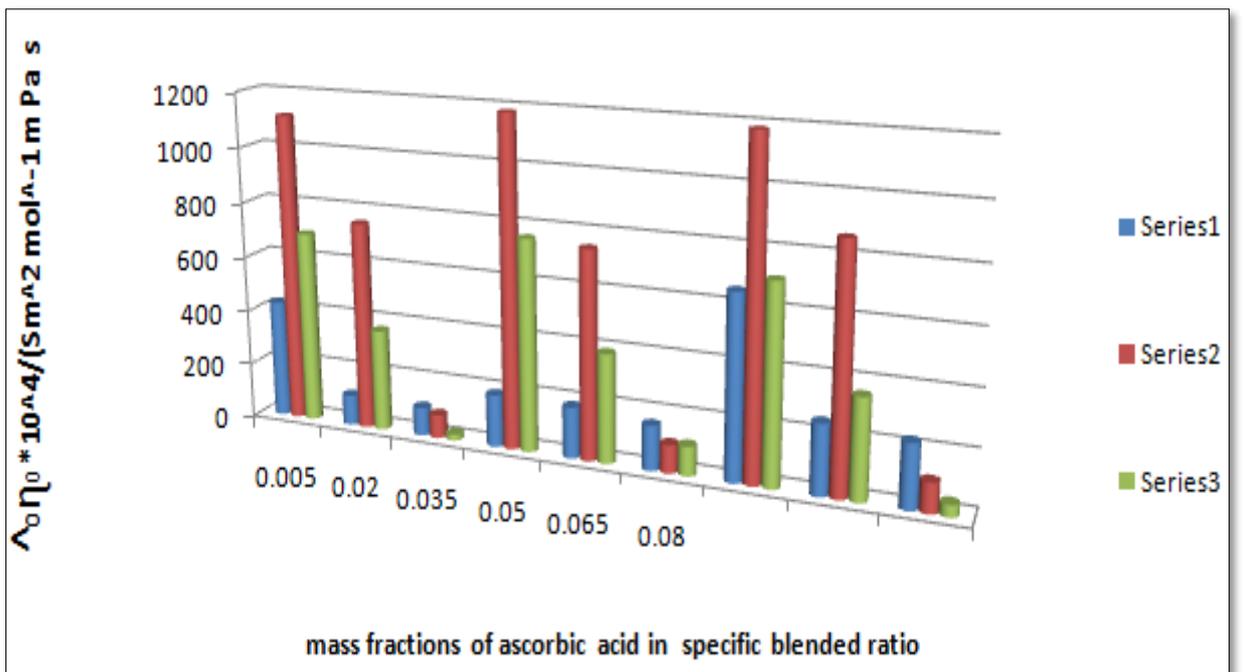
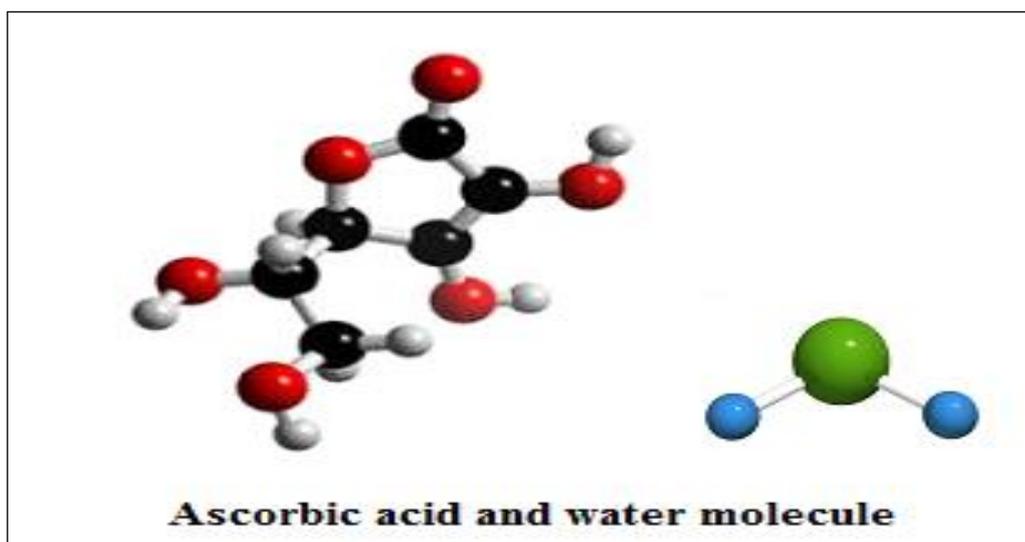
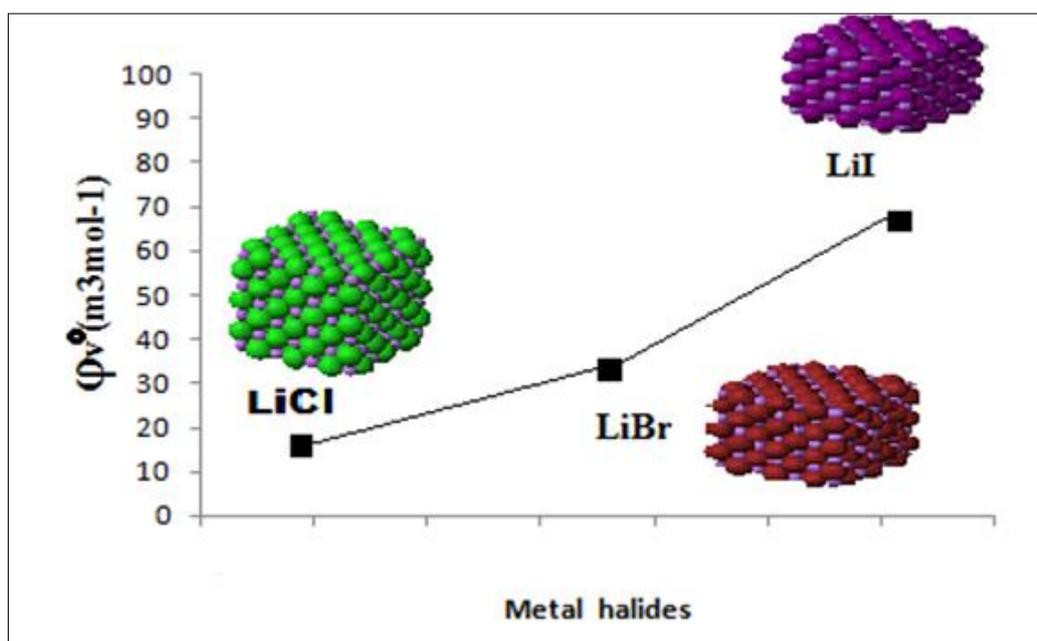


Fig 7. Plot of ionic Walden product ($\lambda_0\eta$) vs mass fraction (w) for LiCl, LiBr, LiI in definite 0.001(m) , 0.003(m), 0.005(m) fractions at the variable ranges of temperatures of 298.15K, 303.15K, 308.15K. Series1 (■) denotes LiCl, Series2 (■) denotes LiBr, Series3 (■) denotes LiI in increasing trends of mass fractions from the left hand side of the graph.

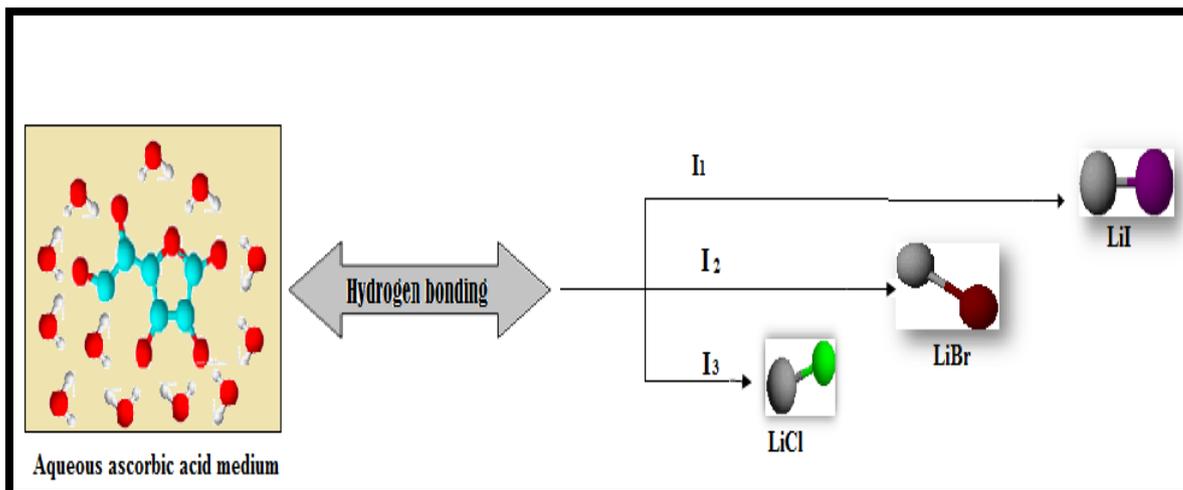
Schemes



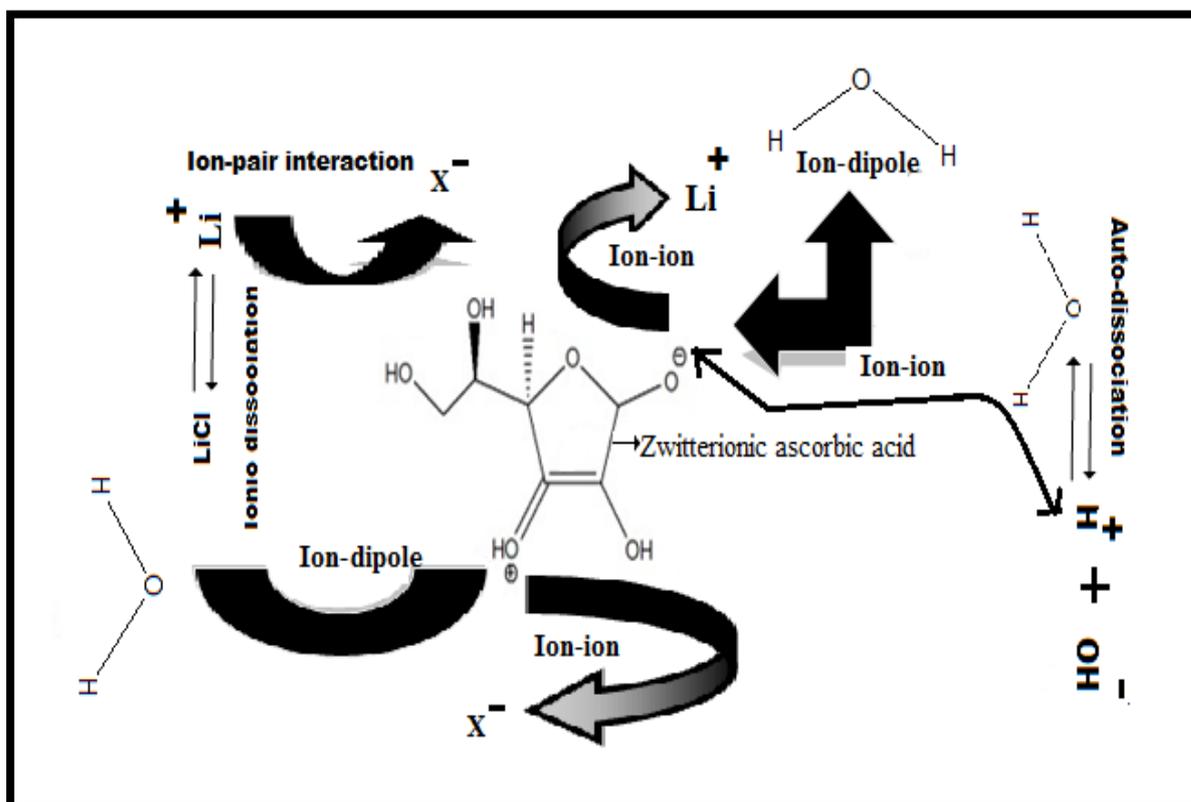
Scheme 1. Three Dimensional Representation of Solvent Cage



Scheme 2. Array of Limiting Apparent Molar Volumes at a definite concentration.

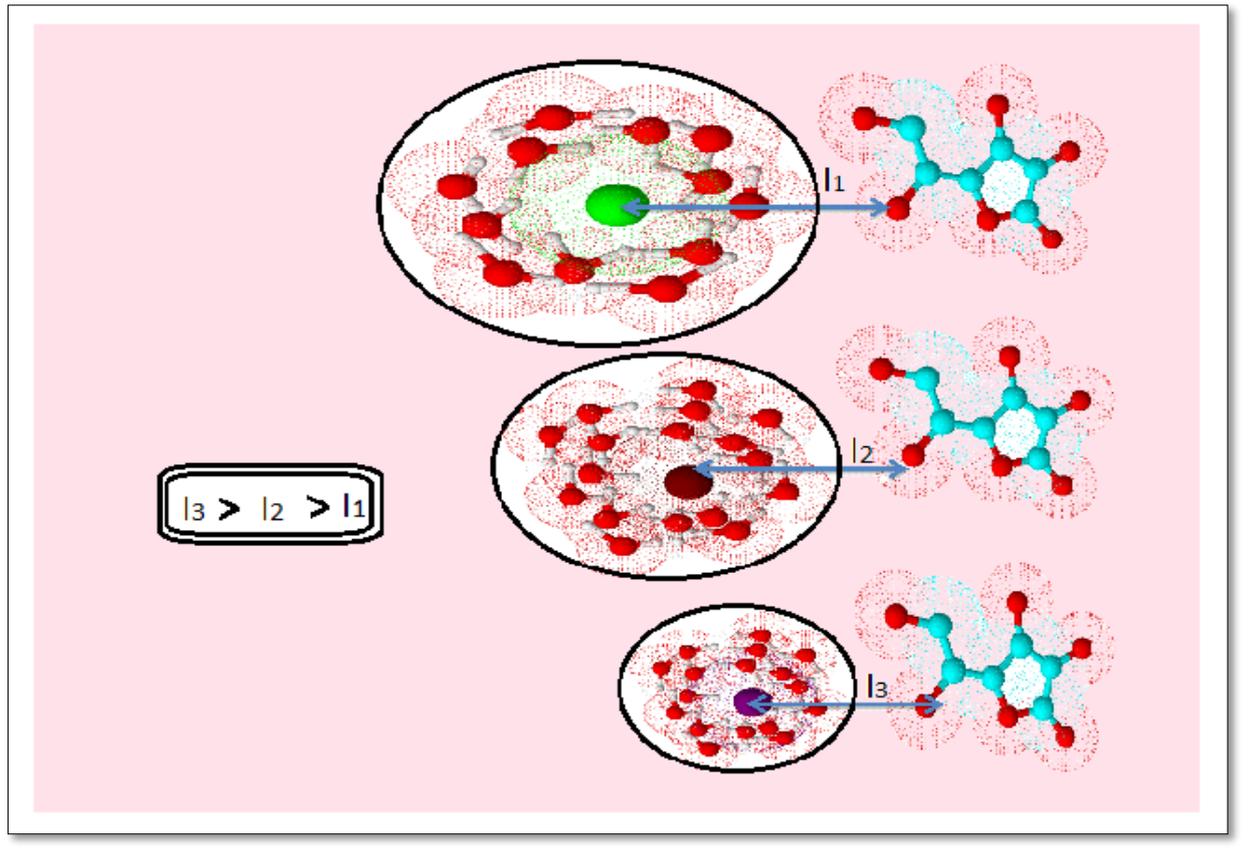


Scheme 3. Array of Molecular Interactions.



Scheme 4. Different possible ionic group interactions in aqueous solutions of ascorbic acid in presence of LiX [$\text{X} = \text{Cl}, \text{Br}, \text{I}$]

Scheme 5 Ion-solvent interaction



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Lithium: multiple levels of action

