Research Journal of Chemical Sciences ______________________________ ISSN 2231-606X
Vol. **2(10),** 49-54, October **(2012)** *Res.J.Chem. Sci.*

Acoustical Properties and Surface Tension study of some Potassium salts in Polyacrylamide solution at 303K

Ravichandran S.[1] and Ramanathan K.[2*]
[1]Department of Physics, Sathyabama University, Chennai - 600119 Tamilnadu, INDIA
[2*]Department of Physics, Thiagarajar college of Engineering, Chennai - 600119 Tamilnadu, INDIA

Available online at: www.isca.in
Received 31st May 2012, revised 19th June 2012, accepted 6th July 2012

Abstract

Ultrasonic velocity and density of potassium nitrate, potassium iodide, potassium chloride and potassium hydroxide solution in polyacrylmaide binary solution has been measured at 303K in different concentration. Ultrasonic velocity has been measured using single frequency interferometer at 2 MHz (Model F-81). From the experimental data, other related thermodynamic parameters, viz adiabatic compressibility, intermolecular free length, acoustic impedance and surface tension are calculated. The compressibility of a solvent is higher than that of a solution and it decreases with the increase in concentration of the solution. The abrupt variation of a velocity indicates the formation of complex. The results have been discussed in terms of solute-solute and solute-solvent interactions between the component and the compatibility of these methods in predicting the interactions in these mistures has also been discussed.

Keywords: Potassium salts with polyacrylamide-ultrasonic velocity-molecular interaction ultrasonic.

Introduction

In the recent years, there has been an increased interest in the physico-chemical properties of aqueous solution in polymer media[1-3]. In the recent years, it has been found that, the acoustical properties of solution have to be important parameters in the study of several chemical reactions and in the investigation of molecular inter actions. These Parameters are required to compute the internal pressure, free volume and other thermodynamic quantities. In many industrial applications, liquid mixtures rather than single component liquid system are used in processing and product formulations. Thermodynamic properties of liquid mixtures have been extensively used[4-5] to study the departure of a real liquid mixture from ideality. The same authors have studied the ultrasonic velocity and densities in mixtures of polyacrylamide solution in sodium (meta) silicate and potassium silicate solutions in different concentrations at 303 K[6]. The interaction of sodium dodecyl sulphate (SDS)/poly (vinyl Alcohol) (PVA) solution was studied by ultrasonic velocity measurements. The studies on ultrasonic parameters have become an emerging field in recent years. The objective of ultrasonic studies is to identify the molecular interaction between solute and solvent and to bring about the structural changes associated with them in terms of acoustic properties like sound velocity, adiabatic compressibility and acoustic impedance etc. Ultrasonic velocity, density, viscosity in mixtures of sodium dodecyl sulphate in polyvinyl alcohol was measured over the entire range of composition were studied by the same authors[7]. The present paper deals with further studies carried out by the authors on the ultrasonic behavior of potassium salts in polyacrylamaide solution at different concentrations.

Material and Methods

AR grade of Polyacrylamide (PAM) is used in the present study with a molecular weight of 5,000,000 g/mol. 5 gm of PAM were dissolved in 500 ml of distilled water to get a PAM solution of 1%. Highly purified quality of potassium nitrate, potassium iodide, potassium chloride and potassium hydroxide were dissolved in distilled water at low temperature to get 0.5 N. The potassium salt solution was added with PAM in different concentration like 10:90, 20:80, 30:70… and ultrasonic parameters were studied. The total volume of a solution should be maintained as 100 ml. For density measurements, the liquid mixtures were taken in a 10 ml gravity bottle (Borosil). The bottle was immersed in a water bath. In order to obtain a constant temperature, the specific gravity bottle was kept inside the water bath for about 30 minutes. Finally, the densities of the pure liquids and liquid mixtures wee measured using an electronic balance. The results of the densities are accurate to ± 0.5%. Ultrasonic interferometer of fixed frequency (2MHz) was used for measuring ultrasonic velocity. (F-81, Mittel Enter Prices, New Delhi). Density and ultrasonic velocity were measured for the different concentration of the mixed solution at 303K. Different acoustic parameters like adiabatic compressibility, acoustic impedance, intermolecular free length and surface tension were calculated at different concentration at 303K temperatures.

A quartz crystal is fixed at the bottom of the cell, which when excited by RF source produces longitudinal ultrasonic waves of particular frequency which propagates in the medium. These waves are reflected at the metallic reflector, attached to a sensitive micrometer which can be moved up and down. The incident and reflected waves form standing wave pattern. By moving the micrometer in the sample, maxima and minima are formed which can be observed in the micrometer of interferometer. These maxima are separated by half integral multiple of the wavelength of the ultrasonic wave. The densities at different temperatures were measured using 10ml specific gravity bottle and single pan macro balance. The uncertainty in density measurements was found to be 0.5kg/m3. These parameters are calculated by using standard relations[6].

Results and Discussion

Ultrasonic velocities of potassium salts solutions in polyacrylamide solution in different concentration at 303K have been determined and are presented in tables 1-4. Ultrasonic velocity varies in accordance with molecular interactions in solutions. The variation of ultrasonic velocity in a solution depends upon the intermolecular free length (Lf). The ultrasonic velocity increases whereas the free length decreases and vice versa. Presence of ion alters the intermolecular free length. Therefore, ultrasonic velocity of a binary solution will be different from that of the solvent. The minimum value of ultrasonic velocity indicates weakening of the molecular association at these concentrations. The variations of ultrasonic velocity with mole fraction of potassium salt solution at different concentrations are shown in Figure 1. It is observed that the ultrasonic velocity varies non-linearly with concentration and a sudden decrease at a particular concentration as reported earlier[8-9].

Density increases with increase in concentration of potassium salts in polyacrylamide solution, due to the presence of ions or particles. The variations in density with increase in concentration are shown in tables 1-4. When an ion is added to a solvent, it attracts certain solvent molecules towards itself by wrenching the molecular from bulk compressibility of a solvent is higher than that of a solution and it decreases with the increase in concentration of the solution. The deviation in adiabatic compressibility can be explained by taking into consideration of the following factor. i. Loss of di-polar association and difference in size and shape of the component molecules which leads to decrease in velocity and increase in compressibility. ii. Dipole-dipole interaction or hydrogen bonded complex formation between unlike molecules which lead to increase in sound velocity and decrease of compressibility.

The actual deviation depends on the resultant effect. The observed decrease/increase in adiabatic compressibility, intermolecular free length, acoustic impedance and relative association with composition is an evidence of significant interaction between the component molecules in the binary mixtures. Adiabatic compressibility (βad) of the solution was calculated using the formula-

$$(\beta ad)=1/(U^2\rho)- \quad (1)$$

Where U is the ultrasonic velocity and ρ is the density of the solution. The variation of adiabatic compressibility with the mole fraction for all the systems is shown in table 1-4. From the data, it is observed that adiabatic compressibility varies non-linearly with mole fraction of the salts solution. The variation of adiabatic compressibility of different potassium salts with polyacrylamide solution is shown in figure 2. In this present study, adiabatic compressibility is decreases with increase in the potassium salts which may be due to departure of solvent molecules around the ions. It means, insolvent interaction increases[9-11].

Acoustic impedance (Z) was calculated using the formula -

$$(Z) = (U\rho) \quad (2)$$

The acoustic impedance (Z) also shows the same trend of relative association. The variation of acoustic impedance with concentration is shown in figure 3. Acoustic impedance is almost reciprocal of adiabatic compressibility. In this present investigation, it is observed that these acoustic impedance (Z) value increase with increase in concentration of potassium salts in polyacrylamide solution. The linear variation of acoustic impedance with concentration confirms the presence of molecular association between the solute-solvent molecules. Such in increasing trends of impedance further support the possibility of molecular interaction between the solute-solvent molecules[12,13].

Intermolecular free length (L) were calculated using the formula –

$$(L_f) = K\sqrt{\beta_{ad}} \quad (3)$$

Where K is the Jacobson's constant, β_{ad} is the adiabatic compressibility of the mixed solution. Intermolecular free length (Lf) decreases with the increase in concentration of the solution. It may be stated that, density and free length are inversely related. The intermolecular free length is decrease with increase in concentration. The inter molecular free length has an inverse behavior. The structural changes are also found to affect the variation of inter molecular free length. An increase in free length produces decrease in ultrasonic velocity. The variation of molecular free length of different potassium salts with polyacrylamide solution is shown in figure 3. The data shows that, the decrease of free length with the increase in concentration of potassium salts and reaches the minimum. The existence of minimum free length is an indication that the structural readjustment in the liquid mixture in the direction of les compressible phase or closer packing of molecules. Consequently the ultrasonic velocity increases. The sudden increase in free length with decrease in velocity at a high concentration of potassium nitrate and potassium iodide at a mole fraction of 0.6666 indicates that there is a significant interaction present between the solute molecules due to which structural arrangements of molecules are considerably affected[14].

Surface tension (σ) were calculated using the formula-

$$(\sigma) = (6.3\times10^{-4})\ \rho U^{3/2} \quad (4)$$

Where U is the ultrasonic velocity and ρ is the density of the solution. Surface tension is used to study the surface composition of aqueous solution of the mixtures. A variation of surface tension shows the attractive interactions between the two solutions. The surface tension of a liquid mixture is not a simple function of the surface tension of the pure Liquids. At the interface, there is migration of the species having the lowest surface tension, or free energy per unit area, at the temperature of the system. This migration at the interface results in a liquid-phase rich in the component with the highest surface tension and a vapor phase rich in the component with the lowest surface tension. Surface tension increases with the addition of solute. The observation is in accordance with the change in mean free length[15]. The velocity, compressibility, impedance and molecular free length of all the systems are studied. Potassium nitrate and potassium iodide shows a non-linear variation with the concentration of solute. Further, the data have exhibited a dip in compressibility, there by indicating the complex formation.

The effect of potassium nitrate on the ultrasonic velocity of polyacrylamide is illustrated in table 1. So there is oscillation with much non-linearity in the results, the general trend appears as an increase with increase in the potassium nitrate concentration. Hence the inter-chain interaction in polyacrylamide may be may be gradually suppressed with increase in the concentration of polyacrylamide. Since in polyacrylamide, there is dipole-dipole and Vander walls force of interaction. The former is more affected by potassium nitrate. In other words, the increase in the dielectric constant of the medium decreases the inter-chain interaction in polyacrylamide solution. The effect of potassium iodide on ultrasonic velocity of polyacrylamide is illustrated in table 2. There is a gradual decrease in velocity was noted within the mole fraction of potassium iodide. Hence potassium iodide might not enhance dielectric constant significantly in order to decrease the inter-chain interaction in polyacrylamide. Since there is a decrease, there must be enhancing interaction in polyacrylamide. The effect of mole fraction of potassium chloride inultrasonic velocity of polyacrylamide is illustrated in table 3. There is a gradual increase in ultrasonic velocity. Hence potassium chloride might significantly alter the dielectric constant of a medium and suppresses the inter-chain interaction in polyacrylamide solution. The effect of mole fraction of potassium hydroxide on velocity is illustrated in table 4. Here also, there is increase in velocity with mole fraction of potassium hydroxide is noted. From the above discussion it is evident that the inter-chain interaction in polyacrylamide is strongly influenced by the dielectric constant of the medium.

Table-1
Experimental values of ultrasonic velocity, density, adiabatic compressibility, acoustic impedance, molecular free length and surface tension of potassium nitrate in polyacrylamide solution

Mole fraction of potassium nitrate	Ultrasonic velocity (U)ms^{-1}	Density (ρ) kgm^{-3}	Adiabatic compressibility (β_{ad})10^{-10} $kg^{-1}ms^2$	Acoustic impedance (Z) $kgm^{-2}s^{-1}$	Free length (L_f) 10^{-10} m	Surface Tension (σ) Nm^{-1}
0.0526	1519	1017	4.2591	1545326	0.8833	37948
0.1111	1524	1025	4.2010	1561686	0.8772	38412
0.1765	1522	1030	4.1891	1568066	0.8760	38545
0.2500	1532	1031	4.1366	1578431	0.8705	38916
0.3333	1530	1039	4.1131	1589168	0.8680	39160
0.4286	1528	1048	4.0854	1601909	0.8651	39449
0.5385	1539	1054	4.0073	1621405	0.8568	40074
0.6666	1522	1058	4.0818	1609584	0.8647	39562
0.8181	1541	1061	3.9718	1634333	0.8530	40413
1.0000	1554	1063	3.8975	1651078	0.8450	41005

Table-2
Experimental values of ultrasonic velocity, density, adiabatic compressibility, acoustic impedance, molecular free length and surface tension of potassium iodide in polyacrylamide solution

Mole fraction of potassium iodide	Ultrasonic velocity (U)ms^{-1}	Density (ρ)kgm^{-3}	Adiabatic compressibility (βad) 10^{-10} $Kg^{-1}ms^2$	Acoustic impedance (Z)$kgm^{-2}s^{-1}$	Molecular free length (Lf)10^{-10}m	Surface Tension (σ) Nm^{-1}
0.0526	1516	1031	4.223	1562526	0.87953	38322
0.1111	1509	1039	4.225	1568300	0.87974	38383
0.1765	1504	1049	4.214	1578112	0.87855	38555
0.2500	1508	1058	4.156	1595449	0.87257	39032
0.3333	1505	1067	4.138	1606067	0.87063	39249
0.4286	1503	1075	4.117	1615569	0.86847	39463
0.5385	1504	1084	4.082	1629599	0.86467	39808
0.6666	1496	1092	4.091	1633851	0.86562	39817
0.8181	1498	1103	4.042	1651605	0.86047	40272
1.0000	1517	1012	4.293	1542148	0.88679	11974

Table-3
Experimental values of ultrasonic velocity, density, adiabatic compressibility, acoustic impedance, molecular free length and surface tension of potassium chloride in polyacrylamide solution

Mole fraction of potassium chloride	Ultrasonic velocity (U)ms^{-1}	Density (ρ)kgm^{-3}	Adiabatic compressibility (βad)10^{-10} $Kg^{-1}ms^2$	Acoustic impedance (Z)$kgm^{-2}s^{-1}$	Molecular free length (Lf)10^{-10}m	Surface Tension (σ) Nm^{-1}
0.0526	1523	1013	4.260	1541749	0.88339	37900
0.1111	1526	1018	4.218	1553382	0.87900	38233
0.1765	1530	1022	4.178	1563875	0.87488	38542
0.2500	1536	1025	4.133	1575163	0.87009	38894
0.3333	1539	1029	4.105	1582974	0.86712	39124
0.4286	1546	1032	4.055	1595255	0.86187	39515
0.5385	1549	1038	4.015	1607523	0.85763	39863
0.6666	1548	1040	4.011	1610185	0.85720	39915
0.8181	1555	1044	3.964	1622651	0.85211	40309
1.0000	1562	1049	3.925	1624502	0.84878	40525

Table 4
Experimental values of ultrasonic velocity, density, adiabatic compressibility, acoustic impedance, molecular free length and surface tension of potassium hydroxide in polyacrylamide solution

Mole fraction of potassium hydroxide	Ultrasonic velocity (U)ms^{-1}	Density (ρ)kgm^{-3}	Adiabatic compressibility (βad)10^{-10} $kg^{-1}ms^2$	Acoustic impedance (Z)$kgm^{-2}s^{-1}$	Molecular free length (Lf)10^{-10}m	Surface tension (σ)Nm^{-1}
0.0526	1516	1014	4.288	1537837	0.88633	37727
0.1111	1523	1015	4.245	1546591	0.88185	38026
0.1765	1526	1016	4.227	1550390	0.87990	38157
0.2500	1534	1022	4.158	1567855	0.87273	38687
0.3333	1537	1025	4.131	1575194	0.86986	38905
0.4286	1548	1028	4.060	1591143	0.86239	39440
0.5385	1567	1031	3.951	1615366	0.85076	40282
0.6666	1572	1035	3.910	1626786	0.84629	40638
0.8181	1571	1043	3.888	1637507	0.84394	40885
1.0000	1574	1051	3.815	1645206	0.84021	41305

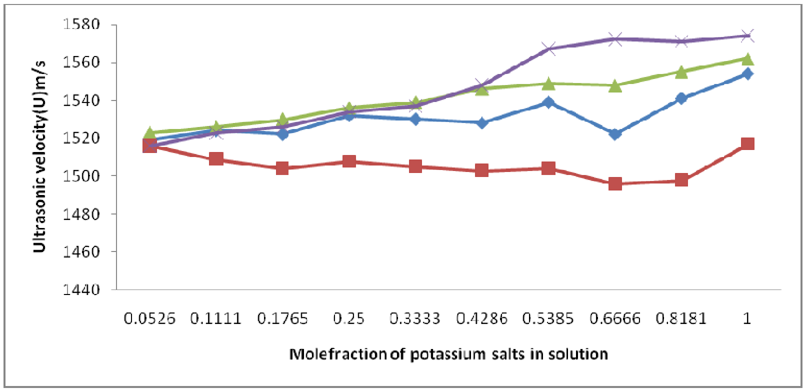

Figure-1
Graph between the variations of ultrasonic velocity of various potassium Salts in polyacrylmaide binary solution at different concentrations

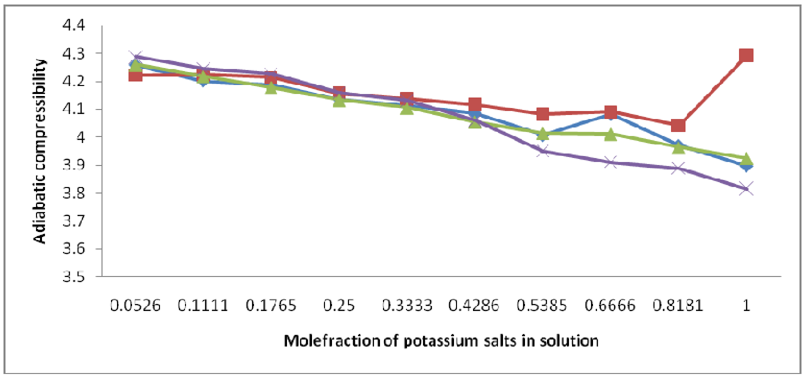

Figure-2
Graph between the variations of adiabatic compressibility of various Potassium salts in polyacrylmaide binary solution at different concentrations

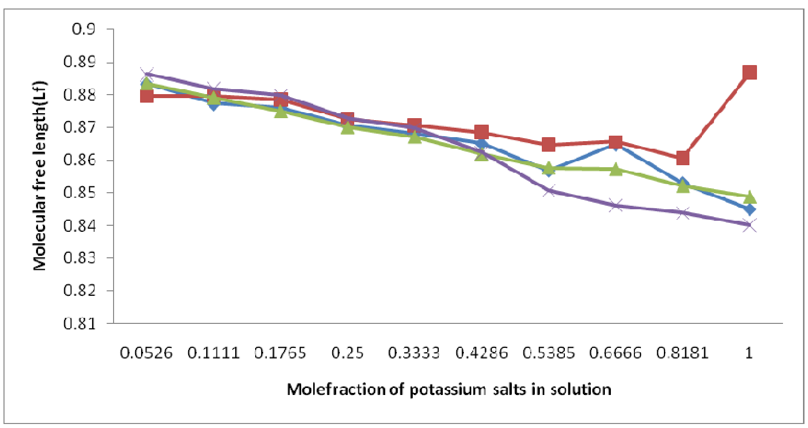

Figure-3
Graph between the variations of molecular free length of various potassium Salts in polyacrylmaide binary solution at different concentrations

Conclusion

In this study, the measurement of ultrasonic velocity and other acoustical parameters of some potassium salts in polyacrylamide solution was studied in different concentrations at 303K. The experimental ultrasonic velocity data and other acoustical parameters contain valuable information regarding the solute-solvent interactions in the aqueous solutions. Based on our measurements, it can be concluded that the concentration of the potassium nitrate affects the dipole-dipole interaction and also affect the dielectric constant of the solution. The concentration of the potassium iodide decreases the inter-chain interaction in the binary solution. In conclusion, the concentration, nature of the solvent, nature of the solute and its potion play an important role in determining the interactions occurring in the solutions. Similarly, potassium chloride and potassium hydroxide were also affecting the dielectric constant of a medium. These conclusions have given scope for further studies on the thermodynamic properties for the system.

Acknowledgement

The authors thanks to Dr. Palanisamy, Professor, Department of Chemistry, Anna University, Chennai, Tamilnadu, Prof. A.N. Kanappan, Department of Physics, Annamalai University, and Dr. Chandramouleeswaran, Professor and Head (Rtd),Government of College of Engineering, Salem, Tamilnadu, India for their support in this work.

References

1. Ravichandran S. and Ramanathan K., Ultrasonic investigations of M_nSO_4, N_iSO4 and C_uSO4 aqueous in polyvinyl alcohol solution at 303K, *Rasayan. J. Chem*., **3**, 375 **(2010)**

2. Syal Anita, Chauhan V.K. and Chauhan Suvarcha, Ultrasonic velocity, viscosity and density studies of poly (ethyleneglycols) (PEG - 8,000, PEG - 20,000) in acetonitrile (AN) and water (H_2O) mixtures at 250C, *J. Pure. Appl.Ultrason*. **27**, 61 **(2005)**

3. Pankaj K., Singh S.C. Bhatt, Investigation of Acoustical Parameters of Polyvinyl Acetate, *App.Phy.Res*., **2**, 1 **(2010)**

4. Krzysztof Bebek, Aleksandra Strugala., Acoustic and Thermodynamic properties of binary liquid mixtures of 2-Methyl-1-Propanol in hexane and cyclohexane at 293.15K., *Mole. Quant. Acoust*., **27**, 337 **(2006)**

5. Krzysztof Bebek, Speed of ultrasound and thermodynamic properties of 1-butanol in binary liquid mixtures at 293.15K., *Mole. Quant. Acous*., **26**, 15 **(2005)**

6. Ravichandran S. and Ramanathan K., Acoustical parameters of polyacrylamide with sodium (meta) silicate and potassium silicate solution at 303 K., *Polym. Chem.,***1,** 698 **(2010)**

7. Ravichandran S. and Rathika Thaya Kumari C., Effect of Anionic Surfactant on the Thermo Acoustical Properties of Sodium Dodecyl Sulphate in Polyvinyl Alcohol Solution by Ultrasonic Method., *E-J. Chem*., **8,** 77 **(2011)**

8. Shanmuga Priya, Nithya, Velraj, Kanappan A.N., Molecular interactions studies in liquid mixture using Ultrasonic technique., *Int. J. Adv. Sci. Tech*., **18**, 59 **(2010)**

9. Anwar Ali, Anil Kumar Nain, Dinesh Chand and Rizwan Ahmad, Volumetric and Ultrasonic Studies of Molecular Interactions in Binary Mixtures of Dimethyl Sulfoxide with Some Aromatic Hydrocarbons at Different Temperatures, *Bull.Chem. Soc. Jpn*, **79**, 702 **(2006)**

10. Anwar Ali, Nabi F. and Tariq M., Volumetric, viscometric, ultrasonic, and refractive index properties of liquid mixtures of benzene with industrially important monomers at different temperatures, *Int. J. Thermophy*, **30**, 464 **(2009)**

11. Anil Kumar Nain., Inversion of the Kirkwood-Buff theory of solutions: Application to tetrahydrofuran + aromatic hydrocarbon binary systems, *J. Solut. Chem*., **37**, 1541 **(2008)**

12. Nain A.K., Densities and volumetric properties of binary mixtures of aniline with 1- propanol, 2-propanol, 2-methyl-1-propanol, 2-methyl-2-propanol at temperatures from 293.15 and 318.15 K., *Int.J.Therm.Phys*, **28,** 1228 **(2007)**

13. Anil Kumar Nain., Ultrasonic and viscometric studies of molecular interactions in binary mixtures of acetonitrile with some amides at different temperatures, *Bull. Chem. Soc. Jpn*, **79**, 11, 1688 **(2006)**

14. Ravichandran S. and Ramanathan K., Molecular Interactions with Polyacrylamide in Ethanolamine, Diethanolamine, and Triethanolamine Solutions Measured Ultrasonically, *Poly. Plast. Tech Engg*, **47,** 169 **(2008)**

15. Ravichandran S. and Ramanathan K., Molecular interactions and Excess Thermodynamic properties of mixed solutions of Zinc sulphate and Zinc nitrate at 303K by Ultrasonic method, *Int. J. App. Bio. Pharm. Tech*., **1,** 705 **(2010)**