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Ultrasonic study of mixture, containing Aqueous solution of 'NaCl' and 'KCl' for different ratios of Sodium to Potassium about Vitality ratio and about Human body Temperature

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Abstract

The *Ultrasonic velocity, density and viscosity have been measured for different ratios of sodium (Na) to potassium (K) about vitality ratio and about normal body temperature. The ratios are analysed in terms of the thermodynamic parameters derived from the ultrasonic data.*

Keywords: Thermodynamic parameters, ultrasonic velocity, vitality ratio.

Introduction

Ultrasonic method finds extensive application in investigating various physicochemical parameters involving molecular interactions in liquid mixtures[1-10]. This technique has also been used in engineering, agriculture and medicine[11-13]. In engineering it is used to study the structure of materials. Ultrasonic pulses can speed up certain chemical reactions and act as a catalytic agent in wheat germination.

We have applied the same to study the variation in the thermodynamic parameters when the ratio of certain minerals like Na to K, Ca to Mg etc are changed. Human body needs many minerals known as essential minerals. These are further divided in two major minerals (like Na, K …) and micro minerals (like Fe, Si,…). The later is required in small amounts. However the amounts needed are not an indicator of their importance. It has been seen that mineral ratios are often more important in studying nutritional deficiencies and excesses than mineral levels alone. Mineral ratios are indicative of disease trends. Ratios also predict future metabolic dysfunction or hidden metabolic dysfunction.

The basic mineral ratios that are important are i. Na; K ii. Ca:Mg iii. Na:Mg iv. Zn:Cu. Sodium to potassium ratio is referred to as the life-death ratio. Sodium is normally extra cellular and potassium is intracellular. An imbalanced sodium potassium ratio is associated with heart, liver, kidney and immune deficiency dieses. The Na:K ratio can be studied through hair analysis or blood serum analysis. Previous analysis pinpoints the development of metabolic dysfunction before symptoms manifest, but the latter does it only when the condition is advanced.

The thermodynamic parameters have been studied for Na:K ratios obtained from hair analysis at different temperatures[14]. In this paper we do similar analysis for Na:K ratio obtained from blood serum analysis at the same temperatures. The ideal Na:K ratio from hair analysis is 2.5 : 1 and from blood serum analysis is 28.5 : 1.

Material and Methods

Experimental technique: The aqueous solution of sodium chloride (NaCl) and potassium chloride (KCl) with different concentrations in mole fraction were prepared. The alytical reagent grade and spectroscopic reagent grade chemicals with minimum assay of 99.9%, obtained from E-Merck Ltd (India) are used for the solutions.

The density, viscosity, and ultrasonic velocity for all the aqueous solutions were measured at temperatures 298K, 303 K 308 K, 310 K, 312 K and 323 K at constant frequency of 3 MHz.

Ultrasonic velocity of the mixtures were measured by using an ultrasonic interferometer (Model M-84, supplied by M/S Mittal Enterprises, New Delhi), with the accuracy of ±0.1m·s−1. The densities of the mixture were measured using a 10-ml specific gravity bottle by relative measurement method with an accuracy of ±0.01 kg·m−3, and an Oswald viscometer (10 ml) with an accuracy of ± 0.001 Ns·m−2 was used for the viscosity measurement. To maintain the constancy of temperature, an electronically operated digital constant temperature bath (Model SSI-03 Spl, supplied by M/S Mittal Enterprises, New Delhi), operating in the temperature range of−10°C to 85°C with an accuracy of ±0.1°C had been used.

Theory: Following relations were used for calculating different acoustic and thermodynamical parameters

Adiabatic compressibility: $\beta = \frac{1}{\rho . U^2} \ldots\ldots (N^{-1}.m^2)$

Free volume: $V_f = \left(\frac{M_{eff}.U}{K\eta}\right)^{3/2}$ ... ... $(m^3.mol^{-1})$

Where: 'K' is a dimensionless constant independent of temperature and liquid. Its value is 4.281 x 10^9.

Internal pressure: $\pi_i = bRT\left(\frac{K\eta}{U}\right)^{\frac{1}{2}}\left(\frac{\rho^{\frac{2}{3}}}{M^{\frac{7}{6}}}\right)$ … … (N.m^{-2})

Where: 'b' stands for the cubic packing factor, which is assumed to be '2' for all liquids and solutions.

Acoustic impedance (Z): $Z = \rho.U$ (Kg.m^2.s^{-1})

Gibb's free energy (ΔG): $\Delta G = 2.30.KT \log\left(\frac{KT\tau}{h}\right)$ (k.J.mol^{-1})

Where: 'K' is the Boltzmann's constant and '*h*' is the Plank's constant.

Molar volume (V_m): $V_m = \frac{M_{eff}}{\rho}$ .... (m^3 mol^{-1})

Rao's constant (R): $R = \left(\frac{M_{eff}}{\rho}\right).U^{\frac{1}{3}} = V_m.U^{\frac{1}{3}}$ (m^3.mol^{-1}.(m/s)$^{1/3}$)

Surface tension (S): $S = 6.3\ X10^{-4}.\rho.U^{\frac{3}{2}}$ (N.m^{-1})

Where: the symbols have their usual meanings

Results and Discussion

Experimental values of density, viscosity are presented in table - 1, ultrasonic velocity is given in table-2. Calculated values of adiabatic compressibility, Gibb's free energy, internal pressure, free volume, molar volume, acoustic impedance and surface tension are reported in table - 3 to table - 9. Variation of some of these parameter's with mole fraction of NaCl are shown in figures-1 to 8.

Sodium ions are largely hydrated and hence are less mobile than potassium ions hence density increases as sodium potassium ratios increases. As the temperature increases, the mobility of ions increases, hence density decreases. Viscosity changes in the same way as density.

Ultrasonic velocity increases and adiabatic compressibility decreases as temperature increases. The same nature of change also occurs when the ratio Na : K increases. This confirms that in both the cases, the intermolecular force increases.

Table–1
Values of Density (ρ) and Viscosity (η) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		Na/K	Density (ρ) (Kg.m^{-3})						Viscosity (η) (x10^{-3} N.s.m^{-2})					
NaCl	KCl		293 K	303 K	308K	310 K	312 K	323 K	293 K	303 K	308K	310 K	312 K	323 K
0.0634	0.0022	22:1	1145.9	1141.9	1138.8	1138.7	1137.9	1134.5	1.28	1.13	1.01	0.89	0.84	0.71
0.0767	0.0022	27:1	1175.8	1171.2	1169.8	1168.7	1167.8	1164.7	1.34	1.20	1.06	1.01	0.95	0.78
0.0793	0.0022	28:1	1179.9	1175.1	1173.5	1171.5	1170.6	1167.4	1.39	1.22	1.08	1.02	0.96	0.81
0.0806	0.0022	28.5:1	1182.8	1179.1	1178.1	1177.5	1176.6	1173.3	1.41	1.26	1.11	1.04	0.98	0.84
0.0819	0.0022	29:1	1186.2	1184.7	1182.8	1180.8	1179.4	1176.9	1.45	1.27	1.12	1.05	0.98	0.78
0.0947	0.0022	34:1	1198.0	1196.9	1194.8	1192.7	1190.1	1187.5	1.49	1.34	1.17	1.01	0.93	0.84

Table–2
Values of Velocity (V) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		Na/K	Velocity(V) ms^{-1}					
NaCl	**KCl**		**293 K**	**303 K**	**308K**	**310 K**	**312 K**	**323 K**
0.0634	0.0022	22:1	1713.0	1721.5	1725.7	1729.2	1730.7	1737.4
0.0767	0.0022	27:1	1747.1	1752.1	1754.1	1755.5	1757.3	1764.2
0.0793	0.0022	28:1	1756.7	1762.4	1764.3	1766.9	1768.7	1776.9
0.0806	0.0022	28.5:1	1766.2	1773.8	1775.8	1777.9	1780.5	1786.2
0.0819	0.0022	29:1	1774.2	1776.9	1779.5	1782.0	1783.8	1788.7
0.0947	0.0022	34:1	1789.1	1795.6	1802.5	1814.7	1822.3	1828.5

Table–3
Values of Adiabatic compressibility (β) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		Na/K	β = Inv(U^2. ρ) x 10^{-10}					
NaCl	KCl		293 K	303 K	308K	310 K	312 K	323 K
0.0634	0.0022	22:1	2.974	2.954	2.948	2.937	2.934	2.920
0.0767	0.0022	27:1	2.786	2.781	2.778	2.776	2.773	2.758
0.0793	0.0022	28:1	2.746	2.74	2.737	2.734	2.731	2.713
0.0806	0.0022	28.5:1	2.710	2.695	2.691	2.687	2.681	2.671
0.0819	0.0022	29:1	2.678	2.673	2.670	2.667	2.665	2.656
0.0947	0.0022	34:1	1.49	1.34	1.17	1.01	0.93	0.84

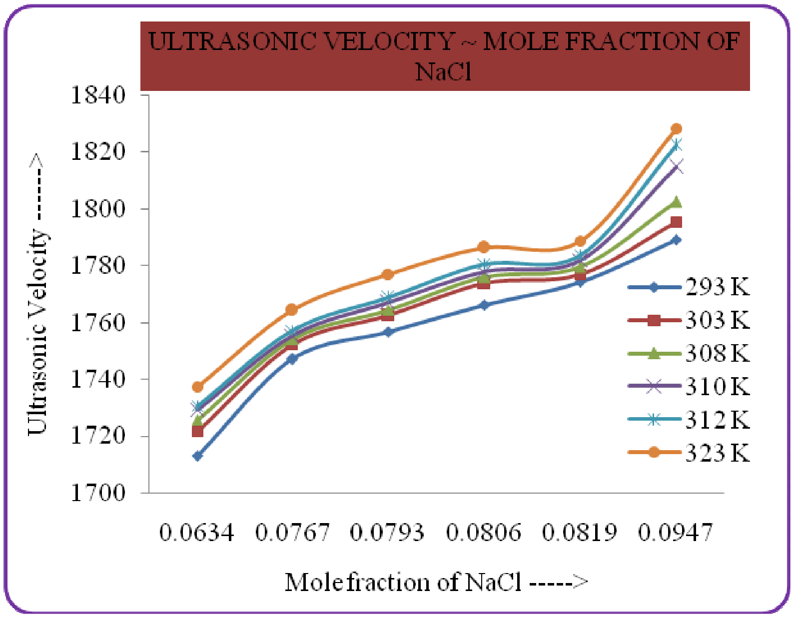

Figure-1
Variation of Ultrasonic velocity with mole fraction of NaCl

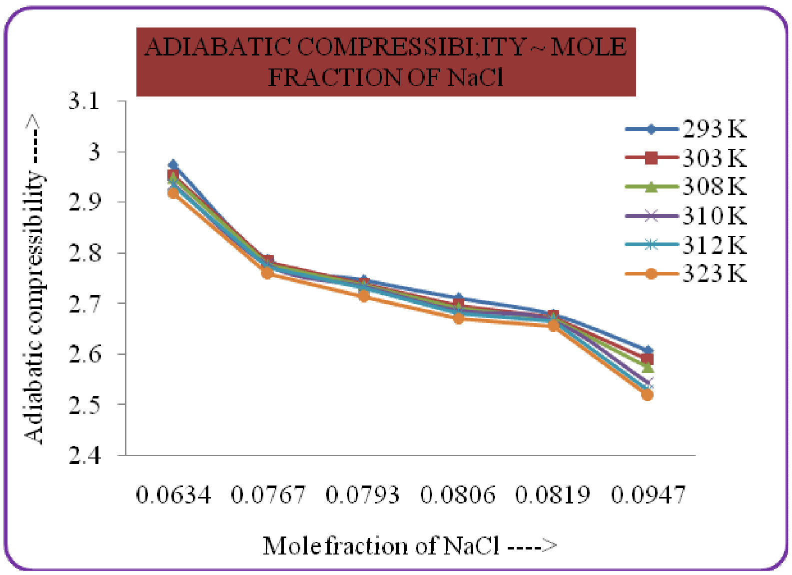

Figure-2
Variation of Adiabatic compressibility with mole fraction of NaCl

Table–4
Values of Gibb's free energy (ΔG) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		**Na/K**	**Gibb's free energy (ΔG) (x 10^{-20} k.J.mol^{-1})**					
NaCl	KCl		293 K	303 K	308K	310 K	312 K	323 K
0.0634	0.0022	22:1	0.4573	0.4320	0.3958	0.3489	0.3272	0.2772
0.0767	0.0022	27:1	0.4509	0.4306	0.3932	0.3769	0.3554	0.2936
0.0793	0.0022	28:1	0.4581	0.4335	0.3953	0.3750	0.3517	0.3033
0.0806	0.0022	28.5:1	0.4601	0.4378	0.3972	0.3770	0.3525	0.3113
0.0819	0.0022	29:1	0.4662	0.4395	0.3988	0.3779	0.3540	0.2743
0.0947	0.0022	34:1	0.4671	0.4498	0.4032	0.3399	0.3072	0.2863

Increase in Gibb's free energy (ΔG) suggests closer approach of molecules in the mixture and vice versa[15]. 'ΔG' in this case decreases as temperature increases for a fixed Na : K ratio. Temperature remaining constant, 'ΔG' increases slowly with increasing Na : K ratio. However at temperatures 310 K and 312 K, 'ΔG' becomes minimum for the Na : K ratio equal to 28:1. Minimum value of 'ΔG' indicates good flow of the mixture.

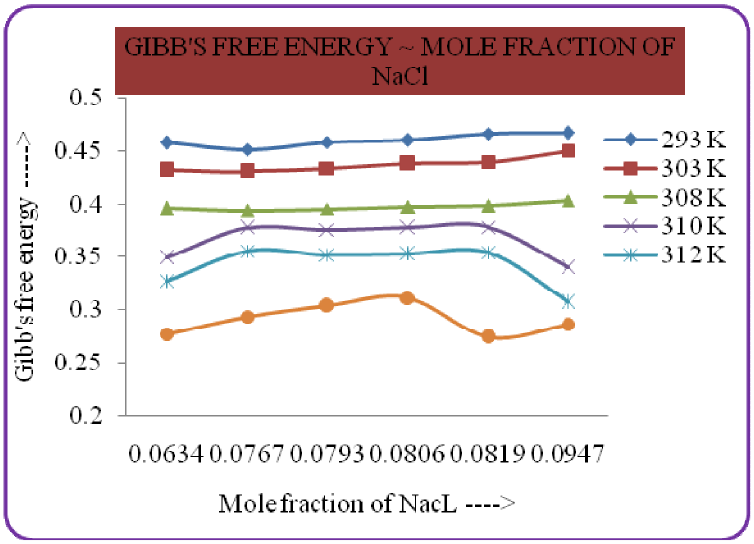

Figure-3
Variation of Gibb's free energy with mole fraction of NaCl

Table–5
Values of Internal pressure (π_i) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		Na/K	Internal pressure (π_i) (x 10^6 N.m^{-2})					
NaCl	KCl		293 K	303 K	308K	310 K	312 K	323 K
0.0634	0.0022	22:1	2780.5	2688.2	2570.9	2436.3	2376.6	2253.1
0.0767	0.0022	27:1	2786.8	2706.9	2587.9	2537.9	2475.4	2314.7
0.0793	0.0022	28:1	2814.4	2719.1	2596.4	2532.9	2465.4	2341.0
0.0806	0.0022	28.5:1	2828.9	2744.9	2615.3	2554.8	2483.7	2375.6
0.0819	0.0022	29:1	2858.1	2760.4	2627.3	2561.5	2490.0	2282.4
0.0947	0.0022	34:1	2827.5	2765.4	2616.4	2433.5	2343.0	2298.7

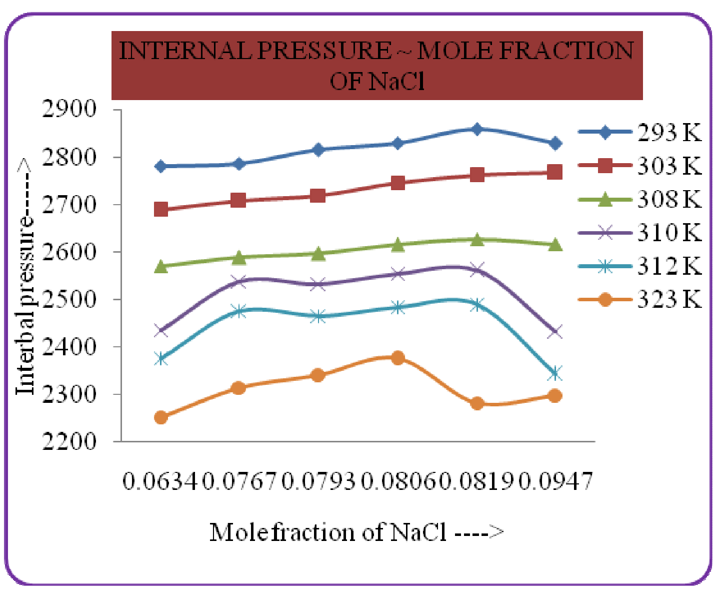

Figure-4
Variation of Internal pressure with mole fraction of NaCl

Na: K ratio remaining constant, internal pressure (π_i) decreases as temperature increases. At any particular temperature, internal pressure increases slowly as the Na : K ratio increases. However 'π_i' becomes minimum for the ratio 28:1 at temperatures 310 K and 312 K. Minimum internal pressure indicates minimum cohesive force which is also observed while studying 'ΔG'.

Free volume is the average volume in which the center of a molecule can move due to the repulsion of the surrounding molecules[16]. For a particular ratio of Na : K , free volume increases as temperature increases. This may be due to the fact that, effective free volume changes due to the transmission of collision effect through the molecules. At a fixed temperature, free volume decreases as the ratio of Na : K increases. However at temperatures 310 K and 312 K free volume becomes maximum for the ratio 28:1. Free volume is maximum when internal pressure is minimum.

Table–6
Values of Free volume (V_f) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		**Na/K**	**Free volume (V_f) (10^{-7} $m^3.mol^{-1}$)**					
NaCl	KCl		293 K	303 K	308K	310 K	312 K	323 K
0.0634	0.0022	22:1	0.1648	0.2003	0.2392	0.2865	0.3143	0.4067
0.0767	0.0022	27:1	0.1638	0.1961	0.2351	0.2537	0.2783	0.3757
0.0793	0.0022	28:1	0.1585	0.1928	0.2320	0.2539	0.2803	0.3612
0.0806	0.0022	28.5:1	0.1561	0.1878	0.2277	0.2487	0.2756	0.3475
0.0819	0.0022	29:1	0.1515	0.1855	0.2252	0.2470	0.2734	0.3923
0.0947	0.0022	34:1	0.1522	0.1796	0.2219	0.2803	0.3187	0.3728

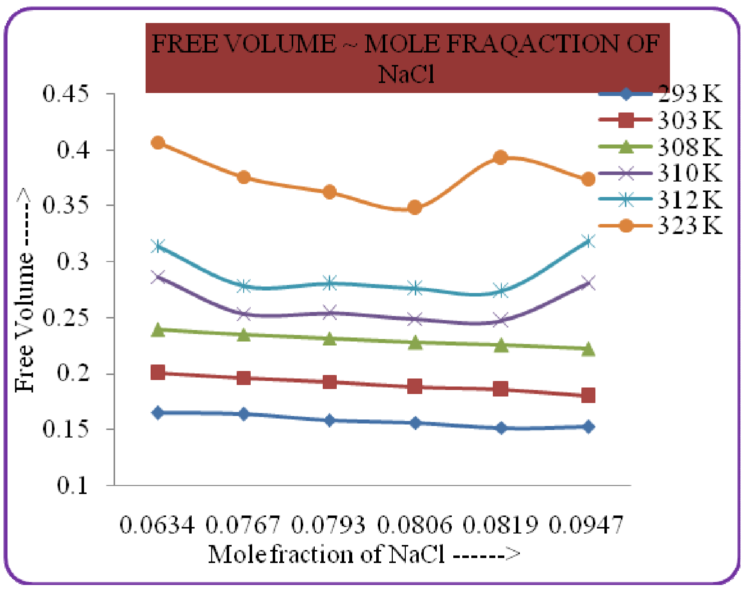

Figure-5
Variation of Free volume with mole fraction of NaCl

Table–7
Values of Molar volume (V_m) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		Na/K	Molar volume (V_m) ($m^3 \cdot mol^{-1}$)					
NaCl	KCl		293 K	303 K	308K	310 K	312 K	323 K
0.0634	0.0022	22:1	0.0181	0.0181	0.0182	0.0182	0.0182	0.0183
0.0767	0.0022	27:1	0.0181	0.0181	0.0182	0.0182	0.0182	0.0182
0.0793	0.0022	28:1	0.0181	0.0182	0.0182	0.0182	0.0182	0.0183
0.0806	0.0022	28.5:1	0.0181	0.0181	0.0182	0.0182	0.0182	0.0182
0.0819	0.0022	29:1	0.0181	0.0181	0.0181	0.0182	0.0182	0.0182
0.0947	0.0022	34:1	0.0183	0.0184	0.0184	0.0184	0.0185	0.0185

Molar volume should increases with increase in temperature as thermal energy facilitates increases in molecular separation. The change is however slow as the effect due to thermal energy is restricted by strong electrostatic force between molecules. Molar volume appears to be practically constant for the Na: K ratios 28:1, 28.5:1 and 29:1 at temperatures 308 K, 310 K, 312K, indicating no change in intermolecular interaction. This is also confirmed by the constancy of the Rao;s constant at the same temperatures and for the same ratios.

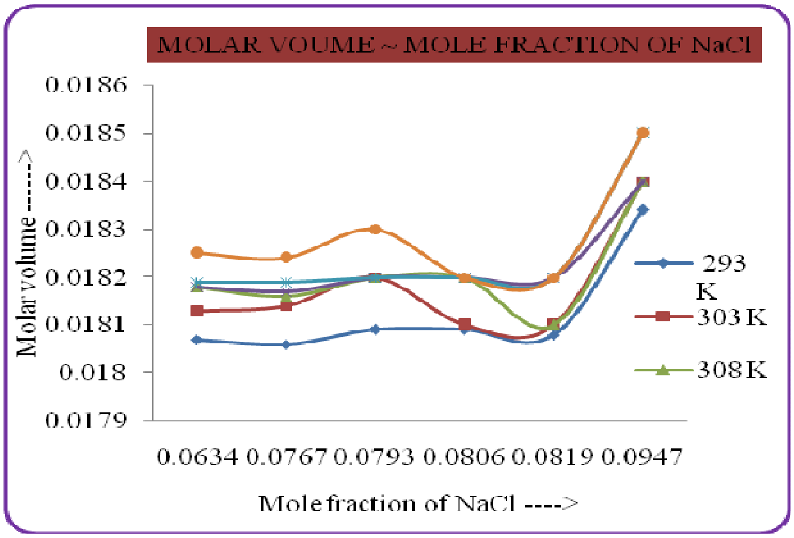

Figure-6
Variation of Molar volume with mole fraction of NaCl

Table–8
Values of Acoustic impedance (Z) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		Na/K	Acoustic impedance (Z)					
NaCl	KCl		293 K	303 K	308K	310 K	312 K	323 K
0.0634	0.0022	22:1	1.963	1.966	1.965	1.969	1.970	1.971
0.0767	0.0022	27:1	2.054	2.052	2.052	2.052	2.052	2.055
0.0793	0.0022	28:1	2.073	2.071	2.070	2.070	2.070	2.074
0.0806	0.0022	28.5:1	2.089	2.091	2.092	2.093	2.095	2.096
0.0819	0.0022	29:1	2.105	2.105	2.105	2.104	2.104	2.105
0.0947	0.0022	34:1	2.143	2.149	2.154	2.164	2.169	2.171

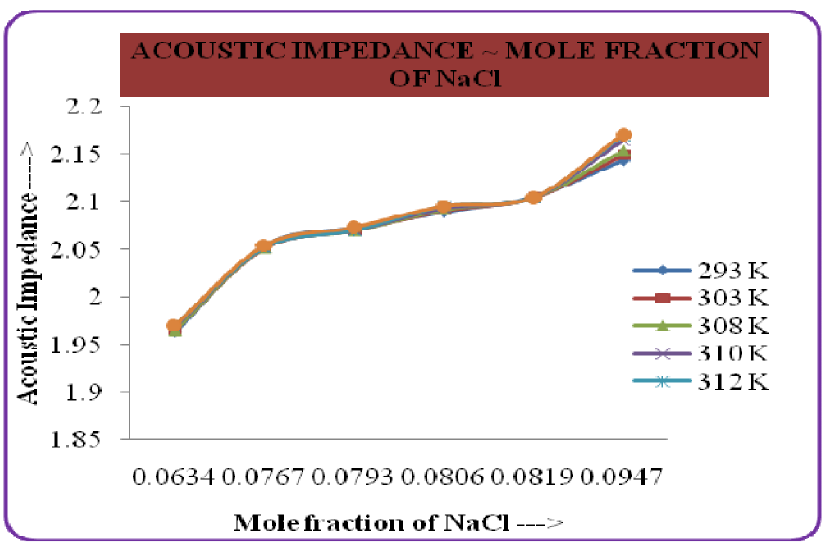

Figure-7
Variation of Acoustic impedance with mole fraction of NaCl

Acoustic impedance remains practically constant, as temperature increases for a particular ratio of Na :K, but increases as Na : K ratio increases when temperature remains constant. The former is true as cohesive force remains practically constant for a fixed Na : K ratio. Temperature remaining constant when Na : K ratio increases cohesion force increases, hence 'Z' increases.

With increase in temperature, surface tension increases very slowly. This is also confirmed by the fact that the ultrasonic velocity increases slowly with temperature. Surface tension also increases with increasing Na : K ratio. However it practically remains constant over the ratio range 27:1 to 29:1 which is near the vitality ratio.

Conclusion

Results indicate that, ultrasonic velocity and other derived parameters depend on the Na : K ratio as well as temperature. The parameters do not show much variation about vitality ratio and near body temperature. For very small and large ratios, the change in the parameters is apparent indicating the deviation from the vitality ratio or healthy ratio.

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Table–9
Values of Surface tension (S) of mixtures at 293K, 303K, 308k, 310K, 312K and 323K

Mole fraction		Na/K	Surface tension (N.m^{-1})					
NaCl	KCl		293 K	303 K	308K	310 K	312 K	323 K
0.0634	0.0022	22:1	51183	51385	51436	51584	51619	51761
0.0767	0.0022	27:1	54094	54115	54143	54157	54198	54373
0.0793	0.0022	28:1	54733	54772	54790	54819	54858	55088
0.0806	0.0022	28.5:1	55309	55494	55545	55612	55691	55803
0.0819	0.0022	29:1	55846	55906	55937	55962	55981	56093
0.0947	0.0022	34:1	57116	57377	57608	58089	58325	58493

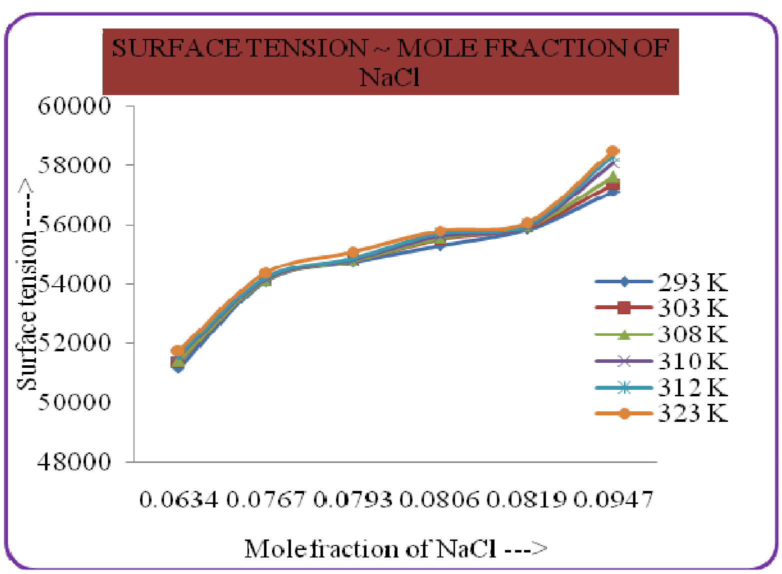

Figure-8
Variation of Surface tension with mole fraction of NaCl

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