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Research Article

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Physicochemical Properties of Aqueous Solution of L-Glutamic Acid Monosodium Salt: A Thermo-Acoustic Approach

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ABSTRACT

Ultrasonic velocity, viscosity and density of aqueous L- Glutamic acid monosodium salt of different concentrations (0.2-1) mol/kg has been measured at 298.15K and 300.15K. A considerable effect of temperature and concentration has been observed on these basic parameters. Using experimentally measured parameters, various derived acoustical parameters such as adiabatic compressibility, acoustic impedance, free length, free volume, internal pressure, molar sound velocity, relaxation time and Gibbs free energy were calculated. These parameters have been used to discuss the nature, strength and order of intermolecular interactions in the present system.

Keywords: Ultrasonic velocity; Molecular interactions; L-Glutamic acid

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INTRODUCTION

Isoflavonoids exhibit a large number of diverse biologic effects, both in vivo and in vitro that may be associated with anticancer activities [1]. The isoflavonoids bind with estrogen receptorsis related to the inhibition of cell cycle and leads to produce anti-cancer activity. As Isoflavonoids have various pharmacological activities, such as antioxidant activity, antiaromatase (CYP19) activity, and inhibition of endothelial proliferation, these should act along the initiation, promotion and progression phase of carcinogenesis. In case of breast cancer, transfer of Isoflavonoids from mother to foetus could affect the preventive effect to mammary gland after birth. It may suppress the development of mammary buds, which leads to the decreased risk of breast cancer in adulthood [2]. Administration of Isoflavonoids showed decreased plasma estradiol level and can reduce the risk of endometrial and ovarian cancer. As dietary soy-phytoestrogens decrease testosterone level and prostate weight, low prostatic cancer incidence occurs. Inhibitory effect of Isoflavonoids on 5-alpha- reductase was considered to be related to prevent prostatic cancer. The proposed mechanisms by which isoflavones may inhibit cancer are, inhibition of DNA topoisomerase, suppression of angiogenesis, induction of differentiation in cancer cell lines, Induction of apoptosis. The antioxidant effect of isoflavonoids reduce the risk of artherosclerosis, hypertension, hyperlipidemia, cardiac infarction and also used for the prevention of osteoporosis [3-5].

In contrast to the flavonoids, the distributions of isoflavonoids are relatively limited, most likely because of the sporadic occurrence of the isoflavone synthase enzyme, which is only produced by plants when required. Although there are several examples of naturally occurring isoflavonoids with potent activity against several ailments, their use as medicaments has been limited due to the following reasons: i) Low abundance of these compounds in the plant material, ii) Tedious extraction and purification techniques which often require extraction with very large quantities of solvents, multiple chromatographic purifications, occasionally including HPLC purifications iii) Unavailability of appropriate biological data. One of the possible solutions to these problems is the development of

efficient synthetic methodologies, which can produce not only the natural products but also their synthetic analogues for pharmacological applications [6-10].Focusing these properties ,we aim to design and synthesize a novel series of derivatives of isoflavonoids and screened for anticancer activity. Figure 1 represents the scheme of the synthesis.

EXPERIMENTAL SECTION

L–Glutamic acid monosodium salt ($C_5H_8NNaO_4.H_2O$, molecular weight 187.13 g/mol) was used as received. The ultrasonic velocities of the solution under the study were measured by using digital ultrasonic pulse echo velocity meter (VCT – 70A) at 2MHz. Digital ultrasonic pulse echo velocity meter is a simple and unique, direct reading digital system to determine the velocity of ultrasonic waves as well as to observe echoes for attenuation measurements with excellent accuracy. One piezo – electric transducer is provided at the end of the liquid cell to generate and receive the ultrasonic echo waves through the solutions under observation. The temperature around the cell was controlled by circulating the water from thermostat manufactured by Acculab scales company (Model – i-therm, AI – 7982). The water was allowed to circulate through the double walled measuring cell which was useful to obtain the desired temperature. The density of the stock solution was measured by using highly accurate specific gravity bottle method. To determine the viscosity of the solutions, an Ostwald's viscometer is used. The viscometer was set with fresh water immersed in the water bath which was kept at the experimental temperature. The flow time for solvent and solution was measured by using a digital stop watch having high accuracy separately. The temperature around the viscometer was maintained by using the same temperature controller.

Mathematical Formulation

Acoustic impedance (Z)

The specific acoustic impedance is given by

Z=U ρ_s Kg m^{-2} s^{-1}

ρ_s=Density of solution

U=ultrasonic velocity of solution

Adiabatic compressibility

$\beta_{ad} = \frac{1}{U^2 \rho_s}$ $N^{-1}m^2$

Free length (L_f)

$L_f = K_T \beta_{ad}^{1/2}$ m

K_T =The temperature dependent constant (199.5×10^{-8})

β_{ad}=Adiabatic Compressibility of solution.

Free volume (V_f)

$V_f = \left(\frac{M_{eff}U}{k\eta}\right)^{3/2}$ m^3mol^{-1}

M_{eff}=Molecular Weight

k=Temperature independent constant (4.28×10^9)

η=Viscosity of solution.

Internal pressure (π_i)

$\pi_i = bRT\left(\frac{k\eta}{U}\right)^{1/2}\left(\frac{\rho^{2/3}}{M_{eff}^{7/6}}\right)$ Pa

b=2 for all liquids

R=Gas const (8.314)

T=Temperature in Kelvin (e.g. 303K)

K=Temperature independent constant (4.28×10^9).

Relaxation time (τ)

$$\tau = \frac{4}{3\beta\eta}$$

where η is the viscosity of solution

Molar sound velocity (R)

$R = \frac{M_{eff}}{\rho}(U)^{1/3}$ m^5N^{-1}

Gibb's free energy

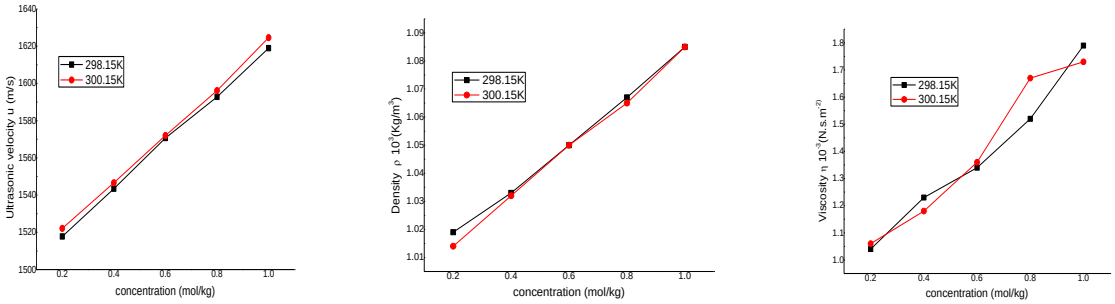
$\nabla G = -kT\log\left[\frac{h}{\tau KT}\right]$ $Jmol^{-1}$.

RESULTS AND DISCUSSION

The experimentally measured values of ultrasonic velocity, density and viscosity of aqueous L-Glutamic acid monosodium salt are given in Table 1 and Figure 1.Various derived acoustic parameters are calculated by using these basic parameters. The calculated values of acoustic parameters are given in Tables 2-4. Figure 2a-2i show the variation of these acoustic parameters with concentration and temperature.

Table 1. Ultrasonic velocity, density and viscosity of aqueous L-Glutamic acid monosodium salt

Conc. (mol/kg)	Ultrasonic velocity (U) ms^{-1}		Density (ρ) 10^3 kg/m^3		Viscosity (η) 10^{-3} $N.s.m^{-2}$	
	298.15K	300.15 K	298.15 K	300.15 K	298.15 K	300.15 K
0.2	1517.784	1522.108	1.019	1.014	1.04	1.06
0.4	1543.446	1546.657	1.033	1.032	1.23	1.18
0.6	1570.690	1572.011	1.050	1.050	1.34	1.36
0.8	1592.765	1596.164	1.067	1.065	1.52	1.67
1	1618.965	1624.591	1.085	1.085	1.79	1.73



(a) **(b)** **(c)**

Figure 1a-c. Variation of ultrasonic velocity, density and viscosity aqueous L-Glutamic acid monosodium salt

Table 2: Adiabatic compressibility, free length and free volume of aqueous L-Glutamic acid monosodium salt

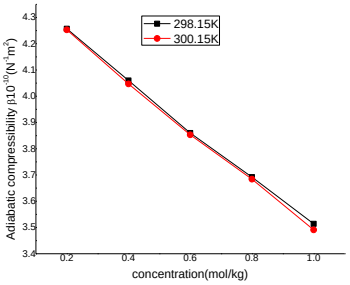
Conc. (mol/kg)	Adiabatic compressibility (β) $10^{-10}(N^{-1}m^2)$		Free length (L_f) 10^{-11}(m)		Free Volume (V_f) 10^{-8} (m^3mol^{-1})	
	298.15K	300.15K	298.15K	300.15K	298.15K	300.15K
0.2	4.257	4.253	4.244	4.256	1.5960	1.5219
0.4	4.060	4.047	4.145	4.152	1.3417	1.4273
0.6	3.860	3.853	4.041	4.051	1.2667	1.2378
0.8	3.692	3.684	3.953	3.962	1.1146	0.973
1	3.514	3.491	3.856	3.857	0.9348	0.989

Table 3: Internal Pressure, Acoustic Impedance and Relaxation Time of aqueous L-Glutamic acid monosodium salt

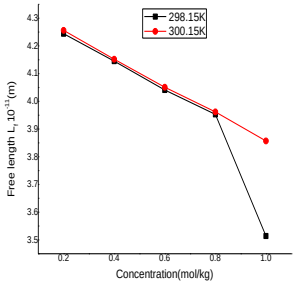
Conc. (mol/kg)	Internal Pressure (π_i) 10^9 (Pa)		Acoustic Impedance (Z) 10^6 ($Kg.m^{-2}.s^{-1}$)		Relaxation Time ζ 10^{-13} (s)	
	298.15K	300.15K	298.15K	300.15K	298.15K	300.15K
0.2	2.841	2.909	1.548	1.545	5.9093	6.0105
0.4	2.974	2.911	1.596	1.598	6.6427	6.3670
0.6	3.001	3.024	1.650	1.651	6.8856	6.9862
0.8	3.104	3.244	1.700	1.701	7.4931	8.2028
1	3.267	3.204	1.758	1.763	8.3862	8.0535

Table 4: Molar Volume, Rao constant and Gibbs free energy of aqueous L-Glutamic acid monosodium salt

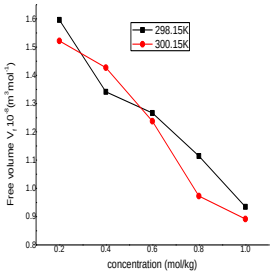
Conc. (mol/kg)	Molar Volume (V_m) $10^{-5}(m^3/mol)$		Rao Constant (R) $10^{-4}\ (m^5N^{-1})$		Gibbs free energy (ΔG) 10^{-21} (J mol^{-1})	
	298.15K	300.15K	298.15K	300.15K	298.15K	300.15K
0.2	1.825	1.804	2.10	2.07	4.350	4.412
0.4	1.858	1.860	2.15	2.15	4.779	4.623
0.6	1.887	1.886	2.19	2.19	4.911	4.964
0.8	1.912	1.916	2.23	2.24	5.221	5.553
1	1.934	1.935	2.27	2.28	5.634	5.485



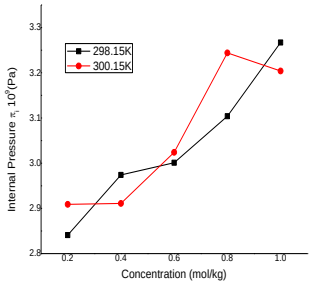
(a)



(b)



(c)



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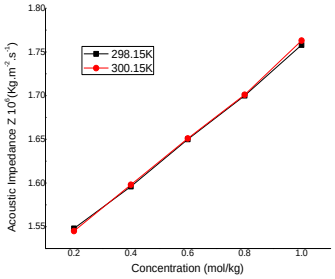

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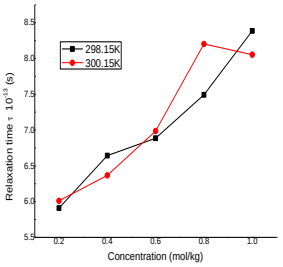
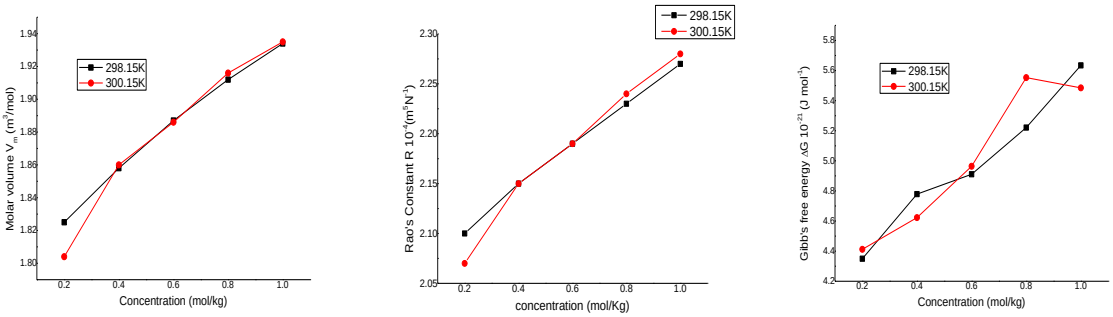


(f)



(g) **(h)** **(i)**

Figure 2a-i. Variation of Adiabatic compressibility, Free Length, Free volume, Internal pressure, Acoustic impedance, Relaxation time, Molar volume, Rao's constant, Gibb's free energy respectively of aqueous L-Glutamic acid monosodium salt

It is evident from fig.1. (a) that the ultrasonic velocity of the aqueous solution of L-Glutamic acid monosodium salt increases with increase in temperature and concentration. The linear increase in the ultrasonic velocity with concentration and temperature suggests that there is no complex formation in the present system [10-11].The increase in ultrasonic velocity indicated that there may be strong solute – solvent interaction. This type of variation occurs because the molecules of solute form strong hydrogen bonds with water molecules [12,13]. Due to hydrogen bond, the intermolecular forces become stronger and the cohesive force between water molecules increases [14].

Fig.1. (b) shows that density of the solution increases with increase in concentration but it decreases with increase in temperature. Density shows normal behavior with rise in concentration and temperature. The viscosity of solution under investigation increases with increase in concentration but linearly decreases with increase in temperature (fig.1. (c)). The increase in viscosity of solution with concentration represents the structure – making nature of solute. The decrease in viscosity with rise in temperature indicates that the molecules acquire more thermal energy which results in increase of motion of molecules and weakening of hydrogen bonding [15-17].

The adiabatic compressibility variation with concentration and temperature in the present investigation is as shown in fig.2.(a). The decrease in β occurs with rise in concentration occurs because of increase in density and electrostriction compression of solvent [18,19] molecule around the solute molecules. This indicates enhanced association between solute – solvent molecules. Free length is the surface to surface distance between two neighboring molecules. In the present investigation, with increase in concentration, free length of the solution decreases as shown in Fig.2 (b). The decrease in intermolecular free length with increase in the solute particles suggests a significant interaction between solute and solvent molecules and a structure making tendency of solute. These results are also supported by the viscosity data [20].

The decrease in free volume with concentration (fig.2(c)) may be due to decreasing space between solute and solvent molecules in the solution. It indicates the strong association between solute and solvent molecules by means of strong hydrogen bonding. The results obtained in the present work are well supported by Giratkar et al. [21]. Internal pressure is another important parameter to understand the intermolecular interactions taking place in the aqueous solution of L – Glutamic acid. From Figure 2d, it is observed that internal pressure increases with increase in concentration but it decreases with rise in temperature. Increase in internal pressure may be due to strengthening of cohesive force between the molecules. As temperature increases, the thermal energy of molecules increases due to which thermal agitation of ions increases. These thermal agitations reduce the possibility of interactions and cohesive forces. Therefore internal pressure decreases with rise in temperature in the present investigation [22].

Acoustic impedance is the opposition that a components of mixture offers opposition to ultrasonic wave propagation in a solution. From fig.2 (e), it can be seen that acoustic impedance increases with concentration and temperature. This may occur due to the change in elastic properties of the aqueous solution of L – Glutamic acid. It indicates strong intermolecular interactions between solute and solvent molecules of the solution via hydrogen bonding [23]. Relaxation time means the time taken by molecules to return from a perturbed system into equilibrium. It represents the presence of intermolecular interactions in present investigation [24-25].

Molar volume is a very useful parameter to study the intermolecular interactions of a solution. It is the volume occupied by one mole of substance at a given temperature and pressure. Figure 2g shows that molar volume increases with concentration and temperature, which suggests the existence of strong solute – solvent interactions in the aqueous solution of L – Glutamic acid [26]. Rao's constant increases linearly with concentration (Figure 2h and

temperature. The increase in Rao's constant confirms that strong intermolecular interactions occur in the present system [27]. The increase in Gibb's free energy with concentration as shown in Figure 2i indicates the strong hydrogen bonding between the molecules of the solution. The decrease in Gibb's free energy with rising temperature suggests that the molecules in the solution take less time to rearrange themselves [28,29].

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