

Volumetric, acoustic and transport properties of L-serine in water and in aqueous solutions of THF at 303.15K.

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Received: April 29, 2018

Accepted: May 30, 2018

ABSTRACT

Density, speed of sound and viscosity of different molalities of L-serine (0.1 - 0.5) mol kg⁻¹ in water and in aqueous solutions of tetrahydrofuran (5%, 10%, 15%, 20%, and 25%) have been measured, at 303.15 K and at atmospheric pressure. From the experimental data, apparent molar volume, limiting apparent molar volume, apparent molar compressibility, limiting apparent molar compressibility, transfer parameters like partial molar volume of transfer, partial molar compressibility of transfer, relative viscosity, Jones-Dole coefficient, relative association, partial molar viscosity of transfer, hydration number etc. have been estimated. The results are examined in terms of hydrophobic - hydrophobic and hydrophobic - hydrophilic, hydrophilic - hydrophilic interactions via cosphere model. It is observed that strong solute-solvent interactions exist in the ternary system which increases with increase in THF concentration.

Keywords: Apparent molar volume, compressibility, L-serine, transport properties

INTRODUCTION

Amino acids, vitamins, nucleotides, nucleosides and proteins along with inorganic salts of many metal ions comes under the category of bio fluids. All these compounds are necessary for driving the life processes. In one or another way, these are essential for life. Among these, amino acids play an important role as these are the building blocks of proteins. These low molecular weight compounds can be regarded as model component of proteins [1-6]. These can be regarded as an important tool for the studying the expected impact of solvation and conformation of proteins [7,8]. Now a day, the amino acids have an application area much more extensive, they are used in feeds, food, medicine, cosmetics and in chemical industries. In animal nutrition, amino acids are added to the feeds, when they are lacking, to improve the economical growth of the animals without affecting their growth response. In Western Europe, for example, L-threonine and L-lysine are usually added to the wheat and barley [9]. The food industry is also a major consumer of amino acids. Beyond their nutritive value, each amino acid has its characteristic taste of sweetness, sourness, saltiness, bitterness or *umami*, which is related to their structure [10]. In the medicine field, many amino acids have been used or studied for pharmaceutical purposes, such as treating type I diabetes, lesions and wounds. They are also used for the treatment of Parkinson's disease and depression related disorders. The chelating ability of amino acids has been used in fertilizers for agriculture to facilitate the delivery of minerals to plants in order to correct mineral deficiencies, such as iron chlorosis. Because of variations in side chains, amino acids have remarkably different biochemical properties and functions [11]. From a chemical viewpoint an amino acid is a base as well as an acid; i.e., it consists both of an amino group and a carboxylic group. The amino acid is, therefore, an amphotelyte since it can react both as a base and as an acid.

The aim of the research work in the present section is the study of interaction parameters such as (volumetric, acoustic and viscometric) of L-serine in water and in varying concentrations of tetrahydrofuran at the temperature of 303.15K. L-serine is an α -amino acid which is used in the biosynthesis of proteins. It is important in metabolism in that it participates in the biosyntheses of purines and pyrimidines. L-serine plays an important role in catalytic function of many enzymes. The water and tetrahydrofuran (THF) has proved to be most interesting solution due to hydrogen bond interaction of water with THF [12-17]. Additionally, THF is used as solvent in many pharmaceutical and synthetic procedures due to its broad solvacy for polar and non-polar compounds [18,19]. As one of the most polar cyclic ethers it is a useful solvent, much less potent anaesthetic and more eco friendly than diethyl ether. Moreover, a literature survey indicates that no physico-chemical study on this system has been reported using THF as solvent.

EXPERIMENTAL

Source and purity of chemicals

L-serine and THF, both having mass fraction purity ≥ 0.990 are obtained from Sigma Aldrich, India. They are used without further purification (Table 1) except that the L-serine was kept in vacuum desiccator

over calcium chloride at room temperature overnight to avoid hydration. All the solutions are prepared in freshly prepared triply distilled water on molality basis. The specific conductance of the triply distilled water used for the preparation of aqueous solutions was found to be $< 1 \times 10^{-6} \text{ S cm}^{-1}$.

Apparatus and procedure

The stock solutions of THF (5%, 10%, 15%, 20% and 25%) are used as solvent to prepare solutions of L-serine of different molal concentrations (ranging from 0.0 to 0.5) mol kg⁻¹. An electronic single pan five digit analytical balance (Model: Mettler AE-240) with a precision of $\pm 0.01 \text{ mg}$ was used to measure the mass. All the solutions were prepared with precaution and stored in special airtight bottles to avoid their exposure to air and evaporation. A vibrating-tube density meter (Model: DMA 5000 M, Anton Paar, Austria) with an uncertainty of $\pm 5 \times 10^{-2} \text{ kg m}^{-3}$ was used to measure the density of solutions. A density calibration was performed first with triply distilled water followed by dry air at 293.15 K at atmospheric pressure before each series of measurement. The density, being extremely sensitive to temperature, was controlled to $\pm 1 \times 10^{-3} \text{ K}$ by built-in Peltier system. The speed of sound of solutions was measured using a single-crystal variable-path multi-frequency ultrasonic interferometer (Model: M-82S, Mittal Enterprises, India) having stainless steel sample cell (with a digital micrometer) operating at a fixed frequency of 7 MHz. The uncertainty in speed measurement was found to be within $\pm 0.5 \text{ m s}^{-1}$. The temperature of solutions was maintained to an accuracy of $\pm 0.02 \text{ K}$ using an electronic controlled thermostatic water bath (Model: TIC-4000N, Thermotech, India).

RESULTS AND DISCUSSION

Apparent molar volume and apparent molar compressibility

The experimental values of density and speed of sound are used to calculate the apparent molar volume, V_ϕ , and apparent molar compressibility, $K_{\phi,s}$, by using the following relations:

$$V_\phi = (M/d) - [(d-d_0)/mdd_0] \quad (1)$$

$$K_{\phi,s} = (MK_s/d) - [(K_s^0 d - K_s d_0)/mdd_0] \quad (2)$$

where M is the molecular mass and m is the molality of solute, d_0 , K_s^0 and d , K_s are the densities and the isentropic compressibilities of solvent (THF + water) and solution (L-serine + THF + water), respectively. The isentropic compressibility is computed by using the following equations:

$$K_s = 1/u^2 d \quad \text{Or} \quad K_s^0 = 1/u_0^2 d_0 \quad (3)$$

where u and u_0 is speed of sound of solution and solvent, respectively.

The experimentally obtained values of density and speed of sound are listed in Table 2. Table 3 shows that positive V_ϕ and negative $K_{\phi,s}$ (evaluated by using equations 1 and 2) of L-serine in aqueous and in aqueous solutions of THF, increases with increase in temperature as well as concentration of L-serine. A representative plot for the variation of V_ϕ as well as $K_{\phi,s}$ with molality of L-serine in 303.15 K is graphically shown in Figures 1 and 2, respectively.

Limiting apparent molar volume and limiting apparent molar compressibility

The limiting apparent molar volume, V_{ϕ}^0 , and limiting apparent molar compressibility, $K_{\phi,s}^0$, are evaluated by least-squares fitting of the following relations to V_ϕ and $K_{\phi,s}$ data as Eqs. (4) and (5):

$$V_\phi = V_{\phi}^0 + S_v m \quad (4)$$

$$K_{\phi,s} = K_{\phi,s}^0 + S_k m \quad (5)$$

The values of V_{ϕ}^0 and $K_{\phi,s}^0$ along with their respective experimental slopes, namely, S_v and S_k are reported in table 4 (parentheses values are standard deviations). At infinite dilution, the solute – solute interactions become negligible and, hence, the limiting apparent molar volume can be analyzed to understand the solute – solvent interactions. The V_{ϕ}^0 values are positive which increase with THF concentration. This means that there is a strengthening of attractive interactions between THF and L-serine. On the other hand, $K_{\phi,s}^0$ values for L-serine in aqueous and aqueous THF solutions are negative which increases with concentration of THF. The increasing trend in the values of $K_{\phi,s}^0$ can be explained in terms of loss of compressibility of surrounding solvent molecules. According to hypothesis of substitution dissolution [20], the large negative value of $K_{\phi,s}^0$ may also indicate the presence of packing or caging effect [20,21]. the release of more water molecules into the bulk, therefore, reduction in electrostriction takes place.

Partial molar volume of transfer and partial molar compressibility of transfer

The solute-solvent interactions can also be explained using partial molar properties of transfer by considering the following equations:

$$\Delta_{tr} V_{\phi}^0 = V_{\phi,aq,THF}^0 - V_{\phi,water}^0 \quad (6)$$

$\Delta_{tr}K^0_{\phi,s} = K^0_{\phi,s,aq,THF} - K^0_{\phi,s,water}$ (7)
 where $V^0_{\phi,water}$ and $K^0_{\phi,s,water}$ are limiting apparent molar volume and limiting apparent molar compressibility of L-serine in water (table 4). The data indicates that V^0_{ϕ} for L-serine in aqueous solution of THF is more than that in aqueous medium, i.e., $\Delta_{tr}V^0_{\phi}$ values are positive and increase with increasing concentration of THF and water. This can be understood by considering the cospHERE overlap model proposed by Gurney [22]. In aqueous medium, when two molecules approach each other, their hydration cospHERE overlaps which results in displacement of cospHERE overlap material with change in thermodynamic properties of solution. According to this model, the first type of interaction results in positive volumes of transfer, while the second and the third type in negative volume of transfer. The values of partial molal volume of transfer, $\Delta_{tr}\phi^0_v$ in Table 5, are positive over entire concentration range for L-serine. It indicates that the ion-hydrophilic interactions are dominating over the second and third type of interactions and the contribution increases with the increase in the concentration of THF. The values of partial molal compressibility of transfer, $\Delta_{tr}K^0_{s}$, shown in Table 3.5 are negative. The negative values may be due to second and third type of interactions (as suggested by Gurney), i.e., hydrophobic-hydrophilic interactions between non-polar parts of amino acid and -O- group of THF and hydrophobic-hydrophobic interactions between non-polar parts of amino acid and of THF.

Hydration number

The hydration number, n_H (or salvation number, n_s), explicitly reveals the hydration degree of solute in water. The hydration number can be calculated from different methods, such as methods bases on volumetric or compressibility data. Here, both the methods have been applied [Table 6]. From volumetric properties, the hydration number can be calculated using the following equation:

$$n_H = \phi^0_{v(elect)} / (\phi^0_{v(e)} - \phi^0_{v(b)}) \quad (8)$$

where $\phi^0_{v(elect)}$ is the electrostriction partial molal/molar volume (also called the free, void or dead volume [23]), $\phi^0_{v(e)}$ is the molal/molar volume of electrostricted water and $\phi^0_{v(b)}$ is the molal/molar volume of bulk water ($18.069 \text{ cm}^3 \text{ mol}^{-1}$ at 25°C).volume, compressibility and viscosity [24,25]. For electrolytic solutions, $(\phi^0_{v(e)} - \phi^0_{v(b)})$ is $-3.3 \text{ cm}^3 \text{ mol}^{-1}$ at 25°C . Using the value of $(\phi^0_{v(e)} - \phi^0_{v(b)})$ and $\phi^0_{v(elect)}$, calculated by various methods, the value of n_H can be determined. The standard partial molal/molar volume, ϕ^0_v , of the amino acids can be examined by simple model:

$$\phi^0_{v(amino\ acid)} = \phi^0_{v(elect)} + \phi^0_{v(int)} \quad (9)$$

$$\phi^0_{v(elect)} = \phi^0_{v(amino\ acid)} - \phi^0_{v(int)} \quad (10)$$

It is important to realize that the electrostriction partial molal volume $\phi^0_{v(elect)}$, represents the contraction of water in the vicinity of charged groups caused by solute-solvent interactions, resulting in a decrease in the overall volume of water in the presence of amino acids [26]. $\phi^0_{v(int)}$ is the intrinsic partial molal volume of the amino acid and $\phi^0_{v(elect)}$ is the electrostriction partial molal volume due to the hydration of the amino acid. The intrinsic volume can be calculated from several methods. One such approach is to estimate the intrinsic volume from crystal molar volume, $\phi^0_{v(crystal)} = \text{mol. wt.} / d_{crystal}$, where $d_{crystal}$ is the density of dry amino acid.

From compressibility data, the number of water molecules, n_H , hydrated to the amino acid can also be calculated by using the following expression:

$$n_H = -\phi^0_{Ks(elect)} / (\phi^0_{v(b)} K_s^0) \quad (11)$$

where K_s^0 is compressibility of pure water or aqueous-THF solvent. Value of $\phi^0_{v(b)} * K_s^0$ is $\approx 0.81 * 10^{-5} \text{ m}^3 \text{ mol}^{-1} \text{ G Pa}^{-1}$ (or, $8.1 * 10^{-15} \text{ m}^3 \text{ mol}^{-1} \text{ Pa}^{-1}$). The electrostriction partial molal compressibility, $\phi^0_{Ks(elect)}$, can be calculated from experimentally measured values of $\phi^0_{Ks(amino\ acid)}$ as :

$$\phi^0_{Ks(elect)} = \phi^0_{Ks(amino\ acid)} - \phi^0_{Ks(int)} \quad (12)$$

Since $\phi^0_{Ks(int)}$ is expected to be small and is less than $5 * 10^{-6} \text{ m}^3 \text{ mol}^{-1} \text{ G Pa}^{-1}$ for ionic crystals and many organic solutes in water, so, one can assume :

$$\phi^0_{Ks(int)} \approx 0, \text{ or } \phi^0_{Ks(elect)} \approx \phi^0_{Ks(amino\ acid)}$$

$$\text{so, } n_H = -\phi^0_{Ks(amino\ acid)} / 8.1 * 10^{-15} \text{ (m}^3 \text{ mol}^{-1} \text{ Pa}^{-1}) \quad (13)$$

Viscosity, relative viscosity and viscosity B-coefficient

The viscosities for L-serine in aqueous and aqueous solutions of THF are also measured 303.15 K (Table 6). The relative viscosity (η_r) has been analyzed in terms of Jones – Dole empirical equation [27] as under:

$$\eta_r = \eta / \eta_0 = 1 + AC^{1/2} + BC \quad (14)$$

where η_r is the viscosity of solution (L-serine + Water + THF) and η_0 is the viscosity of solvent (Water + THF). A is the Falkenhagen coefficient that depends on the long range coulomb forces related to solute – solute interactions [28]. B, called also as viscosity B coefficient [29], is an adjustable parameter which reflects the effects of solute – solvent interactions on the solution viscosity. For non-electrolytes, A is negligible and Jones-Dole equation reduces to:

$$\eta_r = \eta / \eta_0 = 1 + BC \quad (15)$$

The plot of η_r versus c (Fig. 4) is found to be linear at all temperatures. The value of B depends upon the size of solute and nature of solute-solvent interactions and is definite for solute-solvent system. The values of density and speed of sound are also used to calculate the relative association, R_A , using the equation:

$$R_A = (d/d_0) (u_0/u)^{1/3} \quad (16)$$

where symbols have their usual meanings.

The relative association, R_A , is the function of ultrasonic velocity which is influenced by two factors: (a) The breaking-up of the solvent structures on addition of solute to it, and (b) the solvation of solutes. The former results in decrease while the later results in increase in the value of R_A . Table 7 shows that viscosity of solution increases with increase in the concentration solute as well as solvent. It evidences the existence of molecular interactions occurring in the system which, if further analyzed, in terms of Jones-Dole coefficients gives the value of transfer B-coefficient. The evaluation of B-coefficient is as a result of the plots between relative viscosity and molarity presented in Fig 3. The B-coefficient represents measure of order or disorder introduced by the solute into solution. The value of B-coefficient is positive which shows strong alignment of solvent towards solute.

Viscosity B-coefficient of transfer

The partial molar viscosity of transfer/ viscosity B-coefficient of transfer is defined as the difference between the partial molar viscosity in solution and that in pure water.

$$\Delta_{tr}B = B(\text{in aqueous THF}) - B(\text{in water}) \quad (17)$$

Its values are represented in Table 8 and are found to be positive showing the presence of strong intermolecular interactions between solute and solvent.

CONCLUSION

From experimental data of density and speed of sound, the apparent molar volumes, apparent molar isentropic compressibilities, limiting apparent volumes and limiting apparent molar isentropic compressibilities have also been evaluated. Both the limiting values increase with increase in temperature as well as increasing concentration of THF in aqueous medium. The limiting apparent volumes and compressibilities of transfer for L-serine from water to aqueous solution of THF are also evaluated. The positive values suggest dominance of hydrophilic – ionic type of interactions. The other evaluated parameters, namely relative viscosity, viscosity B-coefficients, transfer B-coefficients, hydration numbers also support the fact that L-serine behaves as structure maker in the aqueous THF system. The L-serine – solvent interactions in the ternary system is significantly affected by the temperature, compositions of solute and co-solute

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Table 1. Material used

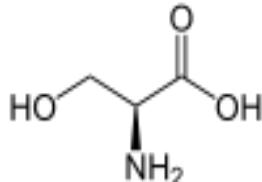
Chemical name	Source	Mass fraction purity	Structure
L-serine	Sigma Aldrich, India	≥0.990	
Tetrahydrofuran	Sigma Aldrich, India	≥0.990	

Table 2: Molality, density, ultrasonic velocity and relative association of L-Serine at 303.15 K in water and in mixed aqueous solutions of THF

m/ (mol kg ⁻¹)	d/ (kg m ⁻³)	u/ (m s ⁻¹)	R _A
L-Serine in aqueous solution			
0.0	995.651	1510.00	
0.1	1000.035	1513.41	1.00365
0.2	1004.346	1517.00	1.00718
0.3	1008.578	1520.78	1.01058
0.4	1012.734	1524.90	1.01383

0.5	1016.795	1529.32	1.01692
L-Serine in 5 % aqueous THF			
0.0	997.879	1538.70	
0.1	1002.189	1542.44	1.00351
0.2	1006.418	1546.42	1.00688
0.3	1010.551	1550.65	1.01008
0.4	1014.594	1555.12	1.01316
0.5	1018.576	1559.82	1.01612
L-Serine in 10 % aqueous THF			
0.0	1000.188	1550.88	
0.1	1004.468	1554.80	1.00343
0.2	1008.634	1558.66	1.00676
0.3	1012.681	1563.45	1.00977
0.4	1016.643	1568.20	1.01269
0.5	1020.447	1573.18	1.01540
L-Serine in 15 % aqueous THF			
0.0	1002.497	1563.14	
0.1	1006.763	1567.21	1.00338
0.2	1010.914	1571.54	1.00658
0.3	1014.956	1576.16	1.00964
0.4	1018.860	1581.10	1.01245
0.5	1022.631	1586.48	1.01498
L-Serine in 20 % aqueous THF			
0.0	1004.683	1575.49	
0.1	1008.916	1579.80	1.00329
0.2	1013.016	1584.36	1.00640
0.3	1017.010	1589.16	1.00935
0.4	1020.905	1594.20	1.01216

0.5	1024.661	1599.59	1.01473
L-Serine in 25 % aqueous THF			
0.0	1006.970	1587.86	
0.1	1011.142	1592.39	1.00319
0.2	1015.183	1597.24	1.00599
0.3	1019.105	1602.40	1.00898
0.4	1022.860	1607.92	1.01153
0.5	1026.486	1613.95	1.01385

Table 3: Molality, compressibility, apparent molal volume and apparent molal adiabatic compressibility of L-Serine at 303.15 K in water and mixed aqueous solutions of THF

m/ (mol kg ⁻¹)	K _s *10 ¹⁰ / (Pa ⁻¹)	Φ _v *10 ⁶ / (m ³ mol ⁻¹)	Φ _{Ks} *10 ¹⁵ / (m ³ mol ⁻¹ Pa ⁻¹)
L-Serine in aqueous solution			
0.0	4.4049		
0.1	4.3659	61.06	-12.509
0.2	4.3265	61.16	-12.866
0.3	4.2870	61.29	-13.194
0.4	4.2464	61.42	-13.715
0.5	4.2050	61.59	-14.242
L-Serine in 5 % aqueous THF			
0.0	4.2326		
0.1	4.1940	61.77	-12.723
0.2	4.1549	61.92	-13.181
0.3	4.1154	62.11	-13.580
0.4	4.0754	62.31	-13.964
0.5	4.0351	62.46	-14.375
L-Serine in 10 % aqueous THF			
0.0	4.1568		
0.1	4.1182	62.03	-12.976
0.2	4.0793	62.34	-13.312
0.3	4.0398	62.67	-13.678
0.4	3.9997	62.92	-14.097

0.5	3.9596	63.29	-14.368
L-Serine in 15 % aqueous THF			
0.0	4.0824		
0.1	4.0441	62.13	-13.080
0.2	4.0053	62.44	-13.445
0.3	3.9660	62.73	-13.822
0.4	3.9261	63.10	-14.202
0.5	3.8852	63.49	-14.672
L-serine in 20 % aqueous THF			
0.0	4.0099		
0.1	3.9714	62.41	-13.534
0.2	3.9326	62.81	-13.768
0.3	3.8935	63.13	-14.040
0.4	3.8542	63.41	-14.304
0.5	3.8142	63.75	-14.639
L-Serine in 25% aqueous THF			
0.0	3.9388		
0.1	3.9002	62.96	-13.774
0.2	3.8611	63.35	-14.118
0.3	3.8215	63.71	-14.481
0.4	3.7814	64.18	-14.807
0.5	3.7399	64.62	-15.335

Table 4: Values of limiting apparent molal volume, corresponding constant S_v , limiting apparent molal compressibility, constant S_K for L-Serine at 303.15 K at different concentrations

Conc.	$\phi^0_v * 10^6 / (m^3 mol^{-1})$	$S_v * 10^6 / (m^3 mol^{-2} kg)$	$\phi^0_{Ks} * 10^{15} / (m^3 mol^{-1} Pa^{-1})$	$S_K * 10^{15} / (m^3 mol^{-2} Pa^{-1} kg)$
0%	60.908 (± 0.02330) [*]	1.32 (± 0.07024)	-12.0107 (± 0.09144)	-4.314 (± 0.27571)
5%	61.583 (± 0.01745)	1.77 (± 0.05260)	-12.3385 (± 0.02413)	-4.087 (± 0.07276)
10%	61.72 (± 0.02966)	3.10 (± 0.08944)	-12.6155 (± 0.03975)	-3.569 (± 0.11984)
15%	61.764 (± 0.04125)	3.38 (± 0.12437)	-12.6619 (± 0.0382)	-3.941 (± 0.11519)
20%	62.118 (± 0.03752)	3.28 (± 0.11314)	-13.2332 (± 0.03328)	-2.746 (± 0.10034)
25%	62.519 (± 0.03957)	4.15 (± 0.11930)	-13.3597 (± 0.06748)	-3.811 (± 0.20345)

*The values in parenthesis indicate error

Table 5: Partial molal volumes of transfer and the partial molal compressibility of transfer of L-Serine at 303.15 K

Conc.	5%	10%	15%	20%	25%
Molality of cosolute, m_B	0.64	1.36	2.15	3.05	4.07
$\Delta_{tr}\phi^0_v / (m^3 mol^{-1})$	0.675	0.812	0.856	1.21	1.611
$\Delta_{tr}\phi^0_{Ks} / (m^3 mol^{-1} Pa^{-1})$	-0.3278	-0.6048	-0.6512	-1.2224	-1.349

Table 6: Electrostriction partial molal volume and hydration number, n_H , calculated from volume and compressibility data

Concentration	Electrostriction partial molal volume $\phi^0_v(\text{elect}) \times 10^6 (\text{m}^3 \text{mol}^{-1})$	Hydration number (n_H)	
		From Volume	From compressibility
0%	-12.4359	3.7685	1.4828
5%	-11.7609	3.5639	1.5233
10%	-11.6239	3.5224	1.5575
15%	-11.5799	3.5091	1.5632
20%	-11.2259	3.4018	1.6337
25%	-10.8249	3.2803	1.6493

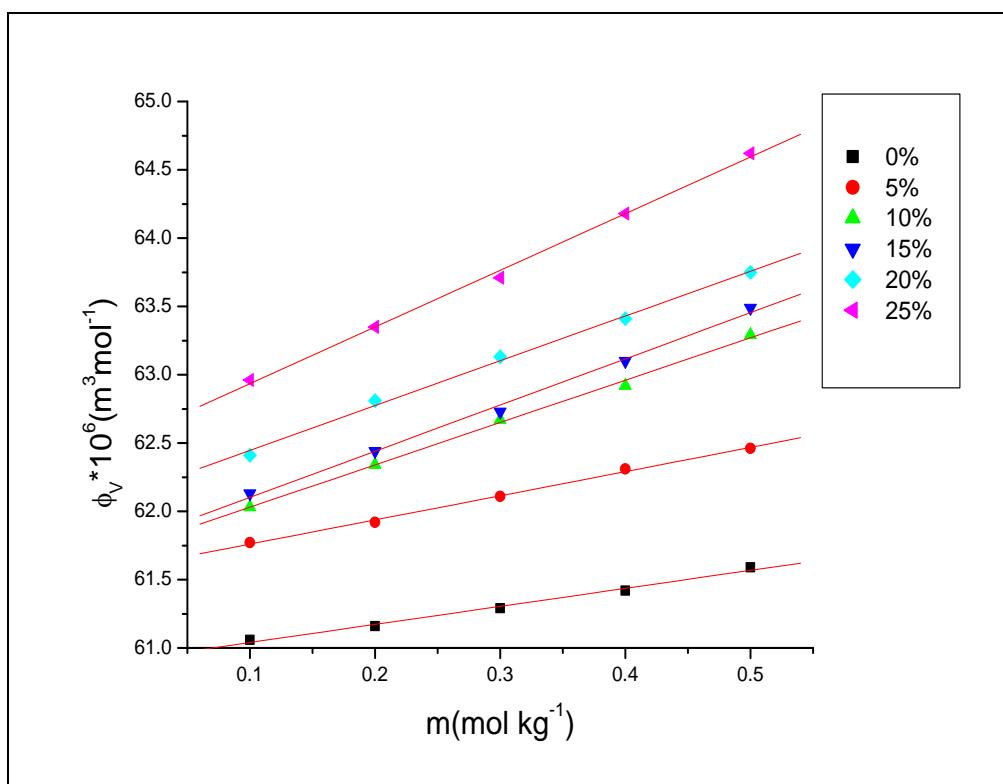
Table 7: Molarity, viscosity, relative viscosity and viscosity B-coefficients of Jones-Dole equation

c / (mol L ⁻¹)	$\eta^* 10^3 /$ (Pa s)	η_r	Viscosity B-coefficient/ (L mol ⁻¹)
L-Serine in aqueous solution			
0.00000	0.7980		
0.10000	0.7691	0.9638	
0.20086	0.8065	1.0106	0.1944
0.30256	0.8422	1.0554	
0.40508	0.8639	1.0826	
0.50837	0.8938	1.1200	
L-Serine in 5 % aqueous THF			
0.00000	0.7747		
0.10022	0.8146	1.0515	
0.20128	0.8558	1.1047	0.3979
0.30316	0.8700	1.1230	
0.40582	0.8969	1.1577	
0.50926	0.9236	1.1922	
L-Serine in 10 % aqueous THF			
0.00000	0.8768		
0.10045	0.9253	1.0553	
0.20172	0.9641	1.0996	0.4834
0.30379	1.0185	1.1616	
0.40664	1.0447	1.1915	
0.51019	1.0870	1.2397	
L-Serine in 15 % aqueous THF			
0.00000	0.9741		
0.10067	1.0383	1.0659	
0.20214	1.0784	1.1071	0.4861
0.30448	1.1233	1.1532	

0.40753	1.1613	1.1922	
0.51129	1.2111	1.2433	
L-Serine in 20 % aqueous THF			
0.00000	0.9968		
0.10089	1.0698	1.0732	
0.20259	1.1123	1.1159	0.4776
0.30509	1.1516	1.1553	
0.40834	1.1861	1.1899	
0.51230	1.2267	1.2306	
L-Serine in 25 % aqueous THF			
0.00000	1.0657		
0.10111	1.1453	1.0747	
0.20303	1.1869	1.1137	0.4811
0.30572	1.2286	1.1528	
0.40913	1.2716	1.1932	
0.51322	1.3161	1.2349	

Table 8: Partial molar viscosity of transfer of L-Serine at 303.15 K

Conc.	5%	10%	15%	20%	25%
Molarity of cosolute, m_B	0.61	1.22	1.82	2.43	3.04
$\Delta_{tr}B$ ($L\ mol^{-1}$)	0.2035	0.2890	0.2917	0.2832	0.2867

**Fig. 1:** Plot of apparent molal volume v/s molality of L-serine

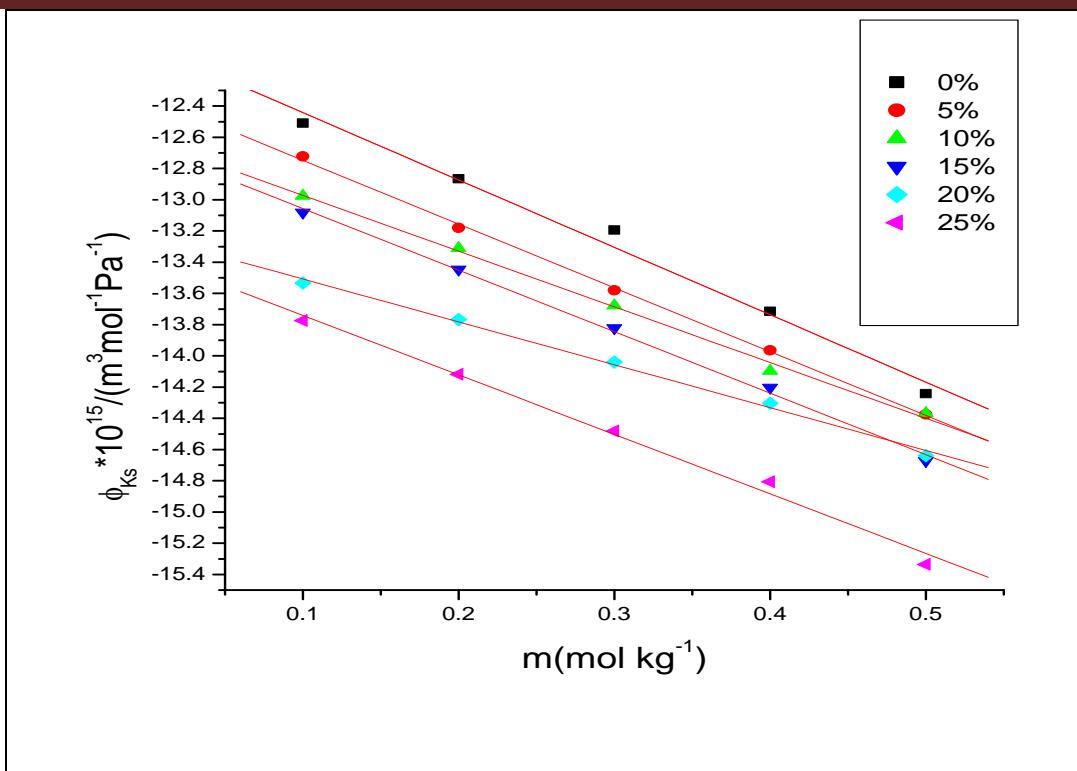


Fig. 2: Plot of apparent molal adiabatic compressibility v/s molality of L-serine

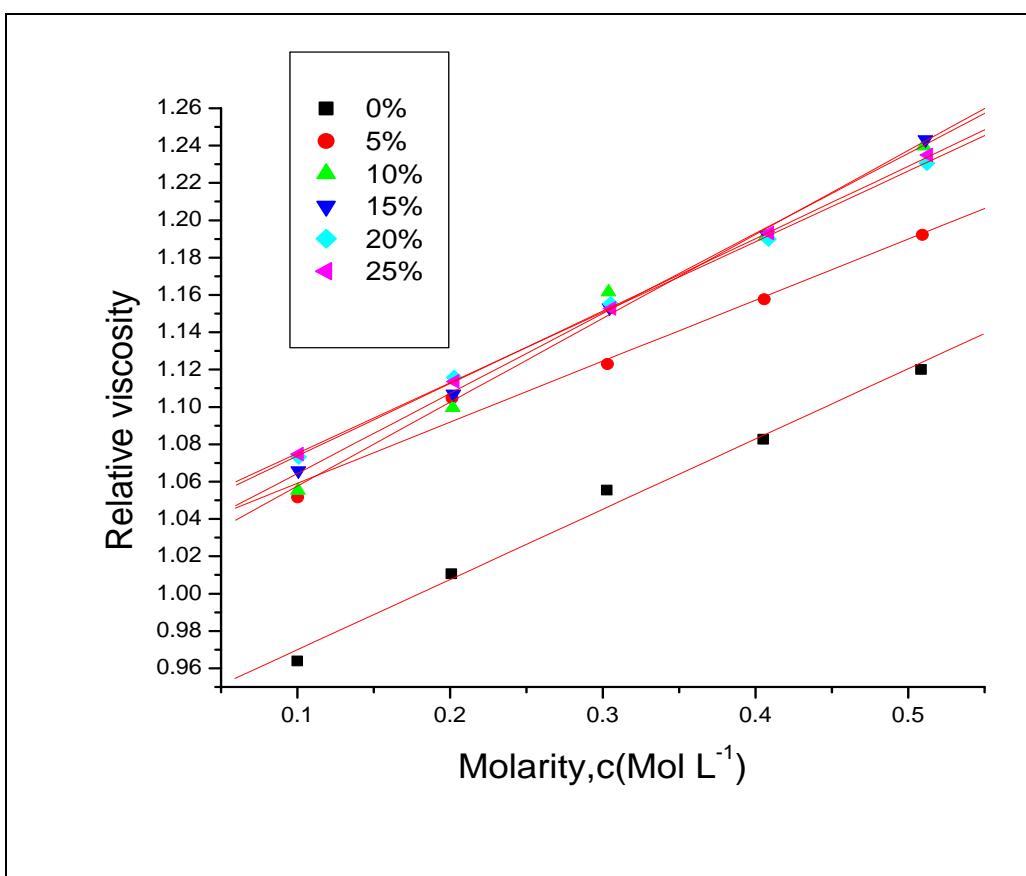


Fig.3: Plot of relative viscosity v/s molarity of L-Serine