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Density and Viscosity of Amino Acid Serine in Aqueous Dimethyl Sulfoxide Solution at Different Temperatures

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Abstract

Densities ρ and viscosity η of serine in 20, 40, and 60% (w/w) dimethyl sulfoxide (DMSO)-water mixtures were measured at 298.15, 303.15 and 308.15k. From these experimental data, apparent molal volume ϕ_v, limiting apparent molal volume ϕ_v^o, the slop S_v, transfer volume ϕ_v^o(tr), Jones-Dole coefficients A and B were calculated. The results are discussed the solute-solvent and solute-solute interaction, and showed that serine behaves as structure-breaker in aqueous DMSO solvent.

Key word: Density, Viscosity, Amino Acid, Serine, dimethyl sulfoxide

Introduction

Amino acid which are the fundamental substances for building blocks of proteins are used as model compounds to study the interactions of proteins in water and different solutions.

A number of workers studied the volumetric and viscometric properties of amino acids in water [1-3]. Ali and Shahjaham [4] studied the volumetric and viscometric behaviour of L-serine, L-threonime, L-glutamine, L-lysine, L-arginine and L-histidine amino acids and their group contributions in aqueous tetramethyl ammonium bromide at different temperatures.

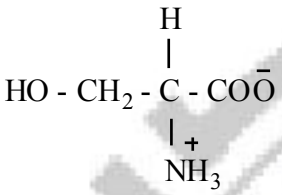
It is well known that the mixed aqueous solvents (with different percent w/w) can influence the solubility behavior of amino acids. Consequently thermodynamic properties, enthalpies, heat capacities, apparent molal volumes and viscosities of amino acids and peptide in mixed aqueous solvents are useful to obtain information about various types of interactions in these solutions [5-6]. Serine (abbreviated as Ser or S) [7], is an amino acid with the formula $HO_2CCH(NH_2)CH_2OH$..

It is one of the proteinogenic amino acids. By virtue of the hydroxyl group, serine is classified as a polar amino acid.

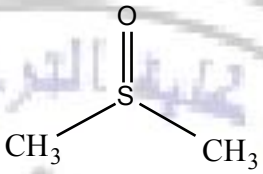
Patel and workers [8] demonstrate the interaction of some amino acids(L-serine, L-threonime, L-glutamine, L-lysine, L-arginine and L-histidine) in aqueous caffeine they got positive values of partial molal volume of transfer of amino acid from water to aqueous-

caffeine ϕ_v^o(tr) (ϕ_v^o,caffeine-ϕ_v^o,water) which indicate the diminishing of electrostrictive effect of amino acids and addition of caffeine. They related the diminishing to shielding of the amino acids zwitterionic groups from water.

The partial molar volumes of tranfere ϕ_v^o(tr) of amino acids from aqueous to aqueous tetramethyl ammonium bromide solution were interpreted in the light of cosphere overlap model. The cosphere overlap model [9] can be used for interpretation of negative ϕ_v^o(tr) values, according to which the overlap of two hydration spheres is destructive.



Serine (Ser)
M= 105.1 g.mol^{-1}



Dimethyl sulfoxide (DMSO)
M=78.13 g.mol^{-1}

In present work viscosities η and densities ρ of serine (0.1, 0.15, 0.20, 0.25, 0.30 and 0.35 molar concentration) were measured in 20, 40 and 60% (w/w) DMSO + water mixtures at 298.15, 303.15 and 308.15k.

Then the apparent molal volumes ϕ_v , limiting molal volumes at infinite dilution ϕ_v^o, transfer volumes at infinite dilution ϕ_v^o(tr) and Jones-Dole coefficients B and D were calculated.

Experimental

Amino acid serine obtained from Fluka company is Analar and used without any further treatment. Dimethyl sulfoxide (DMSO) is aprotic polar liquid with a high dielectric constant obtained from Fluka company (purity >99.7%) used without further purification.

Water used for preparation for all the solution doubly distilled (Sp.conductivity ~10^{-6} ohm^{-1}cm^{-1}). The serine concentration in these mixtures was ranged from(0.1-0.35) mol.dm^{-3}.The viscosity η were determined using a suspended-level ubbelohde viscometer described by findly [10], in a bath controlled to ±0.01K for all measurements.

Densities ρ of all solutions were measured using a vibrating tube with digital Anton Parr densimeter (DMA 60/602) according to shuklu *etal*. Procedure[11], in athermostated bath controlled to ±0.01K.

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Results and Discussion

The results of absolute viscosities η and densities ρ are listed in table 1.

The apparent molal volume ϕ_v of serine in aqueous dimethyl sulfoxide (DMSO+H_2O) is measured at 298.15, 303.15 and 308.15K using the following relation [12].

$$\phi_v = \frac{1}{m}\left[\frac{10^3 + mM}{\rho} - \frac{10^3}{\rho_o}\right] \quad \text{.....(1)}$$

Where ρ and ρ_o are the densities of solution and solvent respectively, M is molecular weight of solute and m is the molality of solution. m is calculated using the following relation $m=1/(P/C - M/10^3)$ where C is the molar concentration. The results of ϕ_v are tabulated in table (1). Table (1) shows that the value of ϕ_v decrease with the increase of concentration of serine but ϕ_v increases with increasing DMSO% content and temperature increase in solution suggesting that the solute-solvent interaction increase with the increase of DMSO%. Since the limting apparent molal voiume ϕ_v were obtained from the realation [13].

$$\phi_v = \phi_v^o + S_v m \quad \text{.....(2)}$$

Where the intercept ϕ_v^o, which is measure of solute-solvent interaction, and the experimental slop S_v, which is aparameter of solute-solte interaction were obtained by the molality fitting of ϕ_v values to eqution(2)in figure(1) and tabulated in table(2). Table 2 reveals that ϕ_v^o are positive and increase with the increase of temperature, indicating the presence of solute-solvent interactions. The increase in ϕ_v^o on going from 20% to 60% DMSO indicates the increasing trends of solute-solvent interaction. Table 2 shows that all the values of S_v are negative pointing the presence of weak solute-solute interactions in solutions. Moreover, the values of S_v become more negative with the increase of DMSO content suggesting decreasing in solute-solute interaction with DMSO-rich solvent. In fact negative S_v values are often obtained in solvent of high dielectric constant such as (DMSO + Water Solvent) [14].

The transfer volumes ϕ_v^o(tr) of serine when transferred from water to (DMSO+Water) mixture solution are found using this equation:

$$\phi_v^o(\text{tr}) = \phi_v^o(\text{DMSO + Water}) - \phi_v^o, \text{water}$$

The values of ϕ_v^o, water for serine are 68.07, 66.28 and 65.28 $cm^3.mol^{-1}$ at 298.15, 303.15 and 308.15K respectively which are estimated from our previous work[15]. The ϕ_v^o(tr) results are listed in table (3).

A perusal of table 3 indicates that ϕ_v^o of serine in mixed liquids (DMSO+ Water) are lower than those in pure water, ϕ_v^o(tr) values are negative for all solutions studied. It is known that zwitterionic groups of amino acids induce a considerable concentration in volume of peripheral solvent (water) due to electrostrictive effect ,which is diminished on addition of DMSO.

Viscosity data were analyzed employing Jone-Dole equation [16].

$$\eta_{rel}-1/\sqrt{C}=A+B\sqrt{C} \quad \ldots\ldots\ldots\ldots(3)$$

Where η and η_o are the viscosity of solution and solvent respectively, the Jones-Dole coefficient, A, reflects the effect of solute-solute interaction and B, is a measure of structural modifications induced by the solute-solvent interaction. The viscosity coefficient A and B were obtained from the intercept and slope of the plots $\eta_{rel}-1/\sqrt{C}$ against $\sqrt{C}$. The values of A and B are listed in table (2). Table (2) shows that the values of A-coefficient are negative whereas those of B-coefficients are positive, suggesting weak solute-solute and strong solute-solvent interaction. The variation of B with T is depicted graphically in figure 1, revealed that the slope ($\partial B/\partial T$) is positive for serine in 20, 40 and 60% DMSO content in solution, serine in all solutions act as structure-breakers[17].

Conclusions, the values coefficient A and B support the behaviors of S_v and ϕ_v^o(tr) which all suggest stronger solute-solvent interactions as compared to solute-solute interactions. The positive ($\partial B/\partial T$) values for all solutions which pointed that the serine acts as a structure-breaker when DMSO added to solutions.

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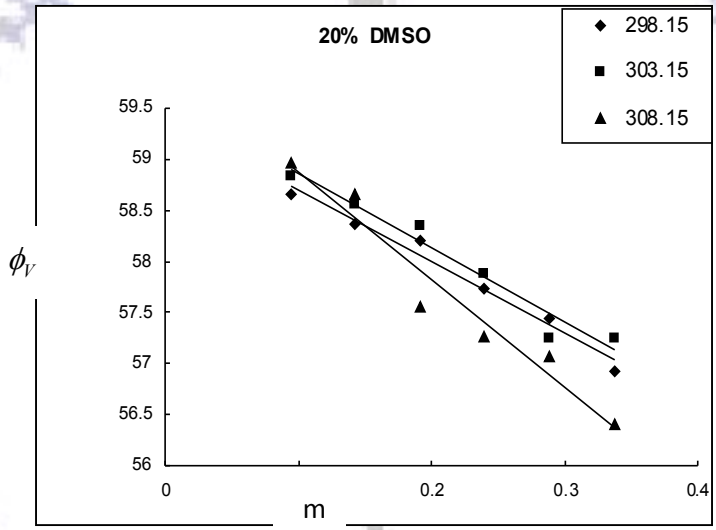
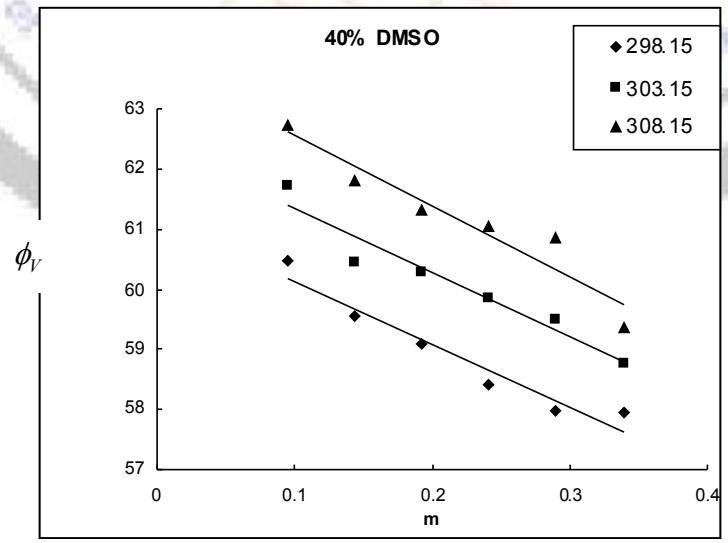
Table(2): Partial molal volume at infinite dilution ϕ_v^o, S_v , Jones-Dole coefficients A and B of serine in various water + DMSO mixtures at different temperatures.

	298.15k	303.15k	308.15k
Solu.	Ser. + H_2O + 20% DMSO		
ϕ_v^o $cm^3.mol^{-1}$	59.41	58.803	59.925
S_v $cm^3.mol^{-2}kg$	-7.0466	-8.586	-10.482
A $L^{1/2}.mol^{-1/2}$	-0.3308	-0.3374	-0.3455
B $L.mol^{-1}$	1.5051	1.5296	1.5900
Solu.	Ser. + H_2O + 40% DMSO		
ϕ_v^o $cm^3.mol^{-1}$	61.193	62.401	63.727
S_v $cm^3.mol^{-2}kg$	-10.606	-10.636	-11.306
A $L^{1/2}.mol^{-1/2}$	-0.3152	-0.3421	-0.3653
B $L.mol^{-1}$	2.3072	2.6084	2.9695
Solu.	Ser. + H_2O + 60% DMSO		
ϕ_v^o $cm^3.mol^{-1}$	64.131	65.121	65.259
S_v $cm^3.mol^{-2}kg$	-11.508	-12.028	-12.441
A $L^{1/2}.mol^{-1/2}$	-0.3270	-0.3631	-0.3927
B $L.mol^{-1}$	0.4727	2.9637	3.1620

Table(3): Partial molal volumes of transfer at infinite dilution ϕ_v^o(tr) of serine from water to mixed liquid (DMSO + Water) at different temperatures.

Serine in mixed liquid (DMSO + Water)	$\phi_v^o(tr)$ ($cm^3.mMol^{-1}$)		
	298.15k	303.15k	308.15k
20% DMSO	-8.660	-7.477	-5.355
40% DMSO	-6.877	-3.879	-1.553
60% DMSO	-3.930	-1.159	-0.021





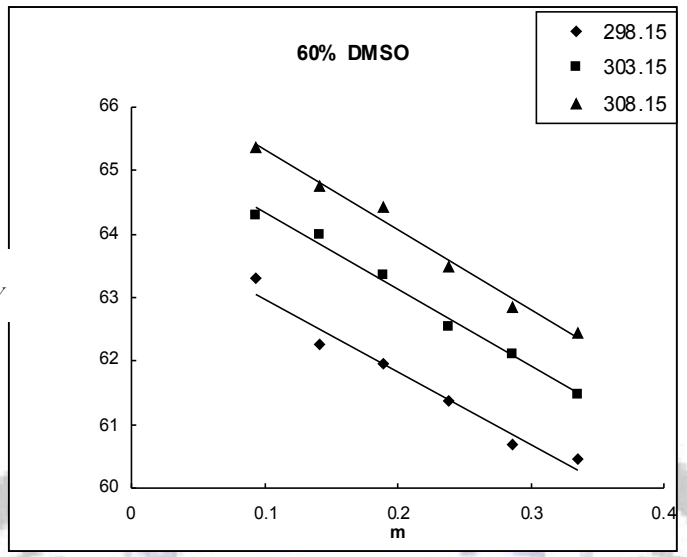


Fig.(1): ϕ_V Against m for serine in various water+DMSO mixture at different temperature

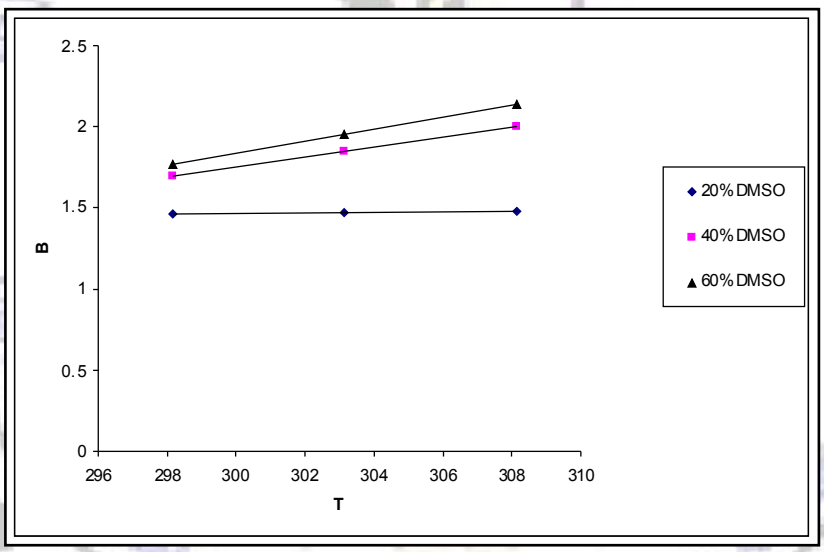


Fig. (2): B-coefficient verses T for serine in various water +DMSO mixtures

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دراسة لزوجية وكثافة الحامض الاميني سيرين في المحلول المائي لداي مثيل سلفوكساييد بدرجات حرارية مختلفة

زينب عباس الدليمي ، زينب وجدي العامل ، رقية سمير الخالصي ، زينة حمودي حسين

قسم الكيمياء ، كلية التربية – أبن الهيثم ، جامعة بغداد

استلم البحث في :23 آب 2011 قبل البحث في :10 تشرين الثاني 2011

الخلاصة

قيست كثافة ρ ولزوجة η محاليل الحامض الاميني سيرين في محاليل لتركيز 20%، 40% ، 60% (w/w) لداي مثيل سلفوكساييد DMSO بدرجات حرارية مختلفة 298.15 , 303.15 , 308.15 كلفن استخدمت هذه النتائج في حساب الحجم المولالي الظاهري ϕ_v والحجم المولالي الظاهري المحدد ϕ_v^o والميل S_v حجم الانتقال ϕ_v^o (tr), ومعاملي جونس ودول A , B .

تمت مناقشة طبيعة التداخلات من نوع مذاب– مذيب ومذاب– مذاب وقد اظهرت النتائج ان السيرين يسلك سلوك مهدم للتركيب في المحاليل المائية لداي مثيل سلفوكساييد.

الكلمات المفتاحية: الكثافة، اللزوجة، الحوامض الامينية، السيرين، داي مثل سلفوكساييد.

Table (1): Densities (ρ) and Viscosities (η) with calculated apparent molal volume (ϕ_v), and the (η_{rel}-$1/\sqrt{C}$) of serine in water at different percent (w/w) of dimethyl sulfoxide mixtures at different temperatures.

20%							40%					
C mol.dm^{-3}	$\sqrt{C}$	m mol.kg^{-1}	ρ g.cm^{-3}	η cp	ϕ_v cm^3.mol^{-1}	η_{rel}-$1/\sqrt{C}$	m mol.kg^{-1}	ρ g.cm^{-3}	η cp	ϕ_v cm^3.mol^{-1}	η_{rel}-$1/\sqrt{C}$	m mol.kg
0.00		0.0000	1.0582	1.0838			0.0000	1.0595	1.1203			0.0000
0.1	0.3162	0.0950	1.0625	1.1403	58.6604	0.1642	0.0949	1.0636	1.2789	60.4768	0.4477	0.0929
0.15	0.3873	0.1430	1.0647	1.1820	58.3692	0.2339	0.1428	1.0658	1.3658	59.5420	0.5658	0.1419
0.2	0.4472	0.1912	1.0669	1.2433	58.2064	0.3291	0.1910	1.0680	1.4655	59.0794	0.6890	0.1898
0.25	0.5000	0.2397	1.0692	1.3125	57.7382	0.4220	0.2394	1.0703	1.5786	58.4142	0.8182	0.2378
0.3	0.5477	0.2886	1.0715	1.3819	57.4413	0.5022	0.2884	1.0726	1.6911	57.9882	0.9303	0.2863
0.35	0.5916	0.3374	1.0739	1.4450	56.9198	0.5633	0.3372	1.0748	1.8459	57.9407	1.0948	0.3350
298.15k												
0.00		0.0000	1.0556	0.9889			0.0000	1.0546	1.0698			0.0000
0.1	0.3162	0.0953	1.0599	1.0365	58.8323	0.1522	0.0954	1.0586	1.2459	61.7253	1.6461	0.0950
0.15	0.3873	0.1435	1.0621	1.0877	58.5618	0.2579	0.1435	1.0608	1.3374	60.4553	1.6676	0.1430
0.2	0.4472	0.1917	1.0643	1.1365	58.3551	0.3337	0.1919	1.0629	1.4504	60.2946	1.7788	0.1913

0.2399	1.8859	59.8395	1.5742	1.0651	0.2407	0.4228	57.8808	1.1977	1.0666	0.2403	0.5000	0.25
0.2888	1.9835	59.5111	1.7064	1.0673	0.2896	0.5024	57.2409	1.2610	1.0690	0.2891	0.5477	0.3
0.3379	2.0845	58.7552	1.8503	1.0697	0.3389	0.5744	56.8013	1.3250	1.0714	0.3383	0.5916	0.35
				303.15k								
0.0000			1.0289	1.0533	0.0000			0.9869	1.0530	0.0000		0.00
0.0952	1.8991	62.7404	1.2243	1.0572	0.0955	0.1520	58.9617	1.0360	1.0573	0.0955	0.3162	0.1
0.1433	1.9995	61.7946	1.3375	1.0593	0.1437	0.2699	58.6584	1.0901	1.0595	0.1437	0.3873	0.15
0.1917	2.0998	61.3237	1.4610	1.0614	0.1922	0.3693	57.5616	1.1499	1.0619	0.1922	0.4472	0.2
0.2403	2.1996	61.0424	1.5947	1.0635	0.2410	0.4448	57.2710	1.2064	1.0642	0.2409	0.5000	0.25
0.2893	2.2997	60.8546	1.7388	1.0656	0.2901	0.5236	57.0667	1.2699	1.0665	0.2893	0.5477	0.3
0.3389	2.3997	59.3639	1.8931	1.0682	0.3394	0.5979	56.3999	1.3360	1.0690	0.3391	0.5916	0.35
				308.15k								

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No.	1	Vol.	25	Year	2012	2012	السنة	25	المجلد	1	العدد