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Role of glycine as a '3D-structure' maker in aqueous mixture of protophilic dipolar aprotic dimethylsulfoxide

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ABSTRACT

Solubilities of an α-amino acid, glycine (Gly.) have been measured using 'formol titrimetry' method at five equidistant temperatures i.e. from 288.15 K to 308.15 K in aqueous mixtures of protophilic dipolar aprotic Dimethylsulfoxide (DMSO). The various solvent parameters as well as thermodynamic parameters like molar volume, densities, dipole moment, solvent diameter of aqueous DMSO have been reported and standard free energies ($\Delta G_t^0(i)$) and entropies ($\Delta S_t^0(i)$) of transfer of glycine from water to aqueous mixture of DMSO have been evaluated in this paper at 298.15 K. The chemical effects of the transfer Gibbs energies ($\Delta G_{t,ch}^0(i)$), as obtained by subtracting theoretically computed $\Delta G_t^0(i)$ due to cavity effect and dipole-dipole interaction effects from the corresponding experimental total transfer free energies. Again $T\Delta S_{t,ch}^0(i)$ have been evaluated after elimination of cavity effect and dipole- dipole interaction effects from the total transfer ($T\Delta S_t^0(i)$) entropies.

Keywords: Aqueous solvent; α-amino acid; dipole-dipole interaction; hydrophobic hydration; transfer energetic

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INTRODUCTION

Amino acids are the chemical units that make up proteins, as they are famously called the "building blocks" of protein. They are organic acids in which one or more hydrogen atoms are replaced by -NH_2 group. Amino acid, glycine contains a carbon atom, a free amino group (containing nitrogen-NH_2) and a carboxyl group (COOH). The amino acid remains predominantly as zwitterions, H_3N^+ -CH_2 -CO_2^- which is capable both accepting and donating protons in biological system.

Protein folding and unfolding process [1, 2] are generally much more important in biological system. The conformation of a protein in solution is generally a function of electrostatic, hydrogen bonding, van der Walls forces, and acid-base interactions, hydrophobic and hydrophilic interactions among the amino acid residues that overall leads to a folded state overcoming an entropic penalty. [3-5] Extraction of proteins from the natural sources and the denaturation process is essential for dissolution and purification of protein. In this regard the thermodynamic properties of proteins as well as amino acids in different solvent systems are important.

On the other hand measurement of solubility and thermodynamic study of the amino acid, glycine in different aquo-organic solvents systems are very important because it has a lot of applications in pharmaceuticals, biochemical and chemical sciences. Such as the pharmaceutical grade glycine is produced for some pharmaceutical applications, e.g. intravenous injections. Technical grade glycine, which may or may not meet USP grade standards, is sold for use in

industrial applications; e.g., as an agent in metal complexing and finishing. Glycine serves as a buffering agent in antacids, analgesics, antiperspirants, cosmetics, and toiletries. In many miscellaneous products glycine or its derivatives are used such as the production of rubber sponge products, fertilizers and metal complexants.

The principal function of glycine is as a precursor to proteins, such as its periodically repeated role in the formation of collagen helix in conjunction with hydroxyproline. It is also a building block to numerous natural products.

Glycine is an intermediate in the synthesis of a variety of chemical products. It is used in the manufacture of the herbicide glyphosate.

In considering the important of the amino acids researchers have been drawn their attention [3-10] for a long time to determine the various thermodynamic properties of amino acids in different aqua-organic mixed solvent systems.

In this regard Tanford, Nozaki and other authors [9,10] reported solubilities, transfer free energies and entropies of some amino acids from water to urea, water-glycerol [11,12,13] and water to ethylene glycol, [14,15] water to *N*,*N*-dimethyl formamide, [16-18] and water to 2-methoxyethanol, [19] water to 1,2-dimethoxyethane, [20] solvents systems. All these experiments tried to give an idea about the relative stabilization of those amino acids and other biomolecules in aqua-organic media with respect to reference solvent (water) and the complex solute-solvent and solvent-solvent interactions therein.

In such context our purposes of such type of study are to know about the nature of solvation as well as interaction of smaller amino acid or biomolecules with dipolar aprotic solvent systems compared to protic solvent, water. Recently solvation chemistry of valine is studied in aqueous mixture of cationophilic dipolar aprotic *N, N*-dimethyl formamide [18] and in DMSO. Dimethylsulphoxide [21] is also a protophilic dipolar aprotic solvent having two hydrophobic groups (i.e. $-CH_3$) as well as soft (>S=O) moiety.

This solvent may also play important role in term of soft-soft, dispersion and hydrophobic interaction to influence solvation chemistry of smaller amino acid glycine. Hence the whole efforts of this manuscript will also be helpful to enrich chemical, biochemical and pharmaceutical sciences in future.

Glycine [> 99.5 %, E Merck] was used after drying as described in previous works [20]. Dimethylsulphoxide [> 99.8 %, Aldrich] rigorously dried over fused $CaCl_2$ for 3-4 days, decanted and then distilled under reduced pressure. The distilled sample was preserved in a well stopper Jena battle in desiccators and redistilled before use [22]. For formol titration standardized NaOH [E Merck] solution and phenolphthalein indicator [LR, BDH] were used. Neutral formaldehyde [E Merck] was used to mask before titration. Triple distilled water was used for the whole experiment.

EXPERIMENTAL SECTION

Aqueous mixtures of cosolvent, DMSO that have been used were 0, 20, 40, 60, 80 and 100 wt %. These were taken in well fitted stoppered glass tubes. Glass tubes were incompletely filled to facilitate good mixing. A low-cum-high temperature thermostat was used for all measurements which is capable of registering temperatures having an accuracy of ±0.1 ^{0}C. A known mass of filtered saturated solution was transferred to a dry conical flask. The solubility of glycine is measured by formol titrimetry method [20, 23] The measurements were taken at 15, 20, 25, 30 and 35 ^{0}C temperatures. Four sets of measurements for all the co-solvent mixtures were made for all temperatures by equilibrating the solutions from both above and below (± 0.1 ^{0}C) the required temperatures and the solubilities were found to agree to within ±0.4 to 1.0 %.

RESULT AND DISCUSSION

COMPUTATION OF TOTAL TRANSFER GIBBS ENERGY AND ENTROPY OF SOLUTION

The important parameters of the amino acid, glycine and co-solvent are presented in the Table 1. The solubilities of the α-amino acid, glycine are measured on molal scale ($mol \cdot kg^{-1}$) and listed in Table 2. The standard deviations, s_f are also estimated for all solubility values to know about the precision and are shown in parentheses (Table 2) only for 40 and 60, 80 wt % of DMSO at all temperatures.

In the previous studies by Bates and coworkers on Tris [24] and by Kundu and coworkers [25, 26] on non-electrolyte like p-nitro aniline (pNA), benzoic acid (HBz) and amino acids, [25] glycine (G), diglycine (DG), and triglycine (TG), the Gibbs energies of solutions (ΔG_s^0) on molal scale were calculated for each solvent using Equation (I).

$$\Delta G_s^0(i) = -RT\ln C\gamma = -RT\ln m \quad \text{(I)}$$

Where γ is the molar activity coefficient of the solutes but taken tentatively to be unity in each solvent since α-amino acids likely to be mostly in zwitterionic forms as in non-aqueous solvent mixtures [27, 28] the involved activity coefficient factor -RTlnγ in ΔG_s^0 arising from interactions of dipolar solutes with large dipole moments may not be so small. But as there is neither the required experimental data nor any appropriate theoretical correlations for computing the same, these have been tacitly taken to be negligibly small, as is usually done for non- electrolytes [29].

The free energies, ΔG_s^0 at different temperatures are fitted by the method of least squares to an equation of the form (Equation II) [11] and presented in the Table 3.

$$\Delta G_s^0 = a + bT + cT\ln T \quad \text{(II)}$$

where T is the temperature in Kelvin scale. The values of the coefficients a, b, c are presented in Table 4**.** These are found to reproduce the experimental data within ±0.04 (kJ·mol^{-1}/ (kJ·mol^{-1}·K^{-1}) respectively.

Transfer Gibbs energies ΔG_t^0 and entropies ΔS_t^0 of the amino acids from water to aquo-organic cosolvent mixtures were calculated at 25 ^{0}c on mole fraction scale by using the following equations (III) & (IV):

$$\Delta G_t^0(i) = {}_s\Delta G_s^0(i) - {}_R\Delta G_R^0(i)$$

$$\text{i.e. } \Delta G_t^0(i) = (a_s - a_R) + (b_s - b_R)T + (c_s - c_R)T\ln T - RT\ln(M_s / M_R) \quad \text{(III)}$$

$$\text{and, } \Delta S_t^0(i) = (b_R - b_s) + (c_R - c_S)(1 + \ln T) + R\ln(M_s / M_R) \quad \text{(IV)}$$

here the subscript 's' and 'R' refer to the co-solvent mixtures and reference solvent (H_2O) respectively and M_R and M_s are the molar mass of the pure and mixed solvent respectively. $\Delta G_t^0(i)$ and $T\Delta S_t^0(i)$ values of α-amino acids thus obtained and presented in the Tables 4 & 5. The involved uncertainties in $\Delta G_t^0(i)$ and $\Delta S_t^0(i)$ are about ±0.05 kJ·mol^{-1}and 2J·K^{-1} mol^{-1}, respectively.

COMPUTATION OF CAVITY, CHEMICAL PARTS OF TRANSFER GIBBS ENERGY AND ENTROPY

Now here the term $\Delta P_t^0(i)$ (where P=G or S) may be ascribed as the sum of the following terms (assuming dipole induced dipole term to be negligibly small).

$$\text{i.e. } \Delta P_t^0(i) = \Delta P_{t,cav}^0(i) + \Delta P_{t,d-d}^0(i) + \Delta P_{t,ch}^0(i) \quad \text{(V)}$$

Here, $\Delta P_{t,cav}^0(i)$ indicates the transfer energy contribution of the cavity effect which is involved due to creation of cavities for the species in H_2O and co-solvent mixed solvent systems and $\Delta P_{t,d-d}^0(i)$ stands for the dipole-dipole interaction effect involving interaction between dipolar-zwitter-ionic amino acids and the solvent molecules.

On the other hand, $\Delta P_{t,ch}^0(i)$ includes all other effects such as those arising from acid-base or short-range dispersion interaction, hydrophilic or hydrophobic hydration and structural effects etc. scaled particle theory (SPT) [1, 25, 30] has been applied for computation of $\Delta P_{t,cav}^0(i)$ as earlier, [20, 21] assuming the solutes and solvent molecules as equivalent to hard-sphere models as are dictated by their respective diameters.(Vide Table 1**)**.
The involved equations are given as follow:

$$\Delta G_{cav}^0(i) = G_C + RT\ln(RT / V_S) \quad \text{(VI)}$$

$$G_C = RT[-\ln(1-Z) + \{3X/(1-Z)\}\sigma_x + \{3Y/(1-Z)\}\sigma_x^{\,2} + \{9X^2/4(1-Z)^2\}\sigma_x^{\,2}]$$

$$\mathrm{Z} = \pi N_A / 6V_s (z_R \sigma_R^{\,3} + z_s \sigma_s^{\,3})$$

Where $X = \pi N_A / 6V_s (z_R \sigma_R^{\,2} + z_s \sigma_s^{\,2})$

$$Y = \pi N_A / 6V_s (z_R \sigma_R + z_s \sigma_s)$$

$$V_s = \mathrm{M}_s / d_s$$

In this expression N_A is Avogadro's number, z_R and z_s are the mole fraction of reference solvent water and co-solvent respectively. 'σ_x', 'σ_R' and 'σ_s' are the hard sphere diameters of amino acid, water and co-solvent respectively. Where the terms M_s, d_s represent for molar mass and molar density of the solvent.

Therefore, the required $\Delta G^0_{t,cav}(i)$ represents the difference,

$$\Delta G^0_{t,cav}(i) =_s \Delta G^0{}_{t,cav}(i) -_R \Delta G^0{}_{t,cav}(i) =_s G_C -_R G_C + RT\ln(V_R/V_s) \quad \text{(VII)}$$

$$\text{Again } \Delta G^0_{t,d-d}(i) = (_s\Delta G^0_{d-d}(i) -_R \Delta G^0_{d-d}(i)) \quad \text{(VIII)}$$

and $\Delta S^0_{t,d-d}(i) = (_s\Delta S^0_{d-d}(i) -_R \Delta S^0_{d-d}(i))$ are calculated by means of the Keesom-orientation expression, [20,32] for $_s\Delta G^0_{d-d}(i)$ in a solvent S, as given below:

$$_s\Delta G^0_{d-d}(i) = -(8\Pi/9)N^2\mu_s^2\mu_x^2\sigma_{s-x}^{-3}(kT)^{-1}v_s^{-1} = \mathrm{A}/\mathrm{T}\,\mathrm{V_s} \quad \text{(IX)}$$

Where $\mathrm{A} = -(8\Pi/9)N^2\mu_s^2\mu_x^2\sigma_{s-x}^{-3}(k)^{-1}$ and $V_s = M_s/d_s$ and that of $\Delta S^0_{d-d}(i)$ as follows-

$$_s\Delta S^0_{d-d}(i) = \{\delta_s \Delta G^0_{d-d}(i)/\delta\Gamma\}_p \quad \text{(X)}$$

i.e. $\mathrm{T}_s\Delta S^0_{d-d}(i) =_s \Delta G^0_{d-d}(i)[1+\mathrm{T}\alpha]$, where N stands for Avogadro's number, μ_s, μ_x are the dipole moment of solvents and solute respectively (Table 1).

σ_{s-x} is the distance at which the attractive and repulsive interactions between the solvent and solute molecules are equal and is generally equal to ½($\sigma_s + \sigma_x$) where σ_s and σ_x are the hard sphere diameter of cosolvent and solute molecules respectively (Table 1) and α is the isothermal expansibility of the solvent and given by $(\delta \ln V_s/\delta\Gamma)_P = -(\delta \ln d_s/\delta\Gamma)$. Following Marcus [31] and Kim *et al.* [32] in order to get this $\Delta P^0_{t,d-d}(i)$ term on mole fraction scale the quantity was again multiplied by the term X_{s1}.

$$\mathrm{X}_{s1} = \mathrm{X}_s(\mu_s/\sigma_s^3)/(\mu_R/\sigma_R^3) \quad \text{(XI)}$$

This is the real mole fraction contribution due to dipole-dipole interaction [31]. Subtraction of $\Delta P^0_{t,cav}(i)$ and $\Delta P^0_{t,d-d}(i)$ from the total we get $\Delta P^0_{t,ch}(i)$ of the solute amino acid. The values of $\Delta P^0_{t,cav}(i)$, $\Delta P^0_{t,d-d}(i)$ and $\Delta P^0_{t,ch}(i)$ are presented in Table 5.

Table 1 Values of solvent parameters (Wt % DMSO, Mole fraction of DMSO (z_s), water ((z_R), mean mol. Weight (M_S), density (d_s), hard sphere diameter of co-solvent (σ_s) (DMSO+H2O) and σ_{s-x} (= ½($\sigma_s + \sigma_x$)), Dipole moment of co-solvent (μ_s), and thermal expansibility constant (α) of the H_2O+DMSO system at 298.15 K

Wt % DMSO	Mole fraction of DMSO(z_s)	Mole fraction of water (z_R)	Molar mass (M_S)	10^3 d $_s$ (kg· m^{-3})	Molar Volume (V_s)	σ_s (Å)	σ_{s-x} (Å)	Dipole Moment of co-solvent (μ_s)	α (x 10^{-3})
0	0.000	1.000	18.015	0.997	18.069	0.274	0.419	1.831	0.257*
20	0.054	0.946	21.260	1.002	21.218	0.286	0.425	1.941	0.296
40	0.133	0.867	26.010	1.009	25.778	0.303	0.434	2.105	0.353
60	0.256	0.744	33.400	1.021	32.713	0.329	0.447	2.359	0.442
80	0.479	0.521	46.810	1.042	44.923	0.378	0.471	2.821	0.604
100	1.000	0.000	78.130	1.091	71.613	0.491	0.528	3.900	0.982

**reference [32]*

Table 2 Solubilities (mol·kg^{-1}) of Glycine in aqueous mixtures of DMSO at different temperature (^{0}C)

Wt % of DMSO	15^{0}C	20^{0}C	25^{0}C	30^{0}C	35^{0}C
0	2.780 (2.680)[24] (2.700)[20] (2.720)[16] (2.998)[34]	3.048 (3.009)[24] (3.045)[20] (3.060)[16] (3.303)[34]	3.344 (3.330)[24] (3.339)[20] (3.340)[16] (3.389)[34]	3.664 (3.670)[24] (3.680)[20] (3.720)[16] (3.547)[34]	4.014 (4.020)[24] (4.042)[20] (4.060)[16] (3.791)[34]
20	1.575	1.698	1.804	2.056	2.269
40	0.685 (±0.002)^b	0.838 (±0.002)^b	0.972 (±0.001)^b	1.058 (±0.002)^b	1.198 (±0.001)^b
60	0.373 (±0.002)^b	0.405 (±0.001)^b	0.445 (± 0.002)^b	0.552 (±0.001)^b	0.602 (±0.001)^b
80	0.285 (±0.001)^b	0.330 (±0.003)^b	0.383 (±0.001)^b	0.396 (±0.001)^b	0.408 (±0.001)^b
100	0.182	0.214	0.252	0.265	0.296

b= standard deviation

Table 3 Standard Gibbs energies of solutions (ΔG_s^0) on molal scale in their respective solubilities of Glycine in aqueous mixtures of dimethylsulfoxide at different temperature (K)

288.15 K		293.15 K		298.15 K		303.15 K		303.18 K	
S (mol·kg^{-1})	ΔG_s^0 (kJ·mol^{-1})	S (mol·kg^{-1})	ΔG_s^0 (kJ·mol^{-1})	S (mol·kg^{-1})	ΔG_s^0 (kJ·mol^{-1})	S (mol·kg^{-1})	ΔG_s^0 (kJ·mol^{-1})	S (mol·kg^{-1})	ΔG_s^0 (kJ·mol^{-1})
2.780	-2.44946	3.048	-2.71628	3.344	-2.99235	3.664	-3.27286	4.014	-3.56058
1.575	-1.08825	1.698	-1.29040	1.804	-1.46252	2.056	-1.81660	2.269	-2.09911
0.685	0.90637	0.838	0.43075	0.972	0.07039	1.058	-0.14210	1.198	-0.46283
0.373	2.36256	0.405	2.20295	0.445	2.00705	0.552	1.49763	0.602	1.30019
0.285	3.00722	0.330	2.70209	0.383	2.37897	0.396	2.33474	0.408	2.29677
0.182	4.08164	0.214	3.75770	0.252	3.41662	0.265	3.34714	0.296	3.11892

Table 4 Coefficients a, b and c, Gibbs energies ΔG_t^0 and entropies $T\Delta S_t^0$ of transfer of Glycine on mole fraction scale from H_2O to H_2O-DMSO mixture at 298.15 K

Wt% of DMSO	a(kJ·mol^{-1})	b(kJ·mol^{-1}·K^{-1})	c(kJ·mol^{-1}·K^{-1})	$\Delta G_t^0(i)$ (kJ·mol^{-1})	$T\Delta S_t^0(i)$ (kJ·mol^{-1})
0	-9.91	0.4705	-0.07878	0	0
20	-160.37	3.8593	-0.58383	1.078	-1.377
40	252.30	-5.2882	0.77968	2.167	3.595
60	-178.88	4.3843	-0.66306	3.399	1.206
80	426.16	-9.3189	1.38544	3.056	-4.381
100	252.61	5.3302	0.78886	2.835	-0.276

Table 5 Gibbs energies of transfer $\Delta G_t^0(i)$, $\Delta G_{t,cav}^0(i)$, $\Delta G_{t,dd}^0(i)$, $\Delta G_{t,ch}^0(i)$ and enthalpy of transfer, $\Delta H_{t,cav}^0(i)$ and entropies of transfer $T\Delta S_t^0(i)$, $T\Delta S_{t,cav}^0(i)$, $T\Delta S_{t,dd}^0(i)$ and $T\Delta S_{t,ch}^0(i)$ of Glycine from H_2O to H_2O-DMSO at 298.15 K (on mole fraction scale) in kJ·mol^{-1}

Wt% DMSO	$\Delta G_t^0(i)$	$\Delta G_{t,cav}^0(i)$	$\Delta G_{t,dd}^0(i)$	$\Delta G_{t,ch}^0(i)$	$T\Delta S_t^0(i)$	$\Delta H_{t,cav}^0(i)$	$T\Delta S_{t,cav}^0(i)$	$T\Delta S_{t,dd}^0(i)$	$T\Delta S_{t,ch}^0(i)$
0	0	0	0	0	0	0	0	0	0
20	1.078	-1.400	0.664	1.814	-1.377	-0.816	0.584	0.630	-2.591
40	2.167	-2.870	2.990	2.047	3.595	-1.369	1.501	2.790	-0.696
60	3.399	-4.420	7.420	0.399	1.206	-1.562	2.858	6.730	-8.382
80	3.056	-6.160	14.700	-5.484	-4.381	-0.778	5.382	12.700	-22.463
100	2.835	-7.540	25.200	-14.825	-0.276	13.225	20.765	19.800	-40.841

The required diameter and other solvent parameters of H_2O and DMSO mixtures are taken from Ref. [31] .The required diameter of Glycine is 5.64 Å as given in Ref.[20, 21]. Dipole-moment value of Glycine is 15.7 D [20].

2.3 ANALYSIS OF SOLUBILITY DATA

Solubility data of glycine are very important in pharmaceuticals; food, cosmetics, biochemical and chemical applications though the experimental results for the solubility of glycine in aqueous mixtures of dimethylsulphoxide were not available in the literature. To cover this lack we have measured the solubility of glycine in water-DMSO solvent system and presented in Table 2. The solubility values of glycine increases with increasing temperature in a particular composition of aqua-organic mixed solvent system but with the increased concentration of DMSO solubility values decreased.

2.4 INTERACTIONS INVOLVED BETWEEN SOLUTE AND SOLVENT MIXTURES: INDIRECT PROOF OF 3D-STRUCTURE MAKER PROPERTY OF GLYCINE

In this work different types of interactions involved between solute and solvent molecules are presented by graphically to signify more clearly. Here Figure 1 represents the variation of $\Delta G_t^0(i)$ for amino acid glycine against the mole % of DMSO at 298.15 K.

Here, $\Delta G_t^0(i)$ is composed of $\Delta G_{t,cav}^0(i)$, $\Delta G_{t,d-d}^0(i)$ and $\Delta G_{t,ch}^0(i)$. [$\Delta G_{t,d-id}^0(i)$ i.e. free energy change due to dipole-induced dipole interaction, it is considered negligible]. The positive increment of $\Delta G_t^0(i)$ value indicates that glycine will be destabilized with the increased concentration of DMSO upto 30 mole % of DMSO in aqueous-DMSO system. In higher concentration, a slower decrement of $\Delta G_t^0(i)$ is observed which indicates that glycine becomes slightly more stabilised in higher content of DMSO. Such type of complicated nature of stability may be guided by the gradual change in cavity interaction, dipole-dipole interaction, dispersion interaction, acidity-basicity and hydrophobic/hydrophilic interactions towards amino acids in this aquo-organic mixed solvent system.

The $\Delta G_{t,cav}^0(i)$, values are gradually decreased with DMSO concentration (Table 5) which indicates that the involved α-amino acid, glycine acquire more stability with the increased mole % of DMSO i.e. it should be easily accommodated in DMSO than H_2O with release of concerned energy due to the greater size of DMSO (0.491Å) than H_2O (0.274 Å). [20, 21, 31]

The $\Delta G_{t,d-d}^0(i)$ (Table 4) values of glycine are increased gradually with increased mole % of DMSO. The dipole moment of DMSO (3.90 D) [21,31] is greater than H_2O (1.83 D) [31] but the involved hard sphere diameter difference of DMSO and H_2O supports such variation.

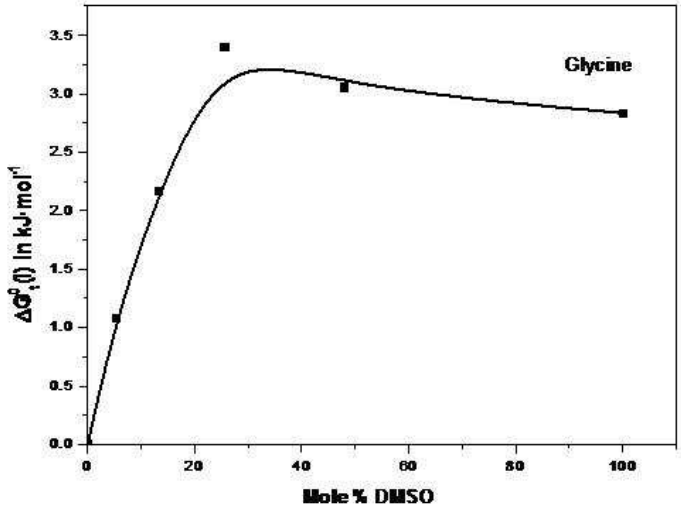

Figure 1. Variation of $\Delta G^0_t(i)$ in kJ·mol^{-1} of glycine in aqueous mixtures of DMSO at 298.15K

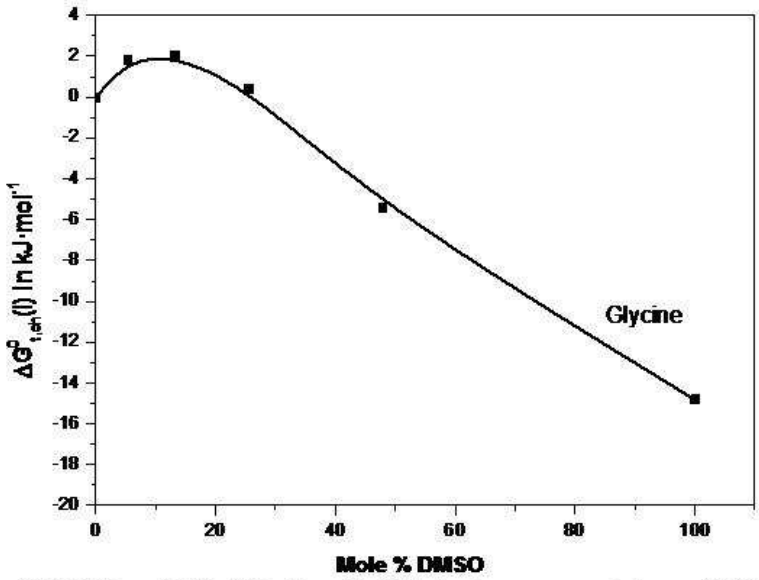

Figure 2. Variation of $\Delta G^0_{t,ch}(i)$ in kJ·mol^{-1} of glycine in aqueous mixtures of DMSO at 298.15 K

$\Delta G^0_{t,ch}(i)$ values for the solute, glycine have computed after subtraction of $\Delta G^0_{t,cav}(i)$ (estimated by the scaled particle theory) [30] $\Delta G^0_{t,d-d}(i)$ from $\Delta G^0_t(i)$. $\Delta G^0_{t,ch}(i)$ value is composed of the chemical interactions like H-bonding, acid-base, hard-soft, dispersion, hydrophilic hydration and hydrophobic hydration, etc. in between solute and solvent molecules in this system. Figure 2 represents the variation of $\Delta G^0_{t,ch}(i)$ with DMSO concentration. The $\Delta G^0_{t,ch}(i)$ value increases up to about 15 mole % of DMSO in the H_2O-DMSO system. This indicates the destabilization of glycine. This occurs due to the breaking of extensive hydrogen bond between protic water and hydrophilic head of amino acid glycine with the introduction of larger dipolar aprotic DMSO in water. This may be due to the 3D-structure breaking propensity of DMSO. After that the gradual stabilization of glycine occurs with the sharp decrement of $\Delta G^0_{t,ch}(i)$ values with DMSO concentration. Here hydrogen bonding capacity of DMSO is weaker than water. This factor will destabilize glycine with the increased concentration of DMSO. On the other hand the greater size of DMSO (0.491 Å) [21, 31] introduces dispersion interaction among DMSO and amino acid, glycine. The stability of α-amino acid glycine due to hydrophilic interaction exerted by the water molecules will be more due to co-solvent induced hydrophilicity with the increased concentration of DMSO. Hence the hydrophilic

and dispersion interactions effect represents such type of stabilization of glycine in aqueous DMSO system. Here it is important to note that in higher concentration of DMSO in aqueous co-solvent system the association of the solvents molecules (i.e. between water and DMSO molecules in 1:2 ratios) [34, 35] [Diagram C) and the self association of DMSO [Diagram A] occurs extensively which may take part in dispersion interaction with the amino acid glycine.

Here a comparative study of $\Delta G^0_{t,ch}(i)$ values of glycine and DL-nor-valine in water-DMSO is represent by Figure 3. The work of DL-nor-valine in water-DMSO system is mentioned in our previous manuscript [21]. The α-amino acid glycine having smaller size (5.64 Å) [20] will be more stabilized with increased concentration of DMSO by dispersion interaction and hydrophilic interaction than DL-nor-valine (6.92 Å) [20]. Though the dispersion interaction is more effective for larger valine than glycine but the higher charge density on glycine is more efficient in hydrophilic interaction. Hence the higher combined effect of dispersion and hydrophilic interactions in glycine than valine is responsible for such type of observation.

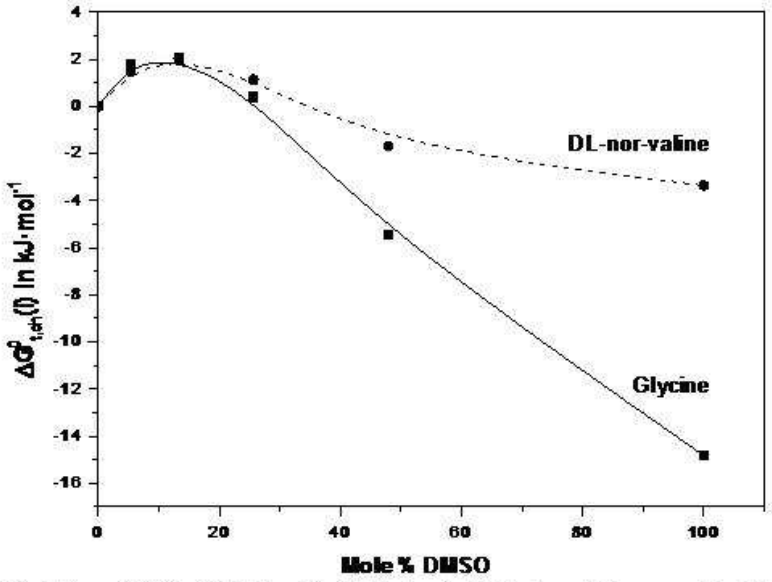

Fig. 3 Variation of $\Delta G^0_{t,ch}(i)$ in kJ·mol^{-1} of glycine (solid line) and DL-nor-valine (dash line) in aqueous mixtures of DMSO at 298.15 K

2.5 ROLE OF GLYCINE FOR CONTROLLING SOLVENT-SOLVENT INTERACTIONS IN AQUEOUS DIMETHYLSULPHOXIDE (DMSO): DIRECT PROOF OF 3D-STRUCTURE MAKER PROPERTY OF GLYCINE

Figure 4 represents the variation of $T\Delta S^0_t(i)$, of glycine against mole % of DMSO in aqueous DMSO. Actually $T\Delta S^0_t(i)$ is composed of cavity, dipole-dipole and chemical interaction effects i.e.

$$T\Delta S^0_t(i) = T\Delta S^0_{t,cav}(i) + T\Delta S^0_{t,d-d}(i) + T\Delta S^0_{t,ch}(i)$$

Now combined effect in $T\Delta S^0_t(i)$ value may represents such behaviour as shown in Figure 4.

$T\Delta S^0_{t,cav}(i)$ values (Table 5) are gradually increased with the mole % DMSO. This indicates that in presence of glycine the co-solvent (DMSO) and reference solvent (H_2O) become separated. With the increased DMSO concentrations the water molecule becomes free from amino acid to allow it to be accommodated by DMSO. $T\Delta S^0_{t,d-d}(i)$ values (Table 5) are also gradually increased with mole % of DMSO concentration. Here with the increased concentration of DMSO the dipolar amino acid glycine become less associated with dipolar co-solvent due to the larger size of DMSO (0.491 Å) and therefore glycine allow water as well as DMSO molecules to be more free as the concentrations of DMSO gradually increased.

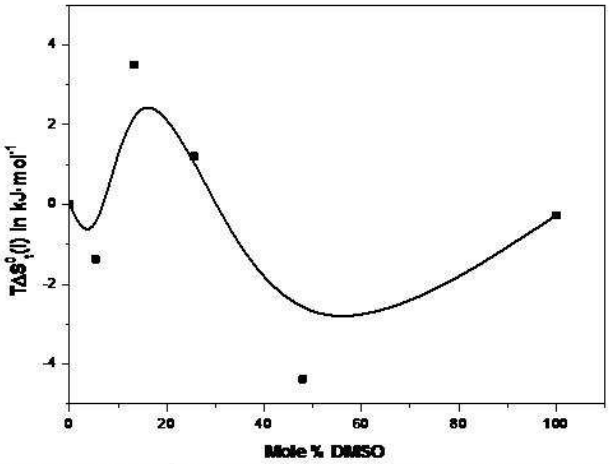

Figure 4. Variation of $T\Delta S^{0}_{t}(i)$ in kJ-mol^{-1} of glycine in aqueous mixtures of DMSO at 298.15 K

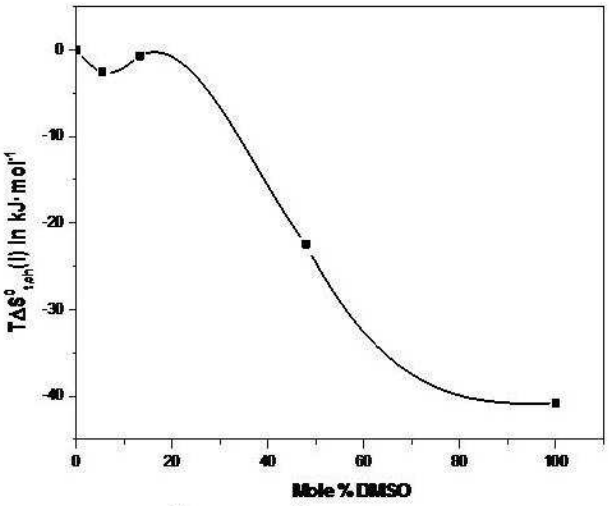

Figure 5. Variation of $T\Delta S^{0}_{t,ch}(i)$ in kJ-mol^{-1} of glycine in aqueous mixtures of DMSO at 298.15 K

$T\Delta S^{0}_{t,ch}(i)$ values are evaluated after subtraction of $T\Delta S^{0}_{t,cav}(i)$ and $T\Delta S^{0}_{t,d-d}(i)$ from $T\Delta S^{0}_{t}(i)$. Figure 5 represents the variation of $T\Delta S^{0}_{t,ch}(i)$ of glycine with increased DMSO concentration in aqueous DMSO mixture at 298.15 K. The nature of the curve with mole % DMSO indicates that the adopted 3-D structure of water due to its extensive intermolecular hydrogen bonding (Diagram B.) is broken due to introduction of DMSO at its lower concentration.

With increase of DMSO concentration from 20 to 100 mole % the $T\Delta S^{0}_{t,ch}(i)$ values are decreased sharply. This indicate that the amino acid glycine induces the solvent molecules to be associated (i.e. between water and DMSO molecules) (Diagram C.) and dimerised of the dipolar aprotic DMSO [33, 34] molecules also at its higher concentration (Diagram A.).

Here the solute (glycine) induces composite effects of increased dispersion interaction, basicity effect, decreased acidity, hydrogen bonding effects, hydrophilic hydration and hydrophobic hydration are responsible for overall decrement of $T\Delta S^{0}_{t,ch}(i)$ values occur throughout the higher concentration of DMSO in this aqueous DMSO mixed solvent system.

Figure 6 represents a comparative study of variation of $T\Delta S^{0}_{t,ch}(i)$ of α-amino acids, glycine and DL-nor-valine in aqueous-DMSO [20] mixed solvent system. Here we see that the amino acid DL-nor-valine induce more dis-

orderness to solvent mixtures in aqueous-DMSO than glycine. The nature of variation of $T\Delta S^{0}_{t,ch}(i)$ in presence of the amino acids is a direct proof of 3D-structure making property of glycine. It also observed that glycine has 3D-water structure making propensity while valine has 3D-structure breaking propensity in aqueous-DMSO solvent system.

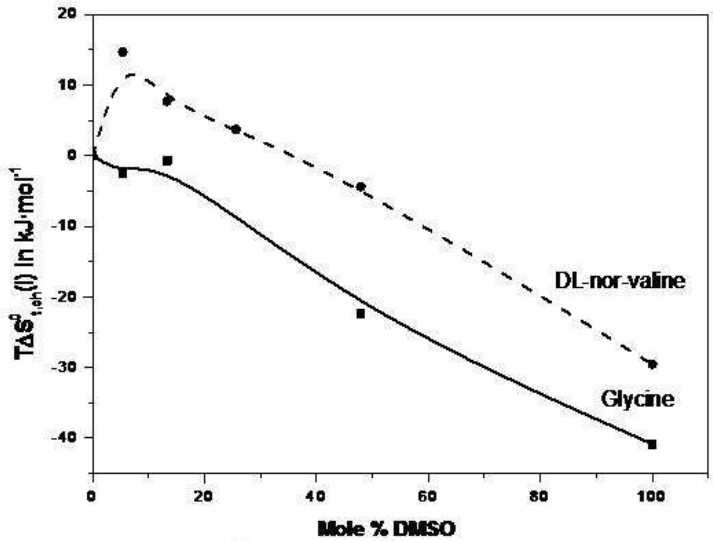

Figure 6. Variation of $T\Delta S^{o}_{t,ch}(i)$ in kJ-mol^{-1} of glycine(solid line) and DL-nor-valine(dash line)in aqueous mixtures of DMSO at 298.15 K

CONCLUSION

Experimental results for solubility values of glycine decreased with the increased concentration of DMSO. Here also observed that due to chemical interactions the amino acids will be stabilized in comparatively larger co-solvent DMSO, with dipolar aprotic character.

The zwitterionic amino acid glycine induces to adopt 3-D-structuredness of water in aqueous DMSO solvent system. Glycine and valine induces DMSO to be dimerised mainly through dispersion interaction in the DMSO rich region of this mixed solvent system. From this study, it leads to a conclusion that the amino acid glycine has 3D-water structure making propensity while valine has 3D-structure breaking propensity.

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