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REVIEW ARTICLE

Investigations of Various Interactions of Protein model compounds in Lithium and Sodium Salt of Nitrates Using Volumetric and Model Approach

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Abstract: Apparent molar volumes, $V_{2,\phi}$ of glycine, DL-α-alanine, DL-α-amino-*n*-butyric acid, L-valine and L-leucine in water and in (0.25, 0.5, 0.75, 1.0, 1.5, 2.0) mol·kg^{-1} aqueous sodium nitrate solutions and in aqueous lithium nitrate solutions at 298.15K have been determined at various temperatures (288.15, 298.15, 308.15 and 318.15) K from density measurements. The standard partial molar volumes at infinite dilution, V_2^0 obtained from $V_{2,\phi}$ have been used to calculate the corresponding volumes of transfer, $\Delta_t V^0$ from water to aqueous sodium nitrate solutions. The hydration number, n_H, side chain contributions and volumetric interaction coefficients of these amino acids have also been calculated. The $\Delta_t V^0$ values for the studied amino acids are positive, and these values increase with an increase in the concentration of $NaNO_3$ as well as with temperature. These parameters obtained from the volumetric study have been used to understand various mixing effects due to the interactions between amino acids and $LiNO_3$, $NaNO_3$ in aqueous solutions. Comparison of partial molar volumes of lithium nitrate and sodium nitrate will indicate a very interesting observations that Li^+ being very small in size will show very high polarization in water and according to cosphere model, lithium ion will occupy very large water molecule because of high hydration; therefore the partial molar volumes of lithium nitrate is lesser as compared to sodium nitrate which is opposite as we supposed.

Key words: Protein Model, Lithium, Volumetric approach, Interactions.

INTRODUCTION:

In order to get an idea about the role of hydration in protein folding / unfolding, it is necessary to study both the native and denatured states of a protein. Therefore the physicochemical properties of amino acids and peptides in aqueous solutions remain a subject of extensive investigations [1] (Zhao et al. 2006).

Salt solutions greatly influence the structure and properties of proteins including their solubility, denaturation, dissociation into subunits and the activity of enzymes[2-4] (Von Hippel et al., (1969); Jencks et al., 1969). Bhat et al., (1987) from volumes and heat capacities of some amino acids and peptides in aqueous NaCl and $CaCl_2$ solutions have concluded that $CaCl_2$ acts as a strong destabilizer of protein conformation as compared to NaCl solutions at the same concentration. Wadi et al. (1990, 1992, 1997)[5-7] reported the apparent molar volumes, viscosities and adiabatic compressibilities of some amino acids in aqueous NH_4Cl, KSCN and Na_2SO_4 solutions at different temperatures. Soto et al. (1999) [8] have reported partial molar volumes of glycine in aqueous $NaNO_3$ solutions only at 298.15K. Therefore, we have undertaken a systematic study on the volumes of some α-amino acids in aqueous $NaNO_3$ solutions at different temperatures. Consequently, in the present paper, the apparent molar volumes, $V_{2,\phi}$, of glycine, DL-α-alanine, DL-α-amino-*n*-butyric acid, L-valine and L-leucine in water and in aqueous sodium nitrate solutions (0.25, 0.5, 0.75, 1.0, 1.5, 2.0) mol·kg^{-1} have been determined by measuring the densities using a vibrating-tube digital densimeter at various temperatures (288.15, 298.15, 308.15 and 318.15) K. From these data, the partial molar volumes at infinite dilution, V_2^0, hydration number, n_H, side chain contributions of amino acids, expansibilities and interaction coefficients have been obtained. The concentration effect of lithium and sodium nitrate on these parameters has also been discussed.

Materials and Methods

Glycine (G-7126, 99 %), DL-α-alanine (A-7502, 99 %), DL-α-amino-*n*-butyric acid (A-1754, 98 %), L-valine (V-0500,

99 %), L-leucine (L-8000, 98 %) from Sigma Chemical Co., Lithium Nitrate and sodium nitrate and (AR, Thomas Baker, India), were used without further purification, however these were dried over anhydrous $CaCl_2$ in a vacuum desiccator before use. Deionized, doubly distilled degassed water with a specific conductance less than 1.3 $\times 10^{-6}$ $\Omega^{-1}\cdot cm^{-1}$ was used for the measurements. All solutions were prepared by mass using a Mettler balance with an accuracy of ± 0.01 mg.

The solution densities were measured using a vibrating-tube digital densimeter (model DMA 60/602, Anton paar), having a precision of ± 1×10^{-3} $kg\cdot m^{-3}$ and an accuracy of ± 3 $x10^{-3}$ $kg\cdot m^{-3}$. Working of the densimeter was checked by measuring the densities of aqueous sodium chloride solutions, which agreed well with the literature values [9](Archer, 1992).

Table 1. Solutions densities, ρ, and apparent molar volumes, $V_{2,\phi}$, for the α-amino acids in aqueous solutions of $NaNO_3$ at different concentrations and at (288.15-318.15)K and in aqueous solutions of $LiNO_3$ at 298.15K.

m_s (mol·kg $^{-1}$)	$\rho\times10^{-3}$ (kg·m^{-3})	$V_{2,\phi}\times10^{6}$ (m^3·mol^{-1})	m_s (mol·kg^{-1})	$\rho\times10^{-3}$ (kg·m^{-3})	$V_{2,\phi}\times10^{6}$ (m^3·mol^{-1})	m_s (mol·kg^{-1})	$\rho\times10^{-3}$ (kg·m^{-3})	$V_{2,\phi}\times10^{6}$ (m^3·mol^{-1})
				T =288.15K				
				Glycine				
				m_s =0.00000				
0.00000	0.999098		0.02529	0.999904	43.17	0.06711	1.001206	43.58
0.01576	0.999604	42.96	0.05342	1.000789	43.35	0.07647	1.001489	43.71
0.02126	0.999778	43.06	0.05979	1.000983	43.47			
				m_s = 0.25 mol·kg^{-1}				
0.00000	1.012001		0.19962	1.018084	44.16	0.35308	1.022436	44.86
0.09884	1.015087	43.56	0.26088	1.019868	44.39	0.42864	1.024487	45.18
0.15806	1.016878	43.84	0.31026	1.021248	44.67			
				m_s = 0.5 mol·kg^{-1}				
0.00000	1.025494		0.16035	1.030284	44.59	0.34636	1.035468	45.38
0.05179	1.027087	43.89	0.22346	1.032087	44.86	0.41345	1.037208	45.74
0.12132	1.029164	44.28	0.28755	1.033884	45.09	0.48416	1.039046	45.98
				m_s = 0.75 mol·kg^{-1}				
0.00000	1.038264		0.20567	1.044273	44.94	0.41676	1.050167	45.29
0.07143	1.040387	44.64	0.27264	1.046179	45.03	0.48511	1.052008	45.42
0.13073	1.042104	44.89	0.34547	1.048204	45.18			
				m_s = 1.0 mol·kg^{-1}				
0.00000	1.053246		0.20367	1.058984	45.63	0.39822	1.063946	46.58
0.06178	1.055041	45.01	0.24744	1.060123	45.92	0.45521	1.065294	46.88
0.13883	1.057214	45.34	0.32849	1.062207	46.29	0.53057	1.067017	47.26
				m_s = 1.5 mol·kg^{-1}				
0.00000	1.080338		0.09839	1.083116	45.18	0.16754	1.084996	45.47
0.03889	1.081449	44.97	0.14717	1.084468	45.27	0.17287	1.085117	45.60
0.06924	1.082303	45.09	0.15661	1.084709	45.39	0.17759	1.085209	45.78
				m_s = 2.0 mol·kg^{-1}				
0.00000	1.104299		0.06661	1.106097	45.77	0.10985	1.107211	46.12
0.02143	1.104886	45.49	0.07408	1.106288	45.88	0.12583	1.107609	46.27
0.03341	1.105208	45.63	0.09413	1.106809	46.01	0.13434	1.107812	46.39

DL-α-Alanine

m_s = 0.00000

0.02442	0.999804	60.17	0.06253	1.000889	60.37	0.09570	1.001804	60.68
0.04683	1.000447	60.23	0.07376	1.001204	60.44	0.10522	1.002062	60.77
0.05256	1.000609	60.28	0.08579	1.001533	60.59			

m_s = 0.25 mol·kg^{-1}

0.06371	1.013808	60.23	0.21756	1.018084	60.37	0.36292	1.022016	60.49
0.12344	1.015486	60.26	0.28724	1.019987	60.41	0.41799	1.023464	60.57
0.17398	1.016887	60.32	0.33242	1.021208	60.44			

m_s = 0.5 mol·kg^{-1}

0.09366	1.028064	60.63	0.24534	1.032046	61.09	0.31916	1.033886	61.37
0.16173	1.029888	60.78	0.26149	1.032446	61.18	0.32853	1.034124	61.38
0.21961	1.031428	60.83	0.29145	1.033204	61.26			

m_s = 0.75 mol·kg^{-1}

0.17818	1.042884	61.48	0.34458	1.046897	62.05	0.52931	1.051188	62.38
0.22218	1.043964	61.67	0.39277	1.048016	62.19	0.56918	1.052061	62.49
0.29068	1.045624	61.88	0.48175	1.050123	62.26			

m_s = 1.0 mol·kg^{-1}

0.03395	1.054109	61.62	0.09876	1.055696	62.08	0.14872	1.056884	62.32
0.05678	1.054683	61.69	0.11290	1.056034	62.16	0.16545	1.057276	62.39
0.06930	1.054983	61.89	0.12442	1.056308	62.22	0.18358	1.057686	62.52

m_s = 1.5 mol·kg^{-1}

0.02217	1.080867	61.99	0.07120	1.082009	62.26	0.21301	1.085207	62.59
0.02779	1.080998	62.08	0.16298	1.084117	62.38	0.21875	1.085318	62.67
0.05164	1.081557	62.17	0.20269	1.085009	62.45			

m_s = 2.0 mol·kg^{-1}

0.02298	1.104816	62.20	0.12787	1.107096	62.58	0.15896	1.107711	62.88
0.03805	1.105148	62.33	0.14485	1.107448	62.67			
0.08231	1.106114	62.49	0.14869	1.107509	62.79			

DL-α-Amino-*n*-butyric acid

m_s =0.00000

0.02145	0.999688	75.60	0.06582	1.000883	75.89	0.17785	1.003833	76.16
0.02960	0.999909	75.68	0.07800	1.001206	75.96	0.18562	1.004017	76.27
0.04207	1.000246	75.77	0.08602	1.001411	76.08			

m_s = 0.25 mol·kg^{-1}

0.07749	1.014014	76.36	0.11688	1.015014	76.48	0.12865	1.015288	76.68
0.09598	1.014488	76.39	0.12213	1.015138	76.56	0.12943	1.015304	76.71
0.11248	1.014906	76.44	0.12547	1.015214	76.63			

m_s = 0.5 mol·kg^{-1}

0.02040	1.026016	76.17	0.08411	1.027607	76.49	0.22223	1.030886	77.06
0.05387	1.026862	76.29	0.10485	1.028114	76.58	0.22814	1.031008	77.14
0.06002	1.027016	76.31	0.14511	1.029062	76.89			

m_s = 0.75 mol·kg^{-1}

0.02191	1.038808	76.23	0.08929	1.040446	76.47	0.13158	1.041445	76.64
0.03452	1.039116	76.34	0.11601	1.041082	76.56	0.13867	1.041604	76.71
0.07682	1.040148	76.41	0.11750	1.041114	76.59			

				m_s = 1.0 mol·kg^{-1}				
0.02609	1.053864	76.50	0.07635	1.055016	76.86	0.16690	1.057014	77.26
0.03604	1.054087	76.79	0.13248	1.056286	76.98	0.22141	1.058198	77.36
0.04078	1.054204	76.64	0.15859	1.056862	77.07			
				m_s = 1.5 mol·kg^{-1}				
0.02654	1.080899	77.28	0.12992	1.083016	77.58	0.16206	1.083604	77.93
0.04736	1.081333	77.36	0.14067	1.083222	77.66	0.17206	1.083777	78.06
0.08449	1.082097	77.47	0.15345	1.083447	77.85			
				m_s = 2.0 mol·kg^{-1}				
0.00613	1.104417	77.57	0.04834	1.105208	77.88	0.10404	1.106217	78.11
0.02668	1.104808	77.68	0.06005	1.105419	77.99	0.11898	1.106478	78.19
0.03682	1.104996	77.79	0.08159	1.105808	78.09			
				L-Valine				
				m_s =0.00000				
0.02218	0.999696	90.14	0.07031	1.000964	90.38	0.11063	1.002007	90.60
0.03033	0.99914	90.18	0.07583	1.001108	90.47	0.11435	1.002106	90.58
0.06451	1.000823	90.26	0.10295	1.001814	90.53			
				m_s = 0.25 mol·kg^{-1}				
0.08106	1.014096	90.29	0.16616	1.016227	90.50	0.28637	1.019114	90.82
0.12006	1.015083	90.37	0.19831	1.017006	90.62			
0.14130	1.015608	90.46	0.24436	1.018123	90.70			
				m_s = 0.50 mol·kg^{-1}				
0.04875	1.026706	90.44	0.10470	1.028062	90.64	0.19598	1.030228	90.80
0.07776	1.027418	90.49	0.14749	1.029088	90.70	0.20580	1.030446	90.87
0.09402	1.027809	90.57	0.15823	1.029336	90.76			
				m_s = 0.75 mol·kg^{-1}				
0.01438	1.038608	90.57	0.11781	1.041033	90.74	0.23367	1.043618	91.06
0.04244	1.039275	90.60	0.15530	1.041888	90.82	0.26197	1.044223	91.16
0.09984	1.040624	90.65	0.16984	1.042204	90.92			
				m_s = 1.0 mol·kg^{-1}				
0.02758	1.053866	90.86	0.15829	1.056688	91.28	0.22142	1.058008	91.38
0.13016	1.056104	91.14	0.17333	1.057004	91.31			
0.13649	1.056223	91.26	0.21410	1.057863	91.34			
				m_s = 1.5 mol·kg^{-1}				
0.01396	1.080614	91.43	0.10396	1.082333	91.78	0.14147	1.082994	92.08
0.02802	1.080887	91.56	0.11911	1.082608	91.87	0.14896	1.083117	92.17
0.04457	1.081204	91.67	0.13032	1.082806	91.96			
				m_s = 2.0 mol·kg^{-1}				
0.03230	1.104866	91.60	0.09910	1.105998	91.84	0.21155	1.107817	92.11
0.04083	1.105011	91.68	0.14597	1.106774	91.93	0.21782	1.107906	92.16
0.06463	1.105418	91.75	0.16606	1.107089	92.03			
				L-Leucine				
				m_s =0.00000				
0.02270	0.999646	107.07	0.07031	1.000774	107.26	0.15815	1.002814	107.38
0.03690	0.999988	107.06	0.07631	1.000906	107.39	0.16357	1.002944	107.35
0.05174	1.000338	107.18	0.08534	1.001123	107.33			

				m_s = 0.25 mol·kg^{-1}				
0.01945	1.012446	107.26	0.08833	1.013996	107.38	0.11599	1.014607	107.43
0.03657	1.012838	107.21	0.09778	1.014203	107.42	0.12008	1.014688	107.51
0.08647	1.013963	107.28	0.10637	1.014388	107.48			
				m_s = 0.5 mol·kg^{-1}				
0.01120	1.025736	107.37	0.08618	1.027338	107.40	0.14968	1.028628	107.70
0.01815	1.025884	107.46	0.12393	1.028114	107.56	0.15857	1.028806	107.73
0.04419	1.026443	107.42	0.14121	1.028462	107.64			
				m_s = 0.75 mol·kg^{-1}				
0.02741	1.038821	107.46	0.08157	1.039887	107.74	0.12970	1.040806	108.92
0.03707	1.039014	107.52	0.11547	1.040554	107.73	0.14677	1.041121	108.01
0.06773	1.039623	107.61	0.12553	1.040732	107.87			
				m_s = 1.0 mol·kg^{-1}				
0.03551	1.053907	107.72	0.08960	1.054886	107.90	0.12465	1.055483	108.16
0.04397	1.054071	107.57	0.09753	1.055022	107.97			
0.06307	1.054408	107.84	0.11440	1.055314	108.06			
				m_s = 1.5 mol·kg^{-1}				
0.01074	1.080508	107.86	0.08633	1.081668	108.11	0.11006	1.081996	108.37
0.04202	1.080997	107.94	0.09616	1.081809	108.19	0.11350	1.082038	108.44
0.07126	1.081446	108.01	0.10526	1.081938	108.26			
				m_s = 2.0 mol·kg^{-1}				
0.02375	1.104606	108.18	0.05607	1.105006	108.40	0.09935	1.105514	108.66
0.04595	1.104888	108.24	0.08981	1.105417	108.49	0.10651	1.105589	108.75
0.04793	1.104908	108.33	0.09641	1.105489	108.57			
				T =298.15K				
				Glycine				
				m_s =0.00000				
				$NaNO_3$				
0.00000	0.997047		0.12135	1.000878	43.37	0.19320	1.003108	43.47
0.05146	0.998683	43.24	0.12874	1.001106	43.40	0.21761	1.003856	43.52
0.06496	0.999108	43.29	0.14406	1.001583	43.42	0.22605	1.004104	43.58
0.10649	1.000414	43.34	0.18364	1.002816	43.44			
				m_s = 0.25 mol·kg^{-1} $NaNO_3$				
0.00000	1.011740		0.15954	1.016614	44.14	0.24294	1.019105	44.26
0.03958	1.012968	43.84	0.17987	1.017234	44.12	0.27227	1.019964	44.33
0.09266	1.014604	43.88	0.20761	1.018063	44.17	0.30605	1.020983	44.29
0.13403	1.015864	43.96	0.23762	1.018965	44.18			
				m_s = 0.5 mol·kg^{-1} $NaNO_3$				
0.00000	1.025077		0.18439	1.030621	44.38	0.31054	1.034306	44.55
0.07109	1.027236	44.24	0.22673	1.031888	44.35	0.32841	1.034836	44.53
0.10588	1.028283	44.28	0.24113	1.032306	44.39	0.33847	1.035102	44.61
0.16197	1.029962	44.32	0.28244	1.033508	44.46			
				m_s = 0.75 mol·kg^{-1} $NaNO_3$				
0.00000	1.037864		0.10634	1.040986	44.94	0.19860	1.043623	45.16
0.03785	1.038983	44.84	0.11539	1.041233	45.08	0.24765	1.045013	45.22
0.04550	1.039206	44.89	0.14435	1.042062	45.15	0.29269	1.046283	45.26
0.07143	1.039963	44.96	0.17390	1.042918	45.13			

				m_s = 1.0 mol·kg^{-1} $NaNO_3$				
0.00000	1.050713		0.18055	1.055783	45.79	0.30418	1.059108	46.08
0.03430	1.051688	45.66	0.22219	1.056923	45.86			
0.09510	1.053408	45.66	0.25548	1.057814	45.96			
0.14803	1.054886	45.73	0.29243	1.058833	45.94			
				m_s = 1.5 mol·kg^{-1} $NaNO_3$				
0.00000	1.075983		0.10648	1.078862	46.29	0.22514	1.081934	46.68
0.03288	1.076886	46.01	0.14951	1.079998	46.40	0.25066	1.082577	46.76
0.07378	1.077994	46.14	0.18424	1.080886	46.57	0.27254	1.083104	46.89
				m_s = 2.0 mol·kg^{-1} $NaNO_3$				
0.00000	1.099888		0.19126	1.104886	46.44	0.35285	1.108886	46.79
0.04339	1.101044	46.18	0.23802	1.105998	46.77	0.39962	1.109983	46.94
0.08213	1.102063	46.27	0.27808	1.107043	46.68			
				DL-α-Alanine				
				m_s =0.00000 $NaNO_3$				
0.04045	0.998206	60.46	0.33138	1.006304	60.69	0.46288	1.009814	60.83
0.08107	0.999362	60.49	0.38689	1.007804	60.73	0.47452	1.010098	60.89
0.14815	1.001256	60.52	0.40867	1.008383	60.76			
0.20700	1.002893	60.59	0.44073	1.009206	60.86			
				m_s = 0.25 mol·kg^{-1} $NaNO_3$				
0.04420	1.012964	60.93	0.15984	1.016104	61.12	0.20973	1.017406	61.32
0.07563	1.013828	60.96	0.16803	1.016310	61.21	0.26413	1.018836	61.38
0.11408	1.014868	61.08	0.17859	1.016583	61.27			
0.15496	1.015983	61.05	0.18335	1.016694	61.36			
				m_s = 0.5 mol·kg^{-1} $NaNO_3$				
0.05611	1.026583	61.28	0.21912	1.030864	61.43	0.37998	1.034887	61.75
0.07586	1.027104	61.36	0.26124	1.031923	61.56	0.38947	1.035102	61.81
0.13353	1.028628	61.39	0.30352	1.033004	61.58			
0.17997	1.029838	61.45	0.34806	1.034106	61.68			
				m_s = 0.75 mol·kg^{-1} $NaNO_3$				
0.04362	1.038996	61.68	0.24638	1.044108	61.94	0.37222	1.047104	62.24
0.08677	1.040104	61.74	0.32642	1.046046	62.08	0.39435	1.047623	62.28
0.15906	1.041943	61.79	0.34578	1.046528	62.06			
0.20134	1.042996	61.87	0.36473	1.046961	62.14			
				m_s = 1.0 mol·kg^{-1} $NaNO_3$				
0.08494	1.052814	62.26	0.22311	1.056107	62.57	0.40228	1.060218	62.82
0.11838	1.053627	62.32	0.26229	1.057024	62.62	0.45252	1.061346	62.87
0.13853	1.054108	62.39	0.33086	1.058617	62.68			
0.20202	1.055628	62.46	0.38324	1.059804	62.76			
				m_s = 1.5 mol·kg^{-1} $NaNO_3$				
0.02027	1.076448	62.96	0.27119	1.081997	63.29	0.34234	1.083383	63.69
0.09301	1.078093	63.08	0.30086	1.082604	63.40	0.36839	1.083886	63.80
0.18181	1.080064	63.17	0.31689	1.082888	63.57			
				m_s = 2.0 mol·kg^{-1} $NaNO_3$				
0.06377	1.101249	63.28	0.24857	1.105004	63.69	0.41597	1.108204	63.99
0.07164	1.101398	63.49	0.35725	1.107148	63.78	0.51309	1.109963	64.18
0.14850	1.102987	63.57	0.40268	1.107998	63.88			

DL-α-Amino-*n*-butyric acid

m_s =0.00000 $NaNO_3$

0.10161	0.999786	76.08	0.25862	1.003909	76.19	0.41077	1.007796	76.26
0.16196	1.001398	76.05	0.30775	1.005186	76.18	0.45164	1.008808	76.31
0.21960	1.002908	76.11	0.34701	1.006184	76.22			

m_s = 0.25 mol·kg^{-1} $NaNO_3$

0.07919	1.013806	76.26	0.24193	1.017962	76.31	0.33481	1.020283	76.35
0.12017	1.014863	76.28	0.27828	1.018863	76.36	0.34528	1.020516	76.41
0.17241	1.016208	76.25	0.31954	1.019884	76.39			

m_s = 0.5 mol·kg^{-1} $NaNO_3$

0.08032	1.027083	76.66	0.16155	1.029083	76.68	0.20479	1.030104	76.84
0.12175	1.028104	76.69	0.18042	1.029533	76.74	0.22669	1.030623	76.88
0.15281	1.028864	76.71	0.19440	1.029863	76.79			

m_s = 0.75 mol·kg^{-1} $NaNO_3$

0.04985	1.039063	76.92	0.13409	1.041062	76.96	0.23342	1.043338	77.16
0.07588	1.039683	76.95	0.15899	1.041628	77.08	0.25679	1.043886	77.12
0.13147	1.040996	76.99	0.20857	1.042776	77.11			

m_s = 1.0 mol·kg^{-1} $NaNO_3$

0.05587	1.051983	77.44	0.12638	1.053557	77.53	0.19662	1.055102	77.58
0.07842	1.052489	77.48	0.14487	1.053962	77.57	0.22104	1.055623	77.64
0.09957	1.052963	77.49	0.17428	1.054618	77.54			

m_s = 1.5 mol·kg^{-1} $NaNO_3$

0.07954	1.077604	78.10	0.22535	1.080448	78.38	0.34590	1.082667	78.64
0.14456	1.078898	78.19	0.30712	1.081996	78.47	0.35577	1.082808	78.75
0.18225	1.079632	78.26	0.32524	1.082308	78.56			

m_s = 2.0 mol·kg^{-1} $NaNO_3$

0.06996	1.101180	78.38	0.16007	1.102783	78.58	0.29566	1.105104	78.78
0.10964	1.101894	78.47	0.23589	1.104096	78.69	0.35506	1.106083	78.87

L-Valine

m_s =0.00000 $NaNO_3$

0.07204	0.998940	90.84	0.15311	1.001040	90.85	0.19248	1.002030	90.95
0.11137	0.999960	90.87	0.16270	1.001280	90.89	0.22862	1.002940	90.98
0.13697	1.000620	90.88	0.17195	1.001510	90.93			

m_s = 0.25 mol·kg^{-1} $NaNO_3$

0.03554	1.012639	90.95	0.08962	1.013983	91.09	0.16054	1.015714	91.20
0.04988	1.012998	90.99	0.11760	1.014672	91.12	0.17311	1.016008	91.27
0.06635	1.013406	91.06	0.13135	1.015008	91.14			

m_s = 0.50 mol·kg^{-1} $NaNO_3$

0.06368	1.026608	91.22	0.14848	1.028614	91.25	0.29493	1.031994	91.30
0.08451	1.027103	91.24	0.17006	1.029113	91.29	0.30463	1.032203	91.34
0.12248	1.027998	91.28	0.23562	1.030628	91.32			

m_s = 0.75 mol·kg^{-1} $NaNO_3$

0.04454	1.038883	91.50	0.11743	1.040517	91.62	0.17944	1.041883	91.68
0.07304	1.039528	91.53	0.13184	1.040833	91.66	0.20044	1.042336	91.72
0.09025	1.039913	91.57	0.14847	1.041207	91.63			

			m_s = 1.0 mol·kg^{-1} $NaNO_3$					
0.05897	1.051983	91.83	0.16517	1.054227	91.87	0.24791	1.055914	91.99
0.11176	1.053104	91.86	0.20787	1.055107	91.93	0.28418	1.056633	92.06
0.13631	1.053618	91.89	0.23591	1.055673	91.97			
			m_s = 1.5 mol·kg^{-1} $NaNO_3$					
0.05893	1.077088	92.54	0.25595	1.080644	92.70	0.34483	1.082096	92.99
0.14295	1.078633	92.59	0.27099	1.080886	92.78	0.39255	1.082888	93.04
0.16897	1.079094	92.66	0.28503	1.081104	92.87			
			m_s = 2.0 mol·kg^{-1} $NaNO_3$					
0.08445	1.101264	92.88	0.15406	1.102333	93.14	0.35556	1.105289	93.45
0.09636	1.101447	92.96	0.26687	1.104044	93.24	0.37701	1.105563	93.54
0.12525	1.101889	93.09	0.33996	1.105096	93.36			
			L-Leucine					
			m_s=0.00000 $NaNO_3$					
0.08225	0.998993	107.58	0.15386	1.000649	107.65	0.17611	1.001143	107.75
0.10904	0.999614	107.63	0.16402	1.000873	107.71	0.18358	1.001308	107.78
0.12199	0.999909	107.68	0.16944	1.000989	107.76			
			m_s = 0.25 mol·kg^{-1} $NaNO_3$					
0.05122	1.012887	107.68	0.14758	1.014994	107.79	0.19779	1.016044	107.96
0.07024	1.013309	107.69	0.17766	1.015634	107.85	0.23933	1.016908	108.03
0.09653	1.013886	107.73	0.18522	1.015789	107.89			
			m_s = 0.5 mol·kg^{-1} $NaNO_3$					
0.06704	1.026483	107.89	0.13641	1.027894	108.04	0.17327	1.028614	108.19
0.09191	1.026994	107.94	0.14746	1.028104	108.13	0.18710	1.028883	108.23
0.11595	1.027483	107.98	0.16448	1.028443	108.16			
			m_s = 0.75 mol·kg^{-1} $NaNO_3$					
0.01232	1.038108	108.01	0.15624	1.040888	108.13	0.21876	1.042046	108.23
0.05199	1.038886	108.06	0.17344	1.041209	108.16	0.23497	1.042338	108.27
0.09654	1.039749	108.09	0.19848	1.041673	108.20			
			m_s = 1.0 mol·kg^{-1} $NaNO_3$					
0.01553	1.050998	108.22	0.16347	1.053643	108.33	0.28100	1.055633	108.5
0.06313	1.051863	108.25	0.24189	1.054998	108.38	0.30329	1.055994	108.55
0.12643	1.052994	108.29	0.25514	1.055204	108.46			
			m_s = 1.5 mol·kg^{-1} $NaNO_3$					
0.07051	1.077044	108.83	0.13636	1.077996	108.98	0.18752	1.078701	109.14
0.10091	1.077488	108.90	0.16673	1.078433	108.99	0.21009	1.079006	109.20
			m_s = 2.0 mol·kg^{-1} $NaNO_3$					
0.08703	1.100944	109.15	0.16157	1.101789	109.37	0.21327	1.102304	109.68
0.12597	1.101399	109.22	0.18410	1.101996	109.61	0.24469	1.102618	109.79
0.13566	1.101502	109.29	0.20041	1.102183	109.59			
			T=298.15K					
			Glycine					
			m_s = 0.25 mol·kg^{-1} Li NO_3					
0.00000	1.007017		0.18576	1.012809	43.55	0.29341	1.016096	43.64
0.03153	1.008009	43.48	0.19482	1.013083	43.58	0.35717	1.018042	43.63
0.07936	1.009506	43.51	0.22687	1.014062	43.62	0.42471	1.020106	43.59
0.12772	1.011008	43.56	0.25669	1.014983	43.60			

			m_s = 0.5 mol·kg^{-1} Li NO_3					
0.00000	1.016703		0.24050	1.024106	43.74	0.31210	1.026209	43.96
0.06171	1.018264	43.64	0.27138	1.025034	43.78	0.34853	1.027273	44.04
0.11406	1.020236	43.72	0.30065	1.025896	43.86	0.37640	1.028108	44.03
0.17485	1.022097	43.76	0.30375	1.025983	43.88			
			m_s = 0.75 mol·kg^{-1} Li NO_3					
0.00000	1.026106		0.19887	1.032097	44.29	0.30203	1.035096	44.50
0.06318	1.028027	44.20	0.24181	1.032998	44.36	0.32221	1.035678	44.53
0.13081	1.030063	44.26	0.25298	1.033682	44.39	0.32835	1.035868	44.50
0.17541	1.031405	44.24	0.28573	1.034626	44.47			
			m_s = 1.0 mol·kg^{-1} Li NO_3					
0.00000	1.035107		0.15678	1.039687	45.06	0.28072	1.043207	45.24
0.07309	1.037264	44.89	0.17168	1.040106	45.13	0.30449	1.043867	45.29
0.10761	1.038282	44.85	0.24079	1.042083	45.18	0.31301	1.044085	45.36
0.13290	1.039008	44.96	0.26882	1.042862	45.26			
			DL-α-Alnine					
			m_s = 0.25 mol·kg^{-1} Li NO_3					
0.00000	1.007017		0.21387	1.012962	60.70	0.33023	1.016043	60.97
0.09287	1.009623	60.64	0.22110	1.013147	60.76	0.37506	1.017207	61.06
0.16477	1.011614	60.68	0.26370	1.014296	60.81	0.41769	1.018353	61.02
0.17846	1.011983	60.73	0.28306	1.014807	60.86			
			m_s = 0.5 mol·kg^{-1} Li NO_3					
0.00000	1.016703		0.26619	1.023864	61.17	0.34251	1.025808	61.36
0.07329	1.018708	61.04	0.29180	1.024523	61.23	0.35397	1.026117	61.33
0.15196	1.020834	61.08	0.31005	1.025006	61.22	0.38102	1.026808	61.36
0.19545	1.021996	61.11	0.33665	1.025683	61.28			
			m_s = 0.75 mol·kg^{-1} Li NO_3					
0.00000	1.026106		0.10928	1.029017	61.35	0.18461	1.030962	61.55
0.05728	1.027638	61.33	0.13186	1.029608	61.39	0.20709	1.031537	61.59
0.07495	1.028006	61.36	0.15082	1.029897	61.46	0.22005	1.031886	61.53
0.09531	1.028644	61.38	0.17159	1.030634	61.49			
			m_s = 1.0 mol·kg^{-1} Li NO_3					
0.00000	1.035107		0.13631	1.038628	61.75	0.25611	1.041583	62.08
0.04141	1.036188	61.64	0.15106	1.038994	61.82	0.27011	1.041908	62.16
0.07693	1.037104	61.72	0.17484	1.039588	61.88	0.29578	1.042533	62.19
0.11649	1.038116	61.78	0.22602	1.040862	61.96			
			DL-α-Amino-n-butyric acid					
			m_s = 0.25 mol·kg^{-1} Li NO_3					
0.00000	1.007017		0.11174	1.009962	76.17	0.19499	1.012104	76.27
0.03555	1.007962	76.10	0.11670	1.010089	76.19	0.22881	1.012962	76.31
0.04790	1.008287	76.14	0.17603	1.011623	76.23	0.25545	1.013633	76.34
			m_s = 0.5 mol·kg^{-1} Li NO_3					
0.00000	1.016703		0.08401	1.018864	76.36	0.16875	1.020993	76.49
0.02293	1.017298	76.26	0.12215	1.019832	76.39	0.20453	1.021882	76.52
0.04953	1.017983	76.31	0.15462	1.020646	76.44	0.21353	1.022104	76.53

			m_s = 0.75 mol·kg^{-1} Li NO_3					
0.00000	1.026106		0.14137	1.029618	76.62	0.23810	1.031962	76.68
0.04687	1.027283	76.54	0.16613	1.030227	76.61	0.23562	1.032614	76.72
0.08837	1.028314	76.59	0.20660	1.031204	76.66	0.28619	1.033098	76.75
			m_s = 1.0 mol·kg^{-1} Li NO_3					
0.00000	1.035107		0.11992	1.037994	76.92	0.18587	1.039527	77.08
0.03625	1.035989	76.83	0.14742	1.038642	76.96	0.25019	1.041024	77.09
0.08178	1.037086	76.87	0.16197	1.038983	76.98	0.27409	1.041562	77.14
			L-Valine					
			m_s = 0.25 mol·kg^{-1} Li NO_3					
0.00000	1.007017		0.11947	1.010064	90.86	0.16380	1.011163	90.95
0.04589	1.008198	90.80	0.12826	1.010283	90.88	0.23756	1.012983	90.98
0.11020	1.009832	90.84	0.14998	1.010824	90.91	0.27399	1.013862	91.03
			m_s = 0.5 mol·kg^{-1} Li NO_3					
0.00000	1.016703		0.11680	1.019604	90.89	0.20879	1.021824	90.99
0.03678	1.017624	90.84	0.13814	1.020123	90.92	0.24080	1.022575	91.06
0.05533	1.018086	90.87	0.19045	1.021386	90.97	0.24901	1.022763	91.09
			m_s = 0.75 mol·kg^{-1} Li NO_3					
0.00000	1.026106		0.12456	1.029063	91.31	0.21774	1.031204	91.43
0.08108	1.028043	91.26	0.15944	1.029874	91.34	0.24875	1.031898	91.49
0.10977	1.028719	91.28	0.18193	1.030389	91.38	0.28283	1.032639	91.56
			m_s = 1.0 mol·kg^{-1} Li NO_3					
0.00000	1.035107		0.10001	1.037406	91.47	0.20241	1.039688	91.60
0.04053	1.036047	91.40	0.13688	1.038234	91.53	0.24010	1.040517	91.62
0.07764	1.036898	91.44	0.17610	1.039108	91.57	0.28413	1.041483	91.62
			T =308.15K					
			Glycine					
			m_s =0.00000					
0.00000	0.994033		0.13756	0.998213	44.58	0.15846	0.998814	44.77
0.02704	0.994862	44.46	0.14575	0.998449	44.66	0.19807	0.999989	44.82
0.09774	0.997014	44.52	0.15124	0.998608	44.70	0.21394	1.000449	44.88
			m_s = 0.25 mol·kg^{-1}					
0.00000	1.011264		0.14141	1.015394	45.49	0.31993	1.020288	46.24
0.06645	1.013246	44.98	0.16607	1.016068	45.73			
0.13369	1.015208	45.21	0.24404	1.018246	45.94			
			m_s = 0.5 mol·kg^{-1}					
0.00000	1.024287		0.21186	1.030273	46.09	0.43610	1.036064	47.01
0.06934	1.026308	45.42	0.28693	1.032264	46.43			
0.13940	1.028274	45.85	0.37326	1.034463	46.84			
			m_s = 0.75 mol·kg^{-1}					
0.00000	1.037442		0.13645	1.041243	46.31	0.28908	1.045226	46.99
0.08417	1.039826	45.94	0.21486	1.043308	46.73	0.36793	1.047194	47.29
			m_s = 1.0 mol·kg^{-1}					
0.00000	1.049864		0.23192	1.055986	47.28	0.48574	1.062047	48.19
0.07494	1.051908	46.67	0.30883	1.057884	47.58			
0.14999	1.053897	46.93	0.36543	1.059208	47.88			

				m_s = 1.5 mol·kg^{-1}				
0.00000	1.071848		0.08896	1.074133	47.58	0.20067	1.076863	48.06
0.02154	1.072410	47.30	0.15926	1.075904	47.69	0.21627	1.077204	48.24
0.04715	1.073068	47.46	0.17415	1.076244	47.87			
				m_s = 2.0 mol·kg^{-1}				
0.00000	1.095014		0.13066	1.098144	48.44	0.17954	1.099248	48.70
0.04137	1.096018	48.27	0.14701	1.098508	48.58	0.19492	1.099563	48.89
0.09208	1.097233	48.36	0.16231	1.098849	48.68			
				DL-α-Alanine				
				m_s =0.00000				
0.03527	0.995011	61.50	0.14971	0.998116	61.77	0.17976	0.998877	62.09
0.06030	0.995699	61.56	0.16884	0.998614	61.88	0.18565	0.999014	62.16
0.14157	0.997914	61.64	0.17653	0.998805	61.97			
				m_s = 0.25 mol·kg^{-1}				
0.08786	1.013606	61.89	0.17332	1.015789	62.29	0.39506	1.021286	62.67
0.13518	1.014847	61.96	0.25559	1.017864	62.44	0.48329	1.023424	62.74
0.16589	1.015624	62.13	0.30608	1.019106	62.56			
				m_s = 0.5 mol·kg^{-1}				
0.07481	1.026196	62.54	0.23679	1.030164	62.96	0.40991	1.034109	63.53
0.16526	1.028447	62.73	0.35386	1.032884	63.29	0.51038	1.036287	63.82
				m_s = 0.75 mol·kg^{-1}				
0.06368	1.039017	62.56	0.23355	1.043108	62.99	0.37101	1.046014	63.88
0.15287	1.041206	62.77	0.31658	1.044984	63.28	0.47269	1.047998	63.47
				m_s = 1.0 mol·kg^{-1}				
0.01241	1.050162	63.05	0.03409	1.050664	63.52	0.04930	1.051004	63.81
0.01450	1.050209	63.25	0.04044	1.050809	63.60	0.06895	1.051448	63.92
				m_s = 1.5 mol·kg^{-1}				
0.01971	1.072289	63.62	0.09179	1.073864	63.88	0.12147	1.074462	64.23
0.06831	1.073364	63.71	0.09406	1.073905	63.96	0.12889	1.074588	64.45
0.07896	1.073592	63.79	0.10911	1.074208	64.15			
				m_s = 2.0 mol·kg^{-1}				
0.02987	1.095617	64.49	0.11271	1.097206	65.01	0.19551	1.098706	65.39
0.04903	1.095996	64.60	0.16113	1.098114	65.13	0.20634	1.098888	65.47
0.07268	1.096448	64.82	0.18349	1.098506	65.28			
				DL-α-Amino-*n*-butyric acid				
				m_s =0.00000				
0.06122	0.995649	76.88	0.11338	0.997004	76.97	0.18758	0.998862	77.29
0.10584	0.996833	76.73	0.13906	0.997648	77.13	0.19393	0.999006	77.38
0.10936	0.996908	76.88	0.14175	0.997706	77.21			
				m_s = 0.25 mol·kg^{-1}				
0.07068	1.013062	76.94	0.30789	1.018862	77.24	0.52996	1.023998	77.48
0.15690	1.015216	77.02	0.39010	1.020823	77.26	0.57648	1.025016	77.57
0.24384	1.017343	77.11	0.42755	1.021664	77.37			
				m_s = 0.5 mol·kg^{-1}				
0.05443	1.025623	77.16	0.21033	1.029326	77.44	0.29616	1.031228	77.79
0.10720	1.026894	77.28	0.24304	1.030062	77.57	0.32620	1.031884	77.88
0.15338	1.027989	77.37	0.26764	1.030604	77.68			

				m_s = 0.75 mol·kg^{-1}				
0.01541	1.037808	77.28	0.05824	1.038809	77.47	0.19142	1.041808	77.86
0.02275	1.037982	77.28	0.07144	1.039114	77.51	0.20046	1.041983	77.99
0.03396	1.038244	77.38	0.17874	1.041557	77.68			
				m_s = 1.0 mol·kg^{-1}				
0.05084	1.050997	77.90	0.24137	1.055064	78.27	0.43629	1.058996	78.53
0.11118	1.052309	78.07	0.29890	1.056238	78.38	0.48427	1.059884	78.68
0.19024	1.053998	78.18	0.37861	1.057862	78.44			
				m_s = 1.5 mol·kg^{-1}				
0.03691	1.072606	78.26	0.08799	1.073614	78.59	0.16192	1.075006	78.98
0.05480	1.072964	78.38	0.10348	1.073908	78.71	0.22110	1.076114	79.08
0.06719	1.073208	78.47	0.12058	1.074223	78.87			
				m_s = 2.0 mol·kg^{-1}				
0.03422	1.095616	79.44	0.09967	1.096717	79.78	0.14853	1.097446	80.32
0.05006	1.095888	79.53	0.11198	1.096908	79.91	0.16033	1.097608	80.47
0.09706	1.096689	79.64	0.12645	1.097114	80.15			
				L-Valine				
				m_s =0.00000				
0.03549	0.994962	91.23	0.17983	0.998628	91.52	0.26103	1.000604	91.72
0.04536	0.995216	91.30	0.23063	0.999886	91.58	0.26671	1.000723	91.80
0.07664	0.996014	91.46	0.23448	0.999977	91.60			
				m_s = 0.25 mol·kg^{-1}				
0.02547	1.011896	91.47	0.15799	1.015104	91.68	0.19766	1.016011	91.88
0.03404	1.012104	91.59	0.18451	1.015723	91.76	0.25058	1.017233	91.96
0.11244	1.014006	91.70	0.18857	1.015806	91.83			
				m_s = 0.50 mol·kg^{-1}				
0.02438	1.024864	91.71	0.15557	1.027886	91.95	0.20121	1.028864	92.23
0.03522	1.025117	91.79	0.16419	1.028062	92.07	0.21245	1.029108	92.26
0.11647	1.027001	91.87	0.18941	1.028614	92.16			
				m_s = 0.75 mol·kg^{-1}				
0.02743	1.038062	91.82	0.26031	1.043088	92.22	0.38129	1.045508	92.50
0.07499	1.039118	91.96	0.35916	1.045108	92.36	0.38833	1.045623	92.57
0.12609	1.040233	92.06	0.37159	1.045333	92.44			
				m_s = 1.0 mol·kg^{-1}				
0.04264	1.050773	92.12	0.18344	1.053664	92.41	0.24248	1.054788	92.71
0.08356	1.051628	92.23	0.20052	1.053998	92.47	0.24974	1.054913	92.75
0.10216	1.052009	92.30	0.21139	1.054206	92.52			
				m_s = 1.5 mol·kg^{-1}				
0.03226	1.072462	92.63	0.08807	1.073489	92.89	0.15175	1.074608	93.18
0.04437	1.072688	92.70	0.11672	1.074006	92.97	0.16233	1.074777	93.29
0.07218	1.073204	92.78	0.14271	1.074462	93.08			
				m_s = 2.0 mol·kg^{-1}				
0.02883	1.095489	93.16	0.15419	1.097462	93.49	0.19371	1.098004	93.81
0.04661	1.095776	93.24	0.16454	1.097608	93.57	0.20238	1.098116	93.89
0.07394	1.096208	93.37	0.17742	1.097776	93.72			
				L-Leucine				

				m_s =0.00000				
0.03662	0.994904	107.82	0.17122	0.998023	107.97	0.21590	0.999233	108.06
0.07844	0.995886	107.88	0.19844	0.998643	107.95	0.23068	0.999344	108.11
0.13149	0.997114	107.94	0.21512	0.999017	107.99			
				m_s = 0.25 mol·kg^{-1}				
0.02534	1.011823	108.11	0.09050	1.013214	108.46	0.11036	1.013601	108.78
0.03302	1.011988	108.22	0.09918	1.013388	108.57	0.11643	1.013722	108.83
0.04800	1.012307	108.38	0.10487	1.013503	108.62			
				m_s = 0.5 mol·kg^{-1}				
0.01653	1.024633	108.10	0.05781	1.025482	108.26	0.14521	1.027233	108.44
0.02908	1.024894	108.13	0.09802	1.026288	108.42	0.15615	1.027448	108.46
0.04435	1.025208	108.20	0.13368	1.027008	108.40			
				m_s = 0.75 mol·kg^{-1}				
0.02172	1.037868	108.20	0.13364	1.039982	108.54	0.15360	1.040306	108.84
0.05776	1.038554	108.46	0.13862	1.040062	108.63	0.16170	1.040444	108.90
0.07401	1.038862	108.49	0.15208	1.040283	108.81			
				m_s = 1.0 mol·kg^{-1}				
0.01491	1.050133	108.57	0.09168	1.051483	108.78	0.13696	1.052233	109.03
0.03479	1.050488	108.63	0.12024	1.051971	108.85	0.15026	1.052446	109.11
0.06279	1.050982	108.70	0.12299	1.052008	108.93			
				m_s = 1.5 mol·kg^{-1}				
0.01405	1.072066	108.88	0.11680	1.073608	109.11	0.13243	1.073804	109.35
0.07410	1.072982	108.97	0.12467	1.073715	109.18	0.13927	1.073886	109.46
0.10551	1.073446	109.06	0.13049	1.073789	109.26			
				m_s = 2.0 mol·kg^{-1}				
0.03538	1.095462	109.21	0.09004	1.096118	109.48	0.21233	1.097508	109.77
0.04724	1.095608	109.27	0.18377	1.097223	109.57	0.22802	1.097666	109.85
0.08028	1.096009	109.38	0.20462	1.097446	109.66			
				T =318.15K				
				Glycine				
				m_s =0.00000				
0.00000	0.990244		0.15963	0.994778	46.63	0.18454	0.995411	47.01
0.09869	0.993088	46.29	0.17590	0.995221	46.72	0.21100	0.996114	47.16
0.15379	0.994642	46.44	0.18000	0.995308	46.88	0.21625	0.996233	47.28
				m_s = 0.25 mol·kg^{-1}				
0.00000	1.004062		0.12004	1.007413	46.92	0.13232	1.007703	47.30
0.02174	1.004677	46.68	0.12397	1.007502	47.08	0.13719	1.007817	47.44
0.06851	1.005988	46.79	0.12865	1.007617	47.19	0.14188	1.007923	47.59
				m_s = 0.5 mol·kg^{-1}				
0.00000	1.016923		0.08419	1.019233	47.18	0.15639	1.021143	47.53
0.01478	1.017335	46.84	0.09443	1.019504	47.27	0.18983	1.022008	47.68
0.03870	1.017994	47.01	0.11553	1.020062	47.40	0.22647	1.022953	47.79
				m_s = 0.75 mol·kg^{-1}				
0.00000	1.029652		0.08889	1.032008	47.80	0.18815	1.034533	48.21
0.01716	1.030114	47.49	0.13205	1.033115	48.01			
0.07043	1.031533	47.63	0.17029	1.034088	48.13			

				m_s = 1.0 mol·kg^{-1}				
0.00000	1.041006		0.07869	1.043004	48.59	0.16601	1.045113	49.09
0.04308	1.042113	48.35	0.09290	1.043352	48.70	0.20373	1.046008	49.22
0.07361	1.042885	48.47	0.11978	1.044006	48.86	0.25129	1.047115	49.39
				m_s = 1.5 mol·kg^{-1}				
0.00000	1.063447		0.12180	1.066335	49.49	0.24039	1.069004	49.89
0.04813	1.064608	49.21	0.15103	1.067004	49.60			
0.06984	1.065117	49.37	0.20026	1.068113	49.77			
				m_s = 2.0 mol·kg^{-1}				
0.00000	1.084235		0.10988	1.086704	50.01	0.17263	1.088004	50.49
0.03353	1.085006	49.64	0.11924	1.086885	50.21			
0.06351	1.085679	49.83	0.15912	1.087732	50.38			
				DL-α-Alanine				
				m_s=0.00000				
0.08272	0.992417	63.04	0.16955	0.994608	63.44	0.18522	0.994911	63.97
0.10583	0.993008	63.16	0.17683	0.994752	63.68	0.19085	0.995016	64.16
0.16248	0.994461	63.23	0.18036	0.994804	63.89			
				m_s = 0.25 mol·kg^{-1}				
0.02418	1.004688	63.01	0.07261	1.005917	63.27	0.10902	1.006817	63.49
0.02882	1.004803	63.18	0.08822	1.006304	63.38	0.11227	1.006886	63.60
				m_s = 0.5 mol·kg^{-1}				
0.02934	1.017652	63.53	0.10764	1.019557	63.78	0.19062	1.021504	64.08
0.07843	1.018853	63.69	0.13145	1.020113	63.94	0.21262	1.022008	64.16
				m_s = 0.75 mol·kg^{-1}				
0.02886	1.030338	64.06	0.10569	1.032115	64.39	0.14615	1.033004	64.68
0.05921	1.031046	64.23	0.12779	1.032608	64.52	0.18611	1.033886	64.80
				m_s = 1.0 mol·kg^{-1}				
0.07375	1.042653	64.87	0.11896	1.043615	65.18	0.16714	1.044613	65.44
0.09944	1.043208	65.01	0.13787	1.044008	65.30	0.18127	1.044885	65.59
				m_s = 1.5 mol·kg^{-1}				
0.06551	1.064808	65.32	0.13636	1.066208	65.70	0.23698	1.068117	66.06
0.08112	1.065115	65.49	0.17816	1.067006	65.89	0.24983	1.068335	66.17
				m_s = 2.0 mol·kg^{-1}				
0.06128	1.085389	66.08	0.11718	1.086404	66.29	0.14175	1.086808	66.57
0.10662	1.086225	66.17	0.12728	1.086573	66.40	0.16630	1.087225	66.69
				DL-α-Amino-*n*-butyric acid				
				m_s=0.00000				
0.07174	0.992088	77.76	0.14273	0.993844	78.11	0.15186	0.994014	78.50
0.13352	0.993644	77.88	0.14593	0.993901	78.27	0.15902	0.994168	78.64
0.14031	0.993804	77.96	0.15015	0.993988	78.39			
				m_s = 0.25 mol·kg^{-1}				
0.01946	1.004553	77.62	0.04208	1.005104	78.04	0.12109	1.007008	78.32
0.03315	1.004888	77.90	0.11251	1.006817	78.18	0.13014	1.007213	78.42
				m_s = 0.5 mol·kg^{-1}				
0.01254	1.017225	78.07	0.05484	1.018223	78.36	0.14633	1.020334	78.58
0.03019	1.017645	78.20	0.12919	1.019957	78.44	0.17634	1.021004	78.69

				m_s = 0.75 mol·kg^{-1}				
0.03409	1.030423	78.74	0.12095	1.032334	79.01	0.14661	1.032853	79.29
0.09004	1.031665	78.89	0.13703	1.032665	79.16	0.15416	1.032998	79.40
				m_s = 1.0 mol·kg^{-1}				
0.07405	1.042574	79.38	0.14383	1.044008	79.55	0.18918	1.044873	79.88
0.12663	1.043665	79.46	0.17470	1.044615	79.70	0.19716	1.045006	80.01
				m_s = 1.5 mol·kg^{-1}				
0.03222	1.064067	79.89	0.13675	1.066009	80.19	0.19342	1.067008	80.40
0.08814	1.065118	80.06	0.16111	1.066443	80.28	0.21321	1.067335	80.53
				m_s = 2.0 mol·kg^{-1}				
0.05148	1.085114	80.50	0.13467	1.086482	80.73	0.17015	1.087004	81.04
0.10728	1.086043	80.62	0.15003	1.086707	80.89	0.20548	1.087533	81.19
				L-Valine				
				m_s=0.00000				
0.07501	0.992088	93.01	0.12375	0.993215	93.49	0.14722	0.993704	93.96
0.09718	0.992614	93.16	0.14145	0.993618	93.61	0.15022	0.993744	94.16
0.11739	0.993088	93.28	0.14519	0.993668	93.88			
				m_s = 0.25 mol·kg^{-1}				
0.04808	1.005208	92.88	0.08078	1.006004	92.60	0.10697	1.006604	92.82
0.07338	1.005817	92.74	0.10279	1.006517	92.71	0.11252	1.006713	93.01
				m_s = 0.5 mol·kg^{-1}				
0.02739	1.017557	92.71	0.09330	1.019034	93.08	0.13212	1.019873	93.29
0.04732	1.018004	92.96	0.11496	1.019508	93.17	0.14142	1.020062	93.40
				m_s = 0.75 mol·kg^{-1}				
0.05060	1.030743	93.29	0.13593	1.032534	93.47	0.16015	1.033004	93.68
0.11037	1.032008	93.38	0.14827	1.032773	93.59	0.20400	1.033885	93.77
				m_s = 1.0 mol·kg^{-1}				
0.06301	1.042262	93.98	0.10824	1.043117	94.30	0.15055	1.043885	94.58
0.09119	1.042804	94.13	0.13465	1.043608	94.42	0.16379	1.044113	94.70
				m_s = 1.5 mol·kg^{-1}				
0.03187	1.064008	94.50	0.11081	1.065335	94.88	0.15288	1.065993	95.16
0.10314	1.065223	94.73	0.13392	1.065704	95.01	0.15450	1.066004	95.25
				m_s = 2.0 mol·kg^{-1}				
0.05832	1.085117	95.06	0.11173	1.085887	95.28	0.12924	1.086114	95.47
0.07812	1.085404	95.17	0.11520	1.085923	95.39	0.15669	1.086483	95.60
				L-Leucine				
				m_s=0.00000				
0.07671	0.992016	108.74	0.16124	0.993901	108.96	0.16790	0.994017	109.16
0.16004	0.993896	108.82	0.16600	0.993988	109.08	0.17734	0.994208	109.26
				m_s = 0.25 mol·kg^{-1}				
0.01145	1.004315	108.72	0.03412	1.004808	108.90	0.08478	1.005886	109.13
0.02641	1.004642	108.82	0.03923	1.004915	109.01	0.12712	1.006773	109.22
				m_s = 0.5 mol·kg^{-1}				
0.04681	1.017884	109.06	0.12494	1.019447	109.21	0.14450	1.019808	109.40
0.06919	1.018335	109.13	0.13757	1.019683	109.32	0.15205	1.019933	109.55
				m_s = 0.75 mol·kg^{-1}				
0.02433	1.030114	109.46	0.12036	1.031888	109.66	0.15976	1.032557	109.96
0.09382	1.031408	109.58	0.12992	1.032044	109.80	0.17937	1.032884	110.08

				m_s = 1.0 mol·kg^{-1}				
0.06398	1.042115	109.92	0.13745	1.043335	110.15	0.17288	1.043885	110.36
0.11737	1.043008	110.08	0.15504	1.043608	110.27	0.18191	1.044009	110.48
				m_s = 1.5 mol·kg^{-1}				
0.04405	1.064088	110.44	0.10123	1.064883	110.68	0.11939	1.065117	110.83
0.08133	1.064617	110.53	0.10346	1.064905	110.76	0.14121	1.065403	110.92
				m_s = 2.0 mol·kg^{-1}				
0.03176	1.084608	110.98	0.06739	1.085008	111.17	0.20039	1.086447	111.39
0.05596	1.084883	111.09	0.17758	1.086223	111.28	0.23224	1.086773	111.45

Table 2.
Standard Partial molar volumes, $V_2^0{}_{,\phi}$ at infinite dilution for some amino acids in water and in aqueous sodium nitrate solutions at (288.15-318.15) K and in aqueous Lithium nitrate solutions at 288.15K.

	$V_2^0{}_{,\phi}$ x 10^6 /m^3·mol^{-1} at various m_s /mol·kg^{-1}[a]						
Amino acids	Water	[a]m_s = 0.25	m_s = 0.5	m_s = 0.75	m_s = 1.0	m_s = 1.5	m_s = 2.0
				T=288.15K			
Glycine	42.82±0.05[b] (11.31) 42.84[c], 42.40[d]	43.10 ± 0.05 (4.96)	43.73±0.07 (4.78)	44.58±0.05 (1.62)	44.70±0.03 (4.82)	44.74±0.12 (4.67)	45.33±0.04 (7.49)
DL-α-Alanine	59.91±0.05[b] (7.95) 59.67[c], 60.10[d].	60.01±0.02[b] (3.38)	60.66±0.06 (8.70)	61.14±0.07 (2.41)	61.43±0.05 (6.04)	61.75±0.04 (4.33)	62.13±0.06 (4.22)
DL-α-Amino-*n*-butyric acid	75.63±0.09 (3.49) 74.67[e]	75.79±0.07 (6.51)	76.07±0.06 (4.73)	76.16±0.03 (3.62)	76.51±0.09 (3.89)	77.10±0.1 (4.79)	77.58±0.06 (5.52)
L-Valine	90.02±0.05 (5.05) 90.08[c]	90.08±0.02 (2.60)	90.31±0.03 (2.63)	90.48±0.05 (2.46)	90.82±0.05 (2.63)	91.39±0.07 (4.55)	91.55±0.03 (2.75)
L-Leucine	107.08±0.09 (2.02) 106.81[c]	107.15±0.06 (2.60)	107.34±0.07 (2.13)	107.53±0.10 (2.58)	107.57±0.03 (4.29)	107.73±0.08 (5.26)	108.01±0.06 (6.28)

			T=298.15K				
Glycine $NaNO_3$	43.17±0.02[b] (1.63) 43.20[d], 43.14[e], 43.23[f,1].	43.75±0.05 (1.97) 44.36[f,2]	44.13±0.04 (1.26) 45.02[f,3]	44.83±0.05 (1.63)	45.54 ± 0.05 (1.51) 46.78[f,4]	45.89±0.02 (3.58)	46.06±0.06 (2.26)
$LiNO_3$	43.17±0.02[b] (1.63) 43.20[d], 43.14[e], 43.23[f,1]	43.50±0.32 (0.34) 44.36[f,2]	43.54±0.06 (1.19) 45.02[f,3]	44.07±0.04 (1.33)	45.72 ± 0.05 (1.96) 46.78[f,4]	---	---
DL-α-Alanine $NaNO_3$	60.40±0.02[b] (0.95) 60.47[c], 60.30[d], 60.62[e].	60.80±0.07 (2.35)	61.20±0.04 (1.38)	61.57±0.04 (1.41)	62.15±0.03 (1.64)	62.84±0.11 (2.23)	63.28±0.08 (1.64)
DL-α-Alanine $LiNO_3$	60.40±0.02[b] (0.95) 60.47[c], 60.30[d], 60.62[e].	60.45±0.04 (1.43)	60.92±0.04 (1.11)	61.22±0.03 (1.57)	61.51±0.04 (2.20)	----	----
DL-α-Amino-*n*-butyric acid $NaNO_3$	75.97±0.03 (0.72) 75.92[e]	76.20±0.03 (0.53)	76.50± 0.04 (1.50)	76.85±0.04 (1.50)	77.39±0.02 (1.04)	77.89±0.05 (2.15)	78.28±0.02 (1.68)
DL-α-Amino-*n*-butyric acid $LiNO_3$	75.97±0.03 (0.72) 75.92[e]	76.08 ± 0.01 (0.95)	76.23 ± 0.01 (1.40)	76.50 ±0.01 (0.80)	76.77 ± 0.03 (1.35)	----	----
L-Valine $NaNO_3$	90.76±0.02 (0.92) 90.98[e]	90.99±0.02 (0.66)	91.21±0.02 (0.40)	91.44±0.02 (1.39)	91.75±0.03 (0.97)	92.39±0.06 (1.59)	92.79±0.06 (1.84)
L-Valine $LiNO_3$	90.76±0.02 (0.92) 90.98[e]	90.75±0.02 (1.03)	90.79±0.02 (1.07)	91.12±0.01 (1.48)	91.37±0.02 (0.99)	-----	-----
L-Leucine $NaNO_3$	107.44±0.03 (1.77) 107.96[e]	107.56±0.03 (1.87)	107.66±0.02 (3.03)	107.98±0.02 (1.10)	108.17±0.04 (1.10)	108.63±0.04 (2.55)	108.71±0.05 (4.46)

			T=308.15K				
Glycine	44.34±0.05[b] (2.37) 43.85[d], 43.80[g].	44.70±0.14 (5.01)	45.18± 0.06 (4.32)	45.63±0.08 (4.66)	46.39±0.06 (3.84)	47.20±0.11 (4.15)	48.04±0.08 (3.85)
DL-α-Alanine	61.31±0.12 (3.75) 61.06[d], 60.90[g], 61.01[h].	61.77±0.11 (2.23)	62.27±0.04 (3.01)	62.39±0.26 (2.85)	62.98±0.09 (14.88)	63.31±0.13 (7.41)	64.37±0.05 (5.14)
DL-α-Amino-*n*-butyric acid	76.46±0.12 (4.53) 76.61[h]	76.83±0.03 (1.23)	76.98± 0.05 (2.61)	77.25±0.07 (3.18)	77.86±0.04 (1.63)	78.17±0.09 (4.64)	79.06±0.12 (8.17)
L-Valine	91.22±0.07 (1.86) 91.55[h]	91.47±0.05 (1.85)	91.63±0.07 (2.71)	91.80±0.05 (1.78)	91.99±0.06 (2.74)	92.47±0.05 (4.64)	93.05±0.08 (3.68)
L-Leucine	107.78±0.04 (1.18) 108.41[h]	107.98±0.08 (6.57)	108.08±0.04 (2.54)	108.15±0.09 (4.15)	108.48±0.05 (3.74)	108.74±0.11 (4.0)	109.14±0.06 (2.80)
			T=318.15K				
Glycine	45.28±0.12[b] (8.80) 44.17[h]	46.43±0.18 (6.38)	46.83±0.04 (4.45)	47.39±0.04 (4.39)	48.19±0.06 (5.01)	49.09±0.03 (3.38)	49.43±0.05 (6.02)
DL-α-Alanine	62.20±0.24 (8.73) 61.31[h]	62.94±0.07 (5.32)	63.43±0.03 (3.47)	63.93±0.04 (4.78)	64.38±0.03 (6.55)	65.10±0.05 (4.22)	65.62±0.07 (6.23)
DL-α-Amino-*n*-butyric acid	77.00±0.22 (8.68) 76.82[h]	77.66±0.12 (5.44)	78.09±0.07 (3.30)	78.49±0.09 (5.17)	78.92±0.10 (4.92)	79.76±0.03 (3.38)	80.18±0.07 (4.74)
L-Valine	91.82±0.16 (14.04) 91.93[h]	92.70±0.16 (1.09)	92.62±0.06 (3.16)	93.07±0.06 (3.38)	93.51±0.03 (7.07)	94.25±0.09 (5.87)	94.73±0.04 (5.53)
L-Leucine	108.39±0.15 (4.06) 109.38[h]	108.75±0.07 (4.09)	108.86±0.09 (3.72)	109.28±0.09 (4.04)	109.58±0.05 (4.53)	110.17±0.05 (5.30)	110.97±0.05 (2.04)

[a]m_s = molality of sodium nitrate in water, mol·kg^{-1}. [b]Standard deviation, brackets contain S_v / m^3·kg·mol^{-2}, [c]Reference(Soto et al., 1999)[8]; [d]Reference(Wadi et al., 1992[6]; [e]Reference(Gurney, 1953) [14]; [f]Reference(Soto et al., 1999)[8] [1 is 0.0 ms , 2 is 0.2 ms 3 is 0.4 ms 4 is 1.0 ms], [g]Reference(Hofmeister, 1888)[15], [h]Reference(Hakin, 1995)[12].

Table 3.
Partial molar volumes, V_2^0, of α-amino acids in aqueous solutions of sodium chloride, sodium sulphate, sodium nitrate and sodium acetate

$V_{2,\phi}^0$ x 10^6 /m^3·mol^{-1} at various m_s /mol·kg^{-1}[a]

Amino acids		$NaNO_3$		$NaCl$[3]		Na_2SO_4[4]		CH_3COONa[5]
Glycine	43.73[a,1] (m_s=0.5),	44.13[b,1] (m_s=0.5),	45.18[c] (m_s=0.5),	44.49[b] (m_s=1.0),	45.58[a] (m_s=0.5),	46.15[b] (m_s=0.5),	46.59[c] (m_s=0.5),	44.82[b] (m_s=0.5),
	44.70[a,1] (m_s= 1.0),	45.54[b,1] (m_s=1.0),	46.39[c] (m_s=1.0),	44.74[b] (m_s=2.0).	47.21[a] (m_s=1.0),	47.70[b] (m_s=1.0),	47.84[c] (m_s=1.0),	46.06[b] (m_s1.0),
	44.74[a,1] (m_s=1.5).	45.89[b,1] (m_s=1.5),	48.04[c,1] (m_s=1.5).		48.43[a] (m_s=1.5).	48.55[b] (m_s=1.5).	48.88[c] (m_s=1.5).	47.54[b] (m_s=2.0).
		46.06[b,1] (m_s=2.0),						
		44.21[b,2] (m_s=0.2),						
		45.02[b,2] (m_s=0.4),						
		45.78[b,2] (m_s=0.6),						
		46.46[b,2] (m_s=0.8),						
		46.88[b,2] (m_s=1.0).						
DL-α-Alanine	60.66[a,1] (m_s=0.5),	61.20[b,1] (m_s=0.5),	62.27[c,1] (m_s=0.5),		62.61[a] (m_s=0.5),	62.90[b] (m_s=0.5),	63.30[c] (m_s=0.5),	61.50[b] (m_s=0.5),
	61.43[a,1] (m_s=1.0),	62.15[b,1] (m_s=1.0),	62.98[c,1] (m_s=1.0),	61.40[b] (m_s=1.0).	62.94[a] (m_s=1.0),	64.36[b] (m_s=1.0),	64.75[c] (m_s=1.0),	62.36[b] (m_s=1.0),
	61.75[a,1] (m_s=1.5).	62.48[b,1] (m_s=1.5).	63.31[c,1] (m_s=1.5).		65.11[a] (m_s=1.5).	65.34[b] (m_s=1.5).	65.80[c] (m_s=1.5).	63.45[b] (m_s=2.0).
DL-α-Amino-*n*-butyric acid		77.39[b,1] (m_s=1.0).	76.30[b] (m_s=1.0).	-	-	-	76.52[b] (m_s=0.5),	
							77.23[b] (m_s=1.0),	
							78.27[b] (m_s=2.0).	
L-Valine		91.75[b,1] (m_s=1.0).	91.85[b] (m_s=1.0).	-	-	-	-	
L-Leucine		108.17[b,1] (m_s=1.0).	108.40[b] (m_s=1.0).				108.17[b] (m_s=0.5),	
							108.77[b] (m_s=1.0),	
							109.76[b] (m_s=2.0).	

[a] [at 288.15 K], [b][at 298.15 K], [c][at 308.15 K], [1] our work, [2] Reference (Soto et al,1999)[8]; [3] Reference(Gurney, 1953)[14], [4] Reference (wadi and Ramasami, 1997)[7]; [5]Reference(Millero et al. 1974)[11].

Table 4.
Hydration number, n_H, for some amino acids in water and in aqueous sodium nitrate solutions at (288.15 -308.15) K

Amino acids	Water	m_s = 0.25	m_s = 0.5	m_s = 0.75	m_s = 1.0	m_s=1.5	m_s=2.0
			T=288.15 K				
Glycine	3.12 ± 0.04	3.05 ± 0.04	2.82 ± 0.07	2.53 ± 0.05	2.49 ± 0.03	2.48 ± 0.12	2.27 ± 0.04
DL-α-Alanine	4.13 ± 0.05	4.10 ± 0.02	3.87 ± 0.06	3.71 ± 0.07	3.61 ± 0.05	3.50 ± 0.04	3.37 ± 0.06
DL-α-Amino-*n*-butyric acid	5.78 ± 0.09	5.73 ± 0.07	5.63 ± 0.06	5.60 ± 0.03	5.48 ± 0.09	5.28 ± 0.1	5.11 ± 0.06
L-Valine	4.17 ± 0.05	4.14 ± 0.02	4.06 ± 0.03	3.90 ± 0.05	3.78 ± 0.05	3.69 ± 0.07	3.63 ± 0.03
L-Leucine	5.81 ± 0.08	5.80 ± 0.06	5.73 ± 0.07	5.67 ± 0.10	5.65 ± 0.10	5.60 ±0.08	5.5 ± 0.06
			T=298.15 K				
Glycine	2.63± 0.02 2.63[a]	2.46 ± 0.05	2.34 ± 0.04 2.2 [b*]	2.13 ± 0.05	1.94 ± 0.04 1.9[b*]	1.81 ± 0.02	1.75 ± 0.06 1.5[b*]
DL-α-Alanine	3.46 ± 0.02 3.41[a]	3.34 ± 0.07	3.21 ± 0.04 3.1[b*]	3.10 ± 0.04	2.93 ± 0.03 3.0[b*]	2.71 ± 0.11	2.58 ± 0.08 2.5[b*]
DL-α-Amino-*n*-butyric acid	4.95 ± 0.03	4.89 ± 0.03	4.80 ± 0.04 3.5[b*]	4.69 ± 0.04	4.53 ± 0.02 3.2[b*]	4.38 ± 0.06	4.26 ± 0.04 2.8[b*]
L-Valine	3.44 ± 0.02	3.37 ± 0.02	3.30 ± 0.02	3.23 ± 0.02	3.14 ± 0.03	2.94 ± 0.06	2.82 ± 0.06
L-Leucine	5.04 ± 0.03 4.96[a]	5.01 ± 0.03	4.97 ± 0.02 5.0[b*]	4.88 ± 0.02	4.82 ± 0.04 5.0 [b*]	4.68 ± 0.01	4.66 ± 0.01 4.8[b*]
			T=308.15 K				
Glycine	1.93 ± 0.05	1.84 ± 0.14	1.72 ± 0.06	1.61 ± 0.08	1.42 ± 0.06	1.21 ± 0.11	1.01± 0.08
DL-α-Alanine	2.58 ± 0.12	2.46 ± 0.11	2.34 ± 0.04	2.31 ± 0.26	2.16 ± 0.09	2.08 ± 0.13	1.81± 0.05
DL-α-Amino-*n*-butyric acid	4.0 ± 0.12	3.93 ± 0.03	3.89 ± 0.05	3.82 ± 0.07	3.67 ± 0.04	3.59 ± 0.09	3.37 ± 0.12
L-Valine	2.72 ± 0.07	2.66 ± 0.05	2.62 ± 0.07	2.58 ± 0.05	2.53 ± 0.06	2.41 ± 0.05	2.27 ± 0.08
L-Leucine	4.11 ± 0.04	4.06 ± 0.08	4.04 ± 0.02	4.01 ± 0.10	3.94 ± 0.05	3.87 ± 0.11	3.77 ± 0.06

[a]Reference([14], [b]Reference [17], *(in sodium acetate).

Table 5.
Contribution of (NH_3^+, COO^-) and (R) groups to the standard partial molar volumes, $V_{2,\phi}^0$ for some amino acids in water and in aqueous sodium nitrate solutions at (288.15-318.15) K

$V_{2,\phi}^0$ x 10^6 /m^3·mol^{-1} at various m_s /mol·kg^{-1}							
Groups	Water	m_s = 0.25	m_s = 0.5	m_s = 0.75	m_s = 1.0	m_s = 1.5	m_s = 2.0
			T = 288.15K				
(NH_3^+, COO^-)	27.49 ± 0.85	27.75 ± 0.85	28.56 ± 0.88	29.41 ± 0.84	29.66 ± 0.80	29.85 ±0.83	30.48 ± 0.86
-(CH_2)	15.87 ± 0.26	15.82 ± 0.26	15.69 ± 0.26	15.52 ± 0.25	15.52 ± 0.24	15.56 ± 0.25	15.47 ± 0.26
-$CHCH_3$	31.74 ± 0.37	31.64 ± 0.37	31.38 ± 0.37	31.04 ± 0.35	31.04 ± 0.34	31.12 ± 0.35	30.93 ± 0.37
-$CHCH_2CH_3$	47.61 ± 0.45	47.46 ± 0.45	47.07 ± 0.45	46.56 ± 0.43	46.56 ± 0.42	46.68 ± 0.43	46.40 ± 0.45
-$CHCH(CH_3)_2$	63.48 ± 0.64	63.28 ± 0.64	62.76 ± 0.64	62.08 ± 0.61	62.08 ± 0.59	62.24 ± 0.61	61.86 ± 0.64
-$CHCH_2CH(CH_3)_2$	79.35 ± 0.58	79.10 ± 0.58	78.45 ± 0.58	77.60 ± 0.56	77.6 ± 0.54	77.8 ± 0.56	77.33 ± 0.58
			T = 298.15K				
(NH_3^+, COO^-)	27.88 ± 0.76 27.72[a] 28.30[b]	28.52 ± 0.71	29.01 ± 0.74	29.68 ± 0.73	30.49 ±0.69	31.02 ± 0.77	31.38 ±0.86
-(CH_2)	15.89 ± 0.23	15.78 ± 0.21	15.70 ± 0.22	15.62 ± 0.21	15.5 ± 0.22	15.50 ± 0.23	15.48 ± 0.26
-$CHCH_3$	31.78 ± 0.32 31.98[a]	31.56 ± 0.30	31.14 ± 0.31	31.24 ± 0.30	31.0 ± 0.31	31.0 ± 0.32	30.96 ± 0.37
-$CHCH_2CH_3$	47.67 ± 0.40 47.97[a]	47.34 ± 0.36	46.71 ± 0.38	46.86 ± 0.36	46.5 ± 0.38	46.5 ± 0.40	46.46 ± 0.45
-$CHCH(CH_3)_2$	63.56 ± 0.56	63.12 ± 0.51	62.14 ± 0.54	62.47 ± 0.51	62.0 ± 0.54	62.0 ± 0.56	61.92 ± 0.64
-$CHCH_2CH(CH_3)_2$	79.45 ± 0.51 79.95[a]	78.90 ± 0.47	77.84 ± 0.49	78.09 ± 0.47	77.5 ± 0.49	77.5 ± 0.51	77.4 ± 0.58
			T = 308.15K				
(NH_3^+, COO^-)	29.18 ± 0.72	29.67 ± 0.78	30.28 ± 0.83	30.71 ± 0.73	31.58 ± 0.81	32.31 ± 0.63	33.47 ± 0.75
-(CH_2)	15.68 ± 0.22	15.63 ± 0.24	15.52 ± 0.25	15.44 ± 0.22	15.32 ± 0.24	15.22 ± 0.19	15.09 ± 0.23
-$CHCH_3$	31.36 ± 0.31	31.26 ± 0.32	31.04 ± 0.34	30.88 ± 0.28	30.65 ± 0.37	30.46 ± 0.27	30.18 ± 0.31
-$CHCH_2CH_3$	47.04 ± 0.38	46.89 ± 0.40	46.56 ± 0.42	46.32 ± 0.36	45.97 ± 0.45	45.68 ± 0.33	45.27 ± 0.38
-$CHCH(CH_3)_2$	62.72 ± 0.54	62.52 ± 0.45	61.98 ± 0.59	61.76 ± 0.52	61.30 ± 0.63	60.93 ± 0.46	60.36 ± 0.54
-$CHCH_2CH(CH_3)_2$	78.4 ± 0.49	78.15 ± 0.51	77.5 ± 0.54	77.2 ± 0.47	76.62 ± 0.58	76.15 ± 0.42	75.45 ± 0.49
			T = 318.15 K				
(NH_3^+, COO^-)	30.27 ± 0.72	31.38 ± 0.55	31.99 ± 0.71	32.56 ± 0.70	33.24 ± 0.42	34.28 ± 0.54	34.53 ± 0.64
-(CH_2)	15.54 ± 0.22	15.44 ± 0.17	15.32 ± 0.21	15.29 ± 0.21	15.29 ± 0.21	15.13 ± 0.16	15.22 ± 0.19
-$CHCH_3$	31.08 ± 0.31	30.88 ± 0.27	30.62 ± 0.30	30.58 ± 0.30	30.38 ± 0.23	30.28 ± 0.23	30.44 ± 0.30
-$CHCH_2CH_3$	46.62 ± 0.38	46.32 ± 0.32	45.94 ± 0.36	45.87 ± 0.36	45.67 ± 0.26	45.41 ± 0.28	45.66 ± 0.35
-$CHCH(CH_3)_2$	62.16 ± 0.54	61.76 ± 0.45	61.24 ± 0.51	61.16 ± 0.51	60.76 ± 0.37	60.56 ± 0.39	60.88 ± 0.50
-$CHCH_2CH(CH_3)_2$	77.70 ± 0.49	77.20 ± 0.42	76.56 ± 0.47	76.45 ± 0.47	76.05 ± 0.35	75.69 ± 0.36	76.10 ± 0.46

[a]Reference(McMillan Jr, 1945)[22]; [b]Reference(Hakin et al. (1995)[12].

Table 6.
Pair and Triplet Interactions coefficients for some amino acids in aqueous sodium nitrate solutions at (288.15-318.15) K

Amino acids	$V_{XY} \times 10^6$ ($m^3 \cdot mol^{-2} \cdot kg$)	$V_{XYY} \times 10^6$ ($m^3 \cdot mol^{-2} \cdot kg^2$)
	T=288.15 K	
Glycine	1.152 ± 0.171	-0.184 ± 0.069
DL-α-Alanine	0.862 ± 0.108	-0.102 ± 0.043
DL-α-Amino-*n*-butyric acid	0.368 ± 0.042	0.043 ± 0.017
L-Valine	0.345 ± 0.085	0.021 ± 0.034
L-Leucine	0.265 ± 0.035	-0.013 ± 0.014
	T=298.15 K	
Glycine	1.382 ± 0.115	-0.215 ± 0.046
DL-α-Alanine	0.917 ± 0.062	-0.061 ± 0.025
DL-α-Amino-*n*-butyric acid	0.672 ± 0.079	-0.026 ± 0.032
L-Valine	0.471 ± 0.071	0.016 ± 0.016
L-leucine	0.372 ± 0.071	-0.011 ± 0.028
	T=308.15 K	
Glycine	0.931 ± 0.081	0.002 ± 0.032
DL-α-Alanine	0.807 ± 0.114	-0.024 ± 0.046
DL-α-Amino-*n*-butyric acid	0.559 ± 0.089	0.026 ± 0.035
L-Valine	0.350 ± 0.028	0.034 ± 0.011
L-Leucine	0.287 ± 0.039	0.017 ± 0.016
	T=318.15 K	
Glycine	1.823 ± 0.112	-0.259 ± 0.045
DL-α-Alanine	1.348 ± 0.032	-0.166 ± 0.013
DL-α-Amino-*n*-butyric acid	1.172 ± 0.046	-0.124± 0.018
L-Valine	1.309 ± 0.276	-0.195 ± 0.111
L-Leucine	0.721± 0.072	0.013 ± 0.029

V_{XY}^a and V_{XYY}^a are the pair and triplet interaction coefficients..

Table 7.
Partial Apparent Molar Expansibility $\phi_E^0 \times 10^{-6}$/m³·mol⁻¹K⁻¹ and $(\partial^2 V_\phi^0 / \partial T^2)_P \times 10^{-6}$ for amino acids in water and in aqueous sodium nitrate solutions at different temperatures

	$\phi_E^0 \times 10^{-6}$ (m³·mol⁻¹K⁻¹)					$(\partial^2 V_\phi^0 / \partial T^2)_P \times 10^{-6}$ (m³·mol⁻¹·K⁻²)
	288.15K	**298.15K**	**308.15K**	**318.15K**	**[b]SD**	
			Glycine			
$NaNO_3$([a]m_S)						
0.0	0.040	0.070	0.100	0.130	0.237	0.0030
0.25	0.028	0.082	0.136	0.190	0.107	0.0054
0.5	0.007	0.069	0.132	0.194	0.011	0.0062
0.75	-0.024	0.052	0.127	0.202	0.092	0.0074
1.0	0.041	0.089	0.137	0.185	0.210	0.0048
1.5	0.088	0.125	0.162	0.199	0.094	0.0037
2.0	0.093	0.126	0.159	0.192	0.411	0.0033
			DL-α-Alanine			
0.0	0.043	0.068	0.093	0.118	0.098	0.0020
0.25	0.069	0.088	0.107	0.126	0.004	0.0019
0.5	0.047	0.078	0.109	0.140	0.098	0.0031
0.75	0.006	0.061	0.117	0.172	0.074	0.0055
1.0	0.046	0.080	0.114	0.148	0.103	0.0034
1.5	0.053	0.088	0.123	0.158	0.434	0.0035
2.0	0.108	0.113	0.118	0.123	0.049	0.0005
			DL-α-Amino-*n*-butyric acid			
0.0	0.032	0.041	0.051	0.060	0.022	0.0010
0.25	0.031	0.052	0.073	0.094	0.044	0.0030
0.5	0.014	0.048	0.082	0.116	0.130	0.0034
0.75	0.030	0.057	0.085	0.112	0.253	0.0027
1.0	0.063	0.072	0.081	0.090	0.224	0.0009
1.5	0.023	0.063	0.103	0.143	0.407	0.0040
2.0	0.054	0.075	0.096	0.117	0.058	0.0021
			L-Valine			
0.0	0.069	0.062	0.055	0.048	0.094	0.0007
0.25	0.059	0.075	0.091	0.107	0.264	0.0016
0.5	0.067	0.071	0.076	0.080	0.235	0.0005
0.75	0.058	0.073	0.089	0.104	0.338	0.0015
1.0	-0.003	0.076	0.156	0.235	0.440	0.0030
1.5	0.028	0.067	0.106	0.145	0.586	0.0039
2.0	0.065	0.087	0.109	0.131	0.537	0.0022
			L-Leucine			
0.0	0.024	0.036	0.049	0.061	0.065	0.0012
0.25	0.025	0.043	0.061	0.079	0.076	0.0018
0.5	0.015	0.038	0.061	0.084	0.058	0.0023
0.75	0.003	0.037	0.071	0.105	0.277	0.0034
1.0	0.026	0.051	0.076	0.101	0.241	0.0025
1.5	0.037	0.064	0.091	0.117	0.472	0.0027
2.0	0.011	0.068	0.124	0.181	0.373	0.0057

[a]m_S : molality (mol·kg⁻¹) of $NaNO_3$ in water. [b]SD: Standard deviation calculated using eq 12.

2. Results and discussion

The densities, ρ, and apparent molar volumes, $V_{2,\phi}$, of amino acids in water and in aqueous sodium nitrate solutions of various molalities (m_S, molality of sodium nitrate solutions, mol·kg⁻¹) at (288.15, 298.15, 308.15 and 318.15) K are given in **Table 1**. Apparent molar volumes of amino acids have been calculated as follows:

$$V_{2,\phi} = M/\rho - [(\rho-\rho_0)/m\cdot\rho\cdot\rho_0], \quad (1)$$

where M is the molar mass of the amino acid, m (mol·kg⁻¹) is the molality of amino acid, and ρ and ρ_0 are the densities of solution and solvent (water or water + sodium nitrate), respectively. At infinite dilution, the apparent molar volumes, $V_{2,\phi}^0$ and partial molar volumes, V_2^0 are identical ($V_{2,\phi}^0 = V_2^0$). In the case of negligible concentration dependence of $V_{2,\phi}$, V_2^0 was determined by taking the average of all the data points. However, where finite concentration dependence was observed, V_2^0 was determined by

least-squares fitting of the data using the following equation.

$$V_{2,\phi} = V_2^0 + S_v m, \quad (2)$$

where S_v is the experimental slope. The V_2^0 values along with their standard deviations are summarized in **Table 2**. The experimental values of V_2^0 for the amino acids in water agreed well with those reported in the literature [5, 8, 4, 10, 11-13] (Wadi et al., 1992; Soto et al., 1999; Bhat et al., 1985; Kharakhoz 1989; Millero et al., 1974; Hakin et al., 1995 & Hepler 1976). The V_2^0 values for the amino acids increase with temperature as well as with the concentration of sodium nitrate. Soto et al. (1999) [8] have also studied the partial molar volumes of glycine in aqueous $NaNO_3$ solutions at 298.15 K only (**Table 2**). Comparison of the results shows that the V_2^0 values obtained by Soto et al.(1999) [8] are slightly higher than the presently obtained V_2^0 values. However it may be noted that Soto et al.(1999)[8] have obtained the V_2^0 values from the apparent molar volumes determined at higher concentration (from 0.5 to 3 molal) of glycine in comparison to the investigations made presently (from 0.01 to 0.5 molal). This may be the reason for the slightly higher values of V_2^0 reported by them.

The standard partial molar volumes of transfer, $\Delta_t V^0$, at infinite dilution from water to aqueous sodium nitrate solutions have been evaluated as follows:

$\Delta_t V^0 = V_2^0$ (in aqueous sodium nitrate) $- V_2^{-0}$ (in water) (3)

The $\Delta_t V^0$ values for the amino acids are illustrated in **Figure 1**. The $\Delta_t V^0$ values for the studied amino acids are positive and increase with the increase in concentration of aqueous $NaNO_3$ solutions at all temperatures studied. It may also be noted that the difference in $\Delta_t V^0$ values among various amino acids decreases with increase in the temperature at lower concentration of $NaNO_3$. The $\Delta_t V^0$ values for the studied amino acids almost at all the temperatures appear in the order: glycine > DL-α-alanine > DL-α-amino-*n*-butyric acid > L-valine > L-leucine. The more positive $\Delta_t V^0$ values in the case of glycine indicate the dominance of the effect of charged end groups (NH_3^+ and COO^-), whereas the decreasing magnitude of transfer volumes from glycine to L-leucine indicates the building up of the ion-hydrophobic interactions.

The cosphere overlap model (Gurney, 1953)[14] can be utilized to rationalize the $\Delta_t V^0$ values in terms of solute-cosolute interactions. According to this model, when two solute particles come close enough together so that due to their cosphere overlap some cosphere material is displaced and this is accompanied by the change in thermodynamic parameters. The positive values of $\Delta_t V^0$ suggest that the ion-ion interactions dominate over the ion-hydrophobic group interactions. Because of the first type of interactions, the electrostriction of water in the neighborhood of charged end groups (NH_3^+, COO^-) of amino acids gets reduced, and this will contribute positively to the volume of transfer. The increase in $\Delta_t V^0$ values with increasing sodium nitrate concentration strengthens this view. Further the decreasing magnitude of transfer volumes from glycine to L-leucine is in consonance with the fact that building up of the ion-hydrophobic interactions are contributing negatively and the effect increases in the above order.

From the comparison of partial molar volumes of studied amino acids in aqueous solutions of $NaNO_3$ (Soto et al., 1999)[8]; NaCl (Bhat et al., 1985) [4]; Na_2SO_4 (Wadi et al., 1997) [7] it may be observed (**Table 3**) that V_2^0 values for glycine, DL-α-alanine and DL-α-amino-*n*-butyric acid decrease in the presence of various electrolytes in the following order:

$$Na_2SO_4 > CH_3COONa > NaNO_3 > NaCl$$

However, in case of L-valine and L-leucine the V_2^0 values decrease in the following order (data in the presence of Na_2SO_4 are not available):

$$CH_3COONa > NaCl > NaNO_3$$

The above observations are the result of various competing interactions in case of glycine, DL-α-alanine and DL-α-amino-*n*-butyric acid. As the anionic part of the salts is mainly modulating the behavior of partial molar volumes because the cationic part is same in the above salts. However in case of L-valine and L-leucine with the increase in the size of nonpolar side chain, the hydrophobic effect also starts influencing the partial molar volumes. Thus there is a competition between interactions due to the anionic part of salts and hydrophobicity of the amino acids which alter the order of the effect of salts on the partial molar volumes of the studied amino acids.

It may further be noted that the order of effect of anions on the stability of proteins according to Hofmeister series (Hofmeister, 1888)[15] is as follows:

$$SO_4^{2-} > CH_3COO^- > Cl^- > NO_3^-$$

Therefore from the above observed effects of salts on the partial molar volumes of amino acids, it may be concluded that the salts effect the V_2^0 values according to Hofmeister series when hydrophobic effect is more (as in case of L-valine and L-leucine) whereas it is not when hydrophilic effect is more (as in case of glycine, DL-α-alanine and DL-α-amino-*n*-butyric acid).

The hydration number (n_H) for these amino acids has been calculated from the V_2^0 values using the method reported by Millero et al., 1974[11]. According to this the value of V_2^0 for the amino acids can be expressed by:

$$V_2^0 = V_2^0 (\text{int}) + V_2^0 (\text{elect}), \quad (4)$$

where V_2^0 (int) is the intrinsic partial molar volume of the amino acids and V_2^0 (elect) is the electrostriction partial molar volume due to the hydration of amino acids. The V_2^0 (int) further consists of two terms: van der Waals volume and volume due to packing effect. Millero et al.,

1974[11]; have obtained the values of V_2^0 (int) for amino acids from their molar crystal volume by using the relationship:

$$V_2^0(\text{int}) = (0.7/\ 0.634)\ V_2^0\,(\text{cryst}), \quad (5)$$

where 0.7 is the packing density for the molecule in an organic crystal and 0.634 is the packing density for a random packing sphere. Then the electrostriction partial molar volumes, V_2^0 (elect) can be estimated from experimentally measured V_2^0 using following equation:

$$V_2^0\,(\text{elect}) = V_2^0\,(\text{amino acid}) - V_2^0\,(\text{int}), \quad (6)$$

Millero et al., 1974[11] reported a relationship between the electrostriction volume and hydration number of the non electrolytes as:

$$n_H = V_2^0\,(\text{elect}) / V_E^0 - V_B^0. \quad (7)$$

where V_E^0 is the molar volume of electrostricted water and V_B^0 is the molar volume of bulk water. For every water molecule taken from the bulk phase to the region near the amino acids, the values for ($V_E^0 - V_B^0$) are (-2.9, -3.3, and -4.0) $cm^3 \cdot mol^{-1}$ at (288.15, 298.15, and 308.15) K, respectively (Yan et al., 2004)[16]. The n_H values for the studied amino acids are given in **Table 4**. The n_H values for the amino acids in the presence of sodium nitrate are less than in water and decrease with increasing concentration of sodium nitrate, which suggests that sodium nitrate has a dehydration effect on the amino acids. Other workers have also reported (Wang et al., 2000 & Khoshhkbarchi et al., 1996)[17-18] the similar observations that electrolytes (CH_3COONa, NaBr) have a dehydration effect on amino acids.

A linear correlation between V_2^0 and number of carbon atoms in the alkyl chain of the amino acids has been observed as follows Zhenning et al., 1998[19]:

$$V_2^0 = V_2^0\,(NH_3^+, COO^-) + n_C\,V_2^0\,(CH_2), \quad (8)$$

where V_2^0 (NH_3^+, COO^-), the zwitterionic end groups and V_2^0 (CH_2), the methylene group are the contributions to V_2^0. The side chain [CH_2-(Gly), CH_3CH-(Ala), CH_3CH_2CH-(Abu), $(CH_3)_2CHCH$-(Val) and $(CH_3)_2CH_2CHCH$-(Leu)] group contribution to V_2^0 values have been calculated for the studied amino acids, by accepting the following assumptions (Hakin et al., 1994 & 1995)[12,20].

$$V_2^0\,(CH_3) = 1.5\ V_2^0\,(CH_2), \quad (9)$$

$$V_2^0\,(CH) = 0.5\ V_2^0\,(CH_2). \quad (10)$$

The results are listed in table 5. However, it may be pointed out that V_2^0 (CH_2) value obtained here characterizes the mean contribution of CH and CH_3 groups to V_2^0 of the α-amino acids. It can be seen that from **Table 5** that the contributions of (NH_3^+, COO^-) groups to V_2^0 are larger than that of the CH_2 group and increases with the increasing concentration of sodium nitrate which indicates that the interactions between sodium nitrate and charged end groups (NH_3^+, COO^-) of amino acids are stronger than those between sodium nitrate and CH_2 groups. The V_2^0 (CH_2) values are almost insensitive to the concentration of sodium nitrate as well as temperature. Similar observations have been reported in aqueous sodium acetate solutions (Wang et al., 2000)[17]. The contribution from side chains increases with the increasing size of side chains of amino acids.

The standard partial molar volumes of transfer of zwitterionic end groups [$\Delta_t V^0$ (NH_3^+, COO^-)] and alkyl side chain groups [$\Delta_t V^0$(R)] of amino acids from water to aqueous sodium nitrate solutions have been calculated by the equation analogous to equation (3) and illustrated in **Figure 2**. The contributions of charged end groups (NH_3^+, COO^-) are positive, and those of CH_2 groups are negative to $\Delta_t V^0$. From these observations, the overall positive $\Delta_t V^0$ values suggest that the effect of charged end groups dominates over that of alkyl side chains. Scrutiny of **Figure 2**, indicates that the $\Delta_t V^0$ (NH_3^+, COO^-) values at lower temperatures sharply increase initially and thereafter increase becomes smaller with the concentration of sodium nitrate whereas at higher temperature the values continue to increase. The partial specific quantities are primarily independent of the size of the solute and reflect the ratio of the effect of the hydrophilic hydration to the hydrophobic hydration, whereas the partial molar quantities are the reflection of the net changes in both hydrations (Mizuguchi et al. 1997)[21]. The standard partial specific molar volumes, υ_2^0 ($\upsilon_2^0 = V_2^0 / M$, where M is the molar mass of the amino acid) for studied amino acids in aqueous sodium nitrate solutions are illustrated in **Figure 3**. The value of υ_2^0 also increases slightly with the increase in the concentration of sodium nitrate, again suggesting the dominance of the interactions between ions of sodium nitrate and studied amino acids. The υ_2^0 values become almost constants as the size of side chains increases. This may be attributed to the negative contribution from the alkyl side chains of amino acids whose magnitude increases with the size of the side chain.

McMillan and Mayer proposed a theory (1945)[22] of solutions that permits the formal separation of the effects due to interactions between the pair of solute molecules and those due to interactions between three or more solute molecules. According to this treatment, at infinite dilution, $\Delta_t V^0$ can be expressed as:

$$\Delta_t V^0 = 2V_{XY} \cdot m_s + 3V_{XYY} \cdot m_s^2 + \cdots\cdots\cdots \quad (11)$$

where X stands for amino acids and Y stands for sodium nitrate. V_{XY} and V_{XYY} are pair and triplet interaction coefficients, respectively and their values are summarized in **Table 6**. V_{XY} and V_{XYY} are positive and negative respectively, for the studied amino acids, however the magnitude of both decreases with the size of the alkyl chain of amino acids. The large positive magnitude of V_{XY} in comparison to that of V_{XYY} shows that interactions between sodium nitrate and amino acids are mainly pair wise. The de-

crease in V_{XY} values from glycine to L-leucine may be due to the difference in the interactions of sodium nitrate with the alkyl side chains of amino acids. Thus, the destruction of hydration spheres of alkyl side chains (hydrophobic groups) of amino acids in aqueous sodium nitrate solutions plays an important role in affecting the transfer volumes. From these observations, it may be said that the amino acids with the longer hydrophobic alkyl side chains undergo a stronger dehydration effect in the presence of sodium nitrate. The dependence of pair interaction coefficients, V_{XY} on the alkyl side-chain length is not linear (plots not shown), and the decrease is sharp initially and then becomes almost constant. This indicates that the influence of the additional CH_2 group decreases with increasing side chain length and after certain length it reaches optimum value.

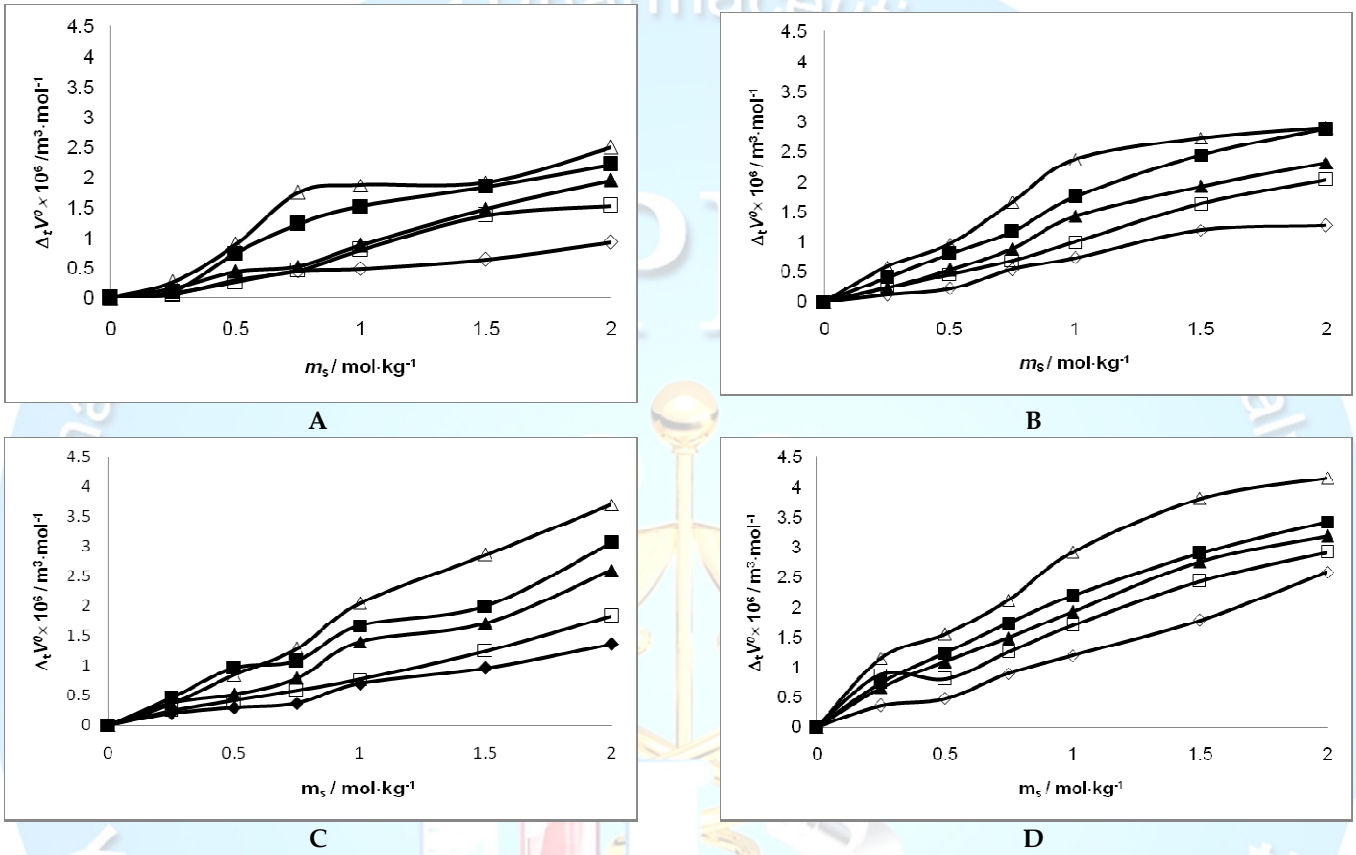

Figure 1. Standard partial molar volumes of transfer, $\Delta_t V^0$, of some amino acids vs. different molalities, m_s, of sodium nitrate solutions: ∆, glycine; ■, DL-α-alanine; ▲, DL-α-amino-*n*-butyric acid; , L- valine; ◊, L-leucine at (a) 288.15 K; (b) 298.15 K; (c) 308.15 K; (d) 318.15 K.

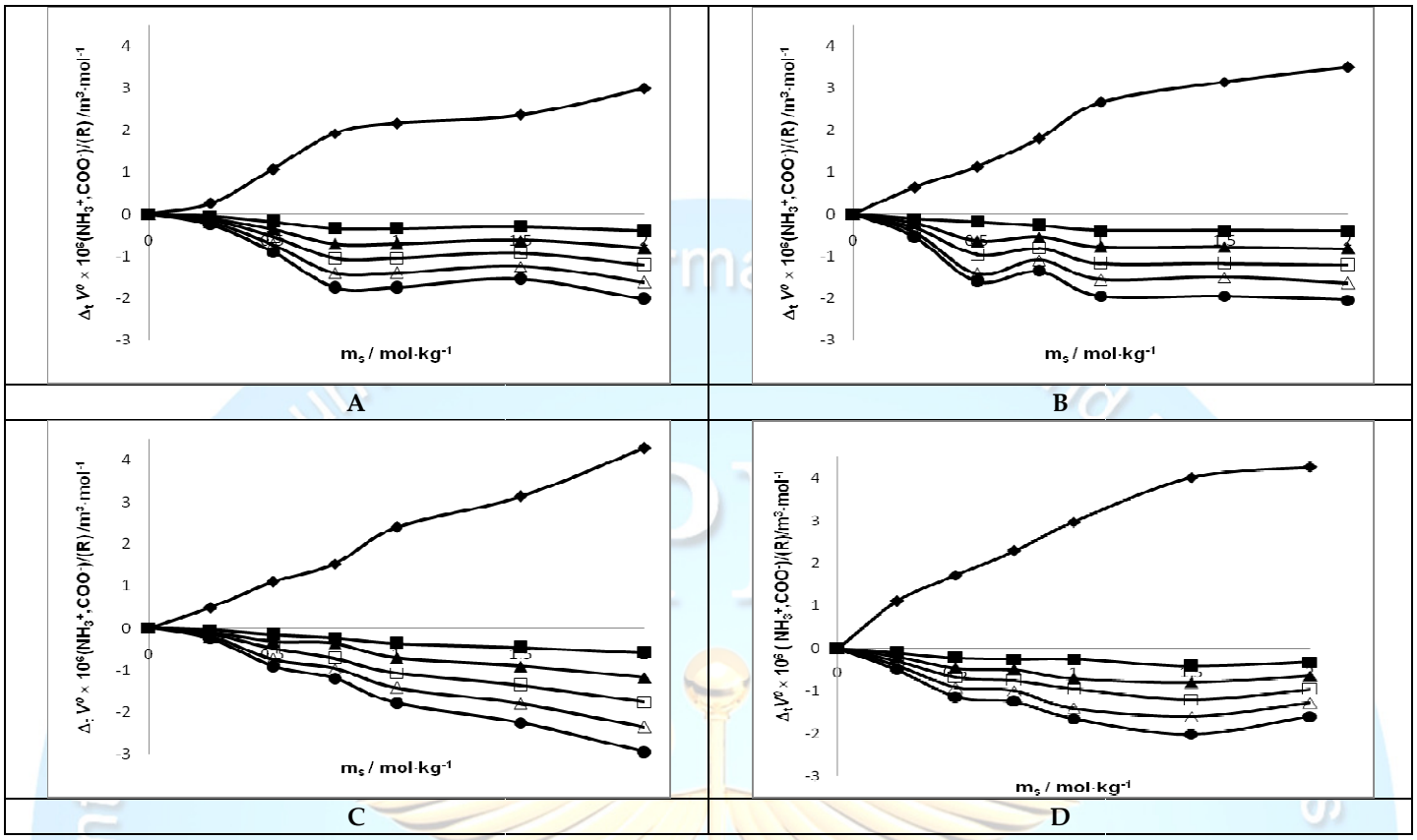

Figure 2. Contributions of :(♦) NH_3^+, COO^-; (■) -CH_2; (▲)-$CHCH_3$; ( ) -$CHCH_2CH_3$; (∆) –$CHCH(CH_3)_2$; (•) $CHCH_2CH(CH_3)_2$ groups to standard partial molar volumes of transfer, $\Delta_t V^0$ vs. different molalities, m_s of sodium nitrate solutions at (a) 288.15 K; (b) 298.15 K; (c) 308.15 K; (d) 318.15 K.

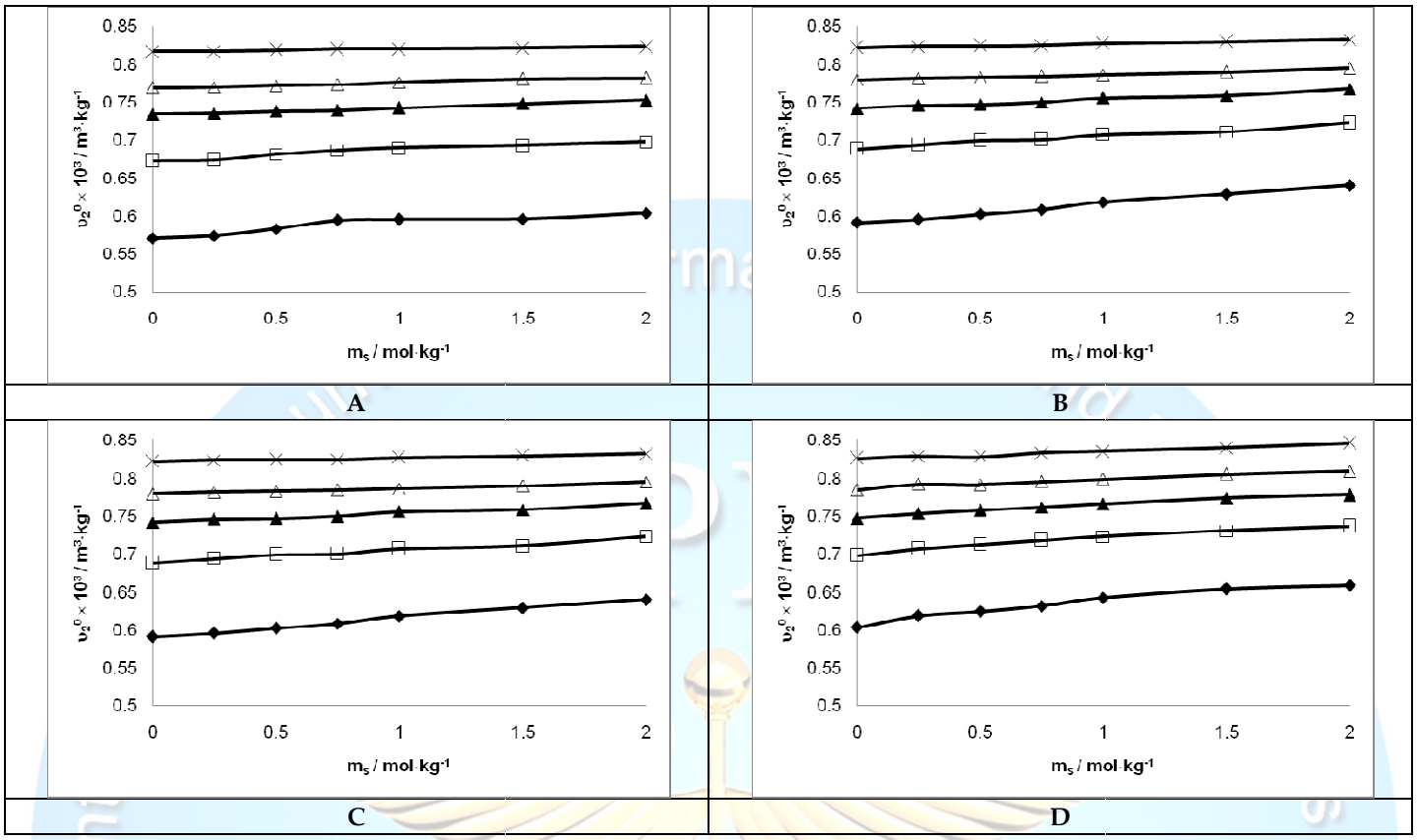

Figure 3. Partial specific volumes, υ_2^0, of amino acids vs. different molalities, m_s, of sodium nitrate solutions: (♦), glycine; ( ), DL-α-alanine; (▲), DL-α-amino-*n*-butyric acid; (Δ), L-valine; (×), L-leucine at (a) 288.15 K; (b) 298.15 K; (c) 308.15 K; (d) 318.15 K

The temperature dependence of V_2^0 for various amino acids in water and in aqueous sodium nitrate solutions can be expressed as follows:

$$V_2^0 = a + b\,T + c\,T^2 \ldots \quad (12)$$

values of various coefficients (a, b, c…..) of the equation for amino acids in water and in aqueous sodium nitrate solutions are recorded in **Table 7**. The partial molar expansibilities, $\phi_E^0 = (\partial V_2^0/\partial T)_P$, calculated from the above equation are given in **Table 7**. Hepler (1976)[13] used the sign of $(\partial^2 V_2^0/\partial T^2)_P$ for various solutes in terms of long-range structure making and breaking capacity of the solutes in aqueous solutions using the general thermodynamic expression:

$$(\partial C_P/\partial p)_T = -T\,(\partial^2 V_2^0/\partial T^2)_P. \quad (13)$$

It has been suggested that for a structure breaking solute, the left side of the equa\tion should be positive, and therefore $(\partial^2 V_2^0/\partial T^2)_P$ values should be negative for structure breaking and positive for structure making solutes. This equation is useful for making a distinction between ionic or polar solutes and those for which hydrophobic hydration is dominant. The presently obtained positive $(\partial^2 V_\phi^0/\partial T^2)_P$ values suggest that studied amino acids are structure maker in water as well as in aqueous $NaNO_3$ solutions.

3. Conclusion

Partial molar volumes, V_2^0 of glycine, DL-α-alanine, DL-α-amino-*n*-butyric acid, L-valine and L-leucine in water and in mixed aqueous solutions of $NaNO_3$ (0.25, 0.5, 0.75, 1.0, 1.5, 2.0) mol·kg^{-1}, have been determined at T = (288.15 to 318.15) K. From these data, transfer volumes, hydration numbers, and side chain contributions have been determined. The $\Delta_t V^0$ values are positive in all the cases, and these values increase with an increase in the concentration of $NaNO_3$ and temperature. V_{XY} values are positive, while V_{XYY} values are negative in all the cases, which suggest that interactions between amino acids and $NaNO_3$ are mainly pair wise. n_H values also decrease both with the increase in concentration of $NaNO_3$ and temperature. These parameters suggest that ion-ion interactions between charged ends of amino acids and ions of $NaNO_3$ dominate over the ion-hydrophobic interactions in these systems. There is also indication that salts effect V_2^0 values according to Hofmeister series when hydrophobic effect is more (as in case of L-valine and L-leucine). The positive $(\partial^2 V^0/\partial T^2)_P$ values suggest that studied amino acids are

structure maker in aqueous $NaNO_3$ solutions.

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