Partial Molar Volumes and Isentropic Compressibilities of *N*-Acetyl Amino Acid Amides in Dilute Aqueous Solutions at (5, 15, 25, 35, and 45) °C

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The densities and sound velocities in dilute aqueous solutions of nine *N*-acetyl amino acid amides were measured at (5, 15, 25, 35, and 45) °C. The *N*-acetyl amino acid amides used were *N*-acetylglycinamide, *N*-acetyl-L-alaninamide, *N*-acetyl-L-valinamide, *N*-acetyl-L-leucinamide, *N*-acetyl-L-methioninamide, *N*-acetyl-L-prolinamide, *N*-acetyl-L-phenylalaninamide, *N*-acetyl-L-tryptophanamide, and *N*-acetyl-L-tyrosinamide. Partial molar volumes and partial molar isentropic compressibilities of these *N*-acetyl amino acid amides at infinite dilution were evaluated. Furthermore, the side chain contribution to the partial molar quantities of the *N*-acetyl amino acid amides can be derived using a group additivity approach. The results were compared with those of amino acids reported in our previous paper.

Introduction

In order to obtain a better understanding of the hydration behavior of proteins, studies have been made on the volumetric properties of amino acids, considered as model compounds, in aqueous solution (Jolicoeur and Boileau, 1978; Jolicoeur *et al*., 1986; Kharakoz, 1989, 1991; Millero *et al*., 1978). However, since amino acids are zwitterions in aqueous solutions, the charged end groups may interfere with the hydration of adjacent amino acid side chains. Thus it seems that the amino acids are not necessarily the most suitable compounds to model the amino acid side chain in proteins.

Hydration effects are known to be very sensitive to temperature (Kharakoz, 1989, 1991; Sakurai *et al*., 1994). While the temperature dependence studies of volumetric properties are useful for a more complete understanding of the solute hydration, the great majority of previous investigations of model compounds has been conducted only at 25 °C.

In view of the above fact, it is of interest to determine the volumetric properties of *N*-acetyl amino acid amides which have no ionic groups as reasonable model compounds and compare the results with those of amino acids.

Volumetric data for amino acids that can be compared have been reported in dilute aqueous solutions at (5, 15, 25, 35, and 45) °C (Kikuchi *et al*., 1995). In the present paper we report the partial molar volumes and isentropic compressibilities of some *N*-acetyl amino acid amides in dilute aqueous solution over the same experimental temperature range as our previous investigation, (5 to 45) °C.

Experimental Section

The *N*-acetyl amino acid amides used, *N*-acetyl-glycinamide (Ac-Gly-NH_2), *N*-acetyl-L-alaninamide (Ac-Ala-NH_2), *N*-acetyl-L-valinamide (Ac-Val-NH_2), *N*-acetyl-L-leucinamide (Ac-Leu-NH_2), *N*-acetyl-L-methioninamide (Ac-Met-NH_2), *N*-acetyl-L-prolinamide (Ac-Pro-NH_2), *N*-acetyl-L-phenylalaninamide (Ac-Phe-NH_2), *N*-acetyl-L-tryptophanamide (Ac-Trp-NH_2), and *N*-acetyl-L-tyrosinamide (Ac-Tyr-NH_2), were extra pure reagents obtained commercially: *N*-acetyl-glycinamide was obtained from Aldrich Chemical Co., Inc., Milwaukee, WI; *N*-acetyl-L-tyrosinamide was obtained from Peptide Institute, Inc., Minoh, Japan. The other compounds were obtained from BACHEM Feinchemikalien AG, Bubendorf, Switzerland. These samples were dried *in vacuo* before the measurements and used without further purification. All solutions were prepared by mass with deionized and distilled water. The solution densities were measured by an oscillating-tube densimeter (DMA 60/601, Anton Paar, Austria) with a precision of $\pm (2 \times 10^{-6})$ g·cm^{-3}. The sound velocities in the solutions were measured at a frequency of about 5 MHz using a sing-around velocimeter constructed in our laboratory. The precision of the measurements of the sound velocity was estimated to be better than 1 cm·s^{-1} for the dilute solution range studied. The temperature of the fluid surrounding the measuring cell of the densimeter or velocimeter was maintained within ±0.002 deg by using a laboratory-made temperature controller using Y-cut quartz. Details of the apparatus, their calibrations, and experimental procedures used have been described previously (Sakurai and Nakagawa, 1982; Sakurai *et al*., 1994, 1995).

With the exception of Ac-Phe-NH_2, Ac-Trp-NH_2, and Ac-Tyr-NH_2, the measurements of the densities and sound velocities of all *N*-acetyl amino acid amide solutions were carried out over the concentration range *ca*. (0.01−0.1) mol·kg^{-1}. Because of the low solubilities of Ac-Phe-NH_2, Ac-Trp-NH_2, and Ac-Tyr-NH_2 in water, the maximum concentration of Ac-Phe-NH_2 was about 0.05 mol·kg^{-1}, and those of Ac-Trp-NH_2 and Ac-Tyr-NH_2 were about 0.01 mol·kg^{-1}. For *N*-acetyl-L-isoleucinamide, owing to the low solubility in water, it was impossible to measure the densities and sound velocities.

Results and Discussion

The apparent molar volumes, V_ϕ, and the apparent molar isentropic compressibilities, $K_{s,\phi}$, of the solutes were calculated from the solution densities and the isentropic compressibilities using the following equations:

$$V_\phi = M_2/\rho - (\rho - \rho_1)/(m\rho\rho_1) \quad (1)$$

and

$$K_{s,\phi} = M_2\kappa_s/\rho - (\kappa_{s,1}\rho - \kappa_s\rho_1)/(m\rho\rho_1) \quad (2)$$

In eqs 1 and 2, M_2 is the solute molar mass, m is the molality, ρ is the density of the solution, and ρ_1 is the density of the pure solvent. In eq 2, κ_s and $\kappa_{s,1}$ are the

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Table 1. Density Differences and Apparent Molar Volumes for Aqueous Solutions of *N*-Acetyl Acid Amides at (5, 15, 25, 35, and 45) °C

t/°C	m/mol·kg^{-1}	$10^3(\rho-\rho_1)$/g·cm^{-3}	V_ϕ/cm^3·mol^{-1}	m/mol·kg^{-1}	$10^3(\rho-\rho_1)$/g·cm^{-3}	V_ϕ/cm^3·mol^{-1}	t/°C	m/mol·kg^{-1}	$10^3(\rho-\rho_1)$/g·cm^{-3}	V_ϕ/cm^3·mol^{-1}	m/mol·kg^{-1}	$10^3(\rho-\rho_1)$/g·cm^{-3}	V_ϕ/cm^3·mol^{-1}
						N-Acetylglycinamide (116.12)[a]							
5	0.011 74	0.325	88.41	0.060 33	1.664	88.39	35	0.015 04	0.370	91.85	0.082 61	2.040	91.63
	0.021 22	0.588	88.35	0.071 76	1.978	88.37		0.026 68	0.658	91.81	0.093 37	2.307	91.59
	0.031 21	0.863	88.38	0.082 43	2.271	88.36		0.042 08	1.039	91.73	0.103 46	2.557	91.57
	0.040 20	1.111	88.38	0.092 72	2.554	88.35		0.054 92	1.356	91.70	0.114 47	2.830	91.53
	0.049 37	1.364	88.37	0.103 20	2.840	88.35		0.069 50	1.717	91.65			
15	0.010 25	0.270	89.80	0.061 33	1.614	89.71	45	0.027 53	0.664	92.62	0.125 80	3.021	92.49
	0.020 27	0.533	89.82	0.072 30	1.902	89.69		0.054 73	1.317	92.60	0.138 79	3.332	92.47
	0.030 67	0.809	89.71	0.084 59	2.225	89.67		0.075 23	1.810	92.56	0.151 81	3.645	92.44
	0.039 84	1.051	89.69	0.095 93	2.522	89.66		0.093 26	2.242	92.53	0.164 15	3.940	92.41
	0.050 72	1.338	89.67	0.107 42	2.823	89.64		0.109 83	2.638	92.52			
25	0.009 61	0.245	90.80	0.071 50	1.816	90.75							
	0.024 05	0.612	90.79	0.082 80	2.101	90.74							
	0.037 26	0.947	90.82	0.093 85	2.380	90.74							
	0.048 99	1.245	90.78	0.106 28	2.694	90.72							
	0.061 10	1.552	90.77										
						N-Acetyl-L-alaninamide (130.2)							
5	0.100 59	2.388	106.20	0.053 37	1.272	106.23	35	0.100 59	2.158	109.03	0.051 77	1.117	109.01
	0.088 21	2.096	106.21	0.042 56	1.016	106.22		0.087 92	1.889	109.02	0.041 12	0.888	109.02
	0.075 78	1.803	106.21	0.033 08	0.792	106.17		0.074 94	1.614	109.01	0.032 17	0.695	109.05
	0.063 79	1.520	106.21					0.062 80	1.355	109.00			
15	0.100 59	2.301	107.15	0.051 79	1.194	107.09	45	0.100 59	2.110	109.86	0.051 72	1.096	109.74
	0.088 44	2.026	107.14	0.041 42	0.957	107.06		0.087 11	1.833	109.81	0.041 62	0.884	109.72
	0.075 26	1.727	107.13	0.032 39	0.750	107.04		0.074 09	1.564	109.77	0.032 47	0.690	109.75
	0.062 96	1.448	107.12					0.062 19	1.314	109.78			
25	0.100 59	2.226	108.08	0.053 14	1.184	108.03							
	0.088 24	1.956	108.07	0.042 21	0.942	108.03							
	0.075 52	1.676	108.08	0.032 84	0.735	107.99							
	0.063 77	1.418	108.07										
						N-Acetyl-L-valinamide (158.2)							
5	0.103 57	2.238	136.28	0.054 45	1.180	136.36	35	0.103 57	1.932	139.99	0.054 50	1.022	140.02
	0.090 95	1.967	136.31	0.043 19	0.937	136.37		0.091 16	1.703	140.00	0.043 19	0.810	140.06
	0.078 15	1.691	136.33	0.033 32	0.723	136.41		0.078 30	1.465	140.00	0.033 47	0.629	140.03
	0.066 04	1.430	136.34					0.066 02	1.236	140.02			
15	0.103 57	2.120	137.54	0.053 97	1.107	137.63	45	0.103 57	1.851	141.27	0.056 20	1.012	141.25
	0.091 53	1.875	137.56	0.042 86	0.880	137.65		0.091 39	1.638	141.25	0.045 13	0.814	141.25
	0.078 28	1.605	137.58	0.033 07	0.680	137.65		0.079 02	1.417	141.26	0.035 16	0.633	141.31
	0.066 09	1.355	137.62					0.067 19	1.208	141.26			
25	0.103 57	2.016	138.80	0.054 19	1.058	138.87							
	0.091 37	1.780	138.82	0.042 67	0.834	138.90							
	0.078 31	1.527	138.84	0.033 09	0.647	138.91							
	0.066 09	1.289	138.87										
						N-Acetyl-L-leucinamide (172.23)							
5	0.097 73	1.880	152.71	0.049 72	0.960	152.78	35	0.097 73	1.528	157.19	0.050 69	0.797	157.23
	0.085 40	1.644	152.73	0.039 60	0.766	152.77		0.085 44	1.339	157.18	0.040 49	0.638	157.22
	0.072 96	1.405	152.75	0.030 81	0.597	152.77		0.073 29	1.149	157.21	0.031 40	0.494	157.26
	0.060 56	1.167	152.78					0.061 78	0.970	157.22			
15	0.097 73	1.736	154.32	0.049 81	0.888	154.38	45	0.097 73	1.423	158.85	0.051 21	0.754	158.80
	0.085 60	1.523	154.33	0.039 67	0.707	154.41		0.085 47	1.250	158.81	0.040 87	0.602	158.81
	0.072 78	1.295	154.35	0.030 75	0.549	154.42		0.073 52	1.080	158.78	0.031 65	0.467	158.81
	0.060 66	1.080	154.38					0.062 15	0.914	158.79			
25	0.097 73	1.624	155.76	0.050 52	0.843	155.82							
	0.085 81	1.428	155.77	0.040 46	0.677	155.81							
	0.073 33	1.221	155.79	0.031 38	0.524	155.85							
	0.061 63	1.027	155.80										
						N-Acetyl-L-methioninamide (190.3)							
5	0.094 30	3.750	149.97	0.048 79	1.952	149.99	35	0.094 30	3.317	155.32	0.047 80	1.692	155.35
	0.082 87	3.301	149.97	0.038 50	1.544	149.97		0.081 96	2.888	155.32	0.037 76	1.339	155.33
	0.070 94	2.830	149.97	0.029 79	1.197	149.94		0.070 26	2.481	155.32	0.029 17	1.035	155.36
	0.059 48	2.376	149.99					0.058 75	2.077	155.34			
15	0.094 30	3.576	151.93	0.048 99	1.873	151.89	45	0.094 30	3.229	156.75	0.048 25	1.666	156.69
	0.082 48	3.134	151.93	0.038 84	1.486	151.92		0.082 38	2.833	156.66	0.037 96	1.313	156.69
	0.070 95	2.702	151.91	0.030 09	1.155	151.85		0.070 60	2.436	156.61	0.029 40	1.016	156.79
	0.059 75	2.279	151.91					0.058 98	2.037	156.63			
25	0.094 30	3.435	153.68	0.048 60	1.782	153.71							
	0.083 42	3.044	153.69	0.038 44	1.412	153.70							
	0.071 56	2.615	153.69	0.029 70	1.092	153.71							
	0.059 68	2.185	153.70										
						N-Acetyl-L-phenylalaninamide (206.25)							
5	0.048 38	1.909	166.47	0.026 89	1.067	166.39	35	0.048 38	1.661	172.45	0.026 31	0.909	172.34
	0.043 00	1.700	166.44	0.022 05	0.877	166.35		0.043 31	1.494	172.32	0.021 15	0.731	172.35
	0.037 37	1.478	166.45	0.016 41	0.655	166.23		0.037 56	1.295	172.35	0.016 21	0.562	172.32
	0.032 00	1.270	166.37					0.031 60	1.092	172.31			
15	0.048 38	1.814	168.56	0.027 03	1.017	168.59	45	0.048 38	1.593	174.43	0.026 82	0.890	174.28
	0.043 00	1.613	168.58	0.022 03	0.830	168.55		0.043 63	1.442	174.32	0.021 58	0.718	174.23
	0.037 38	1.404	168.58	0.016 47	0.621	168.53		0.038 13	1.264	174.24	0.016 91	0.562	174.32
	0.032 05	1.205	168.57					0.032 20	1.069	174.24			
25	0.048 38	1.734	170.51	0.026 53	0.954	170.53							
	0.042 97	1.541	170.51	0.021 41	0.772	170.46							
	0.037 32	1.340	170.51	0.016 17	0.581	170.60							
	0.031 71	1.140	170.48										

Table 1. (Continued)

t/°C	m/mol·kg^{-1}	10^3 ($\rho - \rho_1$)/ g·cm^{-3}	V_ϕ/ cm^3·mol^{-1}	m/ mol·kg^{-1}	10^3 ($\rho - \rho_1$)/ g·cm^{-3}	V_ϕ/ cm^3·mol^{-1}	t/°C	m/ mol·kg^{-1}	10^3 ($\rho - \rho_1$)/ g·cm^{-3}	V_ϕ/ cm^3·mol^{-1}	m/ mol·kg^{-1}	10^3 ($\rho - \rho_1$)/ g·cm^{-3}	V_ϕ/ cm^3·mol^{-1}
					N-Acetyl-L-prolinamide (156.2)								
5	0.107 20	3.425	123.82	0.053 09	1.704	123.88	35	0.107 20	3.084	127.62	0.052 50	1.519	127.67
	0.093 29	2.985	123.83	0.041 71	1.340	123.91		0.093 58	2.697	127.62	0.041 36	1.197	127.70
	0.079 62	2.550	123.85	0.032 64	1.049	123.92		0.079 61	2.297	127.64	0.032 45	0.939	127.72
	0.065 94	2.113	123.89					0.065 50	1.893	127.65			
15	0.107 20	3.292	125.16	0.052 60	1.626	125.16	45	0.107 20	3.009	128.72	0.052 90	1.494	128.74
	0.093 55	2.878	125.16	0.041 60	1.287	125.18		0.093 64	2.632	128.73	0.041 15	1.164	128.75
	0.079 56	2.451	125.16	0.032 54	1.009	125.13		0.079 67	2.245	128.71	0.032 35	0.916	128.74
	0.065 41	2.019	125.16					0.065 99	1.863	128.70			
25	0.107 20	3.183	126.39	0.052 75	1.576	126.41							
	0.093 80	2.789	126.39	0.041 64	1.246	126.39							
	0.079 53	2.369	126.39	0.032 61	0.977	126.38							
	0.065 71	1.961	126.39										
					N-Acetyl-L-tryptophanamide (245.3)								
5	0.013 39	0.768	187.81	0.007 28	0.418	187.83	35	0.013 39	0.683	195.06	0.007 18	0.367	195.02
	0.011 88	0.681	187.81	0.005 79	0.333	187.66		0.011 91	0.608	194.99	0.005 72	0.291	195.20
	0.010 28	0.590	187.86	0.004 44	0.255	187.89		0.010 26	0.524	195.01	0.004 40	0.224	195.15
	0.008 68	0.498	187.88					0.008 62	0.440	194.98			
15	0.013 39	0.732	190.62	0.007 37	0.405	190.46	45	0.013 39	0.669	196.61	0.007 07	0.354	196.56
	0.011 83	0.648	190.57	0.005 92	0.325	190.44		0.011 82	0.592	196.50	0.005 64	0.283	196.46
	0.010 28	0.562	190.64	0.004 53	0.249	190.46		0.010 13	0.507	196.57	0.004 36	0.218	196.63
	0.008 77	0.480	190.60					0.008 51	0.427	196.54			
25	0.013 39	0.706	192.84	0.007 22	0.380	192.96							
	0.011 90	0.628	192.85	0.005 74	0.302	193.02							
	0.010 28	0.543	192.72	0.004 37	0.229	193.16							
	0.008 63	0.455	192.88										
					N-Acetyl-L-tyrosinamide (222.24)								
5	0.011 06	0.582	169.49	0.007 01	0.369	169.55	35	0.011 06	0.520	175.89	0.006 29	0.294	176.15
	0.010 15	0.534	169.57	0.005 99	0.316	169.51		0.009 96	0.468	175.98	0.005 22	0.246	175.84
	0.009 11	0.479	169.63	0.004 81	0.254	169.50		0.008 77	0.413	175.82	0.004 19	0.197	175.99
	0.008 03	0.422	169.67					0.007 50	0.354	175.79			
15	0.011 06	0.556	171.99	0.006 98	0.350	172.14	45	0.011 06	0.507	177.58	0.007 00	0.321	177.59
	0.010 10	0.508	171.92	0.006 02	0.304	171.89		0.010 10	0.463	177.54	0.005 92	0.271	177.61
	0.009 04	0.455	171.99	0.004 84	0.244	171.89		0.009 07	0.416	177.57	0.004 79	0.219	177.71
	0.007 96	0.401	171.90					0.008 01	0.369	177.47			
25	0.011 06	0.537	173.92	0.006 91	0.337	173.88							
	0.010 16	0.495	173.82	0.005 87	0.285	173.97							
	0.009 11	0.444	173.86	0.004 71	0.229	173.85							
	0.007 99	0.388	174.02										

[a] Molecular masses (g/mol) are in parentheses.

isentropic compressibilities of solution and pure solvent, respectively. The isentropic compressibility was determined from the sound velocity, u, and density using the following relation:

$$\kappa_s = 1/(u^2 \rho) \tag{3}$$

The density differences between solution and pure water ($\rho - \rho_1$) at (5, 15, 25, 35, and 45) °C are given in Table 1. The ρ_1 values at various temperatures were taken from the table given by Kell (1975). Values of (0.999 964, 0.999 100, 0.997 045, 0.994 032, and 0.990 213) g·cm^{-3} were used as the density of pure water at (5, 15, 25, 35, and 45) °C, respectively. These values were used to calculate the apparent molar volumes, V_ϕ, of the solutes using eq 1. The calculated V_ϕ values are also given in Table 1.

The sound velocity differences between solution and water ($u - u_1$) at various temperatures are summarized in Table 2. The sound velocities in pure water (u_1) were taken from the table reported by Del Grosso and Mader (1972). Values of (1426.162, 1465.931, 1496.687, 1519.808, and 1536.409) m·s^{-1} were used as the sound velocity in pure water at (5, 15, 25, 35, and 45) °C, respectively.

The density values of the solution used for sound velocity measurements were calculated from V_2° (partial molar volume at the infinite dilution) and S_v (experimental slope) values obtained by using eq 4 (see below) in the same manner reported previously (Sakurai *et al.*, 1994, 1995). These values were used to calculate the apparent molar isentropic compressibilities, $K_{s,\phi}$, of the solutes using eqs 2 and 3. The calculated $K_{s,\phi}$ values are also given in Table 2.

For sufficiently dilute solutions, the variation of the apparent molar quantities, Q_ϕ, with molality can be adequately represented by the linear relation

$$Q_\phi = Q_\phi^\circ + S_q m \tag{4}$$

where Q_ϕ° is the infinite dilution value that is equal to the partial molar quantity at infinite dilution (Q_2°) and S_q is the experimental slope.

Equation 4 was fitted to our V_ϕ and $K_{s,\phi}$ data by the least-squares method outlined earlier (Sakurai *et al.*, 1994). The V_2° and $K_{s,2}^\circ$ values together with their standard deviations are summarized in Table 3 along with the concentration dependence of these thermodynamic functions S_v and S_k. The previously available V_2° values at 25 °C are (90.56, 108.06, 139.00, and 126.51) cm^3·mol^{-1} for Ac-Gly-NH$_2$, Ac-Ala-NH$_2$, Ac-Val-NH$_2$, and Ac-Pro-NH$_2$, respectively (Leslie and Lilley, 1985). The previously available $K_{s,2}^\circ$ values at 25 °C are (−1.99 and −0.72) cm^3·mol^{-1}·GPa^{-1} for Ac-Gly-NH$_2$ and Ac-Ala-NH$_2$, respectively (Hedwig and Hoiland, 1995). To our knowledge, no comparable V_2° and $K_{s,2}^\circ$ data can be found in the literature, except for the above values. For V_2° values, the results obtained from the present study are in good agreement with those available in the literature. However, the corresponding comparison for $K_{s,2}^\circ$ values reveals several differences. We currently have no explanation for these discrepancies in $K_{s,2}^\circ$ values. For Ac-Trp-NH$_2$ and Ac-Tyr-NH$_2$, the absolute values of S_k and its standard deviations are extraordinarily large. These are because these compounds have low solubilities in water, as described in the Experimental Section, and

Table 2. Sound Velocity Differences and Apparent Molar Isentropic Compressibilities for Aqueous Solutions of *N*-Acetyl Amino Acid Amides at (5, 15, 25, 35, and 45) °C

t/°C	m/ mol·kg^{-1}	$(u - u_1)$/ m·s^{-1}	$K_{s,\phi}$/ cm^3·mol^{-1}·GPa^{-1}	m/ mol·kg^{-1}	$(u - u_1)$/ m·s^{-1}	$K_{s,\phi}$/cm^3·mol^{-1}·GPa^{-1}	t/°C	m/ mol·kg^{-1}	$(u - u_1)$/ m·s^{-1}	$K_{s,\phi}$/ cm^3·mol^{-1}·GPa^{-1}	m/ mol·kg^{-1}	$(u - u_1)$/ m·s^{-1}	$K_{s,\phi}$/cm^3·mol^{-1}·GPa^{-1}
						N-Acetylglycinamide (116.12)[a]							
5	0.010 32	0.730	−18.90	0.055 33	3.892	−18.62	35	0.012 58	0.542	4.25	0.061 67	2.695	3.77
	0.018 09	1.279	−18.89	0.065 73	4.613	−18.52		0.022 11	0.967	3.86	0.076 20	3.331	3.72
	0.026 37	1.858	−18.74	0.077 11	5.408	−18.47		0.029 70	1.291	4.00	0.086 15	3.774	3.64
	0.034 88	2.462	−18.81	0.089 05	6.227	−18.33		0.036 36	1.588	3.86	0.099 38	4.342	3.67
	0.045 55	3.203	−18.63	0.101 13	7.056	−18.22		0.049 31	2.155	3.81	0.112 49	4.912	3.65
15	0.014 03	0.846	−8.89	0.063 91	3.810	−8.48	45	0.008 70	0.320	8.44	0.052 65	1.988	7.81
	0.025 95	1.568	−8.96	0.073 61	4.389	−8.49		0.017 17	0.633	8.36	0.065 51	2.464	7.87
	0.035 55	2.118	−8.43	0.083 31	4.960	−8.44		0.024 25	0.923	7.70	0.081 38	3.065	7.81
	0.046 81	2.793	−8.50	0.091 64	5.458	−8.47		0.031 62	1.185	8.02	0.096 35	3.632	7.77
	0.054 99	3.284	−8.54	0.101 14	6.014	−8.41		0.041 11	1.557	7.77	0.111 74	4.210	7.75
25	0.012 86	0.660	−1.61	0.068 13	3.466	−1.40							
	0.022 22	1.124	−1.19	0.077 10	3.919	−1.39							
	0.033 84	1.697	−0.92	0.086 71	4.415	−1.45							
	0.044 92	2.279	−1.30	0.095 57	4.862	−1.43							
	0.055 53	2.823	−1.37	0.104 23	5.296	−1.40							
						N-Acetyl-L-alaninamide (130.2)							
5	0.100 59	8.867	−20.26	0.056 91	5.060	−20.82	35	0.100 59	5.594	5.78	0.057 37	3.189	5.82
	0.090 33	7.986	−20.44	0.048 07	4.281	−20.93		0.090 17	5.017	5.77	0.048 34	2.686	5.83
	0.078 78	6.980	−20.58	0.041 41	3.693	−21.01		0.078 90	4.382	5.83	0.041 69	2.318	5.81
	0.067 30	5.972	−20.68					0.067 56	3.749	5.86			
15	0.100 59	7.666	−9.35	0.056 89	4.370	−9.78	45	0.100 59	4.754	11.07	0.056 94	2.702	10.92
	0.090 01	6.877	−9.48	0.047 96	3.698	−9.98		0.090 02	4.255	11.05	0.048 03	2.279	10.91
	0.078 62	6.013	−9.54	0.041 35	3.198	−10.14		0.078 57	3.721	10.99	0.041 47	1.966	10.93
	0.067 22	5.150	−9.64					0.067 13	3.184	10.94			
25	0.100 59	6.601	−1.10	0.057 27	3.788	−1.43							
	0.089 94	5.913	−1.18	0.048 57	3.219	−1.51							
	0.078 48	5.171	−1.27	0.042 04	2.791	−1.58							
	0.067 39	4.447	−1.34										
						N-Acetyl-L-valinamide (158.2)							
5	0.103 57	12.818	−28.94	0.058 07	7.258	−29.77	35	0.103 57	7.921	8.34	0.058 39	4.505	8.06
	0.092 46	11.470	−29.14	0.048 88	6.121	−29.94		0.092 85	7.111	8.31	0.049 29	3.810	8.01
	0.080 53	10.012	−29.32	0.042 17	5.287	−30.04		0.080 88	6.213	8.20	0.042 52	3.296	7.90
	0.068 64	8.557	−29.56					0.068 95	5.309	8.13			
15	0.103 57	11.017	−13.32	0.059 20	6.367	−13.97	45	0.103 57	6.732	15.75	0.058 89	3.859	15.55
	0.092 79	9.900	−13.49	0.049 87	5.372	−14.04		0.092 70	6.035	15.72	0.049 69	3.255	15.58
	0.081 30	8.690	−13.59	0.043 02	4.642	−14.15		0.081 30	5.304	15.67	0.042 83	2.808	15.56
	0.069 86	7.490	−13.78					0.069 87	4.565	15.63			
25	0.103 57	9.341	−1.00	0.059 28	5.398	−1.40							
	0.092 95	8.408	−1.13	0.050 10	4.570	−1.48							
	0.081 71	7.405	−1.20	0.043 24	3.952	−1.56							
	0.069 89	6.350	−1.31										
						N-Acetyl-L-leucinamide (172.23)							
5	0.097 73	14.828	−38.83	0.055 96	8.585	−40.06	35	0.097 73	8.902	8.69	0.055 17	5.074	8.32
	0.087 34	13.291	−39.15	0.047 28	7.279	−40.44		0.087 27	7.964	8.63	0.046 46	4.279	8.27
	0.076 40	11.662	−39.49	0.040 86	6.301	−40.62		0.076 26	6.976	8.54	0.040 06	3.695	8.22
	0.065 69	10.047	−39.71					0.065 03	5.967	8.41			
15	0.097 73	12.422	−17.40	0.055 33	7.121	−18.33	45	0.097 73	7.453	18.33	0.055 78	4.310	17.84
	0.087 39	11.147	−17.67	0.046 77	6.034	−18.53		0.087 16	6.673	18.18	0.046 93	3.639	17.71
	0.076 62	9.806	−17.92	0.040 30	5.207	−18.63		0.076 56	5.890	17.99	0.040 43	3.141	17.64
	0.065 44	8.396	−18.10					0.065 81	5.072	17.93			
25	0.097 73	10.460	−2.26	0.055 21	5.977	−2.88							
	0.087 05	9.349	−2.45	0.046 62	5.063	−3.05							
	0.075 93	8.176	−2.59	0.040 22	4.377	−3.17							
	0.065 05	7.023	−2.73										
						N-Acetyl-L-methioninamide (190.3)							
5	0.094 30	11.888	−32.75	0.052 81	6.745	−33.99	35	0.094 30	7.377	6.68	0.052 55	4.148	6.35
	0.084 04	10.637	−33.12	0.044 71	5.724	−34.22		0.084 44	6.626	6.57	0.044 22	3.499	6.25
	0.073 00	9.266	−33.40	0.038 75	4.975	−34.49		0.073 09	5.744	6.51	0.038 15	3.020	6.25
	0.062 28	7.935	−33.75					0.062 17	4.897	6.42			
15	0.094 30	10.307	−16.64	0.052 02	5.751	−17.49	45	0.094 30	6.039	15.70	0.053 94	3.494	15.31
	0.083 91	9.205	−16.91	0.043 84	4.863	−17.74		0.084 58	5.422	15.67	0.045 48	2.953	15.24
	0.072 67	8.000	−17.16	0.037 87	4.202	−17.76		0.074 03	4.762	15.55	0.039 31	2.549	15.28
	0.061 81	6.819	−17.32					0.063 49	4.098	15.43			
25	0.094 30	8.404	−1.39	0.052 79	4.764	−2.01							
	0.084 55	7.562	−1.56	0.044 57	4.034	−2.16							
	0.073 29	6.574	−1.71	0.038 51	3.494	−2.28							
	0.062 40	5.615	−1.86										

Table 2. (Continued)

t/°C	m/ mol·kg^{-1}	$(u-u_1)$/ m·s^{-1}	$K_{s,\phi}$/ cm^3·mol^{-1}·GPa^{-1}	m/ mol·kg^{-1}	$(u-u_1)$/ m·s^{-1}	$K_{s,\phi}$/cm^3·mol^{-1}·GPa^{-1}	t/°C	m/ mol·kg^{-1}	$(u-u_1)$/ m·s^{-1}	$K_{s,\phi}$/ cm^3·mol^{-1}·GPa^{-1}	m/ mol·kg^{-1}	$(u-u_1)$/ m·s^{-1}	$K_{s,\phi}$/cm^3·mol^{-1}·GPa^{-1}
						N-Acetyl-L-phenylalaninamide (206.25)							
5	0.048 38	6.905	−35.96	0.027 67	3.987	−37.06	35	0.048 38	4.325	8.17	0.028 09	2.502	8.32
	0.043 59	6.243	−36.34	0.023 27	3.358	−37.26		0.043 96	3.929	8.17	0.023 53	2.085	8.60
	0.038 14	5.470	−36.51	0.020 05	2.902	−37.56		0.038 70	3.449	8.31	0.020 23	1.790	8.68
	0.032 63	4.694	−36.87					0.033 21	2.958	8.34			
15	0.048 38	6.013	−18.14	0.027 61	3.455	−18.70	45	0.048 38	3.459	19.78	0.027 76	1.974	19.93
	0.043 73	5.440	−18.22	0.023 16	2.906	−18.90		0.043 90	3.149	19.63	0.023 31	1.653	20.03
	0.038 19	4.763	−18.42	0.019 92	2.506	−19.12		0.038 45	2.745	19.80	0.020 10	1.426	20.00
	0.032 62	4.077	−18.59					0.032 84	2.338	19.90			
25	0.048 38	5.092	−3.15	0.027 73	2.936	−3.49							
	0.043 78	4.619	−3.28	0.023 34	2.479	−3.68							
	0.038 33	4.045	−3.30	0.020 12	2.144	−3.88							
	0.032 75	3.468	−3.51										
						N-Acetyl-L-prolinamide (156.2)							
5	0.107 20	12.154	−32.93	0.060 12	6.888	−33.80	35	0.107 20	7.659	1.45	0.060 26	4.313	1.45
	0.095 80	10.896	−33.19	0.050 66	5.819	−34.02		0.095 94	6.857	1.45	0.050 78	3.637	1.43
	0.083 12	9.481	−33.42	0.043 78	5.036	−34.15		0.083 22	5.948	1.47	0.043 82	3.139	1.44
	0.071 05	8.129	−33.68					0.071 18	5.090	1.47			
15	0.107 20	10.462	−18.20	0.060 14	5.927	−18.84	45	0.107 20	6.472	8.59	0.060 84	3.694	8.45
	0.095 59	9.356	−18.39	0.050 68	4.999	−18.92		0.096 22	5.815	8.56	0.051 39	3.125	8.40
	0.083 33	8.176	−18.55	0.043 73	4.316	−18.95		0.083 86	5.076	8.53	0.044 41	2.698	8.44
	0.071 08	6.984	−18.65					0.071 64	4.341	8.50			
25	0.107 20	8.798	−6.23	0.060 23	4.988	−6.66							
	0.095 76	7.880	−6.36	0.050 79	4.213	−6.74							
	0.083 42	6.881	−6.47	0.043 81	3.639	−6.81							
	0.071 19	5.883	−6.56										
						N-Acetyl-L-tryptophanamide (245.3)							
5	0.013 63	1.933	−33.64	0.007 98	1.158	−35.95	35	0.013 63	1.181	12.41	0.007 95	0.707	11.12
	0.012 32	1.755	−34.08	0.006 78	0.990	−36.53		0.012 33	1.082	11.81	0.006 74	0.611	10.09
	0.010 85	1.562	−35.19	0.005 85	0.865	−37.76		0.010 86	0.944	12.27	0.005 82	0.527	10.15
	0.009 33	1.350	−35.60					0.009 33	0.829	11.17			
15	0.013 63	1.644	−13.44	0.007 81	0.957	−14.74	45	0.013 63	1.016	20.29	0.007 97	0.590	20.58
	0.012 23	1.476	−13.59	0.006 59	0.807	−14.73		0.012 39	0.914	20.70	0.006 76	0.508	19.93
	0.010 71	1.291	−13.50	0.005 68	0.700	−15.32		0.010 88	0.820	19.77	0.005 84	0.437	20.06
	0.009 22	1.117	−13.88					0.009 36	0.703	19.93			
25	0.013 63	1.428	−0.35	0.007 98	0.860	−2.11							
	0.012 33	1.294	−0.47	0.006 75	0.726	−1.94							
	0.010 84	1.142	−0.65	0.005 84	0.623	−1.37							
	0.009 33	1.005	−2.02										
						N-Acetyl-L-tyrosinamide (222.24)							
5	0.011 06	1.256	−20.81	0.007 01	0.794	−20.57	35	0.011 06	0.726	17.98	0.006 48	0.413	19.14
	0.010 19	1.165	−21.32	0.006 02	0.676	−19.93		0.010 00	0.661	17.73	0.005 52	0.348	19.52
	0.009 18	1.047	−21.16	0.005 13	0.572	−19.42		0.008 79	0.581	17.73	0.004 73	0.290	20.48
	0.008 07	0.915	−20.73					0.007 58	0.497	18.05			
15	0.011 06	1.038	−3.12	0.006 88	0.640	−2.61	45	0.011 06	0.668	21.92	0.006 40	0.371	23.33
	0.010 12	0.946	−2.86	0.005 90	0.547	−2.48		0.010 02	0.605	21.92	0.005 39	0.308	23.77
	0.009 04	0.843	−2.69	0.005 05	0.466	−2.09		0.008 78	0.519	22.65	0.004 65	0.269	23.39
	0.007 93	0.740	−2.75					0.007 53	0.433	23.52			
25	0.011 06	0.901	7.03	0.006 71	0.548	6.90							
	0.010 12	0.834	6.47	0.005 74	0.467	7.11							
	0.008 97	0.730	7.08	0.004 91	0.396	7.48							
	0.007 82	0.637	7.01										

[a] Molecular masses (g/mol) are in parentheses.

the concentration ranges in this measurement are limited.

The temperature dependence of the partial molar volumes is equal to the partial molar expansibility E_2° $(=(\partial V_2^\circ/\partial T)_p)$. Table 4 shows the partial molar expansibilities of *N*-acetyl amino acid amides and amino acids (Kikuchi *et al.*, 1995) in dilute aqueous solution at 25 °C. The E_2° values were estimated by the least-squares fitting to a quadratic equation. With the exception of tyrosine and *N*-acetyltyrosinamide, Table 4 shows that E_2° values for the *N*-acetyl amino acid amide derivative are larger than those for the amino acid derivative. The values of $(\partial^2 V_2^\circ/\partial T^2)_p$ for *N*-acetyl amino acid amides are negative, similar to those of amino acids.

The $K_{s,2}^\circ$ values for all the *N*-acetyl amino acid amides are small or negative within the temperature range (5 to 25) °C. *N*-Acetyl amino acid amides have two amide groups which are able to form hydrogen bonds with water. It has been considered that the hydrogen bonding leads to a decrease in the compressibility (Conway and Ayranci, 1988). Therefore, the small or negative $K_{s,2}^\circ$ values of *N*-acetyl amino acid amides result from the hydrogen bonding interaction between the amide groups and water.

The $K_{s,2}^\circ$ values for *N*-acetyl amino acid amides having aliphatic side chains are plotted in Figure 1 as a function of temperature. The feature of the temperature dependence of $K_{s,2}^\circ$ for these compounds is as follows: with increasing side chain length, the $K_{s,2}^\circ$ values decrease at lower temperatures, are practically constant between (30 and 35) °C, and increase at higher temperatures. This feature is similar to that observed for a series of amino

Table 3. Partial Molar Volumes and Isentropic Compressibilities of *N*-Acetyl Amino Acid Amides in Dilute Aqueous Solutions at (5, 15, 25, 25, and 45) °C

t/°C	V_2°/ cm³·kg·mol⁻²	S_v/ cm³·kg·mol⁻²	$K_{s,2}^\circ$/ cm³·mol⁻¹·GPa⁻¹	S_k/ cm³·kg·mol⁻²·GPa⁻¹
		N-Acetylglycinamide		
5	88.41(0.01)[a]	−0.54(0.15)	−19.05(0.04)	8.06(0.53)
15	89.76(0.02)	−1.07(0.23)	−8.68(0.09)	2.63(1.12)
25	90.84(0.01)	−1.11(0.13)	−1.19(0.11)	−2.54(1.31)
35	91.87(0.01)	−2.85(0.12)	3.96(0.06)	−2.95(0.62)
45	92.70(0.01)	−1.68(0.08)	7.96(0.08)	−1.87(0.93)
		N-Acetyl-L-alaninamide		
5	106.22(0.02)	−0.13(0.24)	−21.54(0.05)	12.43(0.60)
15	107.03(0.02)	1.31(0.27)	−10.48(0.11)	11.34(1.29)
25	108.01(0.03)	0.80(0.32)	−1.88(0.02)	7.69(0.26)
35	109.00(0.03)	0.28(0.32)	5.90(0.05)	−1.19(0.63)
45	109.65(0.03)	2.09(0.34)	10.76(0.04)	3.15(0.45)
		N-Acetyl-L-valinamide		
5	136.45(0.01)	−1.58(0.10)	−30.81(0.03)	18.12(0.36)
15	137.74(0.01)	−1.92(0.12)	−14.75(0.05)	13.79(0.60)
25	138.96(0.01)	−1.52(0.10)	−1.93(0.03)	8.80(0.34)
35	140.07(0.02)	−0.71(0.18)	7.67(0.04)	6.73(0.48)
45	141.27(0.03)	−0.06(0.31)	15.38(0.03)	3.64(0.40)
		N-Acetyl-L-leucinamide		
5	152.84(0.02)	−1.26(0.24)	−41.81(0.10)	30.50(1.20)
15	154.47(0.01)	−1.55(0.17)	−19.54(0.05)	21.59(0.69)
25	155.88(0.01)	−1.13(0.12)	−3.74(0.04)	15.02(0.54)
35	157.27(0.02)	−0.81(0.22)	7.87(0.03)	8.54(0.42)
45	158.75(0.04)	0.86(0.51)	17.15(0.07)	11.89(0.85)
		N-Acetyl-L-methioninamide		
5	149.99(0.02)	−0.19(0.27)	−35.61(0.06)	30.02(0.81)
15	151.86(0.02)	0.82(0.29)	−18.61(0.08)	20.53(1.03)
25	153.73(0.01)	−0.43(0.09)	−2.84(0.04)	15.27(0.49)
35	155.36(0.01)	−0.45(0.15)	5.93(0.04)	7.93(0.48)
45	156.61(0.10)	0.94(1.40)	14.87(0.07)	9.08(0.89)
		N-Acetyl-L-phenylalaninamide		
5	166.23(0.05)	5.10(1.33)	−38.56(0.12)	52.63(3.06)
15	168.57(0.03)	−0.04(0.71)	−19.63(0.09)	31.30(2.24)
25	170.52(0.05)	−0.15(1.19)	−4.18(0.12)	21.37(3.03)
35	172.23(0.09)	3.54(2.28)	8.87(0.13)	−14.98(3.24)
45	174.09(0.11)	5.99(2.86)	20.24(0.16)	−11.15(4.10)
		N-Acetyl-L-prolinamide		
5	123.97(0.02)	−1.36(0.20)	−35.00(0.06)	19.1(0.66)
15	125.17(0.01)	−0.07(0.17)	−19.56(0.06)	12.4(0.67)
25	126.41(0.01)	−0.12(0.12)	−7.21(0.03)	8.93(0.31)
35	127.73(0.02)	−1.05(0.21)	1.46(0.03)	0.02(0.30)
45	128.74(0.02)	−0.19(0.24)	8.29(0.02)	2.84(0.28)
		N-Acetyl-L-tryptophanamide		
5	187.83(0.10)	−0.55(9.07)	−39.96(0.49)	465(43.6)
15	190.39(0.10)	18.6(8.73)	−16.03(0.54)	201(48.5)
25	193.09(0.16)	−21.5(14.2)	−3.70(0.83)	250(74.1)
35	195.11(0.11)	−6.85(9.95)	8.71(0.72)	275(64.0)
45	196.50(0.10)	6.08(8.89)	19.70(0.73)	49.2(64.7)
		N-Acetyl-L-tryosinamide		
5	169.63(0.16)	−7.26(17.2)	−18.96(0.82)	−204(88.8)
15	171.95(0.17)	1.75(18.7)	−1.63(0.23)	−129(25.4)
25	173.97(0.15)	−7.77(16.7)	7.48(0.57)	−61.3(62.4)
35	175.97(0.22)	−5.85(24.5)	20.93(1.02)	−304(112)
45	177.65(0.12)	−8.99(12.9)	25.49(0.59)	−329(64.3)

[a] Standard deviations are in parentheses.

acids and *n*-alcohols (Hoiland, 1980; Kikuchi *et al.*, 1995; Nakajima *et al.*, 1975; Sakurai *et al.*, 1995). The large temperature dependence of $K_{s,2}^\circ$ for the *N*-acetyl amino acid amides having more hydrophobic side chains results from the fact that the sign of a methylene or methyl group contribution to the partial molar isentropic compressibility changes with temperature: large negative at lower temperatures and positive at higher temperatures (Nakajima *et al.*, 1975; Sakurai *et al.*, 1995).

The side chain contributions to the partial molar quantity (Q_2°) of the various *N*-acetyl amino acid amides can be derived from the difference between the properties of each *N*-acetyl amino acid amide and *N*-acetylglycinamide.

$$Q_2^\circ(\mathrm{Rn}) = Q_2^\circ(N\text{-acetyl amino acid amide}) - Q_2^\circ(N\text{-acetylglycinamide}) \quad (5)$$

where Q_2°(Rn) defines the side chain contribution to Q_2° of the *N*-acetyl amino acid amide relative to the −H group of *N*-acetylglycinamide.

Values of V_2°(Rn) and $K_{s,2}^\circ$(Rn) calculated using the V_2° and $K_{s,2}^\circ$ results for the *N*-acetyl amino acid amides are given in Table 5. For the purpose of comparison, V_2°(Ra) and $K_{s,2}^\circ$(Ra) values, which were obtained from V_2° and $K_{s,2}^\circ$ data for amino acids (Kikuchi *et al.*, 1995) in the same manner as above, are also included in Table 5. Table 5 shows that there are differences between Q_2°(Rn) and Q_2°(Ra) values.

With the exception of the alanyl and prolyl side chains, Q_2°(Ra) values are smaller than Q_2°(Rn) values at various temperatures. It seems that these differences arise from the different interactions between the ionic groups in amino acids and the amide groups in *N*-acetyl amino acid amides with water. The amino acids in aqueous solution have two charged groups which influence electrostatically the surrounding water molecules. Electrostriction leads to a decrease in volume and compressibility (Desnoyers *et al.*, 1965; Kharakoz, 1991; Millero, 1971). Consequently, the

Table 4. Partial Molar Expansibilities of *N*-Acetyl Amino Acid Amides and Amino Acids in Dilute Aqueous Solutions at 25 °C

side chain	$10^2 E_2^\circ$/cm³·mol⁻¹·K⁻¹ *N*-acetyl amino acid amide derivative	$10^2 E_2^\circ$/cm³·mol⁻¹·K⁻¹ amino acid derivative[a]
Gly	10(1)[b]	7(1)
Ala	8(2)	6(2)
Val	11(1)	7(1)
Leu	14(1)	9(3)
Met	16(2)	12(6)
Pro	12(2)	8(1)
Phe	19(3)	13(5)
Trp	22(4)	14(4)
Tyr	20(1)	23(11)

[a] Based on V_2° data for the amino acids from Kikuchi *et al.* (1995). [b] Standard deviations are in parentheses.

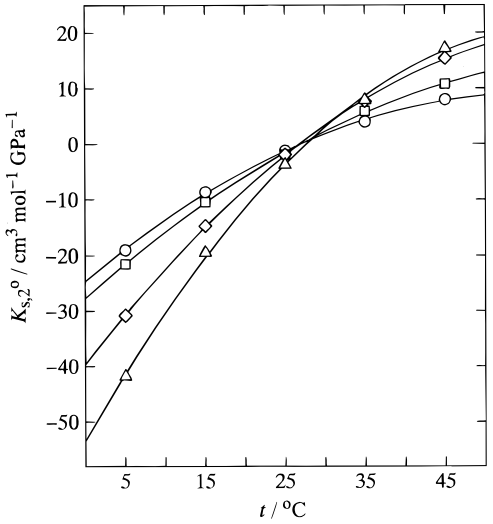

Figure 1. Temperature dependence of the partial molar isentropic compressibilities of *N*-acetyl amino acid amides containing aliphatic side chains in dilute aqueous solution: (circle) *N*-acetylglycinamide; (square) *N*-acetyl-L-alaninamide; (diamond) *N*-acetyl-L-valinamide; (triangle) *N*-acetyl-L-leucinamide. The solid lines represent the results of the approximation by the second polynominal.

Table 5. Side Chain Contributions to V_2° and $K_{s,2}^\circ$ of *N*-Acetyl Amino Acid Amides and Amino Acids in Aqueous Solution at (5, 15, 25, 35, and 45) °C

side chain (R)	t/°C	V_2°(Rn)/ cm^3·mol^{-1}	V_2°(Ra)[a]/ cm^3·mol^{-1}	$K_{s,2}^\circ$(Rn)/ cm^3·mol^{-1}·GPa^{-1}	$K_{s,2}^\circ$(Ra)[a]/ cm^3·mol^{-1}·GPa^{-1}
Ala	5	17.81	17.57	−2.49	−4.50
	15	17.27	17.44	−1.80	0.65
	25	17.17	17.33	−0.69	1.34
	35	17.13	17.15	1.94	2.72
	45	16.95	17.46	2.80	3.71
Val	5	48.04	47.96	−11.76	−16.50
	15	47.98	47.67	−6.07	−7.24
	25	48.12	47.62	−0.74	−3.32
	35	48.20	47.70	3.71	0.03
	45	48.57	47.93	7.42	3.33
Leu	5	64.43	64.54	−22.76	−25.97
	15	64.71	64.29	−10.86	−12.29
	25	65.04	64.57	−2.55	−5.09
	35	65.40	64.99	3.91	1.89
	45	66.05	65.37	9.19	5.21
Met	5	61.58	60.34	−16.56	−24.91
	15	62.10	61.60	−9.93	−12.49
	25	62.89	61.64	−1.65	−6.03
	35	63.49	62.04	1.97	−0.16
	45	63.91	62.51	6.91	3.42
Phe	5	77.82	77.21	−19.51	−33.01
	15	78.81	78.14	−10.95	−18.48
	25	79.68	78.31	−2.99	−8.78
	35	80.36	78.96	4.91	−0.59
	45	81.39	79.90	12.28	3.86
Pro	5	35.56	39.36	−15.95	−8.86
	15	35.41	39.28	−10.88	−1.30
	25	35.57	39.31	−6.02	2.39
	35	35.86	39.41	−2.50	5.45
	45	36.04	39.86	0.33	6.37
Trp	5	99.42	98.55	−20.91	−31.18
	15	100.63	99.09	−7.35	−16.34
	25	102.25	100.19	−2.51	−7.99
	35	103.24	100.85	4.75	−1.39
	45	103.80	101.43	11.74	6.21
Tyr	5	81.22	77.40	0.09	−37.41
	15	82.19	78.63	7.05	−15.56
	25	83.13	81.14	8.67	2.35
	35	84.10	82.82	16.97	2.93
	45	84.95	83.48	17.53	7.18

[a] Based on V_2° and K_2° data for the amino acids from Kikuchi *et al.* (1995).

results suggest that the influence of the electrostriction of the charged groups in amino acids for the hydration of adjacent amino acid side chains appears to be greater than that of hydrogen bonding interaction of amide groups in *N*-acetyl amino acid amides.

For the alanyl and prolyl side chains, contrary to the features of difference between the values of Q_2°(Rn) and Q_2°(Ra) described above, Q_2°(Ra) values are larger. In particular, the feature for the prolyl side chain is remarkable. However, at present we are unable to give a satisfactory explanation for the origin of these unique characteristics.

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