AMINO ACIDS AND PEPTIDES. CIII.*

INFRARED SPECTRA AND CONFORMATIONS OF METHYLAMIDES OF N-ACYLATED AMINO ACIDS WITH A HYDROXYL GROUP IN THE SIDE CHAIN

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Received June 22nd, 1970

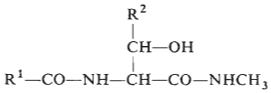
Infrared spectra in the range 3200—3650 cm^{-1}, and their temperature dependence in the range 90—110°C, were measured with methylamides of N-acetyl-L-serine (*I*), N-benzoyl-L-serine (*II*), N-benzoyl-L-threonine (*III*), N-acetyl-L-alanine (*IV*), N-acetyl-L-hydroxyproline (*V*) and N-acetyl-L-proline (*VI*). Six bands in the spectra of substances *I*—*III* were attributed to vibrations of N—H and O—H bonds in folded and extended conformations. In the case of derivative *V* there were 4 bands and from these were inferred one conformation with an interpeptidic hydrogen bond and two conformations without such a bond. The suggested conformations were confronted with data from conformational map $U(\varphi, \psi)$.

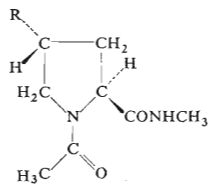
N'-Methylamides of N-acylated α-amino acids are appropriate models for the study of some properties of peptides and proteins. The two amide groupings joined by a C_α-atom of the amino acid residue can be representative of a dipeptide unit. Substances of this type have been used for various chemical[1-3] and physical[4,5] studies, including studies of the infrared spectra of substances with a purely hydrocarbon side chain[6-8]. Since serine is important in stereochemically sensitive enzyme reactions, it was of interest to determine the possible influence of a hydroxyl group in the side chain on the backbone conformation.

To this end we have studied the infrared spectra of the methylamides of N-acetyl-L-serine (*I*), N-benzoyl-L-serine (*II*), N-benzoyl-L-threonine (*III*) and N-acetyl-L-hydroxyproline (*V*). These were compared with the spectra of analogous substances without the hydroxyl group, *i.e.* methylamides of N-acetyl-L-alanine (*IV*) and N-acetyl-L-proline (*VI*). Since these substances are poorly soluble in solvents used for measurement in the region of N—H and O—H bonds, we had to use tetrachloroethylene between 90° and 110°C as a solvent. This range was determined by the insolubility of the

* Part CII: This Journal *36*, 2189 (1971).

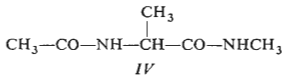
compounds below 90°C and by the boiling point of tetrachloroethylene (121°C). The structural simplicity of the above compounds allowed a calculation of probable conformations of some of them according to Scheraga[9]. Derived spatial arrangements were confronted with experimental data.





I, $R^1 = CH_3$, $R^2 = H$
II, $R^1 = C_6H_5$, $R^2 = H$
III, $R^1 = C_6H_5$, $R^2 = CH_3$

V, R = OH
VI, R = H



IV

The compounds listed were prepared according to published procedures (see Experimental) with the exception of the alanine derivative *IV* and both N-benzoyl derivatives *II* and *III*, which were obtained by the general procedure (*A*) used by Zahn and Reinert[10].

(*A*)* Z-L-Ala-OH → Z-L-Ala-OCH_3 → Z-L-Ala-$NHCH_3$ →
→ H-L-Ala-$NHCH_3$ → Ac-L-Ala-$NHCH_3$

EXPERIMENTAL

Melting points were determined on a Kofler block and were not corrected. Optical rotations were measured in ethanolic solution. Conformational calculations were carried out on a Gier computer.

Substances

N-Acetyl-L-serinemethylamide (*I*), m.p. 117°C (methanol–ether); ref.[10]; N-acetyl-L-hydroxyprolinemethylamide (*V*), m.p. 165°C (methanol), ref.[10], N-acetyl-L-prolinemethylamide (*VI*), m.p. 105°C (methanol–ether), ref.[12]; all prepared as described elsewhere. The syntheses of N-benzoyl-L-serinemethylamide (*II*), m.p. 161°C and N-benzoyl-L-threoninemethylamide (*III*), m.p. 193°C, will be published later[13].

* Standard abbreviations are used for amino-acid residues and protecting groups[11].

N-Benzyloxycarbonyl-L-alaninemethylamide

To a solution of benzyloxycarbonyl-L-alanine (5 g) in dioxane (50 ml) a solution of diazomethane in ether (50 ml) was added; after 10 min standing the reaction mixture was treated with acetic acid (1 ml) and evaporated to dryness. The residue was dissolved in ethyl acetate, the solution was washed with aqueous $NaHCO_3$ (5%), water, then dried with sodium sulphate and evaporated. The residue was dissolved in methanol (10 ml) and treated at −10°C with 2·5 g methylamine in 10 ml methanol. The mixture was allowed to stand at 20°C overnight. Evaporation gave a yield of 3·2 g, m.p. 119–121°C. After crystallisation from dioxan–light petroleum m.p. 122–124°C; $[\alpha]_D^{25}$ −13·4° (*c* 0·50, methanol). For $C_{12}H_{16}N_2O_3$ (236·3) calculated: 61·00% C, 6·83% H, 11·86% N; found: 60·55% C, 6·69% H, 12·04% N.

N-Acetyl-L-alaninemethylamide (*IV*)

Benzyloxycarbonyl-L-alaninemethylamide (1·6 g) was dissolved in 20 ml methanol and hydrogenated in the presence of Pd-C to the point of cessation of carbon dioxide formation. The solution was filtered and the filtrate was evaporated to dryness. The residue was dissolved in 15 ml pyridine, 1·5 g 2,4,5-trichlorophenyl acetate[14] was added along with 1·2 ml N-ethylpiperidine. After 3 days standing at 20°C the mixture was evaporated to dryness, the residue was washed with ether, the product filtered and washed again with light petroleum. The yield was 0·9 g, m.p. 174–177°C (sealed capillary), $[\alpha]_D^{25}$ −54·6° (*c* 0·51 ethanol), in agreement with the published data for the methylamide of *IV* prepared by a different method[12].

Spectroscopic Measurements

The measurements were carried out with a Unicam SP 100 instrument using "Infrasil" cells of the Hellma QI type at 90, 100 and 110°C, all ±0·1°C. Temperature was measured directly in the cells using a copper–constantan thermocouple in a glass probe filled with nujol and sealed about the leads with teflon. The thermocouple potential was measured on a mirror galvanometer, Zeiss Jena 1. Solutions of substances to be studied were prepared by weighing out both substance and solvent directly into the cells the latter being equipped with a mixer and an electric heating jacket. In all cases the reproducibility of initial values at lower temperature was determined. The spectra were numerically separated (Elliott 503 computer) on the assumption that the shape of a given band can be described as a Lorentz (Cauchy) curve using the method of dumped least squares[15,16]. The appropriate programme[17] was written in Elliott Algol 503 Mk. 1.

RESULTS AND DISCUSSION

The measured spectra in the range 3200–3650 cm^{-1} were composed of five overlapping bands ($a - e$) and one isolated band (f), apparently due to free OH groups. The bands were separated out by computer and their parameters were analysed. Further bands in the given spectral range did not occur as testified to by the very small mean deviation calculated for parameters of the individual bands, by the precise fit with the experimentally measured curves and finally by the course of residual values after separation. Examples of separation along with experimental curves are presented in Figs 1 and 2. Wavenumbers of maxima in separated bands in the region 3200 to 3650 cm^{-1} (in tetrachloroethylene) of substances *I* to *VI* are given

in Table I. Wavenumbers of the bands from the entire infra-red range measured in nujol are in Table II.

From the literature[18] it is known that substances similar to those studied here may be associated intermolecularly in tetrachloromethane at a concentration of 10^{-4}M. By our measurements of the concentration dependence of the spectrum of serine derivative *I* in tetrachloroethylene at 100°C (between 0·7 and 2·9 . 10^{-3}M) this substance is completely nonassociated at a concentration of 1·5 . 10^{-3}M, presumably due to the high temperature and the polarity of the solvent. Bands occurring in our spectra can be taken either as caused by vibrations of free bonds or bonds involved in intramolecular hydrogen boud.

The general classification of the bands was carried out on the basis of temperature effects between 90 and 110°C. The intensity of bands *a*, *c* and *e* decreased with increasing temperature, while those of bands *b*, *d* and *f* increased (see Table III). Therefore, bands *b*, *d* and *f* correspond to conformations which are energetically less advantageous than those of *a*, *c* and *e*.

According to Dreiding models, and to previous data for substances with purely hydrocarbon side chains[6–8], two folded conformations, *A* and *B*, and two extended ones, *C* and *D*, can be considered for substances *I*—*IV*. In the first two the seven-membered ring is closed with a hydrogen bond between the acyl carbonyl and the methylamide nitrogen atom. On first approximation both conformations differ only in the position of the C_β atom in relation to the ring. Conformation *A* has the side chain practically in the same plane as the ring, which makes possible the formation of another very strong hydrogen bond between the hydroxyl group in the side chain and the methylamide carbonyl. On the other hand, conformation *B* has the bond C_α—C_β practically perpendicular to the plane of the ring and the formation of a hydrogen bond between the hydroxyl groups and the methylamide carbonyl is out of the question. Of the two extended conformations only conformation *C* (similar to the β-structure of polyamino acids) can exist with a hydro-

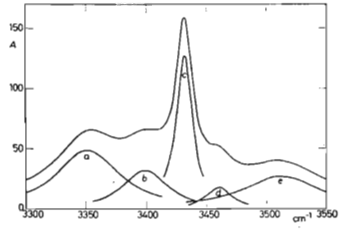


FIG. 1

Separation of Bands in the Spectrum of N-Acetyl-L-serinemethylamide (*I*)

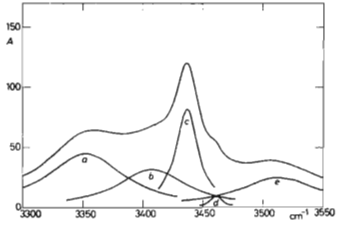


FIG. 2

Separation of Bands in the Spectrum of N-Benzoyl-L-serinemethylamide (*II*)

gen bond between the carbonyl oxygen and the nitrogen atom of the amino acid residue, and with an additional hydrogen bond between the carbonyl group of the acyl residue and the hydroxyl in the side chain. The fourth conformation, *D*, is of necessity less probable because of the proximity of the atom C_β to the oxygen of the acyl group and the hydrogen of the methylamide group.

In interpreting the spectra of substances *I*–*IV* it was not necessary to consider additional conformations. The correlation of individual bands with vibrations

TABLE I

Wavenumbers of Bands in the Range 3200–3650 cm^{-1} in the Infrared Spectra of Compounds *I*–*VI*

The spectra were measured at 90°C using tetrachloroethylene as solvent; concentration $1{\cdot}5 \cdot 10^{-3}$M, cell 2 cm.

Compound	Band						
	a	*b*	*c*	*d*		*e*	*f*
I	3 352	3 399	3 432	3 461		3 512	3 634
II	3 352	3 407	3 438	3 461		3 513	3 635
III	3 354	3 412	3 437	3 466		3 499	3 629
IV[a]	3 365	3 415	3 445	3 464		—	—
V	3 338	—	—	3 451,	3 458	—	3 634
VI[b]	3 335	—	—	3 452,	3 463	—	—

[a] Concentration $4{\cdot}0 \cdot 10^{-4}$M, cell 4 cm; [b] concentration $2{\cdot}4 \cdot 10^{-3}$M.

TABLE II

Wavenumbers (cm^{-1}) of Characteristic Bands in the Spectra of Compounds *I*–*VI* Measured in Nujol

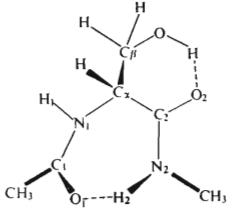
Compound	ν(OH), ν(NH)	Amide-I	Amide-II[a]	Amide-III
I	3 280, 3 165, 3 095	1 679, 1 645	1 571 w, 1 540	1 334, 1 285, 1 255 m
II	3 350, 3 300	1 655, 1 628	1 575 vw, 1 551	1 338 vw, 1 275, 1 240
III	3 355	1 653, 1 625	1 572 vw, 1 557	1 340 vw, 1 289, 1 263
IV	3 270, 3 200, 3 080	1 670, 1 635	1 579, 1 555 sh	1 315, 1 283, 1 259
V	3 470, 3 310, 3 230, 3 160, 3 050	1 670, 1 625	1 540 vs	1 350 s, 1 320, 1 300, 1 286, 1 265, 1 240
VI	3 295, 3 235, 3 085	1 650, 1 624, 1 602	1 557 vs	1 330 w, 1 222

[a] vw Very weak, w weak, m medium, s strong, vs very strong.

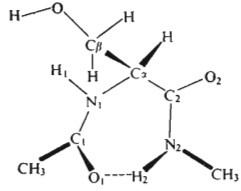
of individual bonds of conformations $A-C$ is derived from their position in the spectra and other parameters in comparison with model substances and published data[6-8,19].

Band *a* has a very low wavenumber of 3350 cm^{-1} for all measured substances and its half-width is in the range 60–80 cm^{-1}. In agreement with published results[6,7] this band is attributed to a hydrogen bond between the acyl carbonyl and the methylamide nitrogen. Band *c* would be attributed to vibration of the free N—H bond in the seven-membered ring. This assumption is supported by the small width of the band, its half-value being 16–22 cm^{-1}. Bands *a* and *c* correspond to the folded conformations *A* or *B*.

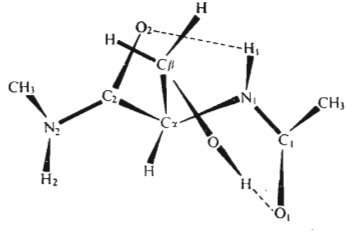
Band *b* can be attributed to the hydrogen bond between the amino-acid nitrogen atom and the carbonyl group (*cf.*[7]). Due to less favourable geometry this bond is weaker than that represented by band *a* and therefore its position is shifted to higher wavenumber values. The half-width is 40–60 cm^{-1}. This band would therefore correspond to extended conformation *C*. The same conformation would also correspond to band *d*, which is related to the vibration of the free methylamide N—H bond. The latter band is common to all measured substances regardless of the nature



a



b



c

of the side-chain, which is in agreement with its location of the periphery of the molecule in extended conformation.

The structural difference between acetyl derivative *I* and benzoyl derivatives *II* and *III* is manifested mainly in bands *b* and *c* which are due to the vibrations of free and bound N—H bonds in the acylamino group. Similarly we found for ν(N—H) in N-acetyl-L-leucine ethyl ester 3436 cm^{-1}, for N-benzoyl-L-leucine ethyl ester 3441 cm^{-1} (*cf.*[20]). These values are entirely in agreement with wavelength values for band *b*. They show that conformation *C* occurs in esters, which is understandable from the presence of a single amide proton.

From bands of stretching vibrations of hydroxyl groups the very wide band *e* can be selected clearly due to a hydrogen bond between the hydroxyl group and one of the carbonyls in the molecule. Both the wavenumber of this band and its half-width (80–100 cm^{-1}) correspond to the value of free hydroxyl groups[19]. This band occurs only with substances *I*–*III* with hydroxyl groups in the side chain, but not in hydroxyproline derivative *V*, in which an analogous hydrogen bond is excluded because of the *trans*-arrangement of both substituents on the pyrrolidine ring. This applies for both folded conformations and for extended conformation *C*. In this manner the slower decrease in intensity of band *e* with increasing temperature as compared with that of bands *a* or *c*, can be rationalised. Vibration of the O—H bond in the free hydroxyl group gives rise to band *f*. In the derivative of hydroxyproline *V* band *f* is the only band of hydroxyl group stretching vibration. The intensity of band *f* in substances *I*–*III* increases with increasing temperature. This is evidence for the prevalence of conformations with a free hydroxyl group, since

TABLE III

Temperature Dependence of the Extinction Coefficients (E^a_{max}) of Bands *a* – *f* for N-Acetyl-L-serinemethylamide (*I*)

95% Confidence limit is given in brackets. Apparent molar extinction coefficient ε^a_{max} is defined by the relation $\varepsilon^a_{max} = E^a_{max}/(c_{anal} \cdot d)$, where E^a_{max} represents apparent extinction at band maximum, c_{anal} the analytical concentration and *d* the cell thickness in cm.

Temperature, °C	*a*	*b*	*c*	*d*	*e*	*f*
89·7	56·65 (0·51)	29·30 (0·58)	138·45 (0·58)	12·95 (0·54)	33·36 (0·27)	—
100·2	52·21 (0·50)	29·49 (0·57)	132·99 (0·56)	12·63 (0·53)	31·91 (0·26)	—
109·8	49·37 (0·56)	30·52 (0·63)	127·16 (0·64)	13·22 (0·60)	30·16 (0·29)	—

the extinction coefficient of the band itself decreases with increasing temperature, as shown by the decreasing amplitude of band *f* with increasing temperature in the spectra of N-acetyl-L-hydroxyprolinemethylamide (*V*). The difference in the positions of either band *e* or *f* of serine derivatives *I* and *II* on the one hand, and substance *III* on the other, is derived from the presence of a methyl group in the side chain of substance *III*, *cf.*[19].

We have attempted to determine the percentage of individual conformations in solutions at 90°C. The percentage of extended conformation *C* was calculated from the parameters of band *d* using the molar extinction coefficient of N-methylbutyramide as a standard. For determination of the percentage of folded conformation *A* or *B* we used band *a*, and as a standard the molar extinction coefficient of the band of the bound N—H group in the system N-methylbutyramide–dimethylformamide or N-methylbutyramide–dimethylbenzamide. The percentage of conformations with a free hydroxyl group was calculated using band *f* and the molar extinction coefficient ε^{a}_{max} of 2,2-dimethylpropanol as a standard. The results are presented in Table IV. In the case of the substances containing a hydroxyl group in the side chain, the difference in the percentage of the extended conformation *C* and the folded conformations *A* and *B* is striking. Even more striking is the difference between the percentages of substances with a hydroxyl group in the side chain (*I*–*III*) and substance *IV* with no such group. Under the conditions of measurement in substances *I*–*III* there is a prevalence of the folded conformation (*A* or *B*) while in substance *IV* there is a prevalence of extended conformation *C*. The percentage of free hydroxyl groups in substances *I*–*III* is practically the same.

In attempts to define the geometry of possible conformations we calculated conformational maps for the methylamide of N-acetyl-L-serine (*I*) according to the procedure of Scheraga[9].

Conformational maps $U(\varphi, \psi)$ were obtained by calculation of values of potential energy in a grid with intervals of 15° in terms of φ and ψ (for definition of angles see[21]).

For each conformation an optimal conformation of the side chain was found (*i.e.* values χ_1 and χ_2) from tables of $U(\chi_1, \chi_2)$ for χ_1 and χ_2 at intervals of 15°. Functions of the Lennard-Jones type (6–12) were taken as potential functions describing nonbonded interactions and the energy of hydrogen bonds. Constants for these calculations were taken from published reports[22,23], and are shown in Table V. For calculation of electrostatic interactions we used the σ-partial charge on the atoms as described by Del Re[24], using parameters of Berthod and Pullman[25]. π-Charges of peptide bonds were taken from published data[23]. The relative dielectric constant *D* was taken as 4. For calculation of distances in the molecule we used the Eyring method[26,27].

From the map in Fig. 3 it would appear that conformation *A* lies at an absolute minimum. It is approximately defined by the pair of torsion angles $\varphi = 90°, \psi = 255°$.

This corresponds in its geometry to conformations advocated under different conditions for the methylamides of N-acetylamino acids with a purely aliphatic side chain[6,7]. Conformation *B*, determined approximately by the coordinates $\varphi = 240°$, $\psi = 150°$, corresponds well with a local minimum. Conformation *C* ($\varphi = 30°$, $\psi = 330°$) is localised in the region of a very shallow and flat local minimum (not very clear on our map but quite evident in the map presented in ref.[7]). Both minima *B* and *C* have about the same energy *U*, higher than the minimum corresponding to the *A* conformation. The conformation *D* (coordinates approximately $\varphi = 300°$, $\psi = 60°$) lies on the edge of an energy barrier and its recognizable population would appear to be excluded. On the other hand, a local minimum with coordinates $\varphi = 240°$, $\psi = 300°$ does not correspond to any conformation which could be taken into account. In a molecule arranged in this manner there can be no interpeptidic hydrogen bonds, so that there must be a considerable dipole–dipole interaction between both carbonyl oxygens. We therefore consider the latter minimum as a calculation artefact (in Fig. 3 denoted with an asterisk).

According to these considerations (as well as the literature[7]) conformation *A* is energetically the most probable, corresponding to the views of Mizushima and coworkers[6]. On the other hand, the calculations of Pullman and coworkers[28], based on quantum chemistry, suggest that derivative *I* has as its most stable arrangement conformation *B*. This view is in agreement with the results of NMR studies of Bystrov and coworkers[8,29] on N-acyldipeptide esters and our own observations[13] on substances *I*–*IV*. Conformations *A* and *B* cannot be spectroscopically differentiated directly by vibration of N—H groups. Some indication can be the vibration of hydroxyl groups. From comparison of data for the acetylalanine (*IV*) and acetylserine (*I*) derivatives there would appear to be a greater percentage of the folded

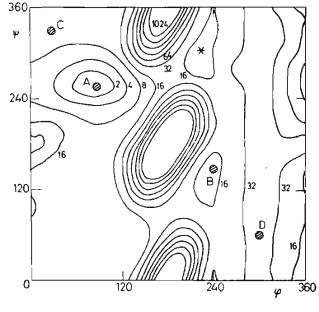


FIG. 3

Conformational Map $U(\varphi, \psi)$ for N-acetyl-L-serinemethylamide (*I*)

Conformations *A* – *D* are discussed in text.

conformation in the latter. The stability of the latter conformation can be attributed to the formation of hydrogen bonds in the side chain, which does in fact occur (see Table IV). The shift $\nu(OH)_{free} - \nu(OH)_{bound}$ is surprisingly small for a strong hydrogen bond, as would be expected in conformation *A*. This would more probably be related to a hydrogen bond between the hydroxyl group and the acylcarbonyl in conformation *B*. The oxygen atom of this group has a decreased proton-acceptor capa-

TABLE IV

The Conformer Percentage of *I*– *VI* in Tetrachloroethylene at 90°C

Compound	Conformation, %[a]		
	A + *B*	*C*	free O–H
I	70 ± 4	24 ± 4	16 ± 1
II	–	12 ± 2	18 ± 1
III	–	14 ± 1	9 ± 4
IV	36 ± 2	60 ± 5	–
V	81(A_1)	16(E_1), 3(E_2)	–
VI	80(A_1)	14(E_1), (5E_2)	–

[a] Standard deviations are given.

TABLE V

Parameter Values Used for the Calculation of Potentials $U(r) = a/r^{12} - b/r^6$

Interaction	$a \cdot 10^{-5}$ kcal . A^{12} mol^{-1}	b kcal . A^6 mol^{-1}
H...H	0·0446	46·7
H...C	0·380	128
H...N	0·270	125
H...O	0·251	124
C...C	2·86	370
C...N	2·16	366
C...O	2·05	367
N...N	1·61	363
N...O	1·53	365
O...O	1·45	367
Hydrogen bond	0·02423	56·08

city, since it is involved in the interpeptidic bond of the seven-membered ring. In principle such bifurcated hydrogen bonds are possible, at least according to X-ray measurements in crystals[30,31].

The very small differences between the spectra of substances *V* and *VI* (Table I), if we do not consider the presence of bands due to free hydroxyl group in the spectrum of substance *V*, suggest that the conformations of both substances are very similar and implicitly, that the presence of a hydroxyl group in the aliphatic side chain does not contribute very much to their stabilisation. Band *a* (in substance *V* at 3338 cm^{-1}, half-width 79 cm^{-1} and in substance *VI* at 3335 cm^{-1}, half-width 60 cm^{-1}) in this case corresponds to conformation A_1, with a *trans*-conformation of the acetamide group and with an interpeptidic hydrogen bond between the acetyl carbonyl and the methylamide proton. It is approximately defined by the pair of angles $\varphi = 120°$, $\psi = 240°$, *i.e.* values near to the coordinates of the *A* minimum in the conformational map of substance *I* (Fig. 3). In this conformation we find about 80% of molecules. Under the conditions of measurement there must, however, be about 20% of conformers with a free N—H group. In the spectra we found two bands indicating the presence of two conformations of this type: 3451 cm^{-1}, half-width 20 cm^{-1}, for substances *V* and *VI* and at 3458 cm^{-1} (substance *V*) or 3462 cm^{-1} (substance *VI*) with half-widths about 10 cm^{-1}. Mizushima and coworkers[6,32] have reported for a solution of N-acetyl-L-prolinemethylamide (*VI*) in tetrachloromethane a prevalence of conformations with interpeptidic bonds and only a small fraction of other conformations; in chloroform they observed an increased population of conformers with a free N—H bond. For conformers without a hydrogen bond we can consider conformations with a *cis*-arrangement of the acetamide bond[5]. If we consider a *trans*-arrangement, the conformations can differ only in the position of the carboxamide group. On the basis of analysis of Dreiding models conformation E_1, with a pair of torsion angles $\varphi = 120°$, $\psi = 120°$ and E_2 with angles $\varphi = 120°$, $\psi = 0°$ would come into question. All three conformations (A_1, E_1, E_2) also correspond to minima of the potential curve calculated by Madison and Schellman[5] for N-acetyl-L-prolinemethylamide with a *trans*-arrangement of the acetamide part of the molecule.

In general, these results indicate that if there is the possibility of interaction between the hydroxyl group of a residue in a peptide and the neighboring peptide bond, the side chain can significantly effect the conformational arrangement of the peptide chain.

We should like to thank Academician F. Šorm for his interest and support, Mrs H. Janešová, Mrs K. Matoušková and Mr P. Formánek for able technical assistance, and the staff of the computing centre at the Institute for Nuclear Research, Prague-Řež, for valuable help in computing.

REFERENCES

1. Zahn H., Mella K.: Z. Physiol. Chem. *344*, 75 (1966).
2. Zahn H., Fölsche E. T. J.: Z. Physiol. Chem. *345*, 215 (1966).
3. Zahn H., Reinert G.: Kolloid Z. *226*, 141 (1968).
4. Madison V., Schellman J.: Biopolymers *9*, 65 (1970).
5. Madison V., Schellman J.: Biopolymers *9*, 511 (1970).
6. Tsuboi M., Shimanouchi T., Mizushima S.: J. Am. Chem. Soc. *81*, 1406 (1959).
7. Avignon M., Huong P. V., Lascombe J.: Biopolymers *8*, 69 (1969).
8. Portnova S. L., Bystrov V. F., Tsetlin V. I., Ivanov V. T., Ovčinnikov Yu. A.: Ž. Obšč. Chim. *38*, 428 (1968).
9. Scheraga H. A.: Advan. Phys. Org. Chem. *6*, 103 (1968).
10. Zahn H., Reinert G.: Z. Physiol. Chem. *349*, 608 (1968).
11. IUPAC-IUB Tentative Rules: European J. Biochem. *1*, 375 (1967).
12. Applewhite T. H., Niemann C.: J. Am. Chem. Soc. *81*, 2208 (1959).
13. Bláha K., Buděšínský M., Vičar J.: Unpublished results.
14. Cade A. R., Gump W. S.: US-Pat. 2 457 805; Chem. Abstr. *43*, 3459 (1949).
15. Meiron J : Opt. Soc. Am. *55*, 1105 (1965).
16. Toman S., Plíva J.: J. Mol. Spectry *21*, 362 (1966).
17. Vítek A.: MPT II Cauchy. FA-520, Program Library. Institute of Organic Chemistry and Biochemistry, Czechoslovak Academy of Sciences, Prague 1968.
18. Mizushima S., Shimanouchi T., Tsuboi M., Sugita T., Kurosaki K., Mataga N., Souda R.: J. Am. Chem. Soc. *74*, 4639 (1952).
19. Bellamy J. L.: *The Infrared Spectra of Complex Molecules*, 1st Ed. Methuen, London 1954.
20. Bláha K., Frič I., Smolíková J.: This Journal *33*, 3170 (1968).
21. Edsall J. T., Flory P. J., Kendrew J. C., Liquori A. M., Némethy G., Ramachandran G. N., Scheraga H. A.: Biopolymers *4*, 121 (1966).
22. Scott R. A., Scheraga H. A.: J. Chem. Phys. *45*, 2091 (1966).
23. Poland D., Scheraga H. A.: Biochemistry *6*, 3791 (1967).
24. Del Re G.: *Electronic Aspects of Biochemistry*. Academic Press, New York 1963.
25. Berthold H., Pullman A.: J. Chim. Phys. *62*, 942 (1965).
26. Eyring H.: Phys. Rev. *39*, 746 (1932).
27. McCullough R. L., McMahon P. E.: Trans. Faraday. Soc. *60*, 2089 (1964).
28. Maigret B., Pullman B., Dreyfus M.: J. Theoret. Biol. *26*, 321 (1970).
29. Bystrov V. F., Portnova S. L., Tsetlin V. I., Ivanov V. T., Ovchinnikov Yu. A.: Tetrahedron *25*, 493 (1969).
30. Smith A. E.: Acta. Cryst. *5*, 224 (1952); Chem. Abstr. *46*, 8927 (1952).
31. Cochran W.: Acta Cryst. *6*, 260 (1953); Chem. Abstr. *47*, 6734 (1953).
32. Mizushima S., Tsuboi M., Shimanouchi T., Sugita T., Yoshimoto T.: J. Am. Chem. Soc. *76*, 2479 (1954).

Translated by J. H. Cort.

STUDIES IN THE QUINOXALINE SERIES. VII.

CYCLIZATION REACTIONS OF SOME 2-METHOXYCARBONYLQUINOXALINE DERIVATIVES

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This Journal *36*, 262 (1971). The correct title of this paper is: Cyclization Reactions of Some 2-Carboxymethylquinoxaline Derivatives

AMINO ACIDS AND PEPTIDES. CIII.

INFRARED SPECTRA AND CONFORMATIONS OF METHYLAMIDES OF N-ACYLATED AMINO ACIDS WITH A HYDROXYL GROUP IN THE SIDE CHAIN

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This Journal *36*, 2474 (1971). In the footnote, the reference to Part CII should read: This Journal *36*, 3470 (1971).