

# SYNTHESES, STRUCTURES, AND REACTIONS OF DI- AND TETRAHYDROPIRROLES

## VII. IMINO-ENAMINE TAUTOMERISM OF PYRROLINES IN SOLUTIONS

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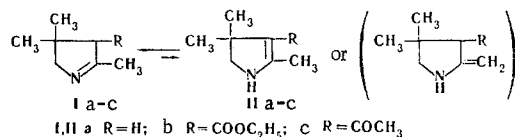
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PMR spectroscopy showed that 2,4,4-trimethyl-, 2,4,4-trimethyl-3-carbethoxy-, and 2,4,4-trimethyl-3-acetyl- $\Delta^1$ -pyrrolines usually exist in solutions exclusively in the imine form, regardless of the polarity of the solvents.

For quite some time the determination of the position of the double bond in pyrrolines ( $\Delta^1$  or  $\Delta^2$ ) was the subject of numerous discussions [1, 2]. Only in recent years by IR spectroscopy has it been shown [1, 3-6] that pyrrolines exist primarily in the imine ( $\Delta^1$ ) form in the solid state.\* The position of the tautomeric equilibrium in solutions has not been studied to any great extent. PMR was used to establish [6] that all of the investigated alkyl-substituted pyrrolines exist only in the imine form in  $\text{CCl}_4$  solution. Data on the determination of the labile hydrogen by the Zerewitinoff determination in solvents of low polarity (ether), which have shown that there is little or no active hydrogen in the investigated pyrrolines [5, 7], are in agreement with this result. In addition, IR spectroscopy and Zerewitinoff determinations of the labile hydrogen in anisole and pyridine established [8] that 94-100% of 2,3-dimethyl-4-carbomethoxyethylpyrroline exists in the  $\Delta^2$  form, while 2,3,3-trimethyl-4-carbomethoxyethylpyrroline in these solvents contains 23% of a form with an exocyclic double bond.

It should be noted that all of the investigations of the imine-enamine equilibrium of pyrrolines in the solid state and solutions were carried out on compounds which contain various substituents. Meanwhile, it is known (in the case of acyclic compounds) that there is a rather strong substituent effect on the position of the imine-enamine equilibrium (see [9], for example).

In this study, by using an extensive set of solvents, we have investigated the imine-enamine tautomerism of pyrrolines in solutions. 2,4,4-Trimethyl- $\Delta^1$ -pyrroline (Ia), 2,4,4-trimethyl-3-carbethoxy- $\Delta^1$ -pyrroline (Ib), and 2,4,4-trimethyl-3-acetyl- $\Delta^1$ -pyrroline (Ic), which are extremely convenient for investigation by the PMR method, were selected as model compounds. The selection of such objects for investigation was due to the fact that the first of them can be a "standard" for alkyl-substituted pyrroline, while the second and third are cyclic derivatives of  $\beta$ -aminocrotonic ester and acetylacetone imine which, as is well known [10], exists exclusively in the cis-enamine form.



\* The appearance in some cases of a small absorption in the region of the valence vibrations of the NH group may be due not only to the tautomeric  $\Delta^2$  form of pyrroline but to traces of moisture or a dimer [6].

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TABLE 1. Table of Chemical Shifts

Comp.	Solvent	Chemical shifts of protons, $\delta$ , ppm					
		(CH <sub>3</sub> ) <sub>2</sub> C	OCH <sub>2</sub> - -CH <sub>3</sub> <sup>a</sup>	C <sub>2</sub> -CH <sub>3</sub> <sup>a</sup> imino form	C <sub>3</sub> -H	C <sub>5</sub> -H <sup>b</sup>	OCH <sub>2</sub> <sup>b</sup>
Ia	CCl <sub>4</sub>	1,0	—	1,8	2,2	3,3	—
Ia	Chloroform	1,02	—	1,9	2,2	3,4	—
Ia	C <sub>6</sub> D <sub>6</sub>	1,05	—	2,08	2,27	3,65	—
Ia	Acetone	1,05	—	1,9	2,25	3,33	—
Ia	Anisole	1,0	—	1,9	2,2	3,3	—
Ia	Dimethyl sulfoxide	0,94	—	1,84	2,2	3,4	—
Ia	Pyridine	0,9	—	1,86	2,1	3,4	—
Ia	Triethylamine	1,0	—	1,9	2,2	3,4	—
Ia	CD <sub>3</sub> OD	1,05	—	1,9	2,35	3,4	—
Ib	Chloroform*	1,0	1,28	1,93	3,69	3,63	4,25
Ib	Chloroform†	1,0	1,28	1,93	3,69	3,63	4,25
Ib	C <sub>6</sub> D <sub>6</sub>	0,78	0,69	1,89	3,65	3,60	3,72
Ib	Tetrachloroethylene	0,95	—	—	—	—	—
		0,96	1,25	2,01	— <sup>c</sup>	3,60	4,23
Ib	Dimethylformamide	0,98	—	—	—	—	—
		0,93	1,19	1,86	— <sup>c</sup>	3,40	4,17
Ib	CD <sub>3</sub> NO <sub>2</sub> ‡	0,92	1,23	1,83	— <sup>c</sup>	3,50	4,22
		0,95	—	—	—	—	—
Ib	CD <sub>3</sub> OD‡	0,98	1,25	1,95	— <sup>c</sup>	3,53	4,15
Ib	Pyridine	0,98	1,05	2,08	— <sup>c</sup>	3,65	4,15
Ic	Tetrachloroethylene	1,11	—	—	—	—	—
		0,86	—	1,81	COCH <sub>3</sub>	3,66	—
		0,95	—	—	2,03	—	—
Ic	Pyridine	0,88	—	2,01	2,23	3,66	—
		1,08	—	—	—	—	—

\* The spectrum was obtained 4 days after preparation of the solution.

† The spectrum was obtained 13 days after preparation of the solution.

‡ The spectra were obtained 8 h after preparation of the solution.

<sup>a</sup> Center of a triplet.

<sup>b</sup> Center of a quartet.

<sup>c</sup> No signal detected.

Moreover, the enamine tautomers of pyrrolines Ib and Ic (IIb and IIc) are related to the uninvestigated "trans-fixed" forms which, because of their structural peculiarities, are incapable of forming the corresponding cis-enamine forms.

In the spectrum of pyrroline Ia that we obtained (the assignment of the signals is given in Table 1) in CCl<sub>4</sub>, the chemical shifts of all of the protons practically coincided with those presented in [6]. A study of the PMR spectra of pyrroline Ia in benzene, chloroform, acetone, anisole, dimethyl sulfoxide, triethylamine, pyridine, and methanol indicated that only imine form Ia (absence of signals from olefin protons) exists in all of these differing solvents. The absence of deuterium exchange of pyrroline Ia in CD<sub>3</sub>OD solution containing NaOD and in pyridine solution containing D<sub>2</sub>O and NaOD also attests to the fact that the equilibrium in alkyl-substituted pyrrolines is markedly shifted to favor the imine forms.

The PMR spectrum of pyrroline Ib in CHCl<sub>3</sub> differs from that of pyrroline I by a shift to weak field of the signal of the H<sub>3</sub> proton (due to the deshielding effect of the carbethoxy group) and by the presence of additional signals of the carbethoxy group (the triplet of the CH<sub>3</sub> group at 1.28 ppm and the quartet of the CH<sub>2</sub> group at 4.25 ppm; J = 7 Hz). A very important circumstance for distinguishing tautomeric forms Ib and IIb is the long-range spin-spin interaction of the homoallyl type between the O<sub>2</sub>-CH<sub>3</sub> group and the H<sub>5</sub> protons (which was proved by the double magnetic resonance method), which is transmitted through the nitrogen atom and leads to splitting of the signals of these groups into a triplet and quartet with J = 1.8 Hz, characteristic for an interaction of this type [11], which we detected for the imino form of Ia. In the enamine form IIb, in which this interaction is absent, the signal of the C<sub>2</sub>-CH<sub>3</sub> group is a singlet. In actuality it turned out that pyrroline Ib exists only in the imine form in solutions in benzene, tetrachloroethylene, dimethylformamide, pyridine, methanol, and nitromethane. The appearance of a singlet at 2.14 ppm after prolonged standing (13 days) of pyrroline Ib in chloroform solution and its absence after storage for 4 days is apparently the result of transformations associated with the instability of this solvent. It should be noted that the spectra of pyrroline Ib in CD<sub>3</sub>OD and CD<sub>3</sub>NO<sub>2</sub> were obtained 8 h after preparation of the solution.

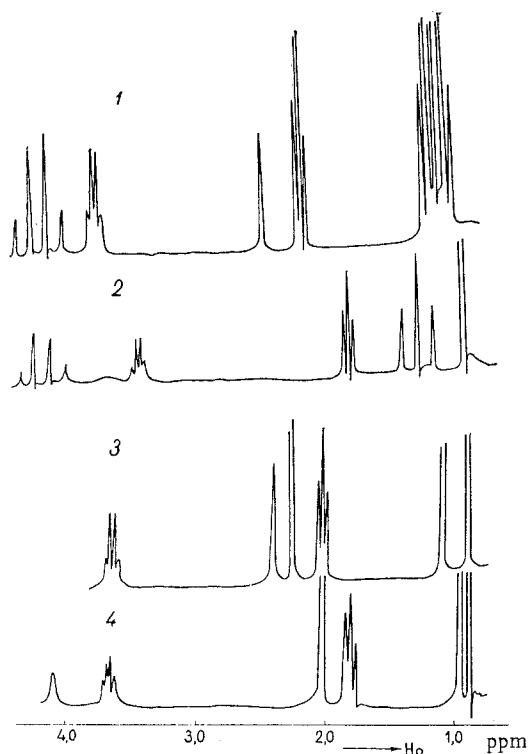


Fig. 1. PMR spectra of 2,4,4-trimethyl-3-carbethoxy- $\Delta^1$ -pyrroline (Ib): 1) in pyridine; 2) in tetrachloroethylene; of 2,4,4-trimethyl-3-acetyl- $\Delta^1$ -pyrroline (Ic); 3) in pyridine; 4) in tetrachloroethylene.

The intensities of the signals of the  $C_2-CH_3$  groups begin to decrease on further standing, and after 10 days the signals of these groups have practically vanished completely, i.e., deuterium exchange occurs. Deuterium exchange by the protons in the methyl group in the 2-position under such mild conditions is apparently associated with the fact that it proceeds through a tautomeric form with an exocyclic double bond, which is present in solution in amounts which are not detectable by PMR.

Pyrroline Ic also exists only in the imine form in benzene, tetrachloroethylene, and pyridine (see Fig. 1; the signal in pyridine at 2.38-2.41 ppm belongs to the methyl group of picoline, which is present as an impurity).

For comparison we point out that a study of the UV spectra of solutions of  $\alpha$ -alkyltetronic acids (the oxygen analog of pyrroline Ib), which are cyclic analogs of  $\alpha$ -alkylacetoacetic ester and are related to the "trans-fixed" enols, indicated the approximately constant percentage of the enol form in such solvents as methanol, alcohol, ether, dioxane, and water [12]. Thus one can probably conclude that the results obtained for alkyltetronic acids and pyrrolines Ib and Ic can probably be considered to be similar, in that the effect of solvents of extremely different character on the position of the tautomeric equilibria of similar "trans-fixed" structures is extremely small. For this reason, pyrrolines Ib and Ic can probably be used as a standard for a trans-enamine form for compounds of related types (see [12, 13], for example).

## EXPERIMENTAL

The PMR spectra were obtained at room temperature with "Perkin-Elmer" (Ia) and "Varian DA-60" (Ib and Ic) spectrometers with an operating frequency of 60 MHz. The internal standards were TMS (tetramethylsilane) and HMDS (hexamethyldisiloxane). The concentration of Ib and Ic in all solvents was 0.2 mole/liter. All of the spectra were obtained at equilibrium concentrations [they were usually established in 3-4 days and did not change later (up to 1 month)]. The PMR spectra of pyrroline Ib in  $CHCl_3$  were obtained after 4 and 13 days (see Table 1), while those in  $CD_3NO_2$  and  $CD_3OD$  were obtained after 8 h.

2,4,4-Trimethyl- $\Delta^1$ -pyrroline (I) was obtained by the method in [14] and was dried by threefold distillation over  $P_2O_5$  (until the signal of water protons at 4.6 ppm was absent in the PMR spectrum of the samples). Pyrrolines Ib and Ic were obtained via the methods in [15, 16].

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