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THERMAL REARRANGEMENT OF 2,5-DIARYL-3,3,4,4-TETRACYANOPYRROLIDINES

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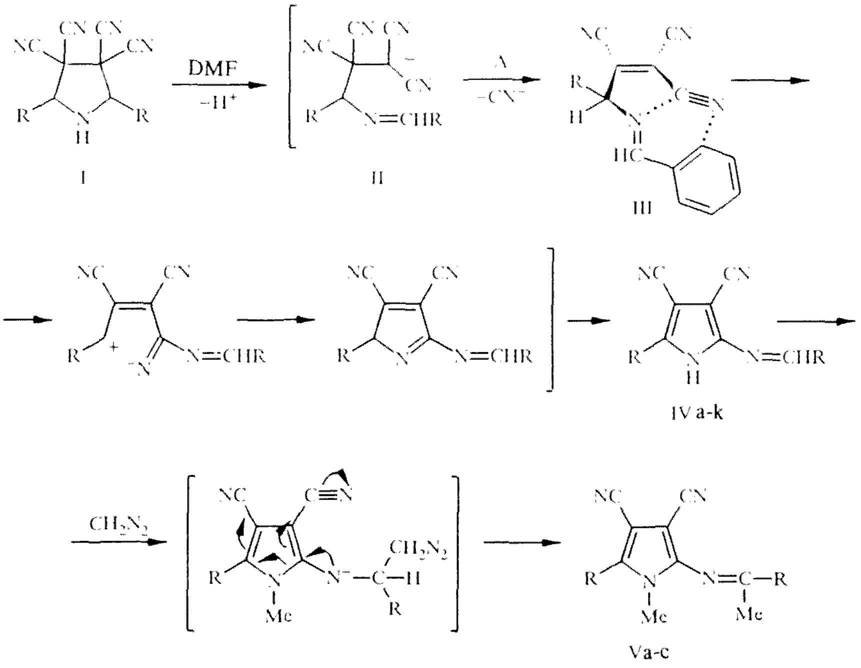
It was shown that briefly boiling solutions of 2,5-diaryl-3,3,4,4-tetracyanopyrrolidines in DMF causes rearrangement into 5-aryl-2-(N-arylidenamino)-3,4-dicyanopyrroles, which are methylated with diazomethane both at the NH bond and at the carbon atom of the azomethine fragment.

Based on an analysis of the mass spectra of 2,5-disubstituted 3,3,4,4-tetracyanopyrrolidines I [1], we suggested the possibility of easy elimination of cyano hydrogen with formation of 2,5-substituted 3,4-dicyanopyrroles. 2-Amino-3,4-dicyanopyrroles are obtained from the corresponding 2-pyrrolines by boiling in DMF [2, 3]. However, when pyrrolidines I are briefly boiled in DMF, 2-(N-arylidenamino)-5-aryl-3,4-dicyanopyrroles IVa-j are unexpectedly formed.



The following hypothesis concerning the course of the process can be advanced based on the structure of dicyanopyrroles IV. Rearrangement probably begins with opening of the ring at the $C_{(2)}-C_{(3)}$ bond. Thermal elimination of a molecule of hydrogen cyanide subsequently occurs with an increase in the temperature, with formation of linear conjugated structure III, where an imino fragment [4] can migrate to an electrophilic carbon atom of the close nitrile group of the dicyanomethylene unit with subsequent cyclization into pyrrole IV. A [4 + 2]-reaction in which an aromatic substituent also participates is probably determining for this migration. This is supported by the fact that such conversion of 2,5-dialkyl-3,3,4,4-tetracyanopyrrolidones cannot be conducted.

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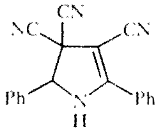
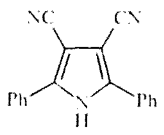
TABLE 1. Properties of Compounds IVa-j, Va-c, VII, VIIIa-c

Compound	Empirical formula	mp, °C	R	Yield, %
IV a	$C_{19}H_{12}N_4$	257....258	C_6H_5	37
IV b	$C_{21}H_{16}N_4O_2$	150...151	$2\text{-}CH_3OC_6H_4$	11
IV c	$C_{21}H_{16}N_4O_2$	253...254	$4\text{-}CH_3OC_6H_4$	62
IV d	$C_{19}H_{10}Cl_2N_4$	229...230	$2\text{-}ClC_6H_4$	19
IV e	$C_{19}H_{10}F_2N_4$	282...283	$4\text{-}FC_6H_4$	39
IV f	$C_{21}H_{16}N_4$	214...215	$3\text{-}CH_3C_6H_4$	37
IV g	$C_{19}H_{10}Cl_2N_4$	145...146	$3\text{-}ClC_6H_4$	40
IV h	$C_{21}H_{16}N_4$	204...205	$2\text{-}CH_3C_6H_4$	31
IV i	$C_{19}H_{10}Br_2N_4$	296...297	$4\text{-}BrC_6H_4$	39
IV j	$C_{19}H_{10}Br_2N_4$	152...153	$3\text{-}BrC_6H_4$	37
V a	$C_{21}H_{16}N_4$	204...205	C_6H_5	47
V b	$C_{21}H_{14}F_2N_4$	237...238	$4\text{-}FC_6H_4$	37
V c	$C_{23}H_{20}N_4O_2$	229...230	$4\text{-}CH_3OC_6H_4$	23
VII	$C_{18}H_{11}N_3$	282...283	C_6H_5	37
VIII a	$C_{12}H_8N_4$	263...264	C_6H_5	71
VIII b	$C_{12}H_7BrN_4$	321...323 (with decomp.)	$4\text{-}BrC_6H_5$	58
VIII c	$C_{13}H_{10}N_4O$	261...262 (with decomp.)	$4\text{-}CH_3OC_6H_4$	68

Two factors are additional evidence of the proposed scheme: the possibility of opening of the pyrrolidone ring of I in DMF [5] and formation of 2,5-diphenyl-3,4-dicyanopyrrole (VII) from 2,5-diphenyl-3,4,4-tricyano-2-pyrroline (VI) on boiling in DMF. These data indicate that the process most probably begins with opening of the ring with subsequent elimination of a molecule of HCN.



VI

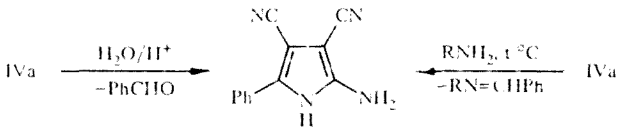


VII

Pyrrole VII was obtained from 2-pyrroline VI [1] with a yield of 74%, and the product of rearrangement was not detected in the reaction mass. Aromatization takes place here by elimination of a molecule of HCN without ring opening.

The ring-chain tautomerism of pyrrolidines I in solution in the presence of a base or in pure DMF which we discovered [5] also indicates the possible occurrence of the process via opened form II. This reaction is very sensitive to impurities in the solvent. The presence of water in the DMF thus decreases the yield of compounds IV.

The IR spectra of compounds IVa-j (Table 2) contain intense absorption bands of stretching vibrations of conjugated cyano groups in the 2250-2225 region and a broadened absorption band of a NH bond at 3370-3200 cm^{-1}. In addition to signals of the carbon atoms in the heterocycle and cyano groups, the ^{13}C NMR spectrum of pyrrole IVa also contains a signal in the 163.68 ppm region characteristic of the carbon atom in a C=N bond.



VIIIa

Hydrolysis with formation of 2-aminopyrrole VIII is also chemical evidence of the structure of compounds IV.

The benzaldehyde separated was identified in the form of 2,4-dinitrophenylhydrazone. In comparison to starting pyrrole IVa, the IR spectrum of compound VIII has absorption bands of NH group stretching and deformation vibrations at 3455-3250 and 1690 cm^{-1} characteristic of an enaminonitrile fragment. The data in the ^{13}C NMR spectrum are in agreement

TABLE 2. IR and Mass Spectra of Pyrroles IV, V, VII, and VIII

Compound	IR spectrum, cm^{-1}			Mass spectrum,* m/z (relative intensity, %)
	ν_{NH}	$\nu_{C\equiv N}$	$\nu_{C=N}$	
IV a	3230	2238, 2248	1610	—
IV b	3370	2210, 2235	1650	—
IV c	3200	2225, 2240	1605	356(100), 355(13), 325(21), 324(51), 222(6), 178(21), 152(9), 129(8), 117(10), 103(15), 77(18)
IV d	3330	2235, 2250	1625	364(100), 363(11), 329(60), 294(22), 226(6), 201(6), 199(13), 192(18), 165(19), 164(18), 89(30)
IV e	3225	2245	1603	332(100), 331(29), 306(7), 237(4), 210(8), 183(17), 166(7), 122(11), 108(15), 107(16), 95(12)
IV f	3260	2235, 2245	1608	324(100), 323(23), 309(13), 298(4), 206(4), 179(7), 118(6), 103(5), 91(11), 89(4), 77(7)
IV g	3300	2210, 2235	1650	—
IV h	3215	2225, 2240	1610	324(100), 323(26), 309(17), 298(12), 206(13), 179(13), 152(13), 129(13), 118(19), 103(28), 89(12)
IV i	3250	2210, 2235	1650	454(100), 453(60), 374(6), 359(24), 294(8), 267(13), 207(6), 164(12), 89(15), 69(11), 55(20)
IV j	3235	2238	1610	—
V a	—	2233	1615	324(100), 310(15), 206(12), 165(22), 118(11), 104(9), 103(34), 77(67), 69(27), 57(28), 55(16)
V b	—	2230	1615	360(100), 346(30), 183(15), 122(8), 121(22), 109(11), 101(11), 95(18), 69(33), 57(18), 55(19)
V c	—	2233	1605	384(13), 370(100), 355(13), 185(18), 134(13), 121(15), 111(17), 97(35), 95(27), 69(73), 55(92)
VII	3285	2235, 2245	—	269(100), 268(12), 267(6), 241(4), 166(5), 165(8), 139(13), 104(5), 77(9), 63(4), 51(6)
VIII a	3460, 3350, 3260, 3190	2230	δ_{NH} 1635	208(100), 192(10), 180(13), 164(11), 139(6), 104(41), 103(14), 69(9), 77(40), 63(8), 51(21)
VIII b	3455, 3330, 3245, 3205, 3190	2235, 2220	1630	—
VIII c	3455, 3335, 3250, 3200	2225, 2220	1630	—

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*The peak of the molecular ion and 10 most intense peaks of fragmentary ions are reported.

with the structure of VIII. Signals characteristic of carbon atoms in pyrrole systems with enaminonitrile fragments are observed in the spectrum at 72 and 149 ppm.

A more convenient method of synthesis of 2-aminopyrroles VIII is transamination of the carbonyl component in compounds IV. When heated in aniline or in isopropyl alcohol in the presence a primary aliphatic amine, pyrroles VIIIa-c are formed with good yields.

In studying the properties of pyrroles IV, it was found that methylation with diazomethane takes place not only at the NH fragment of the pyrrole ring, but also at the sp^2-hybridized carbon of the azomethine substituent with formation of dimethyl derivatives Va-c.

In all known examples [6, 7], C-alkylation with diazomethane takes place if the intermediate carbanion (carbanion formed by the reaction of CH_2N_2 with a π system) is effectively stabilized due to electronegative substituents, delocalization of the π-electron density in the aromatic fragment, and realization of the $p-\pi^*$ interaction with lower-energy neighboring vacant orbitals. The same reasons are also responsible for stabilization of the anion which precedes dimethyl derivative V.

In comparison to the IR spectra of starting pyrroles IV, the absorption bands of NH bond stretching vibrations disappear in the spectra of the methylated analogs (Table 2). In addition to the hydrogen atoms of aromatic rings (8.22-7.62), there are two signals in the PMR spectrum at 3.55 (3H, $N-CH_3$) and 2.66 ppm (3H, $N{=}C-CH_3$). Due to the poor solubility of compounds V, it was not possible to obtain a high-quality ^{13}C NMR spectrum. The data from the x-ray structural study of compound Va are reported in [8].

EXPERIMENTAL

The course of the reactions and purity of the synthesized compounds were monitored by TLC on Silufol UV-254 plates with development in UV light with iodine vapors. The IR spectra were made on a UR-20 in petrolatum. The ^{13}C NMR spectra were made on a Bruker WH-90 spectrometer at a working frequency of 22.63 MHz. The PMR spectra were recorded on a MS 25 PFA KRATOS by direct introduction of the substance into the ion source with ionization energy of 50 eV.

2-(N-Arylidenamino)-5-aryl-3,4-dicyanopyrroles (Va-j). A suspension of 10 mmole of 2.5-diaryl-3,3,4,4-tetracyanopyrrolidine (I) in 5-8 ml of dehydrated DMF was heated to boiling and boiled for 1 min while stirring. After cooling of the solution obtained, the precipitated sediment was filtered off, washed with isopropyl alcohol, and recrystallized from methylcellulose. After cooling, the reaction mass was diluted first with 10 ml of isopropyl alcohol and then with 10 ml of water to separate compounds IVb, d, j. Recrystallization was from acetonitrile or isopropyl alcohol. ^{13}C NMR spectrum of IVa (DMSO): 147.09 ($C_{(2)}$), 90.83 ($C_{(3)}$), 87.91 ($C_{(4)}$), 138.7 ($C_{(5)}$), 163.68 (HC=N), 113.83, 114.67 ppm ($C\equiv N$).

2-(1-Arylethylidenamino)-5-aryl-1-methyl-3,4-dicyanopyrroles (Va-c). A weak current of diazomethane was passed through a suspension of 10 mmole of starting pyrrole IV in 20 ml of dioxane while stirring. The starting substance gradually dissolved, and a sediment precipitated. Feeding of diazomethane stopped, and stirring was continued for another 10 min. It was then cooled with water, the sediment was filtered off, washed with isopropyl alcohol, recrystallized from methyl Cellosolve, and dried, yielding 2 g (74%) of pyrrole VII with mp = 281-282°C. ^{13}C NMR spectrum (DMSO): 141.43 ($C_{(2)(5)}$), 92.66 ($C_{(3)(4)}$), 114.78 ppm ($C\equiv N$).

2-Amino-5-phenyl-3,4-dicyanopyrrole (VIIIa). Here 1 ml of 60% sulfuric acid was added to a suspension of 1 g (3.3 mmole) of pyrrole IVa in a mixture of 50 ml of water and 25 ml of isopropyl alcohol and boiled for 10 min. The isopropyl alcohol and vapor-distilled benzaldehyde separated were then distilled off. After distillation of all of the benzaldehyde, the insoluble residue was filtered from the hot reaction mixture. The filtrate was cooled, the separated sediment was filtered off, washed with water, and recrystallized twice from isopropyl alcohol–water mixture, 1:1, or from acetic acid, dried, and 0.5 g (71%) of a substance with mp = 263-264°C was obtained.

2-Amino-5-aryl-3,4-dicyanopyrroles (VIIIa-c). Here 2-3 ml of a 30% aqueous solution of methylamine was poured into a suspension of 10 mmole of starting pyrrole IV in 15 ml of isopropyl alcohol. The mixture obtained was boiled for 1-2 min. After cooling to room temperature, 10-15 ml of water was added to the reaction mass and it was acidified with acetic acid. The precipitated sediment was filtered off, washed with aqueous isopropyl alcohol (1:1), and recrystallized from acetic acid.

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