STUDY OF THE FISCHER CYCLIZATION OF DIARYLHYDRAZONES AND RELATED SECONDARY HYDRAZONES

I. RELATIVE ORIENTING CAPACITY OF THE p-METHYL AND p-METHOXY GROUPS OF DIARYLHYDRAZINES*

V. A. Zagorevskii, N. F. Kucherova,
N. M. Sharkova, T. I. Ivanova,
and S. M. Klyuev

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A mixture of isomeric N-arylindoles is formed in the Fischer cyclization of N,N-diphenylhydrazones variously substituted in the para position by CH_3 or CH_3O groups. The intramolecular competition method makes it possible to form a judgment regarding the relative orienting capacity of the substituents in the aromatic ring in the step involving rearrangement of the enamine form of the hydrazone; in this case the effect of the rate of protonation and tautomerization of the hydrazone is excluded. It was established that the rate of rearrangement increases for the para substituents in the order $H < CH_3 < CH_3O$.

The Fischer cyclization has been, up until now, the principal method for the synthesis of diverse compounds containing an indole system. However, the absence of sufficiently precise concepts regarding the mechanism of the individual steps of the indolization of arylhydrazones hinders the purposeful synthesis of substituted indoles.

The most widely acknowledged mechanism is that proposed by Robinson (for example, see [3, 4]), which includes the following principal steps: 1) tautomeric conversion of the hydrazone to an enehydrazine; 2) formation of a new C–C bond as a result of intramolecular rearrangement; 3) cyclization with splitting out of ammonia to give an indole structure. At present the problems associated with the role of the first step and the mechanism of the second step remains unclear in many respects and are the subject of extensive discussion (for example, see [3-6]).

In order to accumulate experimental data that make possible a more profound understanding of the mechanism of Fischer indolization with respect to the individual steps of the reaction, we began a systematic study of the direction of indolization of N,N-diarylhydrazones variously substituted in the aryl groups. In the general case this approach makes it possible to ascertain the orienting capacity of the substituents in the aromatic portion of the hydrazine component under conditions of intramolecular competition with exclusion of the effect of the rates of protonation and tautomerization (first step) and cyclization (third step) on the relative rate of the rearrangement (second step). The method of competitive reactions for the study of relative reactivities has been satisfactorily substantiated (when the necessary requirements are satisfied) and is currently widely used (for example, see [7, 8]).

We selected N,N-diarylhydrazines containing methyl or methoxy groups in the para position as the primary subjects of the present investigation.

*See [1] for our preliminary communications; a brief communication regarding the results of cyclization of p-methoxy- and p-chlorodiphenylhydrazines was published simultaneously with it [2].

Scientific-Research Institute of Pharmacology, Academy of Medical Sciences of the USSR, Moscow.
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TABLE 1. Results of Indolization of Diarylhydrazines I-III

Diaryl-hydrazine	Indolization product	Relative yield, %, from PMR data	Chemical shifts,* δ, ppm	
			CH_3–C	CH_3O
I	VII	60	2,50	
	VIII	40	2,08	
II	IX	82		3,60
	X	18		3,33
III	XI	76	2,12	3,70
	XII	24	2,50	3,40
I	XIII	75	2,48	
	XIV	25	2,38	
I	XV	67	2,30	
	XVI	33	2,10	

*For C_6H_6 solutions of VII-XII and $C_6H_6 + CCl_4$ solutions of XII-XVI.

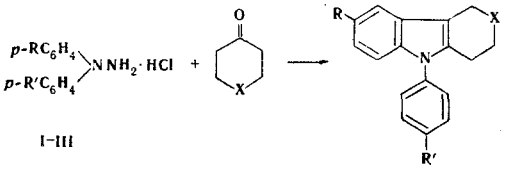
It is known (for example, see [3, 4, 9, 10]) that electron-donor groups in the para position of the aromatic portions of the hydrazine component facilitate cyclization, despite the fact that the indicated substituents occupy the meta position with respect to the carbon atom that participates in the formation of the new C–C bond. This circumstance, together with other factors, was used for serious criticism of earlier concepts regarding the rearrangement of enehydrazines as electrophilic substitution [5].

The acceleration of the rearrangement by electron-donor substituents in the para position and the reverse effect of these same substituents in the meta position with respect to the hydrazine group were explained within the framework of the concept of a [3.3] sigmatropic shift with a different rate of conversion of the hydrazone form to the enehydrazine form because of nonidentical basicities of the β-nitrogen atoms [5].

There are a number of other hypotheses invoked to explain the unusual effect of electron-donor substituents in the para position [7, 11]. It is assumed that the electronic effect of a substituent in the aryl portion of the hydrazone (or N,N'-diarylhydrazine in the case of the benzidine rearrangement [7]) is propagated to the enehydrazine portion of the molecule, as a consequence of which the aromatic ring is subject to nucleophilic attack by the negatively charged carbon atom of the enehydrazine portion of the system. However, these concepts have not been acknowledged [3].

Diarylhydrazines I-III were obtained by nitrosation of the corresponding diarylamine and reduction of the resulting N-nitroso derivative. The reaction between cyclohexanone or tetrahydro-4-thiopyrone and hydrochlorides I-III was carried out by refluxing solutions in absolute alcohol. A 15% solution of hydrogen chloride in absolute alcohol was used for the condensation of 1-methyl-4-piperidone with I.

In all cases (see Table 1), as a result of the cyclization we obtained mixtures of two possible isomers (VII-XVI) in high yields (70-90%).



I-III VII-XVI

I R=H, R'=CH_3; II R=H, R'=OCH_3; III R=CH_3, R'=OCH_3; VII–XII X=CH_2; XIII, XIV X=S; XV, XVI X=NCH_3; VII R=CH_3, R'=H; VIII R=H, R'=CH_3; IX R=OCH_3, R'=H; X R=H, R'=OCH_3; XI R=OCH_3, R'=CH_3; XII R=CH_3, R'=OCH_3; XIII R=CH_3, R'=H; XIV R=H, R'=CH_3; XV R=CH_3, R'=H, XVI R=H, R'=CH_3

Indoles VII-IX, XI-XIII, and XV, the structures of which were established on the basis of UV, IR, and PMR spectroscopic data, were isolated in the individual states, and VIII, IX, and XII were also obtained by Ullmann arylation of the corresponding tetrahydrocarbazoles.

In the case of cyclization of diarylhydrazine III with cyclohexanone it was shown that the heating time and a change in the acidity of the medium (at 10% solution of hydrogen chloride in alcohol) do not affect the ratio of isomers formed.

The relative yields of the indole compounds in the reaction mixtures were determined by PMR spectroscopy by measurement of the intensities of the signals of the protons of the methyl or methoxy groups. The signals of the CH_3 or CH_3O protons of the aromatic portion of the molecule were identified in most

cases by the addition of genuine samples of the substances. The signals of the $N=CH_3$ protons can be identified by protonation. In all of the cases that we investigated, the signals of the protons of the CH_3 and CH_3O groups in the N-aryl portion of the indole molecules was found at stronger field as compared with the signals of the same groups in the indole ring on passing from dilute solutions in CCl_4 to solutions in benzene (see Table 1).

Fragmentation under the influence of electron impact of tetrahydrocarbazole derivatives VII-IX is characterized by successive dehydrogenation of the molecular ion and the resulting ions (M − 1H, M − 2H, M − 3H, M − 4H, M − 5H...), splitting out of the substituents (as $CH_3^{\cdot}$) in the benzene rings, and by the formation of $[M-C_2H_4]^+$ ions as observed for some other tetrahydrocarbazoles, including the N-phenyl derivative (without substituents) [12]; the intensity of the ions of the indole fragments corresponding to splitting out of an aryl residue from the nitrogen atom of the $[M-1]^+$ molecular ion proved to be insignificant ($\leq 3\%$ of the molecular peak), and this hinders the quantitative determination of the isomeric substances in the mixtures by means of mass spectroscopy under variable operating conditions.

It is seen from Table 1 that in the case of para substituents, the orienting capacity of the CH_3O group (for the same ketone component − cyclohexanone) exceeds that of the hydrogen atom by a factor of 4.5 and that the orienting capacity of the CH_3 group exceeds that of the hydrogen atom by a factor of three. In conformity with this, the activating effect of the CH_3 group is higher by a factor of 1.5 than that of the hydrogen atom.* We also noted the effect of the structures of the ketones on the relative yields of isomeric indoles.

Thus our proposed method for competitive closing of the indole ring makes it possible to form a direct judgment regarding the relative rate of the rearrangement, i.e., the second step of the Fischer reaction, inasmuch as the first step (which includes protonation), i.e., tautomerization of the hydrazone to an enehydrazine, in this case is common to the formation of each of the two isomers. In addition, this method can be used to sufficiently unambiguously solve the problem of whether or not the rearrangement of the eneamines is nucleophilic aromatic substitution.

The experimental results obtained in this research cannot be explained by the existing hypotheses regarding the mechanism of the rearrangement of eneamines if additional assumptions are not invoked.

EXPERIMENTAL

The UV spectra of alcohol solutions (c 10^{-4}-10^{-5} M, d 1 cm) of the compounds were recorded with a Perkin-Elmer 402 spectrophotometer. The IR spectra of chloroform solutions (c 0.1 M, d 0.17) were recorded with a Perkin-Elmer 457 spectrometer. The mass spectra were obtained with an MKh-1303 spectrometer with a system for direct introduction into the ion source at an ionizing voltage of 50 or 30 V (the ionization chamber temperature was 150°). The PMR spectra of solutions of the compounds in benzene, carbon tetrachloride, or carbon tetrachloride−benzene were recorded with a Varian T-60 spectrometer or with a Varian HA-100 spectrometer (in the case of CCl_4 solutions of VII and XV). Special attention was directed to the reproducibility of the experiments (particularly in the case of reactions with cyclohexanone) and the convergence of the results of PMR analysis in all of the principal steps of the workup of the reaction mixtures (for example, prior to drying of the extracts over a solid drying agent, if one was used, and after drying; prior to purification by means of Al_2O_3 and after this operation, etc.); the deviations in the analyses during workup of the reaction mixtures were found to be within the limits of the errors in the measurements ($\leq 10\%$ of the relative yields). A loose layer of Al_2O_3 was used for thin-layer chromatography (TLC) [heptane−benzene (9 : 1)]. The chromatographic mobilities of indoles VII and VIII and XIII and XIV proved to be identical, even when the solvent systems and the degree of activity of the Al_2O_3 were varied. The presence or absence of the starting ketones, hydrazines, and the corresponding diphenylamine was also monitored by means of PMR spectroscopy and TLC. Diphenylamines are formed, as a rule, under the conditions of Fischer condensation of hydrazines. These same methods were also used to confirm that hydrazones were absent in the reaction mixtures.

N-(p-Methoxyphenyl)-p-toluidine (IV). A mixture of 74.5 g (0.5 mole) of acetotoluidine, 145 g (0.75 mole) of p-bromoanisole, 69 g (0.5 mole) of calcined potassium carbonate, and 2 g of copper powder was refluxed with stirring in 200 ml of nitrobenzene for 29 h. Alcohol (250 ml) and 175 ml of concentrated

*While the present paper was in press we became aware of a brief communication [13] in which Ishii and co-workers noted that the cyclization of N'-(substituted phenyl)-N'-phenylhydrazones of ethyl pyruvate proceeds mainly in the electron-enriched aromatic ring (no data whatsoever regarding the ratio of the reaction products and the character and orientation of the substituents were presented).

TABLE 2. N,N-Diarylhydrazine Hydrochlorides (I-III)

Compound	mp, °C	Empirical formula	Found, %				Calc., %				Yield, %
			C	H	Cl	N	C	H	Cl	N	
I	136—138[a] (dec.)	$C_{13}H_{14}N_2 \cdot HCl$	66,6	6,4	15,1	11,9	66,5	6,4	15,1	11,9	85
II	118—119[a] (dec.)	$C_{13}H_{14}N_2O \cdot HCl$[b]	62,4	6,0	14,2	11,4	62,3	6,0	14,2	11,2	85
III	109—110[c] (dec.)	$C_{14}H_{15}N_2O \cdot HCl$	63,4	6,6	13,1	10.7	63,4	6,6	13,4	10,6	85

[a] From isopropyl alcohol.
[b] The base had mp 72.5-73.5° (from alcohol) (mp 58-60° [15]). Found: C 72.8; H 6.6; N 13.2%. Calculated: C 72.9; H 6.6; N 13.1%.
[c] From ethyl acetate–chloroform.

hydrochloric acid were added to the residue, and the mixture was refluxed for 5.5 h. It was then poured into a large volume of water and worked up to give 47 g (39.5%) of amine IV with mp 85-86° (successively from alcohol and benzene). Found: C 79.0; H 7.1; N 6.9%. $C_{14}H_{15}NO$. Calculated: C 78.8; H 7.1; N 6.6%.

N-Nitroso-N-phenyl-p-toluidine (V). Concentrated sulfuric acid (3.6 ml) was added with stirring to a suspension of 6 g (32.5 mmole) of N-phenyl-p-toluidine [14] in 80 ml of alcohol, after which the mixture was cooled to −3° and a solution of 2.8 g (40.6 mmole) of sodium nitrite in 8 ml of water was added. The mixture was then stirred at room temperature for 30 min and poured into water. Workup gave 6.5 g (93.5%) of a product with mp 55-56° (from alcohol). Found: C 73.7; H 5.6; N 12.9%. $C_{13}H_{13}N_2O$. Calculated: C 73.6; H 5.7; N 13.2%.

N-Nitroso-N-(p-methoxyphenyl)-p-toluidine (VI). This compound, with mp 68-69° (from hexane), was similarly obtained in 98% yield from amine IV. Found: C 69.7; H 5.9; N 11.7%. $C_{14}H_{14}N_2O_2$. Calculated: C 69.4; H 5.8; N 11.6%.

N,N-Diarylhydrazine Hydrochlorides (I-III, Table 2). A cooled (with ice water) solution of 57 mmole of lithium aluminum hydride in 70 ml of absolute ether was added dropwise to 47 mmole of nitrosamines V, N-nitroso-N'-(p-methoxyphenyl)-N-phenylamine [15], or VI in 80 ml of absolute ether, after which the mixture was cooled and stirred for 2 h. It was then decomposed with moist ether and water, after which the ether solution was separated, and the aqueous solution was extracted with ether. The combined ether solutions were dried with calcined magnesium sulfate, and hydrochlorides I-III were isolated by the addition of a solution of hydrogen chloride in alcohol.

Fischer Condensation of N-Phenyl-N-(p-tolyl)hydrazine Hydrochloride (I). A) With cyclohexanone. A mixture of 2 g (8.5 mmole) of hydrochloride I and 0.92 g (9.4 mmole) of cyclohexanone in 30 ml of absolute alcohol was refluxed for 20 min, after which it was poured into water. The aqueous mixture was extracted with benzene, and the benzene solution was washed successively with 10% hydrochloric acid solution, five to six times with concentrated hydrochloric acid, and water until it was neutral. The benzene solution was then dried with calcined magnesium sulfate and evaporated. The residue was chromatographed on activity IV aluminum oxide with heptane–benzene (9 : 1); 2 g (88%) of a mixture of indoles VII and VIII with R_f 0.59 (activity IV Al_2O_3) was eluted. UV spectrum: λ_{max} 226, 257, and 290 nm (log ε 4.57, 4.16, and 4.03). IR spectrum:* 1600 (s), 1507 (vs), and 1465 cm^{-1} (s). Found: C 87.2; H 7.5; N 5.7%. $C_{19}H_{19}N$. Calculated: C 87.3; H 7.3; N 5.4%.

The mixture of indoles VII and VIII was crystallized from methanol to give indole VII with mp 79.5-80.5° (from alcohol). UV spectrum: λ_{max} 226, 270, and 295 nm (log ε 4.48, 4.12, and 3.9). IR spectrum: 1590 (s), 1498 (vs), and 1465 cm^{-1} (s). IR spectrum (KBr): 699 and 763 (vs, monosubstituted benzene), and 792 and 872 cm^{-1} (vs and m, 1,2,4-trisubstituted benzene). PMR spectrum (in CCl_4): δ 1.5-2.1 (2-CH_2 and 3-CH_2), 2.35 (6-CH_3, s), 2.3-2.9 (1-CH_2 and 4-CH_2), 6.75 (7-H, J_{ortho} = 8.5 Hz, J_{meta} = 1.2 Hz), 7.0 (5-H, J = 8.5 Hz), 7.12 (8-H), and 7.2-7.6 ppm (5-H, C_6H_5). Found: C 87.3; H 7.5; N 5.5%. $C_{19}H_{19}N$. Calculated: C 87.3; H 7.3; N 5.4%.

The mother liquors from the crystallization of indole VII were evaporated, and the residue was dissolved in isopropyl alcohol. The alcohol solution was cooled to 0°, and three portions of precipitates with

*The arbitrary symbols for the intensities of the bands in the IR spectra are as follows: w is weak, m is medium, s is strong, and vs is very strong.

mp 68-71, 47-49, and 44-46° were separated fractionally. The last two portions were combined and recrystallized in the same way, and the precipitate (mp 49-51°) was dissolved in hexane. The hexane solution was cooled to 0° to isolate indole VIII with mp 58-59°. This same substance was obtained by arylation of 58.5 mmole of 1,2,3,4-tetrahydrocarbazole with 8.8 mmole of p-iodotoluene in the presence of 8.7 mmole of calcined potassium carbonate and 0.2 g copper bronze (the product in this case had 59.5-60.5°). IR spectrum (KBr): 745 (vs, 1,2-disubstituted benzene) and 820 cm^{-1} (s, 1,4-disubstituted benzene). PMR spectrum (in CCl_4): δ 1.5-1.9 (2-CH_2 and 3-CH_2), 2.35 (4'-CH_3), 2.3-2.8 (1-CH_2 and 4-CH_2), and 6.8-7.4 ppm (8-H, aromatic protons). Found: C 87.4; H 7.5; N 5.5%. $C_{19}H_{19}N$. Calculated: C 87.3; H 7.3; N 5.4%.

B) With tetrahydro-4-thiopyrone. A 0.82-g (0.7 mmole) sample of tetrahydro-4-thiopyrone was refluxed for 15 min with 1.5 g (0.64 mmole) of hydrochloride I in 12 ml of absolute alcohol, after which the mixture was poured into water, and the aqueous mixture was extracted with ether. The extract was washed with 15% hydrochloric acid and water, dried with magnesium sulfate, and evaporated to give 1.5 g (84%) of a mixture of indoles XIII and XIV with R_f 0.3 (anhydrous Al_2O_3). PMR spectrum (in CCl_4): δ 2.34 (8-CH_3, 4'-CH_3), 2.74 (3-CH_2, 4-CH_2), 3.72 (1-CH_2), and 6.6-7.48 ppm (aromatic protons). PMR spectrum (in CCl_4–benzene): δ 2.38 (4-CH_3, s) 2.48 (8-CH_3, s), 2.78 (CH_2–CH_2), and 3.95 ppm (1-CH_2). Cold ether was added to a mixture of XIII and XIV, and the mixture was filtered to give 0.7 g of indole XIII with mp 93.5-94.5° (from alcohol). PMR spectrum (in CCl_4): δ 2.38 (8-CH_3, s), 2.74 (CH_2–CH_2), 3.74 (1-CH_2, s), 6.65 (7-H, J_{ortho} = 8.8 Hz, J_{meta} = 1.6 Hz), 6.85 (6-H, J_{ortho} = 8.8 Hz), 7.1 (8-H), and 7.2-7.5 ppm (5H, C_6H_5). Found: C 77.3; H 5.9; N 5.1; S 11.3%. $C_{18}H_{17}NS$. Calculated: C 77.4; H 6.1; N 5.0; S 11.5%.

C) With 1-methyl-4-piperidone. A 0.8-g (0.34 mmole) sample of hydrochloride I was refluxed for 30 min with 0.5 g (0.39 mmole) of 1-methyl-4-piperidone in 10 ml of a 15% solution of hydrogen chloride in absolute alcohol, after which the mixture was poured into water. The aqueous mixture was then made alkaline with 40% potassium hydroxide solution and extracted with ether. The ether solution was washed with water, dried with magnesium sulfate, and evaporated to give 0.8 g (95%) of a mixture of XV and XVI with R_f 0.44 and 0.31, respectively (anhydrous Al_2O_3). PMR spectrum (in CCl_4–benzene): δ 2.1 (4'-CH_3, s), 2.3 (all of the remaining CH_3 groups), 2.5 (CH_2–CH_2), and 3.5 ppm (4-CH_2, s). PMR spectrum (in benzene–CF_3COOH–CD_3OD): δ 2.43 (4'-CH_3), 2.6 (6-CH_3, s), and 3.0 ppm (CH_3–$\overset{+}{N}$). The mixture of XV and XVI was crystallized from 70% alcohol to isolate indole XV with mp 126-127°. PMR spectrum (in CCl_4): δ 2.42 CH_3, s), 2.5 (N–CH_3, s), 2.75 (1-CH_2, 2-CH_2), 3.7 (4-CH_2, s), 7.0 (1H, 7-H, J_{ortho} = 8.5 Hz, J_{meta} = 1.6 Hz), 7.3 (8-H, J_{ortho} = 8.5 Hz), 7.4 (5-H, partially overlapped with the low-field component of the 8-H doublet), and 7.5-7.8 ppm (5H, C_6H_5). Found: C 82.8; H 7.5; N 10.4%. $C_{19}H_{20}N_2$. Calculated: C 82.6; H 7.3; N 10.2%.

Condensation of N-Phenyl-N-(p-methoxyphenyl)hydrazine Hydrochloride II with Cyclohexanone. Similarly, 4 mmole of hydrochloride II and 4.5 mmole of cyclohexanone gave 0.84 g (72%) of a mixture of IX and X with R_f 0.27 and 0.43, respectively (activity II Al_2O_3). Found: C 82.5; H 7.0; N 5.2%. $C_{19}H_{19}NO$. Calculated: C 82.3; H 6.9; N 5.0%.

Crystallization of the mixture of IX and X from alcohol gave indole IX with mp 81-82°. UV spectrum: λ_{max} 223, 277, and 302 nm (log ε 4.45, 4.19, and 3.96). IR spectrum: 1615 (m), 1590 (m), 1498 (s), and 1475 cm^{-1} (s). PMR spectrum (in CCl_4): δ 1.6-2.0 (2-CH_2 and 3-CH_2), 2.3-2.9 (1-CH_2 and 4-CH_2), 3.7 (6-CH_3O, s), 6.5 (7-H, J_{ortho} = 9.0 Hz, J_{meta} = 2.5 Hz), 6.75 (5-H, J = 2.5 Hz), 6.9 (8-H, J = 9.0 Hz), and 7.1-7.5 ppm (5H, C_6H_5). Found: C 82.8; H 7.0; N 5.2%. $C_{19}H_{19}NO$. Calculated: C 82.3; H 6.9; N 5.0%.

Tetrahydrocarbazole IX was also obtained by arylation of 6-methoxy-1,2,3,4-tetrahydrocarbazole with iodobenzene; the product had mp 80-81°, and no melting-point depression was observed for a mixture of it with the sample obtained by the Fischer reaction.

Condensation of N-(p-Tolyl)-N-(p-methoxyphenyl)hydrazine Hydrochloride (III) with Cyclohexanone. The reaction was carried out as above to give a mixture of XI and XII in 88% yield. UV spectrum: λ_{max} 223, 276, and 300 nm (log ε 4.73, 4.43, and 4.20). IR spectrum: 1623 (w), 1600 (m), 1520 (m), 1508 (vs), and 1480 cm^{-1} (s).

Heptane was added to the mixture of XI and XII, and the indole (XI) that crystallized out was removed by filtration to give a product with mp 79-80° (from heptane) and R_f 0.21 (activity II Al_2O_3). UV spectrum: λ_{max} 223, 275, and 300 nm (log ε 4.46, 4.19, and 3.95). IR spectrum: 1620 (m), 1590 (m), 1520 (s), and 1480 cm^{-1} (s). IR spectrum (KBr): 795 and 875 (vs and m, 1,2,4-trisubstituted benzene) and 823 cm^{-1} (s, 1,4-disubstituted benzene). PMR spectrum (in CCl_4): δ 1.65-2.05 (2-CH_2 and 3-CH_2), 2.35 (4'-CH_3, s), 2.35-2.85 (1-CH_2 and 4-CH_2), 3.75 (6-CH_3O, s), 6.55 (7-H, J_{ortho} = 9.0 Hz, J_{meta} = 2.5 Hz), 6.75 (5-H, J_{meta} = 2.5 Hz), 6.95 (8-H, J = 9.0 Hz), and 7.15 ppm (4H, C_6H_5). Found: C 82.2; H 7.3; N 5.0%. $C_{20}H_{21}NO$. Calculated: C 82.5; H 7.3; N 4.8%.

The combined mother liquors were evaporated, and indole XII with mp 110-111° (from alcohol) and R_f 0.36 (activity II Al_2O_3), was isolated from the residue by preparative chromatography on a loose layer of aluminum oxide. PMR spectrum (in CCl_4): δ 1.7-2.2 (2-CH_2 and 3-CH_2), 2.4 (6-CH_3, s), and 3.8 ppm (4'-CH_3O, s). Found: C 82.2; H 7.4; N 5.2%. $C_{20}H_{21}NO$. Calculated: C 82.5; H 7.3; N 4.8%.

Indole XII was also synthesized by reaction of 6-methyl-1,2,3,4-tetrahydrocarbazole with p-bromoanisole; the product had mp 110-111°. No melting-point depression was observed for a mixture of a sample of this product with a sample of indole XII obtained as indicated above, and their PMR spectra were identical.

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THERMOLYSIS OF 1-DIALKYLAMINOANTHRAQUINONES — NEW METHOD FOR THE SYNTHESIS OF ANTHRA[1,9-bc]PYRROLE DERIVATIVES

V. Ya. Denisov, L. N. Anishina, and E. P. Fokin

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1-Dialkylaminoanthraquinones undergo cyclization to give anthra[1,9-bc]pyrrole derivatives on thermolysis in pyridine and other polar solvents. The cyclization proceeds through intramolecular rearrangement of 1-dialkylaminoanthraquinones to anthra[1,9-de]-1,3-oxazine derivatives and through subsequent contraction of the 1,3-oxazine ring to a pyrrole ring.

Heterocyclic systems containing an anthracene ring condensed in the 1,9 position with a heterocyclic ring are the basis of many vat and acid dyes and dyes for synthetic materials [1]. One such system is anthra[1,9]bc]pyrrole.*

*This system can also considered to be naphth[1,2,3-cd]indole (see [2]). We have adopted the anthra[1,9-bc]pyrrole designation in order to emphasize the relationship to anthracene derivatives, on the basis of which the synthesis of the system under consideration is usually realized.

Novosibirsk Institute of Organic Chemistry, Siberian Branch, Academy of Sciences of the USSR.

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