Tests of the biological properties of the 1-azafluorene derivatives (on chlorella and sugar beet cells) demonstrated that quaternary salts III and VI have herbicidal and fungicidal activity. Pseudoazulene X displayed herbicidal activity. The toxicity of this compound in mice is relatively high, viz., LD_{50} = 50 mg/kg.

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SYNTHESIS OF 3-AZAFLUORENE AND 2H-2-METHYLINDENO[1,2-c]PYRIDINE

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4-Methyl-3-phenylpyridine was isolated from the mixture of four isomeric methylphenylpyridines formed in the condensation of crotonaldehyde with phenylacetaldehyde (β-phenylethanol or phenylacetylene) with ammonia in the presence of a cadmium-calcium phosphate catalyst. 4-Methyl-3-phenylpyridine was converted to 3-azafluorene by catalytic dehydrocyclization. A representative of a new series of pseudoazulenes, viz., 2H-2-methylindeno[1,2-c]-pyridine, was obtained by treatment of 3-azafluorene methiodide with sodium hydroxide solution; the product was a crystalline black substance that remained unchanged during storage in air for 1 month.

In a previous communication [1] we presented the results of research on the synthesis and study of some transformations of N-substituted 1H-indeno[2,1-b]pyridines. These pseudoazulenes, in which the phenylene ring has a benzenoid structure, were isolated in the form of deeply colored, stable (under ordinary storage conditions), crystalline substances. With respect to their stabilities, they differ from their 1H-indeno[1,2-b]- and 2H-indeno[2,1-c] pyridine analogs, which are unstable and undergo changes in air even at room temperature [2, 3]. The assumption that the instability of these pseudoazulenes is due to the quinoid structure of their phenylene ring is evidently substantiated. Considering this, one might have assumed that N-substituted 2H-indeno[1,2-c]-pyridines would also be stable, since their phenylene ring also has a benzenoid structure.

The most suitable starting compounds for the synthesis of pseudoazulenes of this type are 3-azafluorene and substituted 3-azafluorenes. A relatively simple method for the production of isomeric (with respect to the position of the nitrogen atom) azafluorenes is the catalytic dehydrocyclization of the correspondingly substituted methylarylpyridines. In particular, 4-methyl-3-phenylpyridine (I) can be converted to 3-azafluorene by this method. To synthesize this pyridine base we used the Chichibabin method [4, 5], viz., cyclocondensation of aldehydes with ammonia. The condensation of crotonaldehyde and phenylacetaldehyde with ammonia was carried out in the vapor phase. Instead of aluminum oxide, which was previously used in reactions of this type, we used a cadmium-calcium phosphate catalyst.

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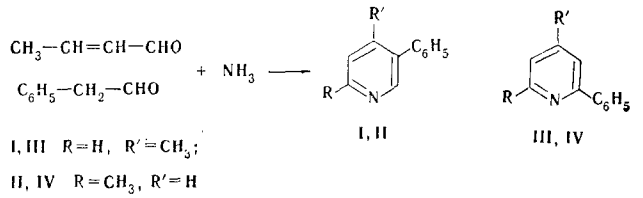
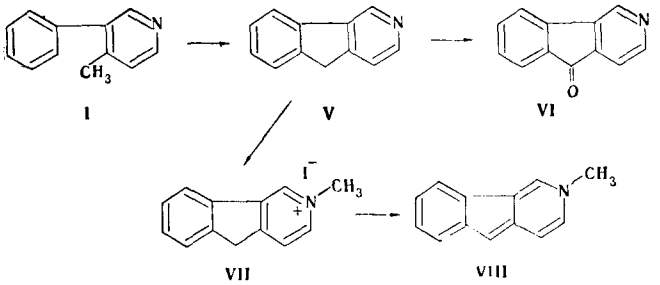


We established that in this case the following isomeric pyridines bases are formed: 4-methyl-3-phenyl- (I), 2-methyl-5-phenyl- (II), 4-methyl-2-phenyl- (III), and 2-methyl-6-phenylpyridine (IV). It was demonstrated by analysis by gas–liquid chromatography (GLC) that substituted pyridines I and II (in up to 27 and 28% yields, respectively) are formed in preponderant amounts. Pyridines III and IV are formed in 1-3% yields.

When β-phenylethanol was introduced in the starting mixture as the phenyl-containing component in place of phenylacetaldehyde, the principal reaction products were (in ∿ 55% overall yield) substituted pyridines I and II, with a threefold preponderance of the second isomer. The phenylethanol is evidently dehydrogenated in the first step to give phenylacetaldehyde, as evidenced by the formation of the same β-phenylpyridines I and II as in the case of the condensation examined above.

The overall yield of bases I-IV decreases considerably when phenylacetaldehyde is replaced by phenylacetylene, and α-phenylpyridine bases III and IV are formed in somewhat greater amounts as compared with β-phenylpyridines I and II. In this case the initial rate-determining step is evidently either hydration of phenylacetylene to acetophenone or its amination to α-aminostyrene. The formation of these intermediates can be assumed on the basis of the fact that substituted pyridines with a phenyl group in the α-position, particularly pyridine IV, can be formed only from them in the condensation step. The isolation of individual II-IV and pyridine base I necessary for the synthesis of 3-azafluorene was carried out by chromatography or crystallization of their picrates.

3-Azafluorene (V) was obtained by catalytic dehydrocyclization of pyridine base I by the method used for the syntheses of 2-azafluorene [6].



3-Azafluorene is described [7] as a relatively unstable and easily oxidizable substance. 3-Azafluorenone (VI) was obtained from a sample of the 3-azafluorene (V) that we isolated by prolonged passage of air through a solution in heptane at room temperature.

N-Methyl-3-azafluorenium iodide (VII) was obtained in quantitative yield from 3-azafluorene (V) and methyl iodide; treatment of VII with sodium hydroxide solution gave 2H-2-methylindeno[1,2-c]pyridine (VIII). Pseudoazulene VIII was isolated in the form of black crystals that remained unchanged when they were stored in air for 1 month. The data from the PMR and mass spectra confirm its pseudoazulene structure. The absorption band in its UV spectrum that is characteristic for pseudoazulenes is shifted to an even greater extent to the long-wave region (at 620 nm) as compared with the analogous band of 1H-1-methylindeno[2,1-b]pyridine (at 580 nm) [1].

EXPERIMENTAL

The PMR spectra were recorded with a Bruker WP-80 spectrometer. The mass spectra were obtained with an MKh-1303 spectrometer at 70 eV. The UV spectra of solutions of the compounds in ethanol were recorded with a Hitachi spectrophotometer. The IR spectra of KBr pellets

TABLE 1. Pyridine Bases I-IV

Compound	mp of the picrate, °C: Found	mp of the picrate, °C: Literature data	PMR spectrum (in CCl_4): Standard	PMR spectrum (in CCl_4): δ, ppm	Yield, % by method: A*	B	C
I	142—143	145 [8]	Tetramethylsilane (TMS) (internal)	2,20 (s, 3H, 4-CH_3), 7,00 (d, 1H, 5-H), 8,27 (br s, 2H, 2-H+6-H), 7,1—7,3 (m, 5H, aromatic protons)	17/27	3/5	15
II	179—181	181—182 [10]	TMS (internal)	2,06 (s, 3H, 2-CH_3), 6,56 (d, 1H, 3-H), 7,11 (d, 1H, 4-H), 8,15 (s, 1H, 6-H), 6,67—7,0 (m, 5H, aromatic protons)	25/28	3/4	40
III	185—186	187,5—188,5 [9]	D_2O (external)	2,20 (s, 3H, 4-CH_3), 6,69 (d, 1H, 5-H), 8,24 (d, 1H, 6-H), 7,0—7,9 (m, 6H, 3-H+ aromatic protons)	~1	4/8	Traces
IV	129—130	131 [10]	D_2O (external)	2,42 (s, 3H, 2-CH_3), 6,72 (d, 1H, 3-H), 7,80—8,00 (m, 2H, 4-H+ortho protons of the phenyl ring) 7,07—7,33 (m, 5H, 5-H + aromatic protons)	1/3	6/15	Traces

*The yield in the case of the smallest amount of crotonaldehyde used in the reaction is indicated in the numerator, while the yield in the case of the maximum aount of crotonaldehyde is indicated in the denominator.

were recorded with a UR-20 spectrometer. Analysis of pyridine bases I-IV by GLC was carried out with an LKhM-7A chromatograph [with a 1.8 × 3 mm column, 5% XE-60 on Chromaton at 150-175°C, helium as the carrier gas (at a flow rate of 75 ml/min), and a catharometer as the detector].

4-Methyl-3-phenyl-, 2-Methyl-5-phenyl-, 4-Methyl-2-phenyl-, and 2-Methyl-6-phenylpyridines (I-IV). A mixture of phenylacetaldehyde, crotonaldehyde, and ammonia (in a molar ratio of 1:2-4:10) was passed at a constant space rate (2 h^{-1}) through a quartz reactor of the flow type filled with 100 ml of a cadmium-calcium phosphate catalyst [10-13% CdO, 41-45% CaO, and 41-45% (by weight) P_2O_5]. The temperature in the reaction zone was 375-400°C. The condensate was treated with 18% hydrochloric acid until it was acidic with respect to Congo. The neutral substances were extracted with ether, and the aqueous solution was treated with sodium hydroxide. The reaction products were extracted with ether, and the ether extract was dried with $MgSO_4$. The residue from the ether extract was dried with $MgSO_4$. The residue from the ether extract data from analysis by GLC are presented in Table 1 (method A)] was distilled with collection of the fraction containing pyridine bases I-IV with bp 100-130°C (2 mm). The pyridine bases that were formed in preponderant amounts were isolated by chromatography [Al_2O_3, elution with ether–heptane (1:1)] or by crystallization of the picrates.

The experiment and workup were carried out similarly for the following molar ratios of the starting substances: phenylacetylene:crotonaldehyde:ammonia = 1:(1-7):10 (Table 1, method B) and β-phenylethanol:crotonaldehyde:ammonia = 1:3:8 (Table 1, method C).

The principal peaks in the mass spectra of pyridine bases I-IV are the molecular-ion peaks (M^+) with m/e 169, which confirm the empirical formulas of these compounds.

Elemental analysis of the picrate compounds I-IV corresponds to the calculated data.

3-Azafluorene (V). A solution of 23 g (0.13 mole) of pyridine I in 30 ml of benzene was at a constant rate in the course of 5 h through a steel reactor containing 50 ml of K-16 catalyst at 520-540°C. The residue after removal of the benzene from the catalysate was distilled with collection of the fraction with bp 120-130°C (2 mm), from which 2.1 g (9%) of azafluorene V was isolated by chromatography [Al_2O_3, elution with ether–heptane (1:1)]. Mass spectrum: M^+ 167 (100), $[M - H]^+$ 166 (17), $[M - HCN]^+$ 140 (18), $[M - H–HCN]^+$ 139 (29). The picrate of V had mp 184-185°C (from ethanol (mp 187°C [8]).

3-Azafluorenone (VI). A stream of air was passed through a solution of 0.11 g (0.65 mmole) of 3-azafluorene (V) in 10 ml of heptane for 36 h, and the resulting precipitate was crystallized from ether–heptane (1:2) to give 0.07 g (57%) of 3-azafluorenone (VI) in the form of yellow crystals with mp 129-130°C (mp 128-130°C [8] and 132-133°C [7]). Mass spectrum: M^+ 181 (100), 154 (20), $[M - CO]^+$ 153 (45), 127 (26), $[M - CO–HCN]^+$ 126 (58), M^{+2} 90.5 (14.5). 3-Azafluorenone oxime had mp 232-234°C (from acetone) (mp 233-235°C [8]).

N-Methyl-3-azafluorenium Iodide (VII). A 1-g (8 mmole) sample of methyl iodide was added to a solution of 0.65 g (3.9 mmole) of 3-azafluorene (V) in 10 ml of acetone, and the mixture was maintained at room temperature for 24 h. The precipitated crystals were removed by filtration, washed with ether, and recrystallized from acetone to give 1.1 g (91%) of N-methyl-3-azafluorenium iodide (VII) as gray-green crystals with mp 188-189°C (from acetone). Found: N 4.4%. $C_{13}H_{12}IN$. Calculated: N 4.5%.

2H-2-Methylindeno[1,2-c]pyridine (VIII). A 2-ml sample of 20% sodium hydroxide solution was added dropwise to a solution of 0.15 g (0.48 mmole) of salt VII in 10 ml of water, and the resulting precipitate was separated and recrystallized from acetone (a dark-blue solution) to give 0.07 g (80%) of 2H-2-methylindeno[1,2-c]pyridine as black crystals with a greenish tint with mp 224-226°C. Mass spectrum: M^+ 181 (66), 167 (27), $[M - CH_3]^+$ 166 (42), $[M - CH_3–HCN]^+$ 139 (32), M^{+2} 90.5 (16), 57 (100), 55 (95). PMR spectrum (in $CDCl_3$): 7.90 (d, J_{21} = 7.0 Hz, 1H, 2-H), 7.82 (s, 1H, 4-H), 7.59 (q, J_{56} = 7.0 Hz, J_{57} = 1.5 Hz, 5-H), 7.30 (m, 7-H), 6.91-7.14 (m, 2H, 6-H + 8-H), 6.69 (q, J_{12} = 7.0 Hz, J_{14} = 1.5 Hz, 1-H), 6.42 (s, 1H, 9-H), and 3.58 ppm (s, 3H, N–CH_3). UV spectrum, λ_{max}(log ε): 258 (4.40), 375 (3.70), 620 nm (3.97). IR spectrum, cm^{-1}: 1645 s, 1600 s, 1525 m, 1450 s, 1355 s, 1228 s, 1170 s, 1150 m, and 1135 m. Found: N 7.3%. $C_{13}H_{11}N$. Calculated: N 7.7%.

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