out until the starting orange compound became completely colorless) and also by refluxing IV in DMF (the mixture was refluxed until the solution turned orange). Found: C 68.5; H 4.3; N 10.0%. $C_{15}H_{12}N_2O_3$. Calculated: C 68.6; H 4.3; N 10.0%.

The alcohol solution after separation of V was evaporated to dryness, and the residue was treated with diethyl ether to remove the ethyl benzoate and crystallized twice from dioxane to give snow-white cubic crystals with mp 216°C that were identified as 1-methyl-3-oximinophenacylbenzimidazolone (III). The yield was 0.06 g (7%).

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RESEARCH ON THE CHEMISTRY OF 2-HETARYLBENZIMIDAZOLES.

2.* SYNTHESIS AND PROPERTIES OF 1-METHYL-2-(1'-METHYL-2'-PYRROLYL)BENZIMIDAZOLE

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UDC 547.748'785.5.07

The condensation of 1-methyl-2-formylpyrrole with o-phenylenediamine gave 2-(1'-methyl-2'-pyrrolyl)benzimidazole, which was subjected to methylation. The alkylation product was subjected to electrophilic substitution. The substituent is incorporated in the 4 or 5 position of the hetaryl ring; however, bromination of 1-methyl-2-(1'-methyl-2'-pyrrolyl)benzimidazole leads to the formation of the mono-, di-, and tribromo derivatives, depending on the conditions. The acidophobic properties of the pyrrole ring are partially lost as a consequence of the effect of the benzimidazole ring.

We have previously studied electrophilic substitution in the furan and thiophene rings in 2-(2'-furyl)benzimidazole (I) and 2-(2'-thienyl)benzimidazole (II) [1]. Despite the acidophobic properties of the furan and thiophene rings and the rather severe conditions of the transformations, electrophilic substitution reactions in these compounds proceed smoothly and give the products in high yields.

It seemed of interest to study the behavior of 2-(2'-pyrrolyl)benzimidazole in electrophilic substitution reactions and to compare the relative reactivities of the furan, thiophene, and pyrrole rings in π conjugation with the benzimidazole ring.

2-(2'-Pyrrolyl)benzimidazole (III) was obtained [2] by reaction of o-phenylenediamine with 2-formylpyrrole and subjected to methylation. In this reaction III reacts only at the NH group of the imidazole ring to give 1-methyl-2-(2'-pyrrolyl)benzimidazole (IV). 2-(1'-Methyl-2'-pyrrolyl)benzimidazole (V) was therefore synthesized from 1-methyl-2-formylpyrrole. The product (VI) of methylation of the latter at the N atom of the imidazole ring was sub-

*See [1] for Communication 1.

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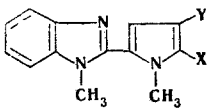
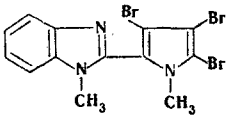
jected to reaction with electrophilic reagents, viz., acetyl nitrate, a mixture of sulfuric and acetic acids, a solution of bromine in dichloroethane, and formaldehyde in an aqueous medium.



VII-XI



XII

VII X=H, Y=NO_2; VIII X=H, Y=SO_3H; IX X=Br, Y=H; X X=Br, Y=Br; XI X=CH_2OH, Y=H

2-(2'-Pyrrolyl)benzimidazole displays less stability with respect to electrophilic agents (resinification processes are observed under severe conditions) than 2-(2'-furyl)- and 2-(2'-thienyl)benzimidazoles, and the reactions were therefore carried out under milder conditions than in the case of I and II. The orientation of the substituent incorporated in the pyrrole ring depends on the pH of the medium. 5-Substituted pyrrolylbenzimidazoles are formed in aprotic solvents. The PMR spectra of IX and XI contain two doublet signals at δ6.5 and 6.15 ppm and at 6.53 and 6.3 ppm with $J_{3,4}$ = 4 and 3 Hz, which are characteristic for the protons attached to the carbon atoms in the 3 and 4 positions.

The protonation of the benzimidazole ring, which increases its electrophilicity, facilitates incorporation of the substituent in the 4 position of the pyrrole ring. Two singlet signals with δ 7.63 and 7.07 and 7.67 and 7.00 ppm, which are related, respectively, to the protons in the 5 and 3 positions of the pyrrole ring, are observed in the PMR spectra of VII and VIII.

The reaction of VI with the electrophilic agents indicated above leads to the production of monosubstituted VII, VIII, and XI. Depending on the conditions, the bromination of VI leads to mono- di-, and tribromo derivatives: the 5-bromo derivative is formed in dichloroethane at 0°C, the 4,5-dibromo derivative is formed in acetic acid at 20°C, and 1-methyl-2-(1'-methyl-3',4',5'-tribromo-2'-pyrrolyl)benzimidazole is formed in dichloroethane at 80°C. They all have high stability, in contrast to the bromo derivatives of pyrrole, which are difficult to obtain and unstable.

EXPERIMENTAL

The IR spectra of solutions of the compounds in chloroform or suspensions in mineral oil were recorded with a UR-20 spectrometer. The PMR spectra of solutions in trifluoroacetic acid were recorded with a Tesla BS-467 spectrometer with hexamethyldisiloxane as the internal standard.

2-(2'-Pyrrolyl)benzimidazole (III). This compound was obtained by the method in [2]. A mixture of 4.32 g (40 mmole) of o-phenylenediamine in 75 ml of isopropyl alcohol, 16 g (80 mmole) of copper acetate in 200 ml of water, and 3.8 g (40 mmole) of 2-formylpyrrole was heated at 80-90°C for 2 h, after which it was cooled, and the precipitated copper salt was separated and suspended in 150 ml of isopropyl alcohol. Hydrogen sulfide was bubbled through the suspension for 1 h, the copper sulfide was removed by filtration, the filtrate was evaporated to half its original volume, and the residue was washed with 250 ml of water to give 3.88 g (53%) of yellow crystals with mp 257-258°C (from ethanol). Found: C 71.7; H 5.0; N 23.0%. $C_{11}H_9N_3$. Calculated: C 72.1; H 4.9; N 22.9%.

1-Methyl-2-(2'-pyrrolyl)benzimidazole (IV). This compound was obtained by alkylation of III by the method in [3] from 1.83 g (10 mmole) of 2-(2'-pyrrolyl)benzimidazole, 1.12 g (20 mmole) of KOH, and 2.84 g (20 mmole) of methyl iodide. The product, with mp 209-210°C (from alcohol), was obtained in quantitative yield. Found: C 73.5; H 5.8; N 21.6%. $C_{12}H_{11}N_3$. Calculated: C 73.0; H 5.6; N 21.3%.

2-(1-Methyl-2'-pyrrolyl)benzimidazole (V). This compound was synthesized from 4.32 g (40 mmole) of o-phenylenediamine, 16 g (80 mmole) of copper acetate, and 4.36 g (40 mmole) of 1-methyl-2-formylpyrrole by the method used to prepare III. Workup of the reaction mixture gave 5.27 g (67%) of V with mp 231-232°C (from alcohol). Found: C 73.3; H 5.8; N 21.1%. $C_{12}H_{11}N_3$. Calculated: C 73.0; H 5.6; N 21.3%.

1-Methyl-2-(1'-methyl-2'-pyrrolyl)benzimidazole (VI). This compound was obtained by alkylation of V by the method in [2] from 1.97 g (10 mmole) of 2-(1'-methyl-2'-pyrrolyl)benzimidazole. The product, with mp 56-57°C (from alcohol), was obtained in quantitative yield. Found: C 73.7; H 6.0; N 19.6%. $C_{13}H_{13}N_3$. Calculated: C 73.9; H 6.2; N 19.9%.

1-Methyl-2-(1'-methyl-4'-nitro-2'-pyrrolyl)benzimidazole (VII). A solution of 1.26 g of nitric acid (sp. gr. 1.5) in 20 ml of acetic acid was added dropwise with vigorous stirring at 0°C at a solution of 2.11 g (10 mmole) of VI in 20 ml of acetic anhydride, after which vigorous stirring was continued for 2 h. The precipitated salt of the nitro derivative was separated and converted to the base to give 1.74 g (68%) of yellow prisms with mp 148-149°C (from methanol). IR spectrum: 1370 cm^{-1} (NO_2). PMR spectrum, δ: 3.47 (s, 3H, N–CH_3), 3.7 (s, 3H, N–CH_3), 7.07 (s, 1H, β_3), 7.4 (s, 4H, aromatic), and 7.63 ppm (s, 1H, α_5); Found: C 61.2; H 5.0; N 22.1%. $C_{13}H_{12}N_4O_2$. Calculated: C 60.9; H 4.7; N 21.9%.

1-Methyl-2-(1'-methyl-4'-sulfo-2'-pyrrolyl)benzimidazole (VIII). A solution of 1.47 g (15 mmole) sample of sulfuric acid (sp. gr. 1.84) in 20 ml of acetic anhydride was added in 1 h at 0°C to a solution of 2.11 g (10 mmole) of VI in 20 ml of acetic anhydride, and the mixture was stirred for 10 min. The precipitated sulfonic acid was separated and recrystallized from aqueous methanol to give 2 g (70%) of colorless crystals of VIII with mp 318-319°C. IR spectrum: 1250 cm^{-1} (SO_2). PMR spectrum, δ: 3.5 (s, 3H, N–CH_3), 3.72 (s, 3H, N–CH_3), 7.0 (s, 1H, β_3), 4.7 (s, 4H, aromatic), 7.67 (s, 1H, α_5), and 12.07 ppm (s, 1H, SO_2OH). Found: C 53.9; H 4.3; N 14.2%. $C_{13}H_{13}N_3O_3S$. Calculated: C 53.6; H 4.5; N 14.4%.

1-Methyl-2-(1'-methyl-5'-bromo-2'-pyrrolyl)benzimidazole (IX). A solution of 0.8 g (5 mmole) of bromine in 10 ml of dichloroethane was added gradually at 0°C to a solution of 1.05 g (5 mmole) of VI in 10 ml of dichloroethane, and the reaction mixture was maintained at this temperature for 2 h with vigorous stirring. The precipitated hydrobromide of the hydrate of IX was separated and converted to the base. Workup gave 0.83 g (57%) of colorless prisms with mp 99-100°C (from aqueous alcohol). PMR spectrum, δ: 3.37 (s, 3H, N–CH_3), 3.67 (s, 3H, N–CH_3), 6.15 (d, 1H, β_4), 6.5 (d, 1H, β_3), and 7.32 ppm (s, 4H, aromatic). Found: C 53.6; H 4.0; N 14.3%. $C_{13}H_{11}BrN_3$. Calculated: C 53.8; H 4.1; N 14.4%.

1-Methyl-2-(1'-methyl-4',5'-dibromo-2'-pyrrolyl)benzimidazole (X). A solution of 4.8 g (30 mmole) of bromine in 20 ml of acetic acid was added gradually with vigorous stirring at 20°C to a solution of 2.11 g (10 mmole) of VI in 50 ml of acetic acid, and the mixture was maintained under these conditions for 2 h. The precipitated hydrobromide of X was separated and converted to the base. Workup gave 2.17 g (59%) of snow-white crystals of X with mp 190-191°C (from alcohol). PMR spectrum, δ: 3.4 (s, 3H, N–CH_3), 3.7 (s, 3H, N–CH_3), 6.57 (s, 1H, β_3), and 7.4 ppm (s, 4H, aromatic). Found: C 42.2; H 3.4; Br 42.9; N 11.2%. $C_{13}H_{12}Br_2N_3$. Calculated: C 42.3; H 3.0; Br 43.3; N 11.4%.

1-Methyl-2-(1'-methyl-5'-hydroxymethyl-2'-pyrrolyl)benzimidazole (XI). A 1.05-g (5 mmole) sample of VI was suspended in 18 ml of 40% formaldehyde solution, and the mixture was refluxed from 4 h. It was then cooled and treated with 40 ml of water, and the precipitated X was separated and dissolved in chloroform and chromatographed with a column filled with aluminum oxide (elution with chloroform) to give 0.62 g (53%) of colorless crystals with mp 150-151°C (from a mixture of ethyl acetate with hexane). IR spectrum, cm^{-1}: 3230 vs (OH). PMR spectrum, δ: 3.42 (s, 3H, N–CH_3), 3.67 (s, 3H, N–CH_3), 5.15 (s, 2H, CH_2), 6.3 (d, 1H, β_4), 6.52 (d, 1H, β_3), and 7.4 ppm (s, 4H, aromatic), Found: C 69.3; H 6.4; N 17.6%. $C_{14}H_{15}N_3O$. Calculated: C 68.9; H 6.4; N 17.9%.

1-Methyl-2-(1'-methyl-3',4',5'-tribromo-2'-pyrrolyl)benzimidazole (XII). A solution of 6.4 g (40 mmole) of bromine in 30 ml of dichloroethane was added gradually at 20°C to a solution of 2.1 g (10 mmole) of VI in 25 ml of dichloroethane, and the mixture was refluxed for 1 h. It was then cooled, and the precipitated hydrobromide of XII was separated and converted to the base. Workup gave 3.3 g (74%) of snow-white crystals of XII with mp 154-155°C (from methanol). Found: C 34.5; H 2.1; Br 53.1; N 9.0%. $C_{13}H_{10}Br_3N_3$. Calculated: C 34.9; H 2.3; Br 53.5; N 9.4%.

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