1-AMINO-3-ALKYL-2-(METHYLTHIO)BENZIMIDAZOLIUM SALTS: SYNTHESIS, REACTION WITH CH-ACID ANIONS, AND CONVERSION TO PYRAZOLO[1,5-*a*]BENZIMIDAZOLE DERIVATIVES

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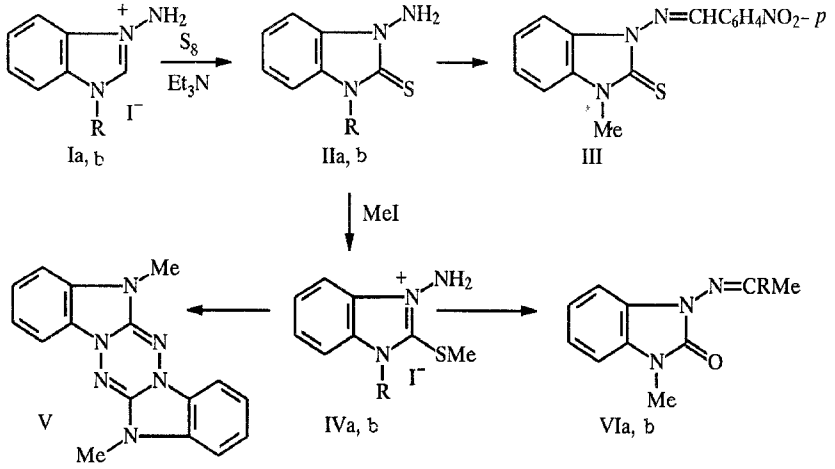
For the first time, 1-amino-3-alkylbenzimidazolinethiones were obtained by heating 1-amino-3-alkylbenzimidazolium iodides with sulfur in the presence of triethylamine. They were converted to 1-amino-3-alkyl-2-(methylthio)benzimidazolium salts, which, during reaction with CH-acid anions, gave the corresponding 1-amino-3-alkyl-2-methylenebenzimidazoline derivatives. Under conditions of alkaline or acid catalysis, the latter derivatives cyclized to 2-amino- or 2-hydroxy derivatives of pyrazolo[1,5-a]benzimidazole.

Previously we reported on the synthesis of 2-alkyl- and 2-aryl derivatives of pyrazolo[1,5-*a*]benzimidazole by the reaction of 1-amino-3-alkyl-2-methylbenzimidazolium salts with anhydrides of appropriate carboxylic acids [1]. However, this method is unsuitable for the preparation of many other derivatives of pyrazolo[1,5-*a*]benzimidazole derivatives, in particular, containing amino and hydroxy groups in the 2 position. An obvious route for the synthesis of such substances by analogy with N-aminopyridinium [2], N-amino-1,2,4-triazolium [3], and N-aminothiazolium [4] salts consists in cyclization of 1-amino-3-alkylbenzimidazolium salts containing such groups as $CH(R)CO_2Et$ and CH(R)CN in the 2 position. These groups can most simply be introduced into the 2 position by nucleophilic substitution of the SMe group by groups of appropriate CH acids. Therefore, the purposes of the present paper were the synthesis of 1-amino-3-alkyl-2-(methylthio)benzimidazolium salts and a study of their reaction with CH-acid anions for subsequent cyclization of the resulting methylene bases.

Previously unknown 1-amino-3-alkylbenzimidazoline-2-thiones (IIa, b) were obtained in good yields by the reaction of 1-amino-3-alkylbenzimidazolium salts (Ia, b) with sulfur in boiling dimethylformamide (DMFA) in the presence of triethylamine. Compounds IIa and IIb reacted facilely with aromatic aldehydes with the formation of Schiff bases III, and in the presence of halo alkyls they were converted to 1-amino-3-alkyl-2-(methylthio)benzimidazolium salts (IVa, b). Salts IV possess significant lability. For example, during heating in xylene they were dealkylated with formation of the starting thiones II. During boiling of iodide IVa in acetonitrile in the presence of triethylamine, not only thione IIa (32% yield), but also dibenzimidazo[3,2-b;3,2-e]tetrazine derivative (V) was obtained, which indicates that nucleophilic substitution of the methylthio group is facile. The formation of methylene bases in the presence of CH acids was studied for the case of salt IVa. Heating of salt IVa with acetophenone



I, II, IV a R=Me, b R=Et; VIa R=Ph, b R=*p*-$NO_2C_6H_4$

Scientific-Research Institute of Physical and Organic Chemistry, Rostov State University, Rostov-on-Don 344006. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 2, pp. 205-214, February, 1992. Original article submitted January 29, 1991.

0009-3122/92/2802-0167$12.50

TABLE 1. Coordinates of Atoms and Their Equivalent (for H, isotropic) Temperature Factors $U_{eq} = 1/3\Sigma_i\Sigma_j U_{ij} a_i^* a_j^* a_i a_j$

Atom	x	y	z	U_{eq}/U_i
$O_{(1)}$	0,7022(2)	0,0000(0)	0,7989(2)	0,060
$O_{(2)}$	0,5862(2)	-0,0994(3)	0,5666(2)	0,0614
$N_{(1)}$	1,1221(2)	-0,2136(3)	0,8318(2)	0,046
$N_{(2)}$	1,0540(2)	0,0329(3)	0,8641(2)	0,046
$N_{(3)}$	0,9834(3)	0,1846(4)	0,8412(3)	0,055
$N_{(4)}$	0,8726(3)	-0,2674(5)	0,4215(3)	0,073
$C_{(1)}$	1,0069(3)	-0,1014(4)	0,7810(2)	0,043
$C_{(2)}$	1,2450(3)	-0,1481(4)	0,9493(3)	0,046
$C_{(3)}$	1,2010(3)	0,0079(4)	0,9695(3)	0,048
$C_{(4)}$	1,2951(4)	0,1068(5)	1,0797(3)	0,059
$C_{(5)}$	1,4339(4)	0,0417(5)	1,1693(3)	0,068
$C_{(6)}$	1,4788(4)	-0,1152(6)	1,1507(3)	0,067
$C_{(7)}$	1,3864(3)	-0,2128(5)	1,0401(3)	0,058
$C_{(8)}$	1,1086(4)	-0,3824(4)	0,7913(4)	0,059
$C_{(9)}$	0,8605(3)	-0,1213(4)	0,6624(2)	0,045
$C_{(10)}$	0,8648(3)	-0,2032(4)	0,5298(3)	0,050
$C_{(11)}$	0,7146(3)	-0,0660(4)	0,6846(3)	0,048
$C_{(12)}$	0,4335(4)	-0,0473(6)	0,5835(6)	0,080
$C_{(13)}$	0,3060(4)	-0,1458(6)	0,4844(5)	0,082
$H_{(1N3)}$	0,988(4)	0,219(5)	0,746(4)	0,07(1)
$H_{(2N3)}$	0,871(3)	0,156(4)	0,834(3)	0,054(8)
$H_{(4)}$	1,260(3)	0,213(5)	1,090(3)	0,062(9)
$H_{(5)}$	1,499(4)	0,105(4)	1,243(4)	0,08(1)
$H_{(6)}$	1,584(4)	-0,156(4)	1,217(3)	0,071(9)
$H_{(7)}$	1,413(3)	-0,325(4)	1,023(3)	0,059(8)
$H_{(81)}$	1,009(6)	-0,414(5)	0,784(5)	0,10(2)
$H_{(82)}$	1,139(3)	-0,409(4)	0,697(4)	0,076(9)
$H_{(83)}$	1,165(4)	-0,453(5)	0,882(4)	0,08(1)
$H_{(121)}$	0,429(5)	0,058(6)	0,548(4)	0,10(1)
$H_{(122)}$	0,429(5)	-0,057(7)	0,694(5)	0,13(2)
$H_{(131)}$	0,199(5)	-0,122(6)	0,497(4)	0,12(1)
$H_{(132)}$	0,333(6)	-0,262(7)	0,515(5)	0,13(2)
$H_{(133)}$	0,316(6)	-0,138(8)	0,371(6)	0,16(2)

TABLE 2. Bond Lengths and Valence Angles for Compound VIIb

Bond	l, Å	Angle	$\omega°$
$N_{(1)}—C_{(1)}$	1,361	$C_{(1)}—N_{(1)}—C_{(8)}$	125,7
$N_{(1)}—C_{(2)}$	1,403	$C_{(1)}—N_{(1)}—C_{(2)}$	109,0
$N_{(1)}—C_{(8)}$	1,459	$C_{(2)}—N_{(1)}—C_{(8)}$	124,4
$N_{(2)}—C_{(1)}$	1,357	$C_{(1)}—N_{(2)}—C_{(3)}$	110,0
$N_{(2)}—C_{(3)}$	1,390	$C_{(1)}—N_{(2)}—N_{(3)}$	128,0
$N_{(2)}—N_{(3)}$	1,403	$C_{(3)}—N_{(2)}—N_{(3)}$	121,5
$N_{(3)}—H_{(1)}$	1,00	$N_{(2)}—N_{(3)}—H_{(1)}$	100,0
$N_{(3)}—H_{(2)}$	0,93	$N_{(2)}—N_{(3)}—H_{(2)}$	106,0
$N_{(4)}—C_{(10)}$	1,152	$H_{(1)}—N_{(3)}—H_{(2)}$	109,0
$C_{(1)}—C_{(9)}$	1,438	$N_{(1)}—C_{(1)}—C_{(9)}$	126,5
$C_{(2)}—C_{(3)}$	1,390	$N_{(1)}—C_{(1)}—N_{(2)}$	107,6
$C_{(2)}—C_{(7)}$	1,392	$N_{(2)}—C_{(1)}—C_{(9)}$	125,9
$C_{(3)}—C_{(4)}$	1,386	$N_{(1)}—C_{(2)}—C_{(3)}$	106,9
$C_{(4)}—C_{(5)}$	1,373	$N_{(1)}—C_{(2)}—C_{(7)}$	131,9
$C_{(5)}—C_{(6)}$	1,396	$C_{(3)}—C_{(2)}—C_{(7)}$	121,3
$C_{(6)}—C_{(7)}$	1,375	$N_{(2)}—C_{(3)}—C_{(2)}$	106,6
$C_{(9)}—C_{(10)}$	1,411	$N_{(2)}—C_{(3)}—C_{(4)}$	131,4
$C_{(9)}—C_{(11)}$	1,427	$C_{(2)}—C_{(3)}—C_{(4)}$	122,1
$C_{(11)}—O_{(1)}$	1,221	$C_{(3)}—C_{(4)}—C_{(5)}$	116,3
$C_{(11)}—O_{(2)}$	1,352	$C_{(4)}—C_{(5)}—C_{(6)}$	122,1
$O_{(2)}—C_{(12)}$	1,456	$C_{(5)}—C_{(6)}—C_{(7)}$	121,6
$C_{(12)}—C_{(13)}$	1,477	$C_{(6)}—C_{(7)}—C_{(2)}$	116,7
		$C_{(1)}—C_{(9)}—C_{(10)}$	118,5
		$C_{(1)}—C_{(9)}—C_{(11)}$	119,6
		$C_{(10)}—C_{(9)}—C_{(11)}$	121,8
		$C_{(9)}—C_{(11)}—O_{(1)}$	125,0
		$C_{(9)}—C_{(11)}—O_{(2)}$	113,0
		$O_{(1)}—C_{(11)}—O_{(2)}$	122,0
		$C_{(11)}—O_{(2)}—C_{(12)}$	115,5
		$O_{(2)}—C_{(12)}—C_{(13)}$	108,8

or p-nitroacetophenone in the presence of sodium methylate or triethylamine gave a significant amount of compound V together with Schiff base VIa, b. Under these conditions, both ketones were obviously not converted to carbanions; therefore, the formation of Schiff bases and hydrolysis of the methylthio group due to evolved water predominated.

We further observed that 1-amino-3-methyl-2-methylenebenzimidazoline derivatives (VIIa-d) formed in good yield in the reaction of iodide IVa with stronger C acids (diethyl malonate, cyanoethyl acetate, nitroethyl acetate, and malonodinitrile) in absolute alcohol in the presence of sodium ethylate or triethylamine. For better understanding of subsequent cyclization of asymmetric methylene bases VIIb and VIIc, it seemed of interest to establish the position of the groups with respect to the exocyclic C=C bond. For that purpose, we carried out an x-ray diffraction investigation of compound VIIb (Fig. 1 and Tables 1 and 2). On the basis of this investigation, the following conclusions were drawn.

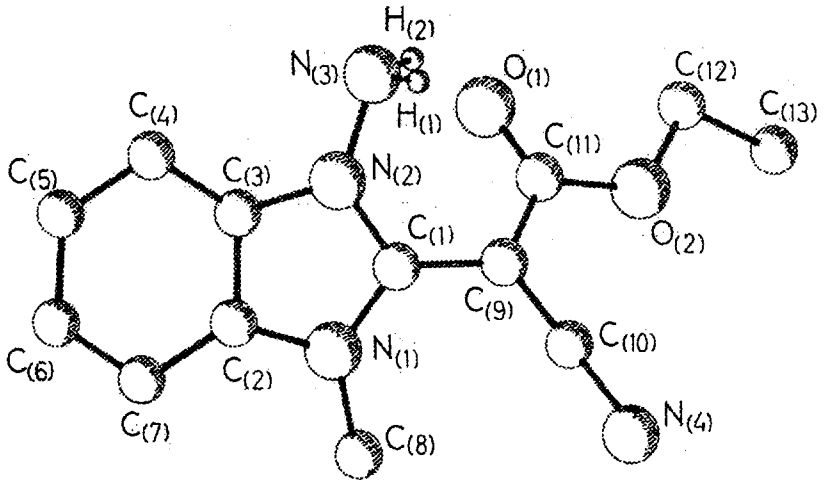


Fig. 1. Crystal structure of compound VIIb.

1. The benzimidazole fragment is essentially planar, and its bending angle along the C_{4a}—C_{7a} bond is only 1.5°.

2. As in other N-aminoazoles [5, 6], the N-amino group has a pyramidal configuration, i.e., the hydrogen atoms in the NH_2 group do not lie in the plane of the benzimidazole system.

3. The substituents are in a Z configuration with respect to the double bond, i.e., the N-amino group and the ethoxycarbonyl group are in the *cis* position with respect to each other. In addition, a hydrogen bridge is formed between the carbonyl oxygen atom and the hydrogen atom of the N-amino group. The parameters of the intramolecular hydrogen bond are: *l* $N_{(3)}...O_{(1)}$ 2.839 (2), $NH...O_{(1)}$ 1.93 (2) Å, and angle N—H...$O_{(1)}$ 146.6°. The second hydrogen atom of the NH_2 group participates in the formation of intermolecular hydrogen bonds at the CN group, leading to the formation of chains of VIIb molecules twisted about helical axis 2_1. The length of the bond $N_{(3)}$—$H_{(2)}...N_{(4)}$ (2 − x, 1/2 + y, 1 − z) 3.056 H...$N_{(4)}$ is 2.23 Å, and the angle $N_{(3)}$—$H_{(2)}...N_{(4)}$ is 148°.

4. The $C_{(1)}C_{(9)}C_{(10)}C_{(11)}$ plane and the plane of the benzimidazole system form an angle of 43.7° with each other. Most probably, the acoplanarity of the methylene group is due to the ensuring of better conditions for the formation of the above-mentioned intramolecular hydrogen bond NH...O=. The conformation of the ethoxycarbonyl group is described by the torsion angles $C_{(11)}O_{(2)}C_{(12)}C_{(13)}$, $C_{(12)}O_{(2)}C_{(11)}O_{(1)}$, and $C_{(12)}O_{(2)}C_{(11)}C_{(10)}$ equal to −156.5, 1.7, and 180.0°.

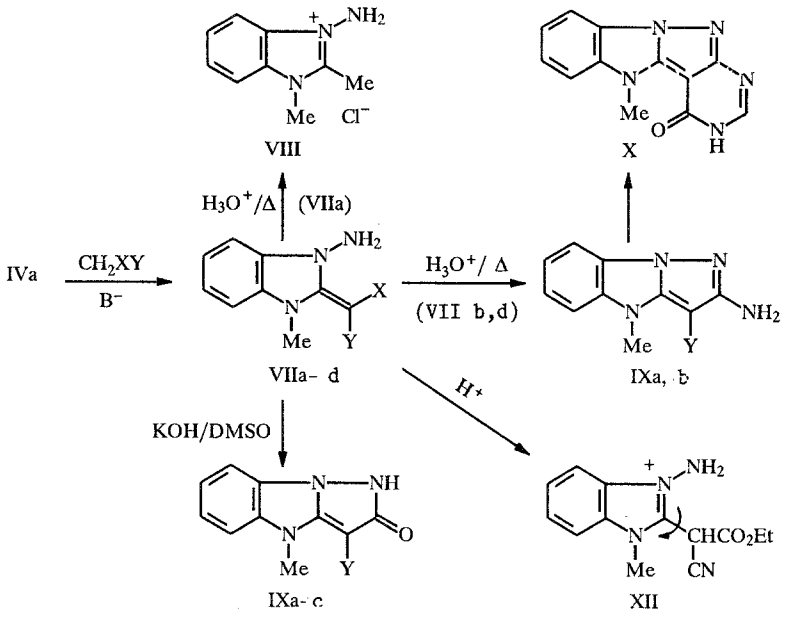
5. Despite the acoplanarity of the benzimidazole and methylene groups, the bonding between them is very significant. This is indicated by leveling of the lengths of the $C_{(1)}$—$C_{(9)}$, $C_{(9)}$—$C_{(11)}$, and $C_{(9)}$—$C_{(10)}$ bonds, equal to 1.438, 1.427, and 1.411 Å, respectively. Usually, the lengths of the double and single bonds in structures of types C=C—C=O are equal to 1.340 and 1.475 Å [7]. The remaining angles and lengths of the bonds in molecule VIIb differ little from those found in analogous structures [7].

As illustrated by methylene bases VIIa and VIIb, we determined that in an acid medium the ethoxycarbonyl groups do not tend to cyclize to the N-amino group. Thus, during boiling of compound VIIa in dilute hydrochloric acid, only hydrolysis of two ethoxycarbonyl groups occurred with subsequent decarboxylation, as a result of which 1-amino-2,3-dimethylbenzimidazolium chloride (VIII) was obtained. Under the same conditions, base VIIb cyclized because of the nitrile group, as a result of which aminopyrazole IXa (in which the ethoxycarbonyl group remained unaffected) formed. It should be noted that conversion of base VIIb to substance IXa was also observed in the absence of acid, i.e., during boiling of compound VIIb in formamide. However, in that case, tetracyclic compound X was also obtained as a by-product, which was obviously a result of cyclization of aminopyrazole IXa in he presence of formamide. Indeed, compound X was the only reaction product during boiling of pyrazole IXa in excess formamide.

We also confirmed the ease of cyclization involving the nitrile group for the case of conversion of dicyanomethylene derivative VIId to aminopyrazole IXb both in an acid medium and also in the KOH—dimethyl sulfoxide (DMSO) system. It is of interest that use of the KOH—DMSO system completely changed the direction of cyclization of methylene bases VIIa-c. During stirring of compounds VIIa-c in a solution of potassium hydroxide in DMSO at 60-70°C, cyclization occurred with participation of the ethoxycarbonyl group, and pyrazolones XIa-c became the products of the respective reactions.

The different direction of cyclization of compounds VIIb in acid and superbasic media can be explained as follows. As is known, methylene bases of azoles are protonated at the exocyclic methylene carbon atom [8]. In our case, a cation of type

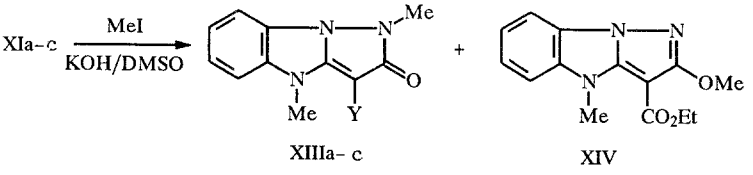
XII should be formed in an acid medium, and in this cation the rotation of the entire $CH(CN)CO_2Et$ group about the C(2)—CH(bond should be relatively free, i.e., both cyano and ethoxycarbonyl groups can participate in cyclization with equal probability. However, on the basis of the values of the σ_I constants of CN (0.56) and CO_2Et (0.30) groups [9], we can conclude that the cyano group has significantly higher electron deficiency; therefore, under these conditions, cyclization occurs with its participation.



VII a X=Y=CO_2Et; b X=CO_2Et, Y=CN; c X=CO_2Et, Y=NO_2; d X=Y=CN; IXa Y=CO_2Et; bX=CN; XIa Y=CO_2Et, bY=CN, c Y=NO_2

Previously, we showed that in the DMSO—KOH system the NH acidity of the amino group in N-amino azoles is in the range of 28-30 units of the pK_a scale [10]. In a superbasic medium, base VIIb and other bases of VII will obviously be converted to the N anion. Because in such an anion the nucleophilicity of the amino nitrogen should increase strongly, it will easily attack the carbonyl carbon atom of the ethoxycarbonyl group, which, according to the data presented above (Fig. 1), is adjacent to the N-amino group. The absence of cyclization of compounds VII in aqueous alkali indirectly supports such an explanation because the formation of the N anion is unlikely under these conditions.

Having studied the methylation of pyrazolones XI in a DMSO medium in the presence of alkali, we determined that under these conditions compounds XIb and XIc are methylated by methyl iodide exclusively at the nitrogen atom with formation of N-methyl derivatives XIIIb and XIIIc. At the same time, pyrazolone anion XIa gives a 7:3 mixture of N- and O-methylation products. Unfortunately, we were unable to separate the mixture of compounds XIIIa and XIV by chromatography or fractional crystallization.



XIII a Y=CO_2Et, b Y=CN. c Y=NO_2

EXPERIMENTAL

The IR spectra were recorded in a thin layer of white mineral oil using a Specord IR-75 spectrophotometer with a NaCl prism. The PMR spectra of compounds II, IVa, VIa, VIb, VIIa, VIIb, IXa, XIa, and XIIIa were recorded on a Tesla BS-487 instrument (80 MHz), those of compounds V, VIIc, VIId, VIII, IXb, X, XIb, XIc, XIIIa-c, and XIV were recorded on a Tesla BS-587 instrument (100 MHz), and the external standard was HMDS. The course of the reaction and the purity of the compounds were monitored by thin-layer chromatography on plates with Al_2O_3 of second activity grade, the eluent was chloroform, and development was with iodine vapor. The melting points were determined in a sealed capillary in a PTP melting-point-measuring instrument, and they were not corrected.

X-Ray Diffraction Analysis of 1-Amino-3-methyl-2-[cyano(ethoxycarbonyl)methylene]benzimidazol-2-ine (VIIb). Crystals of composition $C_{13}H_{14}N_4O_2$ were grown from ethyl acetate. They were monoclinic: a = 8.74(3), b = 8.378(3), c = 9.210(4) Å, β = 106.52(2)°, V = 647.6(7) Å^3, Z = 2, and space group $P2_1$. The structure was interpreted by a direct method and recalculated by the least-squares method in a whole-matrix anisotropic approximation to R = 0.033 (R_w = 0.035) for 1254 reflections with $F2 \geq 3\sigma$ (the diffractometric experiment was set up with a Syntex-P1 diffractometer, $\lambda_{MoK\alpha}$, graphite monochromator, $\theta/2\theta$ scanning, $3 \leq 2\theta \leq 55°$. [The final coordinates of the atoms and their temperature factors are given in Table 1. The bond lengths and the valence angles in compound VIIb are given in Table 2 (the accuracy of determination of the lengths of the C—C, C—N, and N—N bonds was 0.003-0.005 Å, that of the length of the C—H and N—H bonds was 0.02-0.03 Å, that of the valence angles was 0.2-0.4°, and that of the valence angles involving hydrogen atoms was 2-4°.]

1-Amino-3-methylbenzimidazoline-2-thione (IIa, $C_8H_9N_3S$). A. A solution of 2.75 g (100 mmoles) of iodide Ia, 0.32 g (100 mmoles) of elemental sulfur, and 14.0 ml (100 mmoles) of triethylamine in 10 ml of DMFA was boiled for 1 h. After cooling, the dark-brown solution was diluted fivefold with water, and the gray precipitate was filtered and washed with water and alcohol. Colorless crystals with mp 152-153°C (from benzene) were obtained. IR spectrum: 1590, 1630; 3170, 3270 cm^{-1} (NH_2). PMR spectrum ($CDCl_3$): 3.66 (3H, singlet, NCH_3); 4.57 (2H, broadened singlet, which disappeared after deuteration, NH_2); 7.24 ppm (4H, multiplet, 4-7-H). The yield was 1.47 g (81%).

B. A suspension of 0.32 g (1 mmole) of iodide IVa in 3 ml of xylene was boiled for 1 h, and the precipitate gradually migrated into solution. After cooling, the solution was passed through a column with Al_2O_3, with elution by chloroform. A fraction with R_f 0.5 was collected. Colorless crystals with mp 152-153°C (from alcohol) were obtained in a yield of 0.15 g (83%). After the sample was mixed with the sample from run A, no melting-point depression was observed.

1-Amino-3-ethylbenzimidazoline-2-thione (IIb, $C_9H_{11}N_3S$). A solution of 0.58 g (2 mmoles) of iodide Ib, 0.1 g (3 mmoles) of sulfur, and 0.3 ml (2 mmoles) of triethylamine in 3 ml of DMFA was boiled for 2 h. The solvent was evaporated under decreased pressure, and the residue was purified chromatographically on a column with Al_2O_3 (chloroform), with a fraction with R_f 0.5 being withdrawn. Flesh-colored needles with mp 92-93°C (from octane) were obtained. IR spectrum: 1592, 1632; 3170, 3270 cm^{-1} (NH_2). The yield was 0.27 g (69%).

1-(p-Nitrobenzylideneamino)-3-methylbenzimidazoline-2-thione (III, $C_{15}H_{12}N_4O_2S$). A solution of 0.18 g (1 mmole) of thione IIa and 0.15 g (1 mmole) of p-nitrobenzaldehyde in 3 ml of DMFA was boiled for 1 h. After cooling, the precipitate was filtered and washed with alcohol. Yellow needles with mp 224-225°C (from DMFA) were obtained. IR spectrum: 1497, 1515, 1683 cm^{-1}. The yield was 0.24 g (80%).

1-Amino-3-methyl-2-(methylthio)benzimidazolium Iodide (IVa, $C_9H_{12}IN_3S$). A solution of 1.8 g (10 mmoles) of thione IIa and 2 ml (35 mmoles) of methyl iodide in 20 ml of absolute alcohol was boiled for 1 h. From the hot solution, a heavy sandy-colored precipitate was recovered, and it was filtered after cooling and washed with acetone. The prisms had mp 137-142°C (with decomposition, from alcohol). IR spectrum: 1500, 1627; 3140, 3237 cm^{-1} (NH_2). PMR spectrum (DMSO-D_6); 2.83 (3H, singlet, SCH_3); 4.03 (3H, singlet, NCH_3); 6.88 (2H, multiplet, disappearing after deuteration, NH_2); 7.66 (2H, multiplet, 5,6-H) and 7.93 ppm (2H, multiplet, 4,7-H). The yield was 3.1 g (96%).

1-Amino-3-ethyl-2-(methylthio)benzimidazolium Iodide (IVb, $C_{10}H_{14}IN_3S$). A solution of 0.39 g (2 mmoles) of thione IIb and 0.25 ml (4 mmoles) of ethyl iodide in 5 ml of alcohol was boiled for 3 h. The alcohol was driven off to dryness, and the residue was triturated with ether and filtered. Yellowish crystals with mp 105-106°C (with decomposition, from alcohol) were obtained. IR spectrum: 1600, 1625; 3160, 3255 cm^{-1} (NH_2). The yield was 0.58 g (86%).

1,8-Dimethyldibenzimidazo[3,2-b:3,2-e]-1,2,4,5-tetrazine (V, $C_{14}H_{14}N_6$). A mixture of 0.96 g (3 mmoles) of iodide IVa and 0.9 ml (6 mmoles) of triethylamine in 10 ml of absolute acetonitrile was boiled for 2 h. A yellowish precipitate, which was separated after cooling and washed with acetonitrile, began to form immediately from the hot solution. Compound V was obtained in a yield of 0.26 g (58%). It consisted of yellow-green prisms with mp 230-232°C (with decomposition, from DMFA), darkening at >200°C. IR spectrum: 1615, 1663 cm^{-1}. PMR spectrum (CF_3COOH): 3.50 (3H, singlet, NCH_3); 7.16 ppm (4H, multiplet, H_{arom}).

The filtrate was evaporated to dryness, and the residue was triturated with 10 ml of water for removal of triethylamine hydriodide, dissolved in 10 ml of chloroform, and passed through a column with Al_2O_3 (chloroform), with a fraction with R_f 0.5 being withdrawn. Thione IIa, colorless needles with mp 152-153°C (from alcohol), was obtained in a yield of 0.17 g (32%). After mixing with a known sample, a sample of thione IIa did not give a melting-point depression.

1-(2-Phenylethylideneamino)-3-methylbenzimidazol-2-one (VIa, $C_{16}H_{15}N_3O$). To a solution of sodium methylate obtained from 0.046 g (2 mmoles) of metallic sodium in 8 ml of absolute methanol was added 0.24 g (2 mmoles) of acetophenone, and the whole was boiled for 15 min. Then 0.64 g (2 mmoles) of salt IVa was added, and the whole was boiled for 3 h more. A light-brown precipitate of tetrazine V formed immediately, and, after cooling, it was separated and washed with methanol. Yellow-

green crystals with mp 230-232°C (with decomposition, from DMFA) were obtained. The yield was 0.1 g (17%). The physicochemical characteristics were identical to those of a known sample of compound V.

The methanol solution was evaporated, and the residue was chromatographed on a column with Al_2O_3 (chloroform), with a fraction with R_f 0.7 being collected. Compound VIa was obtained in a yield of 0.3 g (60%). It consisted of colorless cottonlike crystals with mp 120-122°C (from octane). IR spectrum: 1585, 1605, 1635, and 1720 cm^{-1} (C=O). PMR spectrum ($CDCl_3$): 2.38 (3H, singlet, CCH_3); 3.38 (3H, singlet, NCH_3); 7.07 (4H, multiplet, H_{arom}); 7.50 (3H, multiplet, H_{arom}) and 8.0 ppm (2H, multiplet, o-HC_6H_5).

1-[1-(p-Nitrophenyl)ethylideneamino]-3-methylbenzimidazol-2-one (VIb, $C_{16}H_{14}N_4O_3$). A solution of 0.64 g (2 mmoles) of iodide IVa, 0.3 ml (2 mmoles) of triethylamine, and 0.48 g (2 mmoles) of p-nitroacetophenone in 7 ml of absolute alcohol was boiled for 5 h. After cooling, a precipitate of tetrazine V was filtered and washed with alcohol. Yellow-green prisms with mp 230-232°C (with decomposition, from DMFA) were obtained in a yield of 0.3 g (50%). From an alcoholic solution, 0.28 g (48%) of compound VIb was obtained as in the preceding run. It consisted of yellow needles with mp 201-203°C (from butanol). IR spectrum: 1498, 1625; 1699 cm^{-1} (C=O).

1-Amino-3-methyl-2-[bis(ethoxycarbonyl)methylene]benzimidazol-2-ine (VIIa, $C_{15}H_{19}N_3O_4$). To a solution of sodium ethylate obtained from 0.046 g (2 mmoles) of metallic sodium in 10 ml of absolute alcohol was added 0.32 g (2 mmoles) of malonic ester, the whole was boiled for 20 min, then 0.62 g (2 mmoles) of iodide IVa was added, and the whole was boiled for 3 h more. The alcohol was driven off to dryness, and the residue was triturated with 20 ml of chloroform and passed through a column with Al_2O_3 (chloroform), with a fraction with R_f 0.2 being withdrawn. Colorless crystals with mp 189-190°C (from ethyl acetate) were obtained. IR spectrum: 1600, 1688 (C=O); 3267, 3312 cm^{-1} (NH_2). PMR spectrum (DMSO-D_6): 1.15 (3H, triplet, J = 7.2 Hz, $CH_2\underline{CH_3}$); 3.63 (3H, singlet, NCH_3); 4.0 (4H, quartet, J = 7.2 Hz, $\underline{CH_2}CH_3$); 6.0 (2H, broadened singlet, disappearing after deuteration, NH_2); 7.48 (2H, multiplet, 5,6-H) and 7.70 ppm (2H, multiplet, 4,7-H). The yield was 0.35 g (57%).

1-Amino-3-methyl-2-[cyano(ethoxycarbonyl)methylene]benzimidazol-2-ine (VIIb, $C_{13}H_{14}N_4O_2$). A solution of 3.21 g (10 mmoles) of iodide IVa, 1.13 ml (10 mmoles) of cyanoacetic ester, and 1.4 ml (10 mmoles) of triethylamine in 30 ml of absolute alcohol was boiled for 4 h. It was cooled, and the resulting precipitate was filtered and washed with cold alcohol. Colorless needles with mp 178-179°C (from ethyl acetate) were obtained. IR spectrum: 1635, 1702 (C=O); 2194 (CN); 3200, 3320 cm^{-1} (NH_2). PMR spectrum ($CDCl_3$): 1.26 (3H, triplet, J = 7.2 Hz, $CH_2\underline{CH_3}$); 3.70 (3H, singlet, NCH_3); 4.20 (2H, quartet, J = 7.2 Hz, $\underline{CH_2}CH_3$); 5.21 (2H, broadened singlet, disappearing after deuteration, NH_2); 7.28 (3H, multiplet, 4-6-H) and 7.59 ppm (1H, multiplet, 7-H). The yield was 1.6 g (62%).

1-Amino-3-methyl-2-[nitro(ethoxycarbonyl)methylene]benzimidazol-2-ine (VIIc, $C_{12}H_{14}N_4O_4$). A solution of 3.21 g (10 mmoles) of iodide IVa, 1.5 g (11 mmoles) of nitroacetic ester, and 1.5 ml (10.4 mmoles) of triethylamine in 20 ml of absolute alcohol was boiled for 3 h, and, after cooling, the precipitate was filtered and washed with alcohol and ether. Grayish prisms with mp 225-226°C (from butanol) were obtained. IR spectrum: 1530, 1605, 1640, 1695 (C=O); 3250, 3330 cm^{-1} (NH_2). PMR spectrum (DMSO-D_6): 1.10 (3H, triplet, J = 7.2 Hz, $CH_2\underline{CH_3}$); 3.80 (3H, singlet, NCH_3); 4.05 (2H, quartet, J = 7.2 Hz, $\underline{CH_2}CH_3$); 6.43 (2H, broadened singlet, disappearing after deuteration, NH_2); 7.65 (2H, multiplet, 5,6-H) and 7.85 ppm (2H, multiplet, 4,7-H). The yield was 1.65 g (59%).

1-Amino-3-methyl-2-(dicyanomethylene)benzimidazol-2-ine (VIId, $C_{11}H_9N_5$). A solution of 1.6 g (5 mmoles) of iodide IVa, 0.33 g (5 mmoles) of malonodinitrile, and 0.8 ml (5.5 mmoles) of triethylamine in 15 ml of absolute alcohol was boiled for 1 h 30 min; after 10 min, a heavy precipitate began to form from the hot solution, and the precipitate was filtered and washed with alcohol after cooling. Grayish prisms with mp 270-271°C (from DMFA) were obtained; they hardened at 273-274°C and melted at 315-320°C (they underwent thermal cyclization to compound IXb). IR spectrum: 1612, 1643; 2178 and 2203 (CN); 3215, 3298 cm^{-1} (NH_2). PMR spectrum (DMSO-D_6): 3.75 (3H, singlet, NCH_3); 5.99 (2H, broadened singlet, disappearing after deuteration, NH_2); 7.33 (3H, multiplet, 4-6-H) and 7.49 ppm (1H, multiplet, 7-H). The yield was 1.0 g (95%).

1-(p-Nitrobenzylideneamino)-3-methyl-2-(dicyanomethylene)benzimidazol-2-ine ($C_{18}H_{12}N_6O_2$). A mixture of 0.10 g (0.5 mmole) of enamine VIId, 0.08 g (0.5 mmole) of p-nitrobenzaldehyde, and 1 drop of piperidine in 3 ml of alcohol was boiled for 30 min; an orange precipitate formed from the hot solution, and the precipitate was separated after cooling and washed with alcohol. Yellow needles with mp 247-249°C (from DMFA) were obtained. IR spectrum: 1570, 1575, 2187, and 2208 cm^{-1} (CN). The yield was 0.16 g (93%).

1-(p-Nitrobenzylideneamino)-3-methyl-2-[cyano(ethoxycarbonyl)methylene]benzimidazol-2-ine($C_{20}H_{17}N_5O_4$). This compound was similarly obtained in 93% yield. Orange crystals with mp 240-241°C (from DMFA) were obtained. IR spectrum: 1665 (C=O); 2188 cm^{-1} (CN).

1-Amino-2,3-dimethylbenzimidazolium Chloride (VIII, $C_8H_{12}N_3Cl \cdot H_2O$). A solution of 0.3 g (1 mmole) of enamine VIIa in 10 ml of conc. HCl was boiled for 40 min. The solvent was evaporated to dryness under decreased pressure, and the residue was triturated with acetone. Colorless crystals with mp 244-246°C (with decomposition, from alcohol) were obtained; they began to crystallize at 125°C. IR spectrum: 1547, 1660; 3120, 3220 (NH_2); 3360, 3400 cm^{-1} (H_2O). PMR spectrum (DMSO-D_6): 2.87 (3H, singlet, CCH_3); 3.98 (3H, singlet, NCH_3); 6.80 (2H, broadened singlet, disappearing after deuteration, NH_2); 7.59 (2H, multiplet, 5,6-H) and 7.88 ppm (2H, multiplet, 4,7-H). The yield was 0.24 g (90%).

2-Amino-4-methyl-3-(ethoxycarbonyl)pyrazolo[1,5-*a*]benzimidazole (IXa, $C_{13}H_{14}N_4O_2$). A. Into a solution of 0.51 g (2 mmoles) of enamine VIIb in 7 ml of dry dioxane was passed a stream of dry HCl for 30 min, after 2-3 min a precipitate formed from the solution, and the precipitate was filtered, worked upon the filter with a 10% NH_4OH solution, and washed with water. Colorless needles with mp 192-194°C (from alcohol) were obtained. IR spectrum: 1584, 1608; 1670 (C=O); 3260, 3415 cm^{-1} (NH_2). PMR spectrum ($CDCl_3$): 1.33 (3H, triplet, J = 7.2 Hz, $CH_2\underline{CH_3}$); 4.0 (3H, singlet, NCH_3); 4.31 (2H, quartet, J = 7.2 Hz, $\underline{CH_2}CH_3$); 4.88 (2H, broadened singlet, disappearing after deuteration, NH_2); 7.22 (3H, multiplet, 5-7-H) and 7.57 ppm (1H, multiplet, 8-H). The yield was 0.45 g (87%).

B. A suspension of 0.51 g (2 mmoles) of enamine VIIb in 30 ml of conc. HCl was boiled for 7 h, the precipitate was filtered after cooling, and the base was recovered as indicated above. Colorless needles with mp 194-195°C (from alcohol) were obtained. The physicochemical characteristics were identical to those of the sample obtained by method A. The yield was 0.5 g (97%).

2-Amino-4-methyl-3-cyanopyrazolo[1,5-*a*]benzimidazole (IXb, $C_{11}H_9N_5$). A. This compound was obtained similarly to compound IXa in dioxane in 88% yield. Cream-colored needles with mp 318-320°C (with decomposition, from DMFA) were obtained. IR spectrum: 1530, 1608, 1625; 2212 (CN); 3300, 3393 cm^{-1} (NH_2). PMR spectrum (DMSO-D_6): 3.77 (3H, singlet, NCH_3); 5.84 (2H, broadened singlet, disappearing after deuteration, NH_2); 7.27 (2H, multiplet, 5,6-H) and 7.54 ppm (2H, multiplet, H_{arom}).

B. A suspension of 0.32 g (1.5 mmoles) of enamine VIId and 0.1 g (2.5 mmoles) of powdered NaOH in 3 ml of absolute DMSO was stirred at 70°C for 2 h. After cooling, 10 ml of water was added, and the precipitate was separated. Cream-colored needles with mp 318-320°C (with decomposition, from DMFA) were obtained. After mixing with a sample obtained by method A, the sample gave no melting-point depression. The yield was 0.32 g (quantitative).

11-Methyl-1,2-dihydro-1-oxopyrimido[4,5:3,4]pyrazolo[1,5-*a*]benzimidazole (X, $C_{12}H_9N_5O$). A. A solution of 0.42 g (2 mmoles) of enamine VIIb in 3 ml of formamide was boiled for 1 h, and, after cooling, the precipitate was filtered and washed with water, alcohol, and ether. The precipitate weighed 0.35 g. According to data of thin-layer chromatography, the precipitate in chloroform consisted of a mixture of pyrazolobenzimidazole IXa and compound X in an approximately 1:1 ratio. For separation of the mixture, the precipitate was worked up with 30 ml of hot chloroform, and 0.2 g (42%) of compound X was filtered. Flesh-colored crystals with mp >330°C (from DMFA) were obtained. IR spectrum: 1495, 1573, 1633; 1682 (C=O), 2740 cm^{-1} (assigned to NH). PMR spectrum (DMSO-D_6): 4.18 (3H, singlet, NCH_3); 7.44 (2H, multiplet, arom. proton); 7.68-7.89 (3H, multiplet, arom. proton) and 11.72 ppm (1H, multiplet, NH).

From a chloroform filtrate, 0.15 g (30%) of compound IXa was recovered. Colorless needles with mp 192-194°C (from alcohol) were obtained. After mixing with a sample of known structure, the sample did not give a melting-point depression.

B. A mixture of 0.26 g (1 mmole)of compound IXa and 5 ml of formamide was boiled for 5 h, and, after cooling, the precipitate was filtered and washed with water and alcohol. Flesh-colored crystals with mp 330°C (from DMFA) were obtained. The yield of compound X was 0.19 g (80%). Its physicochemical characteristics were identical to those of a known sample of compound X.

2-(p-Nitrobenzylideneamino)-4-methyl-3-cyanopyrazolo[1,5-*a*]benzimidazole ($C_{18}H_{12}N_6O_2$). A solution of 0.21 g (1 mmole) of compound IXb and 0.15 g (1 mmole) of p-nitrobenzaldehyde in 4 ml of DMFA was boiled for 1 h, and, after cooling, the yellow precipitate was filtered and washed with alcohol. Fibrous yellow needles with mp 236-237°C (from butanol) were obtained. IR spectrum: 1530, 1600, 1650; 2232 cm^{-1} (CN). The yield was 0.3 g (88%).

4-Methyl-3-(ethoxycarbonyl)-1,2-dihydro-2-oxopyrazolo[1,5-*a*]benzimidazole (XIa, $C_{13}H_{13}N_3O_3$). A mixture of 0.3 g (1 mmole) of enamine VIIa and 0.56 g (10 mmoles) of powdered potassium hydroxide in 5 ml of absolute DMSO was stirred at 60-70°C for 2 h, and, after cooling, 15 ml of water was added, and the whole was neutralized with acetic acid to pH 5-6. The lilac-colored precipitate was filtered and washed with water. Colorless needles with mp 180-182°C (from alcohol) were obtained. IR spectrum: 1625, 1660, and 1708 (C=O); 3210, 3315 cm^{-1} (NH). PMR spectrum (DMSO-D_6): 1.29 (3H, triplet, J = 7.2 Hz, $CH_2\underline{CH_3}$); 4.0 (3H, singlet, NCH_3); 4.25 (2H, quartet, J = 7.2 Hz, $\underline{CH_2}CH_3$); 7.30 (2H, multiplet, H_{arom}) and 7.57 ppm (2H, multiplet, H_{arom}). The yield was 0.22 g (90%).

4-Methyl-3-cyano-1,2-dihydro-2-oxopyrazolo[1,5-*a*]benzimidazole (XIb, $C_{11}H_8N_4O$). A mixture of 0.39 g (1.5 mmoles) of enamine VIIb and 0.1 g (2.5 mmoles) of powdered NaOH in 4 ml of absolute DMSO was stirred at 60-70°C for 1 h. After cooling, the gradually formed heavy precipitate was filtered and washed with alcohol and ether. The sodium salt of compound XIb was obtained in a yield of 0.3 g (85%). The substance dissolved well in water, and, during acidification of the aqueous solution by acetic acid, a precipitate of XIb formed. Colorless crystals with mp 310-312°C (with decomposition, from butanol) were obtained. IR spectrum: 1516, 1593, 1626; (C=O); 2210 (CN); 2653 cm^{-1} (assigned to NH). PMR spectrum (DMSO-D_6): 3.77 (3H, singlet, NCH_3); 7.33 (2H, multiplet, H_{arom}) and 7.60 ppm (2H, multiplet, H_{arom}).

4-Methyl-3-Nitro-1,2-dihydro-2-oxopyrazolo[1,5-a]benzimidazole (XIc, $C_{10}H_8N_4O_3$). To a warm solution of 0.28 g (1mmole) of enamine VIIc in 3 ml of absolute DMSO was added 0.1 g (2.5 mmoles) of powdered NaOH, and the solution was immediately colored bright yellow. The mixture was stirred at 60-70°C for 1 h. A heavy yellow precipitate formed from the warm solution, and the precipitate was filtered and washed with alcohol after cooling. The sodium salt of compound XIc was obtained in a yield of 0.23 g (98%). During acidification of the aqueous solution of the obtained salt by acetic acid, a colorless gelatinous precipitate formed, and it was separated and washed with water and alcohol. Pale-yellow needles with mp 206-207°C (with decomposition, from butanol) were obtained. IR spectrum: 1552, 1592, 1608, 1628, 1704 (C=O); 2400-2800 cm^{-1} (assigned to NH). PMR spectrum (DMSO-D_6): 4.14 (3H, singlet, NCH_3); 7.41 (2H, multiplet, H_{arom}) and 7.71 ppm (2H, multiplet, H_{arom}).

1,4-Dimethyl-3-(ethoxycarbonyl)-1,2-dihydro-2-oxopyrazolo[1,5-*a*]benzimidazole (XIIIa) and 2-Methoxy-4-methyl-3-(ethoxycarbonyl)pyrazolo[1,5-*a*]benzimidazole (XIV). A suspension of 0.3 g (1 mmole) of compound VIIa and 0.08 g (2 mmoles) of powdered NaOH in 5 ml of absolute DMSO was stirred at 60-70°C for 30 min, 0.12 ml (2 mmoles) of methyl iodide was added after cooling, stirring was continued at 20°C for 1 h, and a solution formed after 5 min. To the solution was added 30 ml of water, and the whole was extracted with 2 × 20 ml of chloroform. The product was purified chromatographically on a column with Al_2O_3 (chloroform). Pale-pink crystals with mp 213-215°C (from ethyl acetate) were obtained. IR spectrum: 1587, 1620, 1660, and 1683 cm^{-1} (C=O). PMR spectrum ($CDCl_3$): 1.23 (3H, triplet, J = 7.2 Hz, $CH_2\underline{CH_3}$); 3.43 (3H, singlet, $N_{(1)}CH_3$); 3.69 (1H, singlet, OCH_3); 3.99 (3H, singlet, $N_{(4)}CH_3$); 4.18 (2H, quartet, J = 7.2 Hz, $\underline{CH_2}CH_3$); 7.13 ppm (4H, multiplet, 5-8-H). According to data of PMR spectroscopy, the reaction mixture consisted of 1-methyl isomer XIIIa and 2-methoxy derivative XIV in a 7:3 ratio, and after twofold crystallization from ethyl acetate the ratio of the mixture components was 6:1.

1,4-Dimethyl-3-cyano-1,2-dihydro-2-oxopyrazolo[1,5-*a*]benzimidazole (XIIIb). A suspension of 0.2 g (0.9 mmole) of the sodium salt of compound XIb and 0.06 ml (1 mmole) of methyl iodide in 3 ml of absolute DMSO was stirred at 20°C for 2 h and then diluted fivefold with water, and colorless prisms with mp 310-312°C (from DMFA) were filtered. IR spectrum: 1593, 1620, 1660; 2204 cm^{-1} (CN). PMR spectrum (DMSO-D_6): 3.56 (3H, singlet, $N_{(1)}CH_3$); 3.78 (3H, singlet, $N_{(4)}CH_3$); 7.34 (2H, multiplet, arom. proton) and 7.72 ppm (2H, multiplet, H_{arom}). The yield was 0.15 g (74%).

1,4-Dimethyl-3-nitro-1,2-dihydro-2-oxopyrazolo[1,5-*a*]benzimidazole (XIIIc). To a suspension of 0.23 g (1 mmole) of compound XIc and 0.07 g (1.2 mmoles) of powdered KOH in 3 ml of absolute DMSO was added 0.07 ml (1.2 mmoles) of methyl iodide, and the whole was stirred at 20°C for 1 h. The resulting precipitate was filtered and washed with water, alcohol, and ether. Pale-yellow needles with mp >320°C (from DMFA) were obtained. IR spectrum: 1585, 1620; 1685 cm^{-1} (C=O). PMR spectrum (DMSO-D_6): 3.60 (3H, singlet, $N_{(1)}CH_3$); 4.16 (3H, singlet, $N_{(4)}CH_3$); 7.41 (2H, multiplet, arom. proton) and 7.82 ppm (2H, multiplet, arom. proton). The yield was 0.18 g (73%).

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