eluted with a 5:1 hexane-ethyl acetate mixture. Yield, 0.08 (44%) of ether XII, mp 164... 166°C (heptane). A sample mixed with the compound obtained by method A, did not give a depression of the melting point.

C. A drop of water was added to an emulsion of 0.1 g (0.5 mmole) of the diazo compound I and 0.2 g (1.4 mmole) of boron trifluoride etherate in 25 ml of absolute ether, purged with a current of nitrogen and cooled to 0°C. The mixture was stirred for 3 h at 0°C, and then treated as indicated in procedure B. Yield, 40 mg (44%) of ether XII, mp, 164...166°C (heptane).

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HETEROARYLATION BY N-METHOXYCARBONYL- AND N,N-DIALKYL(ARYL)-CARBAMOYLBENZOPYRIDINIUM SALTS IN SITU

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The conditions for the heteroarylation of indole and malononitrile by quinoline and isoquinoline in the presence of methyl chloroformate and N,N-dialkyl(aryl)-carbamoyl chlorides were studied. Aromatization of the obtained compounds by 2,2,6,6-tetramethyl-1-oxopiperidinium and triphenylcarbenium perchlorates gave for the first time α-substituted and unsubstituted stable N-methoxycarbonyl- and N,N-dialkyl(aryl)carbamoylbenzopyridinium perchlorates.

Heteroarylation of N-heteroaromatic bases in the presence of acyl halides includes three stages, i.e., the formation of the salts of the N-acylheteroaromatic cations, nucleophilic addition of the organic compounds to them, and aromatization of the obtained N-acyl-1,2-dihydro derivatives [1-3]. Nucleophilic addition takes place more readily the stronger the electron-withdrawing effect of the N-acyl residues, and the heteroaromatic cations are consequently stronger electrophiles. The aromatization stage, on the other hand, is facilitated with decrease in the electron-withdrawing characteristics of the N-acyl residues of the respective N-acyl-1,2-dihydro compounds [3]. In this connection it seemed of interest to study the effect of chloroformates and carbamoyl chlorides, which are acid chlorides containing electron-donating substituents and therefore possessing the lowest electron-withdrawing power of all the possible acyl halides, on the two stages of the heteroarylation processs.

It is known that chloroformates are used to activate the pyridine [4] and phenanthridine [5] rings in reactions with potassium cyanide (the Reissert reaction) and of pyridine in reaction with Grignard reagents [6]. Diphenylcarbamoyl chloride was used to active isoquinoline during heteroarylation of N-methylpyrrole [7], where the authors noticed that the heteroarylating agent in this case was significantly less active than normal N-acylpyridinium salts. The use of carbamoyl chlorides in heteroarylation reaction has been restricted to these few examples (see also [8]), although there is significantly more information on the formation of the corresponding N-acylpyridinium salts with various substituents [2].

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TABLE 1. The Characteristics of Compounds (Ia-i, IIa,c, IIIa)

Compound	Molecular formula	mp, °C	IR spectrum, cm^{-1}	Yield, %
Ia	$C_{19}H_{16}N_2O_2$	160...162	1614 (C=O), 3278 (N—H)	52
Ib	$C_{14}H_{11}N_3O_2$	133...135	1672 (C=O), 2250 (C—N)	50
Ic	$C_{20}H_{19}N_3O$	232...234	1610 (C=O), 3273 (N—H)	40
Id	$C_{22}H_{23}N_3O$	109...110	1600 (C=O), 3298 (N—H)	63
Ie	$C_{30}H_{23}N_3O$	125...127	1630 (C=O), 3280 (N—H)	87
If	$C_{32}H_{27}N_3O$	198...199	1615 (C=O), 3279 (N—H)	83
Ig	$C_{17}H_{18}N_4O$	168...169	1700 (C=O), 2246 (C—N)	49
Ih	$C_{25}H_{18}N_4O$	152...153	1656 (C=O), 2234 (C—N)	85
Ii	$C_{27}H_{22}N_4O$	165...167	1630 (C=O), 2250 (C—N)	82
IIa	$C_{19}H_{19}N_2O_2$	163...165	1670 (C=O), 3358 (N—H)	48
IIc	$C_{20}H_{19}N_3O$	226...228	1674 (C=O), 3352 (N—H)	35
IIIa	$C_{23}H_{18}N_2O_2$	222...223	1674 (C=O), 3302 (N—H)	72

TABLE 2. The Parameters of the PMR spectra (DMSO-d_6) of 1,2-Dihydrobenzopyridines (I-III)

Compound	Proton chemical shifts, ppm, SSCC						Aromatic protons of isoquinoline, indole, and phenyl fragments
	$C_{(1)}$—H	$C_{(2)}$—H	$C_{(3)}$—H*	$C_{(4)}$—H*	R¹—H	R²—H	
Ia	6,68 s	—	—	6,07 d	3,62 s	10,90s	6,74...7,72 (9H)
Ic	6,66 s	—	6,9 d	6,16 d	2,0 s	11,04 s	7,08...7,96 (9H)
Id	6,4s	—	6,78 d	5,94 d	0,92 t 3,08 dd., J=8 Hz	10,86 s	6,76...7,76 (9H)
If	6,5s	—	—	6,0 d	4,24 dd., J=16 Hz	10,84 s	6,74...6,76 (20H)
Ih	6,08 d; J_1=6 Hz	—	6,62 d	5,74 d	—	5,26 d, J=6 Hz	6,96...7,22 (14H)
Ii	5,26 d; J=6 Hz	—	6,74 d	6,04 d	4,3dd J=14 Hz	5,88 d, J=6 Hz	7,06...7,44 (14H)
IIa	—	6,36 d, J=4 Hz	—	—	3,8 s	10,92 s	6,46...7,5 (11H)
IIc	—	5,96 d, J=8 Hz	—	—	2,76 s	10,98s	6,40...7,7 (11H)
IIIa	—	6,5 d, J=4 Hz	—	—	3,8 s	10,94s	6,6...8,35 (13H)

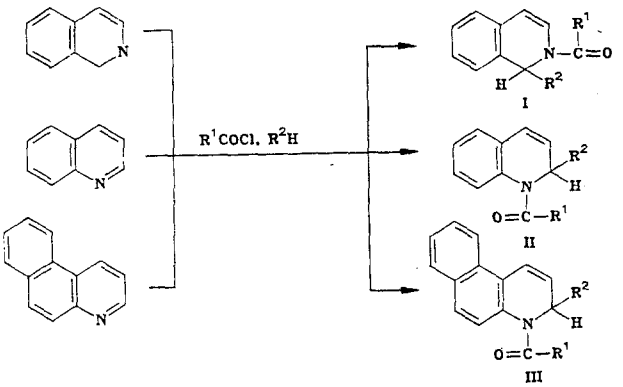
*$J_{3,4}$ = 8 Hz.

The use of carbamoyl chlorides in heteroarylation (as agents which activate the aromatic ring) makes it possible to obtain dihydrobenzopyridines, which are derivatives of a physiologically active class of compound, i.e., tetrasubstituted ureas.

We conducted the reaction of the "soft" and "hard" nucleophiles indole and malononitrile with isoquinoline, quinoline, and benz[f]quinoline in the presence of methyl chloroformate and a whole series of various carbamoyl chlorides. The choice of the "soft" and "hard" nucleophiles as subjects for heteroarylation is explained by the fact that in these reactions the "soft" nucleophiles frequently attack the α or γ position of the heteroaromatic ring, whereas the attack by "hard" nucleophiles takes place at the harder electrophilic center, i.e., the exocyclic carbonyl carbon atom attached to the nitrogen atom carrying the positive charge, and cleavage of the $>N-\overset{|}{C}=O$ bond and acylation occur instead of heteroarylation of the nucleophilic agent [2].

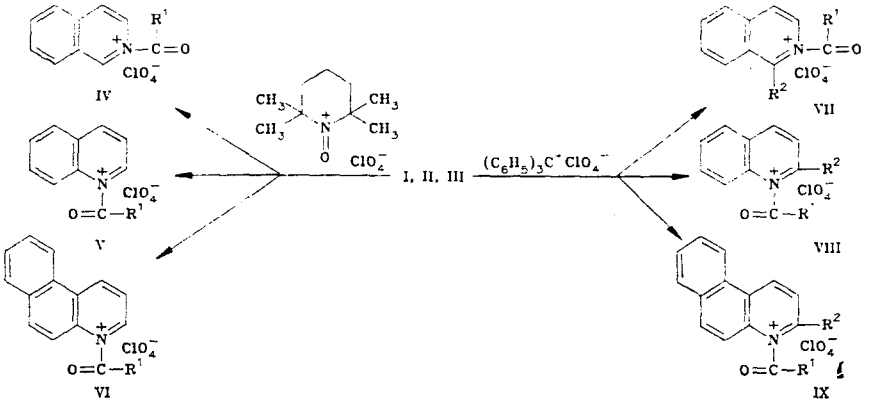
As found, heteroarylation of both indole and malononitrile occurred when the carbamoyl chlorides and methyl chloroformate were used as agents which activate the heteroaromatic ring. The reaction only took between 1 h 30 min and 2 h at a reaction temperature of 70-80°C (Table 1).

We realized the aromatization of the obtained compounds by two methods, i.e., by the action of triphenylmethyl perchlorate and by the reaction with 2,2,6,6-tetramethyl-1-oxopiperidinium perchlorate. In the first case the indole and malononitrile residues were re-



a $R^1=OCH_3$, R^2=3-indolyl; b $R^1=OCH_3$, $R^2=CH(CN)_2$; c $R^1=N(CH_3)_2$, R^2=3-indolyl d $R^1=N(C_2H_5)_2$, R^2=3-indolyl; e $R^1=N(C_6H_5)_2$, R^2=3-indolyl; f $R^1=N(CH_2C_6H_5)_2$, R^2=3-indolyl; g $R^1=N(C_2H_5)_2$, $R^2=CH(CN)_2$; h $R^1=N(C_6H_5)_2$, $R^2=CH(CN)_2$; i $R^1=N(CH_2C_6H_5)_2$, $R^2=CH(CN)_2$

moved; and we obtained the unsubstituted N-acylbenzopyridinium salts (IV-VI), and in the second case dehydroaromatization occurred with the formation of the substituted salts (VII-IX):



The similar dual behavior of 1,2-dihydro compounds in aromatization reactions was discussed in detail in [3]. It is evidently due to the oxidizing and electrophilic characteristics of the aromatizing agent. The 2,2,6,6-tetramethyl-1-oxopiperidinium cation, which is a stronger oxidizing agent with reduced electrophilicity (as a result of steric hindrances), is a selective dehydroaromatizing agent [9], whereas the stronger electrophile triphenylmethyl cation most often aromatizes with elimination of the α-substituents [10].

The structure of the obtained compounds (I-III) was proved by means of the IR and PMR spectra. Thus, the IR spectra of these compounds contain characteristic bands for the stretching vibrations of the carbonyl group in the region of 1630 cm^{-1} for the carbonyl derivatives and in the region of 1670 cm^{-1} for the methoxycarbonyl derivatives (a, b). The PMR spectra contain signals for the protons of the NH group of the indole (10.88 ppm), the hydrogen atom attached to the α-carbon atom of the heterocycle (7.04 ppm), the CH_3O and $(CH_3)_2N$ methyl groups in the regions of 3.80 and 2.00 ppm respecctively, and other signals (Table 2) which confirm the proposed structures.

The IR spectra of the salts (IV-IX) show characteristic bathochromic shifts of the carbonyl stretching vibrations of the acyl residue by approximately 100 cm^{-1} compared with the initial dihydro compounds (I-III). This is due to the adjacency of the carbonyl group to the nitrogen heteroatom in their molecules (Table 3) [11].

EXPERIMENTAL

Heteroarylation of Indole and Malononitrile by Benzopyridines in the Presence of Chloroformates and Carbamoyl Chlorides (general procedure). To a solution of 0.01 mole of benzopyridine and 0.005 mole of methyl chloroformate or carbamoyl chloride in 15 ml of dry benzene we added a solution of 0.005 mole of indole or malononitrile in 5 ml of an-

TABLE 3. The Characteristics of Compounds (IV-IX)

Compound	Molecular formula	mp, °C	IR spectrum, cm^{-1}	Yield, %
IVa	$C_{11}H_{10}ClNO_6$	110...111	1810 (C=O); 1100, 620 (ClO_4^-)	99
IVb	$C_{11}H_{10}ClNO_6$	108...109	1770 (C=O); 1100, 614 (ClO_4^-)	98
IVc	$C_{12}H_{13}ClN_2O_5$	95...96	1756 (C=O); 1100, 617 (ClO_4^-)	99
IVd	$C_{14}H_{17}ClN_2O_5$	96...97	1740 (C=O); 1086, 603 (ClO_4^-)	99
IVe	$C_{22}H_{17}ClN_2O_5$	195...196	1742 (C=O); 1086, 614 (ClO_4^-)	99
IVf	$C_{24}H_{21}ClN_2O_5$	87...89	1720 (C=O); 1100, 612 (ClO_4^-)	99
IVg	$C_{14}H_{17}ClN_2O_5$	96...98	1728 (C=O); 1072, 614 (ClO_4^-)	99
IVh	$C_{22}H_{17}ClN_2O_5$	194...196	1730 (C=O); 1072, 614 (ClO_4^-)	99
IVi	$C_{24}H_{21}ClN_2O_5$	87...89	1725 (C=O); 1100, 614 (ClO_4^-)	99
Va	$C_{11}H_{10}ClNO_6$	126...128	1805 (C=O); 1100, 620 (ClO_4^-)	99
VIa	$C_{15}H_{11}ClNO_6$	174...175	1800 (C=O); 1100, 612 (ClO_4^-)	99
VIIa	$C_{19}H_{15}ClN_2O_6$	163...165	1800 (C=O); 3270 (N—H); 1099, 625 (ClO_4^-)	98
VIIb	$C_{14}H_{10}ClN_3O_6$	130...131	1800 (C=O); 2307 (C—N); 1086, 617 (ClO_4^-)	98
VIIc	$C_{20}H_{18}ClN_3O_5$	102...104	1734 (C=O); 3350 (N—H); 1086, 611 (ClO_4^-)	98
VIId	$C_{22}H_{22}ClN_3O_5$	138...139	1734 (C=O); 3335 (N—H); 1078, 610 (ClO_4^-)	99
VIIe	$C_{30}H_{22}ClN_3O_5$	154...155	1734 (C=O); 3340 (N—H); 1090, 611 (ClO_4^-)	99
VIIf	$C_{32}H_{20}ClN_3O_5$	163...165	1720 (C=O); 3342 (N—H); 1100, 617 (ClO_4^-)	99
VIIg	$C_{17}H_{17}ClN_4O_5$	71...71,5	1730 (C=O); 2458 (C—N); 1100, 618 (ClO_4^-)	99
VIIh	$C_{25}H_{17}ClN_4O_5$	200...201	1735 (C=O); 2450 (C—N); 1086, 614 (ClO_4^-)	99
VIIi	$C_{27}H_{21}ClN_4O_5$	94...95	1742 (C=O); 2456 (C—N); 1100, 614 (ClO_4^-)	99
VIIIa	$C_{19}H_{15}ClN_2O_6$	171...171,5	1800 (C=O); 3286 (N—H); 1109, 620 (ClO_4^-)	99
IXa	$C_{23}H_{16}ClN_2O_6$	141...143	1814 (C=O); 3372 (N—H); 1088, 617 (ClO_4^-)	99

hydrous benzene. The mixture was kept at 70-80°C for 2 h, after which it was treated with a 10% solution of ammonia (30 ml) and was then washed with water and with a weak solution (1:3) of hydrochloric acid. The precipitate was washed with ether and recrystallized from ethanol. The characteristics of the obtained compounds are given in Table 1.

Aromatization of 1,2-Dihydrobenzopyridines (I-II) (general procedure). A. To a solution of 0.01 mole of triphenylmethyl perchlorate in 5 ml of anhydrous acetonitrile we added in portions with stirring an equivalent amount of a solution of the dihydro compound in 5 ml of anhydrous acetonitrile. After 1 h the reaction mixture was poured into 50 ml of dry diethyl ether. The precipitate was filtered off and recrystallized from acetonitrile.

B. To a solution of 0.01 mole of the respective compound (I-III) in 5 ml of acetonitrile we added a twofold excess of 2,2,6,6-tetramethyl-1-oxopiperidinium perchlorate. After 1 h the reaction mixture was poured into 450 ml of dry ether, and the precipitate was filtered off and recrystallized from acetonitrile.

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