washed on the filter with dry ether, and dried in vacuum over calcium chloride. Yield 0.18 g (75%), mp 260° (with decomposition). IR spectrum (KBr): 3307 (NH), 3320-2100 cm^{-1} (NH_3^+). Found, %: C 68.0, H 6.3, Cl 14.2, N 11.2. $C_{14}H_{14}N_2 \cdot HCl$. Calculated, %: C 68.1, H 6.1, Cl 14.3, N 11.3.

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SYNTHESIS OF 1-SUBSTITUTED 1,2,3,9a-TETRAHYDRO-9H-IMIDAZO[1,2-a]INDOL-2-ONES

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1-R-9,9,9a-Trimethyl-1,2,3,9a-tetrahydro-9H-imidazo[1,2-*a*]indol-2-ones and the corresponding 2-methylene-2,3-dihydroindoles were obtained by the reaction of 2,3,3-trimethyl-3H-indole with a number of N-substituted chloroacetic acid amides and subsequent reaction of the resulting quaternary salts with bases. The kinetics of intramolecular cyclization of 1-(N-alkylcarbamoylethyl)-2-methylene-2,3-dihydroindoles under the influence of acetic acid were studied. Under the influence of strong protic acids 1-R-imidazo[1,2-*a*]indol-2-ones undergo decyclization and are converted to 3H-indolium salts.

As we have already reported [1], the reaction of 2,3,3-trimethyl-3H-indole (I) with α-chloroacetamide with subsequent treatment of 1-carbamoylmethyl-3H-indolium chloride (IIa) with bases leads to the formation of imidazo[1,2-*a*]indol-2-one (IIIa) or the corresponding 2-methylene-2,3-dihydroindole (IVa). It seemed of interest to us to study the alkylation of I with N-substituted chloroacetamides and to determine the effect of substituents attached to the nitrogen atom of the carbamoyl group on the formation of the imidazolidine ring.

The reaction of 3H-indole I with chloroacetic acid alkyl-, cyclohexyl-, allyl-, and benzylamides yielded salts IIb-h, which, without isolation, were subjected to the action of potassium hydroxide at 40°C; this procedure gave mixtures of imidazo[1,2-*a*]indol-2-ones (IIIb-h) and methylene bases IVb-h. The degree of conversion of 1-(N-benzylcarbamoylmethyl)-3H-indolium chloride (IIh) to the corresponding imidazo[1,2-*a*]indol-2-one under the indicated conditions reaches 90%, as compared with 3-5% in the case of 1-(N-cyclohexylcarbamoylmethyl)-3H-indolium chloride (IIf). For the separation of III and IV ether or benzene solutions of the mixtures were treated with 2-3% hydrochloric acid; IIIb-h remain primarily in the organic solvent, while methylene bases IVb-h pass into the acidic layer in the form of indolium salts IIb-h. Perchlorates IIi-k crystallize out when the calculated amount of perchloric acid is added to ethanol solutions of imidazo[1,2-*a*]indolones IIIb-d.

Opening of the imidazolidine ring of 1-methyl-imidazo[1,2-*a*]indol-2-one (IIIb) by strong protic acids is confirmed by the fact that in the PMR spectrum of a solution in CF_3COOH, instead of a singlet of a $CONCH_3$ group, one observes a doublet at 2.65 ppm with a spin—spin coupling constant (SSCC) of 4.7 Hz, which is peculiar to the methyl protons of the $CONHCH_3$

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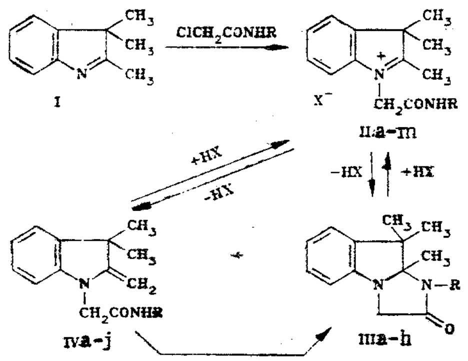

II—IV a $R=H$, b $R=CH_3$, c $R=C_2H_5$, d $R=n\text{-}C_3H_7$, e $R=n\text{-}C_4H_9$, f $R=C_6H_{11}$, g $R=CH_2CH=CH_2$, h $R=CH_2C_6H_5$; II i $R=CH_3$, j $R=C_2H_5$, k $R=n\text{-}C_3H_7$, *l* $R=C(CH_3)_3$, m $R=C_6H_5$; IV i $R=C(CH_3)_3$, j $R=C_6H_5$; II a–h, *l*, m $X=Cl$, i–k $X=ClO_4$

group of the cation of salt IIb. Methylene bases IVb-h are primarily formed in the neutralization of cooled (to 0°C) solutions of IIIb-h in hydrochloric acid or perchlorates IIi-k with sodium carbonate. Individual 1-(N-alkylcarbamoylmethyl)-2,3-dihydroindoles IVb-f were obtained by this method.

An investigation of the reaction of 1-(N-tert-butylcarbamoylmethyl)- and 1-(N-phenylcarbamoylmethyl)-3H-indolium chlorides (II*l*,m) with potassium hydroxide at 40°C showed that the formation of an imidazolidine ring does not occur and that the final products are methylene bases IVi,j.

Like the compound with a primary amide group (IVa), N-substituted 1-carbamoylmethyl-2,3-dihydroindoles IVb-h undergo cyclization to imidazo[1,2-*a*]indol-2-ones (IIIb-h) under the influence of weak carboxylic acids such as acetic or propionic acid. We studied the kinetics of the conversion of IVa-e to imidazo[1,2-*a*]indol-2-ones (IIIa-e) in a 5% solution of acetic acid in deuteroacetone. The kinetics were investigated by the usual PMR spectroscopic methods [2]. Under the indicated conditions the cyclization is described by a first-order reaction equation [3]. The rate constants (K_{eff}) obtained are presented in Table 1. It is apparent from these data that the rate of cyclization depends substantially on the nature of the substituents attached to the nitrogen atom of the carbamoyl group. The significant increase in the rate of formation of IIIb as compared with the rate of formation of IIIa is explained by the increased nucleophilicity of the amide nitrogen atom under the influence of the electron-donor methyl radical. However, in the case of further lengthening of the alkyl chain the effect of the developing frontal strains in the transition state in the formation of the imidazolidine ring leads to a significant decrease in the rate constants, and cyclization of 1-(N-cyclohexylcarbamoylmethyl)-, 1-(N-tert-butylcarbamoylmethyl)-, and 1-(N-phenylcarbamoylmethyl)-2,3-dihydroindoles (IVf, i, j), under the influence of carboxylic acids does not occur.

The structures of the synthesized compounds were confirmed by the results of spectral studies. The IR spectra of IIIb-h in the 1685-1700 cm^{-1} region contain an absorption band

TABLE 1. Effective Rate Constants for the Conversion of IVa-e to IIIa-e in 5% Solutions of Acetic Acid in $(CD_3)_2CO$ at 40°C*

Compound	$K_{eff} \cdot 10^4$, sec^{-1}
IVa	0,895
IVb	1,750
IVc	0,992
IVd	0,794
IVe	0,682

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*The starting concentration of IVa-e was 0.31 M.

TABLE 2. I-R-Imidazo[1,2-*a*]indol-2-ones (IIIb-h)

Compound	mp,* °C	IR spectrum, ν_{CO}, cm⁻¹	Found, %			Empirical formula	Calc., %			Yield, %
			C	H	N		C	H	N	
IIIb	42—43	1700	72,8	8,0	12,3	$C_{14}H_{18}N_2O$	73,0	7,9	12,2	63
IIIc	82—83	1695	74,0	8,4	11,8	$C_{15}H_{20}N_2O$	73,7	8,3	11,5	42
IIId	90—91	1685	74,7	8,8	11,1	$C_{16}H_{22}N_2O$	74,4	8,6	10,8	21
IIIe	59—60	—	75,2	8,6	10,2	$C_{17}H_{24}N_2O$	75,0	8,9	10,3	19
IIIf	146—147	1700	76,8	9,0	9,5	$C_{19}H_{26}N_2O$	76,5	8,8	9,4	11
IIIg	104—105	1700	74,9	8,0	10,9	$C_{16}H_{20}N_2O$	75,0	7,9	10,9	30
IIIh	146—147	1700	78,3	7,3	9,1	$C_{20}H_{22}N_2O$	78,4	7,2	9,1	77

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*Compound IIIb was distilled in vacuo at 172-173°C (4.66 hPa). Compounds IIIc,f were crystallized from acetone, IIId,e were crystallized from cyclohexane—hexane, and IIIg,h were crystallized from alcohol.

TABLE 3. PMR Spectra (in $CDCl_3$) of I-R-Imidazo[1,2-*a*]-indol-2-ones (IIIb-h)

Compound	δ, ppm				
	9,9-CH_3 (two s)	9a-CH (s)	NCH_2CO (AB system)*	aromatic	R (except for aromatic protons)
IIIb	1,12; 1,36	1,43	3,75; 3,97 (15,0)	6,60—7,26	2,89 (3H, s, NCH_3)
IIIc	1,01; 1,38	1,44	3,66; 4,01 (15,0)	6,60—7.26	1,28 (3H, t, $J=7$ Hz CH_3); 2,78—3,88 (2H, m, CH_2)
IIId	1,01; 1,40	1,44	3,65; 4,03 (15,5)	6,63—7,26	0,93 (3H, t, $J=7$ Hz, CH_3); 1,43—3,73 (4H, m CH_2CH_2)
IIIe	1,01; 1,40	1,44	3,65; 4,03 (15,5)	6,63—7,26	0,93 (3H, t, $J=7$ Hz, CH_3); 1,11—3,73 (6H, m, $CH_2CH_2CH_2$)
IIIf	1,16; 1,40	1,49	3,68; 3,93 (15,0)	6,55—7,26	1,05—3,10 (11H, m, cyclohexyl)
IIIg	1,08; 1,37	1,43	3,70; 4,01 (15,5)	6,63—7,26	3,46—4,30 (2H, m, NCH_2); 4,93—6,09 (3H, m $CH{=}CH_2$)
IIIh	1,04; 1,40	1,40	3,83; 4,18 (15,3)	6,69—7,43	4.22 and 4.95 (2H, AB-system, $J=15,3$ Hz, CH_2)

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*Parameters of the AB system: δ_A, δ_B (J_{AB}, Hz).

of a carbonyl group (Table 2), which is shifted 20-30 cm⁻¹ to the shorter-wavelength side in the spectra of perchlorates IIi-k and methylene bases IVb-f,i. In addition, absorption bands peculiar to secondary amides at 1550-1580 cm⁻¹ (amide II) and 3300-3370 cm⁻¹ (NH) are observed in the IR spectra of IIi-k and IVb-f,i. Absorption bands that are characteristic for the perchlorate anion, viz., 620-630, 940-960, and 1040-1150 cm⁻¹ [4], are also isolated in the spectra of salts IIi-k. The PMR spectra of IIIb-h are characterized by the presence of an AB system of methylene protons of the imidazolidine ring (Table 3). The signal of these protons in the PMR spectra of IVb-f,i (in $CDCl_3$), as well as perchlorates IIi-k and chloride IIi (in CF_3COOH), is observed in the form of a narrow singlet at, respectively, 4.00-4.15 and 5.00-5.10 ppm. An overall singlet of geminal methyl groups of IVb-f,i,j is present at 1.34-1.37 ppm, as compared with 1.23-1.34 ppm for perchlorates IIi-k. A signal of protons of the 2-CH_3 group of perchlorates IIi-k is observed at 2.38-2.50 ppm. The protons of the terminal methylene group of IVb-f give a somewhat broadened singlet at 3.90-3.95 ppm, which, in the case of IVi, is converted to an AB quartet centered at 3.94 ppm with a characteristic SSCC of 2.8 Hz [5]. Peaks of ions with m/z 230 $(M)^{+\bullet}$, 215 $(M - CH_3)^+$, 200 $(M - CH_3 - CH_3)^+$, and a peak of an ion formed after fragmentation of the imidazolidine ring with m/z 172 $(M - CONHCH_3)^+$, as well as characteristic (for indole systems [6]) signals of ions with m/z 144 and 130, are observed in the mass spectrum of IIIb.

EXPERIMENTAL

The IR spectra of KBr pellets of the compounds were recorded with a UR-20 spectrometer. The PMR spectra were obtained with a Tesla BS-487C spectrometer (80 MHz) with hexamethyldisiloxane as the internal standard. The mass spectra were recorded with a Riber-1010

TABLE 4. 1-Carbamoylmethyl-2-methylene-2,3-dihydroindoles (IVb-f,i,j)

Compound	mp,* °C	N found, %	Empirical formula	N calc., %	Yield, %
IVb	100—101	12,4	$C_{14}H_{18}N_2O$	12,2	72
IVc	74—75	11,5	$C_{15}H_{20}N_2O$	11,5	76
IVd	71—72	10,9	$C_{16}H_{22}N_2O$	10,8	82
IVe	50—52	10,1	$C_{17}H_{24}N_2O$	10,3	68
IVf	106—107	9,3	$C_{19}H_{26}N_2O$	9,4	61
IVi	140—141	10,5	$C_{17}H_{24}N_2O$	10,3	82
IVj	76—77	9,6	$C_{19}H_{20}N_2O$	9,6	40

*Compounds IVb-e,j were crystallized from cyclohexane—hexane, and IVf,i were crystallized from alcohol.

spectrometer with direct introduction of the substances into the ion source; the ionizing voltage was 100 eV. The course of the reactions and the purity of the substances were monitored by thin-layer chromatography (TLC) on activity II aluminum oxide in an acetone—hexane system (2:5) with development by iodine vapors. In the investigation of the kinetics by PMR spectroscopy the reactions were carried out in standard ampuls for spectral recording. Integration of the areas of the signals of the protons of the methylene groups of the starting compounds and final products in the PMR spectra was accomplished every 30 min over a period of 8 h.

1-Substituted 9,9,9*a*-Trimethyl-1,2,3,9*a*-tetrahydro-9H-imidazo[1,2-*a*]indol-2-ones (IIIb-h) (Tables 2 and 3). A mixture of 6.37 g (40 mmole) of 2,3,3-trimethyl-3H-indole and 6.46 g (60 mmole) of chloroacetic acid N-methylamide was heated at 135-140°C for 5.5 h. The reaction products were dissolved in 20 ml of acetone, the solution was poured into 150 ml of 5% HCl, and the excess amide was extracted with ether (two 20-ml portions). A solution of potassium hydroxide was added to the heated (to 40°C) acidic solution until the mixture was alkaline, and the liberated substance was extracted with ether (two 20-ml portions) or benzene. The extract was washed with 2-3% HCl until removal of the starting indole and methylene base IVb was complete (monitoring by TLC: IIIb has R_f 0.52, and methylene base IVb has R_f 0.44). The organic layer was separated, and the acidic solution, which contains primarily the product of alkylation of the 3H-indole that has not undergone cyclization, was treated repeatedly with potassium hydroxide. The alkaline solution was again extracted with the same solvent, and the extract was washed with 2-3% HCl. The indicated process was repeated three times. The extracts were combined, washed with 75 ml of water, and dried with calcium chloride. The solvent was removed by distillation, and the resulting IIIb was distilled in vacuo.

Compounds IIIc-h were similarly obtained and were recrystallized from the solvent indicated in Table 2.

1-(N-Alkylcarbamoylmethyl)-2,3,3-trimethyl-3H-indolium Perchlorates (IIi-k). A solution of 2.30 g (10 mmole) of 1-methylimidazo[1,2-*a*]indol-2-one IIIb in 5 ml of alcohol was neutralized with 60% perchloric acid, and the mixture was cooled to 0°C. The crystalline substance was removed by filtration and recrystallized from isopropyl alcohol. The yield of perchlorate IIi, with mp 218-219°C, was 0.83 g (25%). Found, %: Cl 10.7, N 8.6. $C_{14}H_{19}ClN_2O_5$. Calculated, %: Cl 10.7, N 8.5. Perchlorates IIj,k were similarly obtained. The yield of perchlorate IIj, with mp 209-210°C (from isopropyl alcohol), was 52%. Found, %: Cl 10.3, N 8.3. $C_{15}H_{21}ClN_2O_5$. Calculated, %: Cl 10.3, N 8.1. The yield of perchlorate IIk, with mp 152-153°C (from isopropyl alcohol), was 66%. Found, %: Cl 9.6, N 7.8. $C_{16}H_{23}ClN_2O_5$. Calculated, %: Cl 9.9, N 7.8.

1-(N-Alkylcarbamoylmethyl)-3,3-dimethyl-2-methylene-2,3-dihydroindoles (IVb-e) (Table 4). A solution of 2.30 g (10 mmole) of IIIb in 10 ml of acetone was poured into 50 ml of 5% HCl, and the mixture was cooled to 0°C and neutralized with cooling by means of sodium carbonate to pH 9. The liberated substance was extracted with ether (two 20-ml portions), and the extract was washed with 20 ml of water and dried with sodium sulfate. The solvent was removed by distillation, and IVb was reprecipitated from cyclohexane by the addition of hexane and dried in vacuo. Compounds IVc-e were similarly obtained.

3,3-Dimethyl-2-methylene-1-(N-cyclohexylcarbamoylmethyl)-2,3-dihydroindole (IVf, Table 4). A mixture of 4.78 g (30 mmole) of 2,3,3-trimethyl-3H-indole and 7.90 g (45 mmole) of chloroacetic acid N-cyclohexylamide in 8 ml of xylene was heated at 140°C for 5.5 h. The reaction products were dissolved in 30 ml of acetone, and the solution was poured into 150 ml of 5% HCl; the mixture was extracted with ether (two 20-ml portions) to remove the excess amide. The acidic solution was neutralized to pH 9 with sodium carbonate and extracted with ether (two 25-ml portions). The extract was dried with sodium sulfate, the solvent was removed by distillation, and IVf was crystallized twice from alcohol.

3,3-Dimethyl-2-methylene-1-(N-phenylcarbamoylmethyl)-2,3-dihydroindole (IVj, Table 4). This compound was obtained from 4.78 g (30 mmole) of 2,3,3-trimethyl-3H-indole and 7.63 g (45 mmole) of chloroacetic acid anilide, as in the synthesis of IVf, and crystallized twice from cyclohexane—hexane.

*1-(N-tert-Butylcarbamoylmethyl)-2,3,3-trimethyl-3H-indolium Chloride (II*l*) and 3,3-Dimethyl-2-methylene-1-(N-tert-butylcarbamoylmethyl)-2,3-dihydroindole (IVi,* Table 4). A mixture of 7.96 g (50 mmole) of 2,3,3-trimethyl-3H-indole and 11.22 g (75 mmole) of the N-tert-butylamide of chloroacetic acid in 8 ml of xylene was heated at 140°C for 4.5 h. The liberated crystalline substance was removed by filtration, washed with 20 ml of acetone, and dried to give 5.4 g (35%) of chloride II*l* with mp 230-231°C (from methanol). Found, %: Cl 11.7, N 9.0. $C_{17}H_{25}ClN_2O_5$. Calculated, %: C 11.5, N 9.1. To obtain methylene base IVi, a solution of 3.09 g (10 mmole) of chloride II*l* in 50 ml of water was treated to pH 9 with sodium carbonate, and the mixture was extracted with ether (two 20-ml portions). The extract was washed with 20 ml of water and dried with calcium chloride. The solvent was removed, and IVi was crystallized from the solvent indicated in Table 4.

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