of the xylene and ethyl acetate by distillation was separated with a chromatographic column packed with aluminum oxide [elution with ether and ether—isopropyl alcohol (3:1)] to give 0.9 g (55%) of 6-amino derivative II and 0.3 g (20%) of pyrroloisoquinoline I.

B) A 1.36-g (0.035 mole) sample of sodium amide was added with stirring to a heated (to 100°C) solution of 1.68 g (0.01 mole) of pyrroloisoquinoline I in 25 ml of dimethylaniline, and the mixture was stirred at 135-140°C for 1.5 h. It was then cooled and hydrolyzed with 30 ml of water, and the precipitate was separated, washed with water and benzene, and dried to give 1.65 g (90%) of product.

1H,7H-Pyrrolo[2,3-f]isoquinol-6-one (III). A mixture of 1.68 g (0.01 mole) of pyrroloisoquinoline I and 5.6 g (0.1 mole) of potassium hydroxide was fused at 250-260°C for 6 h, after which it was cooled and treated with 25 ml of water. The aqueous mixture was neutralized with hydrochloric acid, and the precipitate was removed by filtration, washed with water, and dried to give 0.99 g (54%) of product.

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SYNTHESIS OF THIIRANE DERIVATIVES OF DECAHYDROQUINOLINE BY THE REACTION OF α,β-EPOXY ALCOHOLS WITH THIOUREA

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The reaction of α,β-epoxy alcohols of the decahydroquinoline series with thiourea in water in the presence of sulfuric acid leads to 1-alkyl-, 1,2-dimethyl-, and 1,2,2-trimethyl-4-thiiranyl-trans-decahydro-4-quinolol carbamates, the structures of which were established by spectral methods.

It is known that thiiranes are formed in the reaction of epoxides with thiourea, in which the formation of the thiirane ring from the oxirane ring is facilitated as the pH of the medium, the temperature, and the polarity of the solvent are increased [1]. The maximum yields of thiiranes are obtained when the reaction is carried out in aqueous solution with catalysis by acids [2]. In contrast to epoxides, thiirane derivatives could not heretofore be obtained in the reaction of α,β-epoxy alcohols with thiourea [3]. We used the previously synthesized [4] 1-alkyl-, 1,2-dimethyl-, and 1,2,2-trimethyl-4-oxiranyl-trans-decahydro-4-quinolols (I-VIII) as the starting compounds. As we demonstrated in [5], the reaction of epoxy alcohols I-VIII with thiourea in aqueous solution, which is accompanied by an increase in the pH of the medium, gives rise to migration of the epoxide ring to give the corresponding spirooxiranyloxymethyl-trans-decahydroquinolines, which were not altered further under the influence of thiourea. In the reaction of epoxy alcohols I-VIII with

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TABLE 1. Thiiranyldecahydroquinolol Carbamates IX-XVI

Compound	Configuration of the $C_{(4)}-O$ bond	R_f	mp, °C	Found, %				Empirical formula	Calc., %			
				C	H	N	S		C	H	N	S
IX	e	0,27	165—166	57,4	8,4	10,1	11,7	$C_{13}H_{22}N_2O_2S$	57,7	8,2	10,4	11,8
X	a	0,47	180—181	58,0	8,3	10,4	11,5	$C_{13}H_{22}N_2O_2S$	57,7	8,2	10,4	11,8
XI	e	0,24	137—138	59,0	8,7	10,1	11,4	$C_{14}H_{24}N_2O_2S$	59,1	8,5	9,8	11,3
XII	a	0,53	120—121	58,8	8,5	10,0	11,0	$C_{14}H_{24}N_2O_2S$	59,1	8,5	9,8	11,3
XIII	e	0,50	200—201	59,0	8,4	9,8	11,1	$C_{14}H_{24}N_2O_2S$	59,1	8,5	9,8	11,3
XIV	a	0,67	185—186	59,3	8,5	9,9	11,4	$C_{14}H_{24}N_2O_2S$	59,1	8,5	9,8	11,3
XV	a	0,64	201—202	58,8	8,4	10,1	11,2	$C_{14}H_{24}N_2O_2S$	59,1	8,5	9,8	11,3
XVI	a	0,70	215—216	60,1	9,0	9,4	10,5	$C_{15}H_{26}N_2O_2S$	60,0	8,8	9,4	10,7

TABLE 2. PMR Spectra of Thiiranyldecahydroquinolol Carbamates IX-XVI

Compound	δ, ppm			J, Hz			δ, ppm							J, Hz						
	A	B	X	AB	AX	BX	R^1	$CONH_2$	$2\text{-}H_e$	$2\text{-}H_a$	$3\text{-}H_e$	$3\text{-}H_a$	$2\text{-}CH_3$	3a, 3e	3e, 2e	3e, 2a	3a, 2e	3a, 2a	2e, 2a	2H, $2\text{-}CH_3$
IX	2,27	2,54	3,26	1,6	6,0	6,0	2,29	4,66	2,87	2,42	1,26	2,77	—	13,1	2,3	2,4	4,5	13,1	11,6	—
X	2,23	2,40	3,23	1,7	5,7	6,5	2,26	4,65	2,71	2,31	2,65	1,21	—	13,3	2,7	2,7	4,3	13,3	11,4	—
XI	2,29	2,56	3,26	1,6	6,2	6,4	0,99*	4,57	2,93	2,70	1,22	2,86	—	13,2	2,6	2,6	4,3	13,2	11,7	—
XII	2,24	2,39	3,21	1,7	5,8	6,8	1,03*	4,61	2,75	2,56	2,65	1,24	—	13,1	2,4	2,5	4,4	13,1	11,5	—
XIII	2,29	2,54	3,25	1,7	5,6	6,9	2,28	4,53	—	2,45	1,23	2,50	1,11	12,0	—	2,3	—	12,0	—	6,0
XIV	2,22	2,39	3,20	1,8	5,8	5,8	2,24	4,63	—	2,31	2,59	1,31	1,11	13,8	—	2,4	—	12,2	—	6,4
XV	2,22	2,39	3,17	1,7	6,0	6,8	2,29	4,57	3,17	—	2,64	1,42	1,09	13,7	1,8	—	6,2	—	—	6,7
XVI	2,22	2,37	3,14	1,6	6,0	6,8	2,20	4,53	—	—	2,57	1,08	1,04 1,14	13,8	—	—	—	—	—	—

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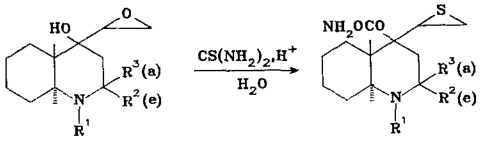
*The $1\text{-}CH_3$ values are presented.

thiourea in aqueous solution at room temperature in the presence of sulfuric acid as the catalyst we obtained thiiranyldecahydroquinolol carbamates IX-XVI (see Table 1).



I-VIII IX-XVI

I, II, IX, X $R^1=CH_3$, $R^2=R^3=H$; III, IV, XI, XII $R^1=C_2H_5$, $R^2=R^3=H$; V, VI, XIII, XIV $R^1=R^2=CH_3$, $R^3=H$; VII, XV $R^1=R^3=CH_3$, $R^2=H$; VIII, XVI $R^1=R^2=R^3=CH_3$

Absorption bands at 1700-1730 (amide I) and 1627-1637 cm^{-1} (amide II), which are characteristic for a carbamic acid ester fragment [6], are observed in the IR spectra of carbamoyl derivatives IX-XVI. In the spectra of solutions of the indicated compounds the amide II band is shifted to 1585 cm^{-1}, whereas the position of the amide I band remains virtually unchanged. In addition, two absorption bands at 3435 and 3555 cm^{-1} (NH) are present in the spectra of solutions of the compounds.

Resonance of the protons of the $CONH_2$ group is observed at 4.53-4.66 ppm in the PMR spectra of IX-XVI (Table 2). The presence in the PMR spectra of IX-XVI of signals of an ABX system, in which the chemical shifts and spin—spin coupling constants, which were confirmed by homonuclear double resonance, are characteristic for the protons of the thiirane ring, constitutes evidence that IX-XVI are actually thiirane derivatives. The assignments of the protons of the piperidine ring of IX-XVI were confirmed by homonuclear double resonance. In the case of the isomers with an equatorial 4-O-carbamoyl substituent (IX, XI, and XIII) the resonance of the $3\text{-}H_a$ protons is observed at 2.50-2.85 ppm, and the resonance of the $3\text{-}H_e$ protons is observed at 1.08-1.25 ppm. However, in the case of X, XII, and XIV-XVI, the O-carbamoyl group of which is axially oriented, the $3\text{-}H_e$ protons resonate at 2.57-2.65 ppm, and the $3\text{-}H_a$ protons resonate at 1.00-1.30 ppm. The substantial difference (∿1.5 ppm) in the chemical shifts of the axial and equatorial protons in the $3\text{-}C_{(3)}$ position is evidently due to their different degrees of shielding under the influence of the magnetic anisotropy of the $OCONH_2$ group.

TABLE 3. Mass Spectra of Thiiranyldecahydroquinolol Carbamates IX-XVI, m/z (%)

Compound	$[M]^{+\cdot}$	$[M+1]^+$	$[M-OCONH_2]^+$	$[M-HOCONH_2]^{+\cdot}$	$[M-CH_3]^+$	$[M-CH_3-HOCONH_2]^+$
IX	270 (78)	271 (19)	210 (19)	209 (43)	—	—
	270 (21)	271 (4)	210 (33)	209 (12)	—	—
X	270 (100)	271 (16)	210 (13)	209 (16)	—	—
	270 (15)	271 (2)	210 (27)	209 (5)	—	—
XI	284 (100)	285 (29)	224 (21)	223 (54)	269	
	284 (25)	285 (5)	224 (45)	223 (15)	269 (7)	208 (8)
XII	284 (100)	285 (17)	224 (12)	223 (16)	269 (2)	—
	284 (33)	285 (5)	224 (80)	223 (10)	269 (8)	208 (8)
XIII	284 (85)	285 (6)	224 (19)	223 (39)	269 (21)	208 (33)
	284 (21)	285 (3)	224 (59)	223 (5)	269 (19)	208 (100)
XIV	284 (100)	285 (15)	224 (11)	223 (15)	269 (11)	208 (35)
	284 (17)	285 (3)	224 (41)	223 (4)	269 (5)	208 (67)
XV	284 (100)	285 (19)	224 (15)	223 (15)	269 (10)	208 (28)
	284 (33)	285 (5)	224 (15)	—	269 (16)	208 (100)
XVI	298 (79)	299 (16)	238 (13)	237 (17)	283 (82)	222 (100)
	298 (6)	299 (1)	238 (19)	237 (2)	283 (11)	222 (100)

TABLE 3 (continued)

Compound	$[M-C_3H_7]^+$	$[M-C_3H_7-HOCONH_2]^+$	$[M-HS]^+$	$[M-OCONH_2-H_2S]^+$	$[M-OCONH_2-HS]^+$
IX	227 (13)	166 (13)	237 (14)	176 (100)	177 (29)
	227 (6)	166 (26)	237 (11)	176 (100)	177 (19)
X	227 (19)	166 (16)	237 (10)	176 (78)	177 (21)
	227 (6)	166 (26)	237 (4)	176 (100)	177 (16)
XI	241 (17)	180 (16)	251 (14)	190 (94)	191 (33)
	241 (7)	180 (30)	251 (14)	190 (100)	191 (19)
XII	241 (7)	180 (11)	251 (6)	190 (30)	191 (10)
	241 (7)	180 (50)	251 (8)	190 (100)	191 (18)
XIII	241 (7)	180 (13)	251 (6)	190 (100)	191 (30)
	241 (5)	180 (36)	251 (6)	190 (85)	191 (16)
XIV	241 (8)	180 (8)	251 (4)	190 (82)	191 (13)
	241 (3)	180 (17)	251 (3)	190 (100)	191 (13)
XV	241 (5)	180 (9)	251 (7)	190 (24)	191 (7)
	241 (4)	180 (39)	251 (9)	190 (70)	191 (13)
XVI	—	194 (6)	265 (9)	204 (26)	205 (10)
	255 (4)	194 (6)	265 (2)	204 (11)	205 (2)

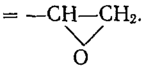
A common pattern is observed in the mass-spectral fragmentation of IX-XVI; data on their fragmentation are presented in Table 3. The mass spectra for each compound were obtained at 12 eV (upper line) and 70 eV (lower line). The mass spectra unambiguously confirm the presence of a side $OCONH_2$ group. In fact, this radical is readily eliminated from M^+. Also characteristic for 4-thiiranyl-trans-decahydro-4-quinolol carbamates IX-XVI are $[M - OCONH_2 - HS]^+$ and $[M - OCONH_2 - H_2S]^+$ ions; the intensity of the latter ion is maximal at 70 eV in the case of IX-XVI. The higher intensities of the $[M - HOCONH_2]^{+\cdot}$ peaks as compared with the intensities of the $[M - OCONH_2]^{+\cdot}$ peaks constitutes evidence that the regular ejection of an $HOCONH_2$ molecule rather than an $OCONH_2$ radical from $M^{+\cdot}$ is preferable at 12 eV. An $HOCONH_2$ molecule is eliminated particularly readily from the typical (for decahydroquinoline derivatives) $[M - CH_3]^+$ and $[M - C_3H_7]^+$ ions, which are formed by splitting out of alkyl substituents from the carbon atoms of the heterocyclic ring (XIII-XVI), cleavage of the C—C bond in the C_2H_5 group attached to the nitrogen atom (XI and XII), and as a result of cleavage of the carbocyclic ring. The ion peak corresponding to the $[M - HS]^+$ fragment has low intensity in the mass spectra of IX-XVI, and this constitutes evidence for the stability of the thiirane ring with respect to electron impact.

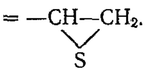
A comparison of the ^{13}C NMR spectra of 4-thiiranyl-trans-decahydro-4-quinolol carbamates IX, X, XII, and XIV with the spectra of the corresponding 4-vinyl- and 4-oxiranyl-trans-decahydro-4-quinolols (XVII-XX and I, II, V, and VI, respectively) (Table 4) made it possible to determine the chemical shifts of the carbon atoms of the thiirane ring, which are in agreement with the literature data [8]. On the basis of the chemical shift and the absence of $^1H-^{13}C$ SSCC the signal at 157.92-158.99 ppm for IX-XVI was assigned to the resonance of the carbon nuclei in the $OCONH_2$ group. The 4.38- and 4.12-ppm shifts to weak field of the signal of the methylidyne carbon atom of the thiirane ring of isomers X and

TABLE 4. ^{13}C NMR Spectra of Some 4-Vinyl-, 4-Oxiranyl-, and 4-Thiiranyl-trans-decahydroquinolines

Compound[a]	Configuration of the $C_{(4)}-O$ bond	δ, ppm		Compound[b]	δ, ppm		Compound[c,d]	δ, ppm		
		$C'_{(1)}$	$C'_{(2)}$		$C'_{(1)}$	$C'_{(2)}$		$C'_{(1)}$	$C'_{(2)}$	$OCONH_2$
XVII	e	140,54	115,18	I	54,17	46,18	IX	36,70	19,19	158,77
XVIII	a	146,86	113,41	II	58,95	45,39	X	41,08	21,79	158,99
XIX	e	141,08	115,18	V	54,76	46,21	XIII	36,90	19,08	157,92
XX	a	146,93	113,46	VI	58,95	45,39	XIV	41,02	20,88	158,66

[a] $4\text{-R} = -CH{=}CH_2$.

[b] 4-R =


[c] 4-R =


[d] In the case of IX, X, XIII, and XIV, $J_{^1H^{13}C} > 160$ Hz, in agreement with the literature data [8].

XIV, respectively, constitute evidence for an axial orientation of the indicated substituent in IX and XIII and an equatorial orientation in X and XIV and correspond to the orientation of the oxirane substituent in starting epoxy alcohols I, II, V, and VI.

The production of thiiranyldecahydroquinolol carbamates IX-XVI from the corresponding epoxy alcohols of the decahydroquinoline series (I-VIII) and thiourea is a consequence of the formation of urea in the process of nucleophilic substitution of the epoxide oxygen atom by a sulfur atom, the products of the reaction of which with alcohols are known [9] to be carbamic acid esters. Thus the reaction of epoxy alcohols of the decahydroquinoline series (I-VIII) with thiourea in the presence of sulfuric acid makes it possible to simultaneously introduce two functional groups, viz., a thiirane ring and a carbamido group, into the decahydroquinoline molecule.

EXPERIMENTAL

The IR spectra of KBr pellets and 1-mm-thick layers of solutions ($2 \cdot 10^{-2}$ mole/liter) of the compounds in $CHCl_3$ were recorded with a UR-20 spectrometer. The PMR spectra of solutions of the compounds in $CDCl_3$ were recorded with a Brucker WM-360 spectrometer relative to tetramethylsilane (TMS). The mass spectra were obtained with an LKB-2091 spectrometer with a system for direct introduction of the samples into the ion source at ionizing-electron energies of 12 and 70 eV, an emission current of 25 μA, and an ion-source temperature of 200°C. The ^{13}C NMR spectra of solutions in CD_3OD were recorded with a Brucker WP-80DS spectrometer (20.1 MHz) relative to TMS. The course of the reactions was monitored by thin-layer chromatography (TLC) on Woelm neutral Al_2O_3 in a chloroform–ethanol system (10:1).

General Method for the Synthesis of 4-Thiiranyl-trans-decahydro-4-quinolol Carbamates IX-XVI. A 0.011-mole sample of thiourea and 11 ml (0.11 mole) of 2 N sulfuric acid were added to 0.01 mole of the epoxy alcohol in 50 ml of water, and the mixture was maintained at room temperature for 4 days. At the end of the reaction, the solution was neutralized with 25% ammonium hydroxide, and the product was extracted with chloroform. The extract was dried over magnesium sulfate, and the solvent was removed at reduced pressure. The crude reaction products were purified by crystallization from methanol (IX, X, and XIII-XVI) and ethyl acetate (XI and XII). The yields of carbamates IX-XVI ranged from 80% to 87%.

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INVESTIGATION OF THE BARRIERS TO RETARDED INTERNAL ROTATION IN N-ACYL-1-METHYL-1,2,3,4-TETRAHYDROISOQUINOLINES

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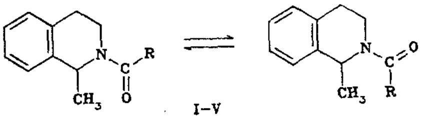
The effect of a number of alkyl substituents attached to the carbon atom of the acyl group on the activation parameters of retarded internal rotation about the C—N bond in N-acyl-1-methyl-1,2,3,4-tetrahydroisoquinolines was studied. Correlation of the free energies of activation $\Delta G_{298}^{\neq}$ with the steric factors (Es) and the σ^* substituent constants was examined.

It is known that the C—N bond in amides has partially double character, and this leads to the possibility of the existence of amides in the form of an equilibrium mixture of two relatively slowly interconverting conformers. The conformational equilibria in a number of N-acyl-1-methyl-1,2,3,4-tetrahydroisoquinolines were previously studied by NMR spectroscopy [1]. In the present research we investigated the effect of alkyl substituents attached to the carbon atom of the acyl group in I-V on the parameters of activation of retarded rotation about the C—N bond.



I-V

Z conformer E conformer

I R=H; II R=CH_3; III R=C_2H_5; IV R=*n*-C_3H_7; V R=*t*-C_4H_9

The determination of activation barriers by NMR spectroscopy with the necessary degree of accuracy requires an analysis of the complete form of the spectral line. For this, we used the DNMR3 program [2, 3], which we adapted to the technical possibilities of the BESM-6 computer. The ^{1}H NMR spectra of I-V at low exchange rates consist of two groups of signals corresponding to Z and E conformers, which exist in equilibrium. The assignment of the signals and the determination of the chemical shifts, spin—spin coupling constants (SSCC), and the parameters of the conformational equilibrium were previously accomplished in [1]. In the present research the populations of the conformers in the calculations were assumed to be independent of the temperature, since the determination of the rate constants for internal rotation for each of the examined compounds was carried out over a rather narrow temperature range, within the limits of which the equilibrium constant changes only slightly [1]. This assumption also seems justified because of the fact that the sensitivity of the form of the line to the equilibrium constants decreases sharply as the rate constant of a dynamic process increases [4].

The rate constants (k) and their temperature dependences necessary for calculation of the activation parameters were determined on the basis of a comparison of the experimental spectra with the theoretical spectra obtained by model calculations by means of the DNMR3 program (see Figs. 1 and 2). For all of the investigated compounds the dependence

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