RING-CHAIN TAUTOMERISM OF SUBSTITUTED HYDRAZONES. 22.* SYNTHESIS, STRUCTURE, AND OXIDATION OF ALKYLIDENE DERIVATIVES OF 2-AMINOETHYLHYDRAZINES

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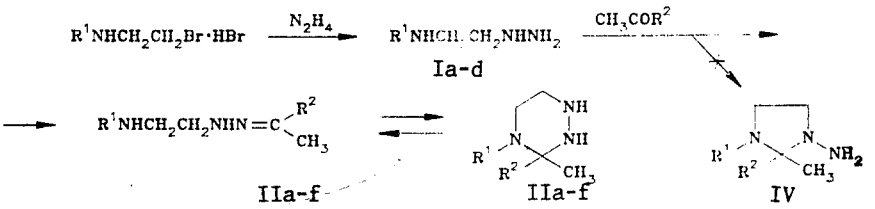
Alkylidene derivatives of 2-aminoethylhydrazines exist in solutions either as 2-aminoethylhydrazones or as the ring-chain tautomeric mixtures of the hydrazone—perhydro-1,2,4-triazine depending on the structure. The oxidation of perhydro-1,2,4-triazines leads to the formation of 2,3,4,5-tetrahydro-1,2,4-triazines.

The products of the condensation of N-methyl-N-(2-aminoethyl)hydrazines with carbonyl compounds occur in the form of tautomeric mixtures of the hydrazone—perhydro-1,2,4-triazine [2]. In the interaction of 2-aminoethylhydrazines, not having a second substituent in the hydrazine fragment, with carbonyl compounds, the formation of heterocyclic compounds of another type — the N-aminoimidazolidines (IV) — could be expected together with the tautomeric systems of the hydrazone (II) — the triazine (III), as also takes place analogously in the reactions of 2-aminoacylhydrazines with acetaldehyde [3].

With the object of studying this problem, we obtained the alkylidene derivatives (IIa-f) and (IIIa-f) of 2-aminoethylhydrazines (Ia-d).



I a R^1=H; b R^1=CH_3; c R^1=C_2H_5; d R^1=$C(CH_3)_3$; II, III a R^1=R^2=H; b R^1=H, R^2=CH_3; c R^1=CH_3, R^2=H; d R^1=R^2=CH_3; e R^1=C_2H_5, R^2=H; f R^1=$C(CH_3)_3$, R^2=H

The structure of the compounds (IIa-f) and (IIIa-f) was established using PMR spectroscopy. The PMR spectra (cf. Table 1) indicate unambiguously the presence of both the hydrazone and the cyclic form in the solutions. The fact of the occurrence of the mutual conversion of these forms is confirmed by the dependence of their relative content on the temperature and the solvent.

It is more complicated to make a choice between the two possible cyclic isomers (III) and (IV). The perhydrotriazine structure of the compound (IIIc) is shown by the PMR spectrum (270 MHz) allowing the determination of the SSCCs of the CH_2CH_2 fragment (Table 1). These SSCCs are characteristic of six-membered rings and are very close to the values previously obtained for the known perhydro-1,2,4-triazines [2].†

The equilibrium concentration of the cyclic forms (IIIa, e) is too low to permit the analogous analysis for these compounds. Here, the following factors are in favor of the six-membered triazine structure: first, the oxidation of the perhydrotriazine (IIIa) to the tetrahydrotriazine (VIIa) which is considered below, second, the analogy with the structurally close compound (IIIc), and third, the interconversion between the compounds (IIIa, c, e) and the hydrazones isomeric to them, which is natural for the perhydrotriazines and which should hardly be expected for the N-aminoimidazolidines [3].

*For Communication 21, see [1].

†The SSCCs of the CH_2CH_2 fragment permit the calculation [4] of the R-factor (2.42) and the torsion angle N—C—C—N (60°). These values are close to those obtained by us for other perhydro-1,2,4-triazines [2].

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TABLE 1. PMR Spectra (C_2Cl_4) of the Compounds (IIa-f)

Compound	Chemical shifts, δ, ppm (SSCC, J, Hz)			
	R^1	R^2	CH_3	CH_2CH_2
E-IIa*		7,15 (q, J=5,0)	1,90 (d, J=5,0)	
Z-IIa		6,70 (q, J=5,0)	1,80 (d, J=5,0)	2,5...3,2
IIIa		3,85 (q J=6,5)	1,15 (d, J=6,5)	
IIb		1,75 (s)	1,92 (s)	2,6...3,3
E-IIc		6,94 (q, J=5,0)	1,84 (d, J=5,0)	
Z-IIc	2,44 (s)	6,55 (q, J=5,0)	1,74 (d, J=5,0)	—†
IIIc	2,16 (s)	—**	1,10 (d, J=7,0)	—‡
IId	2,48 (s)	1,82 (s)	1,98 (s)	2,7...3,3
		6,96 (q, J=5,0)	1,85 (d, J=5,0)	2,6...3,4
E-IIe				
Z-IIe	1,12 (t, J=7,0)†	6,52 (q, J=5,0)	1,73 (d, J=5,0)	
IIIe		—**	1,10 (d, J=7,0)	
E-IIf	1,00 (s)	7,05 (q, J=5,5)	1,80 (d, J=5,5)	2,6...2,9
Z-IIf		6,60 (q, J=5,5)	1,65 (d, J=5,5)	

*Isomerism in relation to the C=N bond.

†The signal is not seen due to the low concentration and (or) the overlapping with other signals.

‡2.03 (H_a); 2.53 (H_e); 2.77 (H_a'), 2.09 (H_e'); $J_{H_aH_a'}$ = 11.4; $J_{H_eH_e'}$ = 2.6; $J_{H_aH_e'}$ = 3.0; $J_{H_a'H_e}$ = 2.8; $J_{H_aH_e}$ = 11.5; $J_{H_a'H_e'}$ = 11.8 Hz.

TABLE 2. Constants of the Tautomeric Equilibrium (II) ⇄ (III)

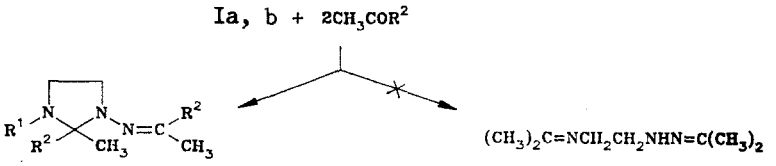
Compound	K_T=[III]/[II], 35 °C		Compound	K_T=[III]/[II], 35 °C	
	C_2Cl_4	$CDCl_3$		C_2Cl_4	$CDCl_3$
II, IIIa	1,3	1,6	IId	<0,05	<0,05
IIb	<0,05	<0,05	II, IIIe	0,1	0,2
II, IIIc	5,0	6,0	IIf	<0,05	<0,05

The constants of the ring-chain tautomeric equilibrium (cf. Table 2) were obtained from the PMR spectra by means of quantitative analysis.

In the series of compounds (IIa-f) and (IIIa-f), features of the structural influence on the position of equilibrium, which are known for other ring-chain tautomeric systems [2, 5-8], are confirmed. The increase in the substitution of the multiple bond C=N leads to the shift of the equilibrium in favor of the open tautomer. The increase in the volume of the alkyl substituent R^1 on the amine nitrogen atom causes the relative destabilization of the cyclic form, up to its complete disappearance in the case of $R^1 = C(CH_3)_3$. However, the transition from $R^1 = CH_3$ to $R^1 = H$ [the compounds (IIc, a) and (IIIc, a)] leads to a marked increase in the share of the hydrazone in the equilibrium mixture.

Comparing the results under consideration with the data of the work [2], it can be ascertained that the substitution of the alkyl group in the hydrazine fragment (the position 1 of the ring) by the hydrogen atom leads to a sharp shift of the equilibrium in favor of the open form; this may be associated with the additional stabilization of the hydrazone by the intramolecular hydrogen bond. Such an influence of the substitution in the hydrazone fragment on the position of equilibrium is well known for hydroxy- and mercapto-substituted hydrazones [6-8].

Therefore, in contrast to 2-aminoacylhydrazines [3], the 2-aminoethylhydrazines do not form derivatives of N-aminoimidazolidines in reactions with equimolar amounts of carbonyl compounds. However, as in the case of 2-aminoacylhydrazines [3], they react with 2 moles of the carbonyl compound giving N-alkylidenaminoimidazolidines (Va-c).



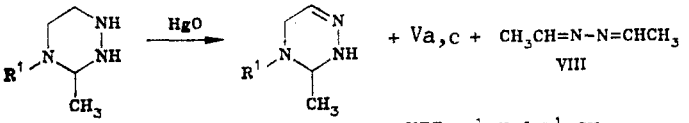
Va-c VI

V a $R^1=R^2=H$; b $R^1=H$, $R^2=CH_3$; c $R^1=CH_3$, $R^2=H$

The structure of these substances is confirmed by the PMR spectra. The compound (Vb) was described previously by the authors [9], who assigned to it the unsubstantiated structure of the iminohydrazone (VI). However, the PMR spectral data indicate unambiguously the imidazolidine structure (V).

Taking into account the ease of oxidation of the compounds containing the NH—NH fragment in the molecule [10], we turned to the study of the oxidation of the perhydro-1,2,4-triazines (IIIa, c) obtained by us. It was thereby possible to expect the isolation of unknown analogs of cyclic azo compounds containing a third nitrogen atom in the ring, which could be precursors of the not readily available azetidines [11].

Notwithstanding our expectations, the main products of the oxidation of the perhydrotriazines (IIIa, c) by yellow mercury oxide proved to be the 2,3,4,5-tetrahydro-1,2,4-triazines (VIIa, b).

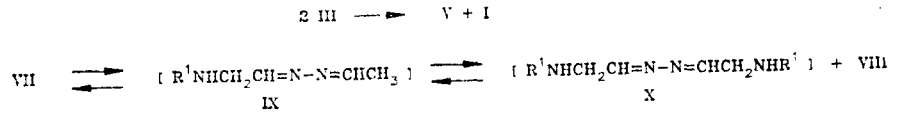


IIIa,c VIIa,b VIIa $R^1=H$; b $R^1=CH_3$

The structure of the compounds (VIIa, b) was established by the methods of PMR and IR spectroscopy. Therefore, the direction of the oxidation of perhydro-1,2,4-triazines differs from that for other 1,2-disubstituted hydrazines, both cyclic and acyclic [10].

The imidazolidines (V) and the acetaldazine (VIII) were found together with the tetrahydrotriazines (VIIa, b) among the oxidation products. The yields of compounds (V) and (VIII) are low and vary strongly from experiment to experiment, reaching 20-25% in individual cases.

In all probability, the imidazolidines (Va, c) are obtained as a result of the disproportionation of the initial perhydrotriazines (III). The resulting aminoalkylhydrazines are probably oxidized immediately by mercury oxide. The acetaldazine (VIII) may be formed via the mixed azines (IX), the cyclic form of which is represented by the triazines (VII), by means of their symmetrization.



However, the azines of the aminoaldehydes (X) were not isolated; this is probably due to their high boiling temperature and, possibly, their low stability.

Taking into consideration the direction of the oxidation of the perhydro-1,2,4-triazines, it was also possible to expect the oxidation of the 2-aminoethylhydrazones not prone to cyclization. However, when the hydrazones (IId, f) are treated with yellow mercury oxide, they are unchanged both in the conditions of the oxidation of the triazines (IIIa, c) and in more drastic conditions (boiling in ether for 60 h). Only those alkylidene derivatives of 2-aminoethylhydrazines, which are characterized by a cyclic structure, are oxidized comparatively readily.

EXPERIMENTAL

The PMR spectra were obtained on the Bruker HX-270 (270 MHz) and Variant HA-100-D-15 (10 MHz) instruments. The internal standard was HMDS. The concentration of the solutions was 1 M. The IR spectra were taken on the UR-20 instrument. The 5% solutions in CCl_4 were utilized.

Gas chromatographic analysis was performed using the Tsvet-100 chromatograph with a silanized glass column 2.5 m × 3 mm with 7% Polyox-100 containing 1.5% polyethylenepolyamine on Celite-545 (40-60 mesh). The temperature of the column was 90-130°C; the gas carrier was helium at 20-40 ml/min. The purity of all the compounds obtained was not less than 95%.

The physicochemical characteristics of the compounds are presented in Table 3.

TABLE 3. Physicochemical Characteristics of the Compounds Synthesized

Compound	Empirical formula	bp, °C (mm of Hg stem) [mp, °C]	d_4^{20}	n_D^{20}	MR_D*1			Yield, %
					a	b	c	
Ia*2	$C_2H_9N_3$	100...102 (27)	1,0300	1,4959	21,29	21,93	—	38
Ib	$C_3H_{11}N_3$	100...102 (42)	0,9609	1,4735	26,11	26,77	—	40
Ic	$C_4H_{13}N_3$	111...112 (31)	0,9368	1,4704	30,07	31,41	—	44
Id	$C_6H_{17}N_3$	90 (10)	—	1,4568	—	—	—	46
II, IIIa	$C_4H_{11}N_3$	77...80 (6) [21...22]		—	—	—	—	88
IIb*3	$C_5H_{13}N_3$	77...78 (9)	0,9630	1,4829	34,44	34,82	34,20	75
II, IIIc	$C_5H_{13}N_3$	62...64 (8) [41...42]		—	—	—	—	72
IId	$C_6H_{15}N_3$	77...78 (8)	0,9109	1,4730	38,96	39,66	39,04	82
II, IIIe	$C_6H_{15}N_3$	102...103 (24)	0,9112	1,4620	39,02	39,66	39,04	68
IIf	$C_8H_{19}N_3$	84...88 (6)	0,8775	1,4572	48,80	48,95	48,33	76
Va	$C_6H_{13}N_3$	79...83 (10)	0,9943	1,5006	37,66	—	37,78	73
Vb*4	$C_8H_{17}N_3$	83...84 (9)	0,9566	1,4872	46,69	47,69	47,07	42
Vc	$C_7H_{15}N_3$	71...73 (12)	0,9254	1,4820	43,50	—	42,62	85
VIIa	$C_4H_9N_3$	92...93 (10) [26...27]		—	—	—	—	65
VIIb	$C_5H_{11}N_3$	52...53 (1)	1,0229	1,5007	32,58	33,76	33,14	50

*1a) Found; b) calculated for the open isomer; c) calculated for the cyclic isomer.
*2According to the data of [13], bp 87-88°C (16 mm Hg stem); n_D^{20} 1.4945; d_{20}^{20} 1.0308.
*3According to the data of [9], bp 78-80°C (8 mm Hg stem); n_D^{20} 1.4828; d_{20}^{20} 0.9637.
*4According to the data of [9], bp 72-75°C (1.5 mm Hg stem); n_D^{20} 1.4870; d_{20}^{20} 0.95705.

The aminoalkylhydrazines (Ia-d) and their alkylidene derivatives (II) and (IIIa-f) were synthesized by methods described in the works [2, 12].

2-Methyl-1-ethylidenaminoimidazolidine (Va). To the solution of 2.25 g (0.03 mole) of 2-aminoethylhydrazine in 10 ml of methanol was added the solution of 3.1 g (0.07 mole) of acetaldehyde in 10 ml of benzene. After 10 min, the solvent was distilled off, and the residue was distilled in vacuo. The PMR spectrum (CCl_4) was as follows: 1.32 ppm (3H, d, J = 6.3 Hz, 2-CH_3), 3.75 ppm (1H, q, J = 6.3 Hz, 2-H), 1.93 ppm (3H, d, J = 5.0 Hz, =CCH_3), 6.73 ppm (1H, q, J = 5.0 Hz, =CH), 2.5-3.5 Hz [4H, m, $(CH_2)_2$], and 3.23 ppm (1H, s, NH).

1,2-Dimethyl-3-ethylidenaminoimidazolidine (Vc). This compound was obtained analogously. The PMR spectrum (CCl_4) was as follows: 1.18 ppm (3H, d, J = 6.0 Hz, 2-CH_3), 2.17 ppm (3H, s, 1-CH_3), 1.77 ppm (3H, d, J = 5.0 Hz, =CCH_3), 6.39 ppm (1H, q, J = 5.0 Hz, =CH), and 2.2-3.2 ppm (5H, 2-H, CH_2CH_2).

1-Isopropylidenamino-2,2-dimethylimidazolidine (Vb). The solution of 4.6 g (0.04 mole) of acetone 2-aminoethylhydrazone (IIb) and 4.7 g (0.08 mole) of acetone in 20 ml of benzene was boiled for 3 h with dry potassium carbonate. After the disappearance of the initial hydrazone from the reaction mixture (monitoring by the method of GLC), the reaction product was separated by distillation in vacuo. The PMR spectrum (CCl_4) was as follows: 1.13 ppm (6H, s, 2-CH_3), 1.82 ppm (3H, s, N=CCH_3), 1.83 ppm (3H, s, N=CCH_3), and 3.0-3.5 ppm [4H, m, $(CH_2)_2$].

3,4-Dimethyl-2,3,4,5-tetrahydro-1,2,4-triazine (VIIb). To the solution of 11.5 g (0.1 mole) of the perhydrotriazine (IIIc) in 30 ml of diethyl ether were added, with stirring, 23.8 g (0.11 mole) of yellow mercury oxide. The reaction mixture was stirred for 2 days at room temperature. After the disappearance of the initial triazine (monitoring by the method of GLC), the ether solution was separated, and the resulting mercury was washed with

chloroform. The combined solutions were dried with Na_2SO_4 and distilled on a column. The yield of 0.8 g (19%) of the acetaldazine (VIII) was thereby obtained, with 1.1 g (16%) of the imidazolidine (Vc) and 5.5 g (50%) of the tetrahydrotriazine (VIIb). The PMR spectrum ($CDCl_3$) was as follows: 1.15 ppm (3H, d, J = 6.0 Hz, 3-CH_3), 3.65 ppm (1H, q, J = 6.0 Hz, 3-H), 2.25 ppm (3H, s, 4-CH_3), 3.05 ppm (1H, m, J = 19.5 Hz, J = 3.5 Hz, $C_{(5)}H_2$) and 3.20 ppm (1H, m, J = 19.5 Hz, J = 1.0 Hz, $C_{(5)}H_2$), 6.45 ppm (1H, m, J = 3.5 Hz, J = 1.0 Hz, 6-H), and 5.50 ppm (1H, 2-H). The IR spectrum was characterized at the $\nu_{C=N}$ of 1640 cm^{-1}.

3-Methyl-2,3,4,5-tetrahydro-1,2,4-triazine (VIIa). This compound was obtained analogously. The PMR spectrum ($CDCl_3$) was as follows: 1.00 ppm (3H, d, J = 6.0 Hz, 3-CH_3), 3.80 ppm (1H, q, J = 6.0 Hz, 3-H), 3.22 ppm (1H, m, J = 20.0 Hz, J = 2.8 Hz) and 3.39 ppm (1H, m, J = 20.0 Hz, J < 1 Hz, $C_{(5)}H_2$), 6.65 ppm (1H, m, J = 2.8 Hz, J < 1 Hz, 6-H), and 5.60 ppm (2H, NH). The IR spectrum was characterized at the $\nu_{C=N}$ of 1630 cm^{-1}.

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