LITERATURE CITED

1. T. P. Antsupova and K. Samikov, Khim. Prir. Soedin., 257 (1984).
2. G. R. Newkome and N. S. Bhacca, Chem. Commun., 385 (1969).
3. R. H. F. Manske and R. G. A. Rodrigo, The Alkaloids, Academic Press, New York, vol. XX (1981), p. 4.
4. H. F. Hodson, B. Robinson, and G. F. Smith, Proc. Chem. Soc., 465 (1961).
5. I. J. Grant, T. A. Hamor, J. M. Robertson, and G. A. Sim., J. Chem. Soc., 5678 (1965).
6. International Tables for X-Ray Crystallography, Kynoch Press, Birmingham, Vol. III (1962).
7. S. M. Nasirov, A. A. Ibragimov, V. T. Andrianov, S. Kh. Maekh, Yu. T. Struchkov, and S. Yu. Yunusov, Khim. Prir. Soedin, 334 (1976).
8. V. I. Andrianov, Z. Sh. Safina, and B. L. Tarnopol'skii, Rentgen-75, Automation of Systems of Programs for Interpreting Crystal Structures [in Russian], Chernogolovka (1975).

THE STRUCTURE OF THE ALKALOID NITRARAMINE FROM *Nitraria schoberi*

B. Tashkhodzhaev, A. A. Ibragimov, and S. Yu. Yunusov

UDC: 547.944/945+548.737

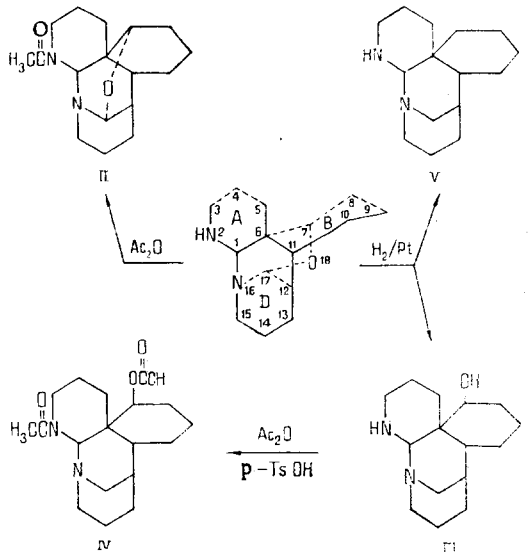
The spatial structure of the alkaloid nitraramine has been determined by x-ray structural analysis. This has shown that it has the structure of 2,1'-epoxy-1,3-propanoperhydrobenzo[3',2'-d]-1,8-naphthyridine.* Its reactivity has been studied.

The alkaloid nitraramine (I) has previously been isolated from the epigeal part of *Nitraria schoberi* L. [1, 2]. On the basis of spectral characteristics and chemical properties [2], a modified sparteine structure [3] of the type of *Ormosia* alkaloids was proposed for it. Having isolated this base again, having repeated some reactions, and having analyzed the available information, we have come to the conclusion that the formula proposed previously is doubtful. Thus, the dehydrogenation of (I) and of the *Ormosia* alkaloids under comparable conditions [2, 4] led to different products. The IR and PMR spectra of the N-acetyl derivative (II) showed the absence of active hydrogen from it. An x-ray structural study performed with the aim of establishing the structure of nitraramine unambiguously showed that its molecule was based on a 2-azaspiroundecane system. Compound (I) contained the nitramine (isonitramine) skeleton [5], to which, in positions 1 and 11, a piperidine ring has been attached to its positions 1 and 3. Furthermore, the C(2) atom of the piperidine moiety and the C(7) atom of the isonitramine (nitramine) moiety are linked by an oxygen bridge.

Structure (I) established by x-ray structural analysis makes it possible to suggest the following scheme of chemical transformations and of treating the spectral results.

*The original nomenclature and numbering (based on that of nitramine) have been retained. [Translator].

Institute of the Chemistry of Plant Substances, Academy of Sciences of the Uzbek SSR, Tashkent. Translated from Khimiya Prirodnykh Soedinenii, No. 5, pp. 692-698, September-October, 1985. Original article submitted November 1, 1984.



Scheme of the transformation of nitraramine.

The acetylation of (I) with acetic anhydride both in the presence of pyridine and in its absence led to a mono-N-acetyl derivative (II) in the IR spectrum of which intense absorption of an amide carbonyl (1620 cm^{-1}) had arisen and, as already mentioned, the band of active hydrogen had disappeared.

The hydrogenation of (I) over platinum in ethanol was not accompanied by the absorption of hydrogen. However, the use of **glacial** acetic acid as the medium led, after 22 h, to the formation of five compounds. The main product resulted from the addition of one molecule of hydrogen (III) and was formed through the reductive cleavage of the C(17)—O(18) bond in the 1,3-oxazine ring E (C(1)C(6)C(7)O(18)C(17)N(16)). Such a 1,2-cleavage has been described for oxazine and its derivatives under the conditions of reduction by sodium amalgam and Raney nickel [6]. The acetylation of (III) led to the O,N-diacetyl derivative (IV), the IR spectrum of which contained intense absorption in the region of ester and amide carbonyls [12]. The composition of the hydrogenation product (V) corresponded to a deoxanitraraminane and was apparently formed by the reduction of the axial C(7)—O(18) bond in (III).

The other hydrogenation products were isolated in very small amounts and require additional purification. However, their preliminary mass spectra show that they were formed from (V) by the reductive cleavage of C—N bonds. The acetylation of (I) with acetic anhydride at 100°C in the presence of p-toluenesulfonic acid led to a O,N-diacetyl derivative [2], which was probably formed through a stage of the acid cleavage of the C(17)—O(18) bond [6]. This reaction is undergoing study.

The strongest-field signals in the PMR spectrum of (I) were a broadened one-proton singlet ($W_{1/2}$ = 5 Hz) in the 4.37 ppm region and a one-proton doublet (J = 3 H) at 4.10 ppm, due to two protons geminal to an ether oxygen atom. In the spectrum of (III) the signal at 4.37 ppm was not observed, while the signal at 4.01 ppm had remained unchanged.

The spectrum of (I) had a narrow one-proton singlet at 3.28 ppm from an axial proton at C(1), which is surrounded by two nitrogen atoms and a quaternary carbon atom. In the spectrum of **ormojanine**[4] a similar signal of a proton located between the nitrogen atom, a double bond, and a quaternary carbon atom is observed in the 3.16 ppm region, and the signal of the proton in the $>N-CHR-N<$ system in the spectra of the *Ormosia* alkaloids and model compounds is located between 3.20 and 3.60 ppm [4, 7, 8]. In the spectrum of (II), this singlet is highly descreened, which also confirms the assignment made. The equatorial protons at C(3) and C(15) resonate in the 3.03 ppm region (m, 2 H, J_{gem} = 12 Hz). The axial protons geminal to them give a signal at 2.64 ppm in the form of a two-proton multiplet. A slightly broadened singlet (1 H) at 2.42 ppm must be assigned to the proton of a >NH group, as was confirmed by recording the spectrum with deuterium exchange. The other protons of the nitraramine molecule give a methylene hump in the 2.30-0.90 ppm region.

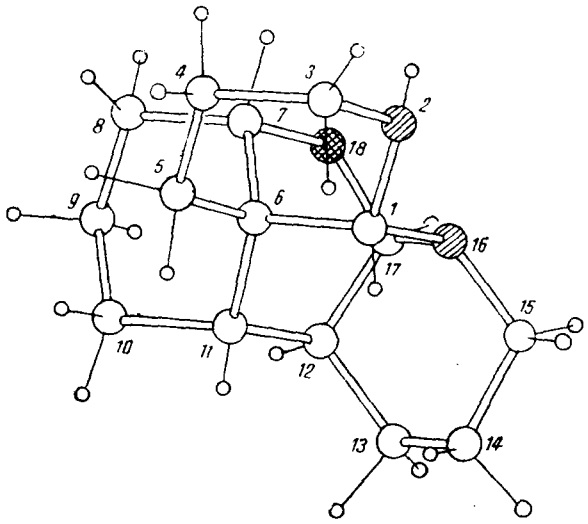


Fig. 1. Projection of the nitraramine molecule on the bc plane of the elementary cell of the crystal.

TABLE 1. Coefficients of the Equations Ax + By + Cz = D of the Main Planes of the Fragments of the Nitraramine Molecule and the Deviation of the Atoms (δ, Å) from the Planes

Plane	Atom	δ	A	B	C	D
Ring A	C(1)	0,003	−6,21	−0 44	6,94	2,08
	N(2)	−0,003				
	C(3)	−0,658				
	C(4)	0,003				
	C(5)	−0,003				
	C(6)	0,676				
Ring B	C(6)	−0 748	−7,15	8,75	−1,71	1,98
	C(7)	−0,016				
	C(8)	0,015				
	C(9)	0,595				
	C(10)	−0,015				
	C(11)	0,016				
Ring D	C(12)	0,029	−6,77	9,57	2,65	5,54
	C(13)	−0,028				
	C(14)	−0,606				
	C(15)	0,029				
	N(16)	−0,0 0				
	C(17)	0,709				
Bicyclo[2.2.2]-octane	C(6)	0 016	5,25	8 65	−5,22	7,07
	C(11)	−0,025				
	C(12)	0,026				
	C(17)	−0,016				
	C(1)	−0,036	−0,50	1 49	11,07	9,74
	C(6)	0,021				
	N(16)	0,036				
	C(17)	−0,021				
	C(6)	0,003	4,31	9,44	5,89	16,37
	C(7)	−0 006				
	C(17)	−0,004				
	O(18)	0,006				

The structure found for (I) by x-ray structural analysis is shown in Fig. 1 as a projection on the plane of the b and c axes. The main numerical results characterizing the conformations of the rings are given in Table 1. The numbering of the atoms corresponds to that of nitramine (or isonitramine) [5, 9]. Hence, it must be mentioned that the nitramine moiety of the molecule of (I) corresponds to the optical antipode of the nitramine conformer found by x-ray structural analysis [9]. The nitramine moiety of the molecule of (I) consists of rings A (the C(1)N(2)C(3)C(4)C(5)C(6) atoms) and B (the C(7)C(8)C(9)C(10)C(11) atoms) which have the chair conformation. The C(1)C(6)C(7)O(18)C(17)N(16)C(11)C(12) atoms form a bicyclo[2.2.2]

TABLE 2. Interatomic Distances (r, Å) and Valence Angles (ω, deg)

Distance	r	Angle	ω	Angle	ω
C(1)—C(6)	1.539(4)	N(2)C(1)C(6)	111.6(3)	C(7)C(8)C(9)	112.0(3)
C(1)—N(2)	1.512(4)	N(2)C(1)N(16)	107.8(3)	C(8)C(9)C(10)	112.2(3)
C(1)—N(16)	1.436(4)	C(6)C(1)N(16)	111.8(2)	C(9)C(10)C(11)	112.0(3)
N(2)—C(3)	1.511(4)	C(1)N(2)C(3)	113.1(3)	C(10)C(11)C(6)	110.5(3)
C(3)—C(4)	1.507(4)	N(2)C(3)C(4)	109.1(3)	C(10)C(11)C(12)	111.7(3)
C(4)—C(5)	1.509(4)	C(3)C(4)C(5)	111.9(3)	C(12)C(11)C(6)	108.1(3)
C(5)—C(6)	1.542(4)	C(4)C(5)C(6)	112.4(3)	C(11)C(12)C(13)	114.3(3)
C(6)—C(11)	1.558(4)	C(5)C(6)C(7)	113.6(3)	C(11)C(12)C(17)	107.3(3)
C(7)—C(8)	1.523(4)	C(5)C(6)C(1)	108.7(2)	C(13)C(12)C(17)	110.8(3)
C(7)—O(18)	1.448(4)	C(5)C(6)C(11)	112.2(3)	C(12)C(13)C(14)	112.2(3)
C(8)—C(9)	1.533(5)	C(1)C(6)C(7)	110.3(3)	C(13)C(14)C(15)	110.5(3)
C(9)—C(10)	1.524(4)	C(1)C(6)C(11)	105.3(3)	C(14)C(15)N(16)	113.0(3)
C(10)—C(11)	1.540(4)	C(7)C(6)C(11)	106.5(3)	C(16)N(16)C(1)	113.3(3)
C(11)—C(12)	1.556(4)	C(6)C(7)C(8)	112.8(3)	C(15)N(16)C(17)	109.3(3)
C(12)—C(13)	1.542(4)	C(8)C(7)O(18)	108.5(3)	C(1)N(16)C(17)	109.3(3)
C(12)—C(17)	1.501(4)	C(8)C(7)O(18)	109.0(3)	C(7)O(18)C(17)	113.5(3)
C(13)—C(14)	1.544(4)				
C(14)—C(15)	1.518(4)				
C(15)—N(16)	1.476(4)				
N(16)—C(17)	1.472(4)				
C(17)—O(18)	1.407(4)				

TABLE 3. Coordinates ($\times 10^4$) of the Basic Atoms and their Temperature Parameters (Å^2)

Atom	x/a	y/b	z/c	B_{iso}
C(1)	4891(4)	8493(2)	7907(3)	2.26
N(2)	3728(3)	8269(2)	6861(3)	2.88
C(3)	2431(4)	8847(2)	6682(3)	3.27
C(4)	3284(4)	9689(2)	6547(3)	3.03
C(5)	4427(4)	9931(2)	7593(3)	2.72
C(6)	5772(4)	9353(2)	7780(3)	2.08
C(7)	7080(4)	9390(2)	6775(3)	2.47
C(8)	8135(4)	10202(2)	6698(3)	3.70
C(9)	8975(4)	10461(2)	7895(3)	3.71
C(10)	7752(4)	10363(2)	8947(3)	3.37
C(11)	6760(4)	9522(2)	8975(3)	2.60
C(12)	7944(4)	8849(2)	9148(3)	3.04
C(13)	7589(4)	8341(2)	10293(3)	3.65
C(14)	5920(4)	7787(2)	10209(3)	3.62
C(15)	5782(4)	7359(2)	9004(3)	3.55
N(16)	6073(3)	7912(2)	7973(2)	2.64
C(17)	7783(4)	8330(2)	8046(3)	2.89
O(18)	8175(3)	8775(1)	6992(2)	3.11
		Anionic moiety		
N	3959(4)	7909(2)	3872(3)	2.53
O(1)	3639(4)	7988(2)	2783(2)	4.20
O(2)	4911(3)	8437(2)	4394(3)	3.97
O(3)	3361(4)	7309(2)	4432(3)	4.70

octane system consisting of three ideal boats. Heterocycle D (the C(12)C(13)C(14)C(15)N(16)C(17) atoms) has the chair conformation (see Table 1).

The lengths of the valence bonds of (I) are given in Table 2. Within the limits of experimental error, they are close to the corresponding standard values. The mean N(2)—C distance is 1.511 Å, which is typical for a protonated quaternary nitrogen atom $\overset{+}{N}—C_{sp^3}$ [10], while for the tertiary nitrogen atom N(16) this magnitude ranges from 1.436 to 1.476 Å. The lengths of the $C_{sp^3}—C_{sp^3}$ bonds average 1.533 Å, but close to the heteroatoms a tendency is observed to an appreciable decrease from the standard 1.540 Å [11]. The distance O...N donor-acceptor interaction (2.87 Å) also agrees with that in alkaloid nitrates (see, for example, [9]). The nitrate (anion) in (I) is planar, and no anomalies are observed in the N...O distances (averaging 1.242 Å) and the valence angles (120°). The valence angles in the cation are, on the whole, close to the standard values [11].

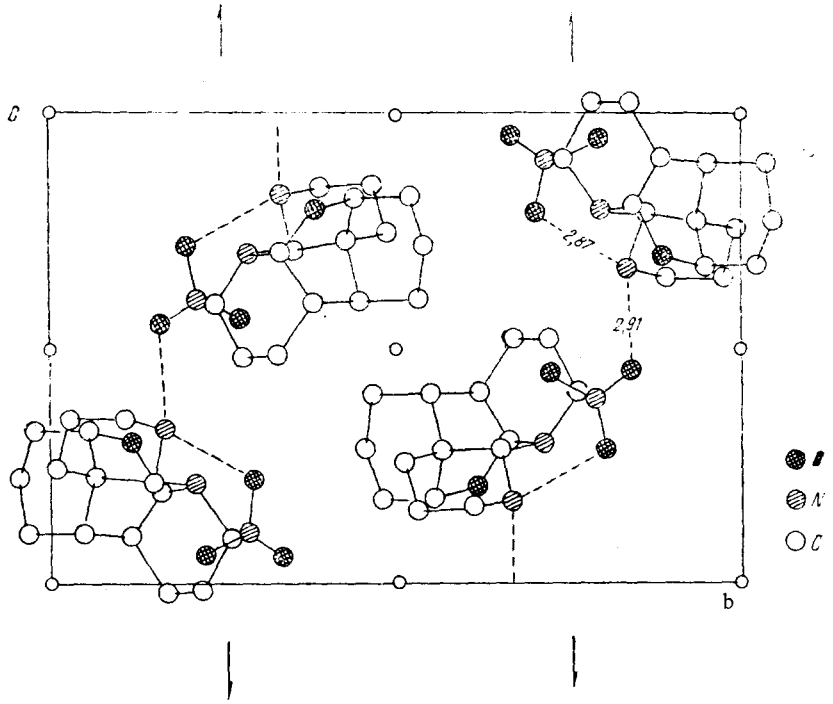


Fig. 2. Packing of the nitraramine molecule.

The packing of the molecules of (I) projected on the plane of the b and c axes is shown in Fig. 2. Analysis of the intermolecular contacts shows the possibility of weak intermolecular H bonds of the N–H...O type between the N(2) atoms of the nitramine molecules and the O(2) and O(3) atoms of the nitrate: N(2)...O(2) (2.91 Å) and N(2)...O(3) (3.14 Å). The O(1) atom of the nitrate ion, transformed by a 2_1 screw axis, approaches the N(2) atom from the side of the free electron pair, forming a donor-acceptor bond. Thus, the nitraramine molecules bound by 2_1 screw axes are linked through the anions into infinite chains directed parallel to the crystallographic c axis.

EXPERIMENTAL

PMR spectra were obtained on a JNM-4H-100 instrument (0 – HMDS, δ scale) in deuterochloroform. IR spectra were obtained on a UR-20 spectrophotometer and mass spectra were taken in a MKh-1303 instrument with a system for the direct introduction of the substance into the ion source. For thin-layer and column chromatography we used silica gel and the following solvent systems: 1) benzene–methanol (4:1); 2) chloroform–methanol (4:1); 3) chloroform–methanol–water (65:45:6); 4) chloroform–ethanol–water (65:50:6); and 5) chloroform–methanol–25% ammonia (65:45:4-10).

Isolation of Nitraramine in the Form of the Nitrate. The alkaloid was isolated by a procedure described in the literature [1, 12]. The combined ethereal extracts of the pH 6 and pH 6.5 fractions from the polybuffer separation of the total alkaloids of *N. schoberi* (11.4 g) were dissolved in acetone, the solution was cooled with ice, and a 30% solution of nitric acid in acetone was added dropwise to bring the pH to 4. The crytals of the nitrate that deposited (0.85 g) were separated off; mp 200-201°C (prisms from ethanol–acetone (3:1)).

Nitramine. A solution of 0.5 g of the nitrate in a small amount of water was treated with 25% ammonia solution. The base was extracted with chloroform. The solvent was evaporated off, and the oily residue was dried in vacuum. On standing, nitraramine crystallized in the form of white rosettes (0.38 g), mp 85-86°C (petroleum ether); $[\alpha]_D \pm 0°$.

N-Acetylnitraramine. A mixture of 0.05 g of nitraramine and 1.5 ml of freshly distilled acetic anhydride was stirred vigorously at room temperature. After 2 days the reaction had taken place to the extent of ~70%, and after 4 days the situation had not changed. Then 0.5 ml of freshly distilled pyridine was added and the reaction was continued for another day (chromatographic monitoring). The solvent was evaporated off, the oily residue was dissolved in chloroform, the solution was washed with 10% sodium carbonate solution, and the chloroform was evaporated off. This gave (II) in quantitative yield (amorphous), ν_{max} 1620 cm^{-1} (N–$COCH_3$), M^+ 290.

Hydrogenation of Nitraramine. a) A 50-ml round-bottomed flask was charged with 0.15 g of nitraramine, 6 ml of glacial acetic acid, and 70 mg of platinum oxide. The reaction mixture was saturated with hydrogen with continuous shaking, the temperature being kept between 50 and 70°C. After 22 h (chromatographic monitoring), the reaction was stopped, the catalyst was filtered off, and the solvent was driven off in vacuum. The dry oily residue was dissolved in a small volume of 10% sulfuric acid, and the acid solution was washed with ether. After decomposition with a 10% solution of caustic potash, the reduction products were extracted with chloroform. TLC in system 5 showed five spots with a clear predominance of a product with R_f 0.5. The mixture of products was transformed to a column 8 mm in diameter containing 15 g of type KSK silica gel (particle size 100-200 mμ) and the substances were eluted with system 3. Fractions with a volume of 5-6 ml were collected. Fractions 15-19 yielded the individual substance (III) in the form of an oil (46 mg); M^+ 250. From various fractions four other products of the reaction (I) were isolated in amounts of 3-5 mg.

b) Simultaneously, 27 mg of nitraramine was hydrogenated in 5 ml of ethanol in the presence of 15 mg of a platinum catalyst at room temperature. Practically no reaction had taken place after 22 h.

O,N-Diacetyldihydronitraramine [12]. A solution of 30 mg of the dihydro product in 2.5 ml of purified acetic anhydride was treated with 60 mg of p-toluenesulfonic acid. The mixture was heated in the water bath for 2 h. Then it was cooled in ice, a solution of sodium carbonate was added, and the reaction product was extracted with chloroform. After the solvent had been distilled off, the residue was dried in vacuum. On cooling, it crystallized in the form of rosettes of needles, but at room temperature (IV) exists in the form of an oil.

X-Ray Structural Analysis. Crystals of nitraramine nitrate were first investigated by a photomethod. The space group and the parameters of the elementary cell were determined in a precession camera and were refined in a Syntex $P2_1$ diffractometer using CuK_α radiation: a = 8.022 (1); b = 16.769(2); c = 11.125(1) Å; γ = 96.40(1)°; d_{calc} = 1.392 g/cm³; space group $P2_1/n$; z = 4. A three-dimensional set of intensities was obtained on the diffractometer mentioned with $\theta \leqslant 57.5°$. The number of independent nonzero reflections measured was 2200. The calculations were performed with 1592 structure factors exceeding 2σ. The structure was interpreted by the direct method using the Rentgen-75 program [13] in the automatic regime. The model found was refined first by successive electron-density (ED) syntheses (R = 0.17) and then by the method of least squares (MLS) first in the block-diagonal isotropic approximation (R = 0.128) and then in the anisotropic approximation (R = 0.108). At this stage a ED difference synthesis was made and the positions of 21 H atoms out of the 24 was revealed. The final value of the R factor after refinement by the MLS taking the coordinates of the H atoms into account was 0.071. The coordinates of the basis atoms of the nitraramine nitrate molecule are given in Table 3.

SUMMARY

The structure of the alkaloid nitraramine — 2,1'-epoxy-1,3-propanoperhydrobenzo[3',2'-d]-1,8-naphthyridine — has been established by x-ray structural analysis. Its reactivity has been studied.

LITERATURE CITED

1. A. I. Ibragimov, N. Yu. Novgorodova, and Kh. N. Aripov, Khim. Prir. Soedin., 84 (1977).
2. N. Yu. Novgorodova, S. Kh. Maekh, and S. Yu. Yunusov, Khim. Prir. Soedin., 435 (1975).
3. T. E. Monakhova, O. N. Tolkachev, V. S. Kabanov, M. E. Perel'son, V. I. Sheichenko and N. F. Proskurina, in: Abstracts of Lectures at the IIIrd Indo-Soviet Symposium on the Chemistry of Natural Compounds [in Russian], Tashkent (1973), p. 124.
4. Z. Valenta, P. Deslonchamps, M. H. Rasid, R. H. Wightman, and J. S. Wilson, Can. J. Chem., 44, 2525 (1966).
5. A. A. Ibragimov, Z. Osmanov, B. Tashkhodzhaev, N. D. Abdullaev, M. R. Yagudaev, and S. Yu. Yunusov, Khim. Prir. Soedin., 623 (1981).
6. R. C. Elderfield, Heterocyclic Compounds, Vol. 6, Wiley, New York (1957).
7. E. M. Wilson, Chem. Ind. (London), 472 (1965).
8. E. M. Wilson, Tetrahedron, 21, 2561 (1965).
9. B. Tashkhodzhaev, Khim. Prir. Soedin., 75 (1982).
10. G. L. Birnbaum, Acta Crystallogr., 23, 526 (1967).
11. International Tables for X-Ray Crystallography, Kynoch Press, Birmingham, vol. III (1962).

12. N. Yu. Novgorodova, Author's Abstract of Candidate's Dissertation, Tashkent (1975).
13. V. I. Andrianov, Z. Sh. Safina, and B. L. Tarnopol'skii, Automated System of Programs for Interpreting Crystal Structures [in Russian], Chernogolovka, (1975).

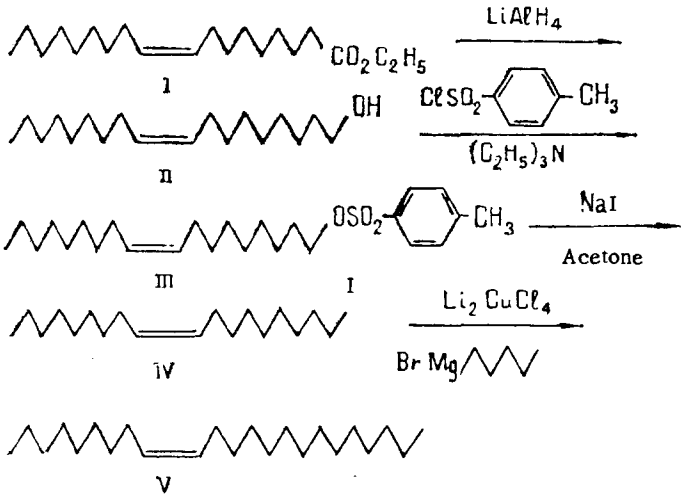
SYNTHESIS OF MUSCALURE — THE PHEROMONE OF *Musca domestica*

G. G. Verba, V. S. Abdukakharov,
and A. A. Abduvakhabov

UDC: 577.19

A method for obtaining cis-tricos-9-ene (muscalure) — the pheromone of the housefly — from the readily available ethyl oleate has been developed.

The sex pheromone of the housefly *Musca domestica* L. was isolated by Carlson in 1971 and was identified as cis-tricos-9-ene (muscalure) [1]. Field trials have shown its high attractive capacity [2].



In 1979, Shani [3] reported a synthesis of muscalure from the oil of the seeds of *Simmondsia chinensis*, and also from technical oleyl alcohol.

Our aim was to develop a simple method of obtaining cis-tricos-9-ene. We have investigated a synthetic route to muscalure based on the readily available ethyl oleate, which was selected as the starting material. Ethyl oleate (I) was reduced to oleyl alcohol (cis-octadec-9-en-1-ol) (II) with lithium tetrahydroaluminate in absolute ether. The excess of lithium tetrahydroaluminate was decomposed with moist ether and then with a saturated solution of Na_2CO_3, and not with ethyl acetate, since in this case oleyl acetate may be formed as a by-product [3]. Oleyl p-toluenesulfonate (III) was obtained by the reaction of purified [4] p-toluenesulfonyl chloride in absolute ether with oleyl alcohol in the presence of triethylamine. Oleyl iodide (IV) was formed by treating oleyl p-toluenesulfonate (III) with anhydrous sodium iodide in boiling acetone. The condensation of oleyl iodide with amylmagnesium bromide using Li_2CuCl_4 as catalyst [5] at 0°C gave the final product cis-tricos-9-ene (V), which was purified on a column of silica gel. The PMR spectrum of the purified cis-tricos-9-ene corresponded completely to that reported previously [6].

An attempt to obtain cis-tricos-9-ene by condensing oleyl p-toluenesulfonate with amylmagnesium bromide in the presence of Li_2CuCl_4 at −5°C proved unsuccessful. Oleyl alcohol and p-tolyl amyl sulfone were isolated, which agrees completely with information [7] on the

Institute of Bioorganic Chemistry, Academy of Sciences of the Uzbek SSR, Tashkent.
Translated from Khimiya Prirodnykh Soedinenii, No. 5, pp. 698-700, September-October, 1985. Original article submitted October 16, 1984.

0009-3130/85/2105-0655$09.50