Tetrahedron Vol. 43, No. 22, pp. 5461 to 5466, 1987
Printed in Great Britain

0040-4020/87 $3.00 + .00

STEREOCHEMICAL STUDIES, 131[1]; SATURATED HETEROCYCLES, 133[1]

NITRILIMINE AND NITRILE OXIDE CYCLOADDITION TO *cis*-CONDENSED 1,3-DIHYDROOXAZINES

GÉZA STÁJER, GÁBOR BERNÁTH* and ANGELA E. SZABÓ

Institute of Pharmaceutical Chemistry, University Medical School, POB 121, H-6701 Szeged, Hungary

PÁL SOHÁR

Spectroscopic Department, EGIS Pharmaceuticals, POB 100, H-1475 Budapest, Hungary

GYULA ARGAY and ALAJOS KÁLMÁN

Central Research Institute for Chemistry, Hungarian Academy of Sciences, POB 17, H-1525 Budapest, Hungary

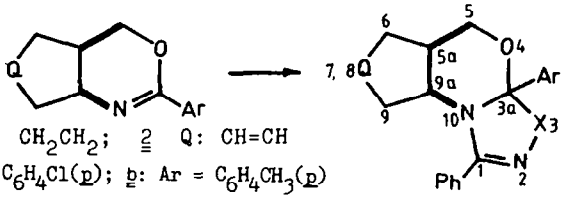
(*Received in UK 9 September* 1987)

Abstract - *cis*-5,6-Tetramethylene-4*H*-1,3-dihydrooxazine (1) and an analogue unsaturated in the carbocyclic ring (2) give adducts at the heterodouble bond with diphenylnitrilimine or benzonitrile oxide, furnishing 1,3-oxazino-1,2,4-triazolines (3 and 4) or oxadiazolines (5 and 6), respectively. The site-selectivity of the cycloaddition differs from that of the earlier studied norbornene-condensed dihydrooxazines, where the nitrile oxide dipole attacks first the C=C and not the C=N bond. The conformation of the oxazine rings, the annelation of the hetero rings and the configuration at C-3a have been elucidated by ^{1}H and ^{13}C n.m.r. spectroscopy and for 4 by X-ray analysis. The crystallographic data show that the hetero rings are *cis*-fused, in accordance with the conclusions inferred from the n.m.r. spectra. The lone pair of the pyramidal N(10) atom is eclipsed with the 3a-aryl ring.

The present work discusses the 1,3-dipolar cycloaddition of the dipolarophiles 1a,b and 2a,b with diphenylnitrilimine (DPNI) and benzonitrile oxide (BNO). In the similar cycloadditions of the analogous *diexo* and *diendo* norbornene-fused dipolarophiles, it was found that the dipole adds first to the olefinic bond, and not to the C=N bond.[4,5] Our aim was to study the site-selectivity for compounds 2a,b.

RESULTS

The dipolarophiles 1a,b and 2a,b were reacted by refluxing in benzene with equimolar DPNI,[6] generated *in situ* from *N*-(α-chlorobenzylidene)-phenylhydrazine with triethylamine, or at room temperature with BNO[7] prepared from benzhydroxamoyl chloride in ethereal solution (Scheme). The hexahydro- (3) and tetrahydro-3,1-benzoxazino-1,2,4-triazolines (4) and 1,2,4-oxadiazolines (5 and 6) were obtained after purification by column chromatography.



1 Q: CH_2CH_2; 2 Q: CH=CH
a: Ar = $C_6H_4Cl(p)$; b: Ar = $C_6H_4CH_3(p)$

	Q	X	Ar
3	CH_2CH_2	NPh	$C_6H_4Cl(p)$
4	CH=CH	NPh	$C_6H_4Cl(p)$
5	CH_2CH_2	O	$C_6H_4CH_3(p)$
6	CH=CH	O	$C_6H_4CH_3(p)$

Scheme

As expected, the cycloadducts 3-6 are formed by saturation of the C=N bond. In the reaction studied earlier, the BNO cycloaddition took place first at the C=C and not the C=N bond of the bicycloheptene skeleton. In the present case, however, the selectivity is reversed and the reaction afforded 1,2,4-oxadiazolines and not isoxazolines. For the norbornene derivatives, the increased dipolarophilic activity of the olefinic bond was explained by the strained bicyclic ring, the hyperconjugative interactions with the π-bond,[8] and the steric hindrance of the C=N bond in the diendo bicycloheptene-condensed 1,3-oxazines.[4,5] The non-occurrence of C=C addition in the present reaction confirms our interpretation, in agreement with Huisgens' theory[8] concerning the anomalous cycloaddition of the norbornene dipolarophiles.

STRUCTURE

The structures of compounds 3-6 follow unambiguously from their ^{1}H and ^{13}C n.m.r. data (Tables 1 and 2). The practically identical spectral data for the cyclohexane- (3 and 5) and cyclohexene-fused (4 and 6) derivatives indicate that the molecules have analogous structures.

For compounds 3 and 5, the dt multiplicity of the H-9a signal and the value of ~13 Hz for one of the coupling constants unequivocally prove the axial position of H-9a (this splitting is due to the H-9',9a diaxial interaction[9]). Thus, the molecules containing cis annelated 1,3-oxazine and cyclohexane rings have conformations in which N-10 is equatorial, while the 5-methylene group is axial to the alicyclic ring, in accordance with our earlier results.[10,11] It was found that in cis-tetramethylene-1,3-, or 3,1-oxazines the methylene group is always equatorial and the oxygen or nitrogen heteroatom is axial, with the exception of the 3,1-positional isomers in which the nitrogen linked to the ring annelation is substituted.

In accordance with this, the signal of the axial 5-methylene protons reveal a splitting of about 11 Hz, indicating a diaxial interaction due to the H-5'(ax),H-5a(ax) vicinal coupling, for in the cyclohexane ring equatorial H-5a is axial to the oxazine ring.

On the above basis, the C-3a configuration can be elucidated. The trans-annelation of the hetero rings and the synchronous trans position of the C_{3a}-aryl group relative to H-5a,9a can be ruled out, as this would involve a very strong hindrance between the aryl group and H-9(ax),5(ax). Similarly, the trans-annelation and simultaneous cis-aryl configuration can be neglected, because of the extremely high ring strain and the interaction between H-5a and the aryl group. If there were a cis annelation of the hetero rings and a cis aryl group (R^* or S^* relative configuration of C_{3a} for 3 and 5, respectively), a very strong steric hindrance would arise between N-3 and H-9'(ax),5'(ax), and the anisotropic effect of the near lone pair of N-3 would lead to strong deshielding being observed on the latter protons.[12] Since no sign of this is observable, the trans position of the 3a-aryl substituent, i.e. the S^* (3) or R^* (5) configuration of C-3a, can be regarded as proved.

This means that the preferred conformation of the starting compounds 1a,b (where the sp^2 nitrogen is axial) is changed, as indicated by the upfield shift (steric compression shift[13]) of the ^{13}C n.m.r. signals of C-5,9 (6.2 or 6.5 ppm for C-5 and ~4 ppm for C-9; Table 2), which reveals a considerable steric hindrance.

The conformation of compounds 1a,b and 2a,b, in which the nitrogen is axial to the alicyclic ring, follows from the 4.5-6.3 Hz splitting of the quartet of the geminal (H-9a) proton. If this proton were in the axial position, the interaction with one of the 9-methylene protons would necessarily be diaxial, with resulting higher coupling constants.[10,11,14] For easy comparison of the spectroscopically analogous atoms, we use the numbering of 3-6 for the starting compounds, too. Due

Table 1. ^{1}H n.m.r. data on compounds 1a,b, 2a,b and 3-6[a]

Compd.	H-5 dd + t (2x1H)[b]		H-5a m(1H)	H-6,9 m's (4H)	H-7,8 s/m's[c] (2/4H)	H-9a qa/dt/dd (1H)[d]	CH_3 s(3H)
1a	4.20	4.31	2.00	1.35-2.05 (8H)[e]		3.71	-
1b	4.14	4.26		1.3-2.0 (9H)[e]		3.67	2.35
2a	4.14	4.35	~2.5[f]	~1.9 (3H), ~2.2 (3H)	5.60	3.76	-
2b	4.16	4.25[g]		1.9-2.4 (4H)[e], ~2.6 (1H)[h]	5.61	3.80	2.35[e]
3	3.88	4.04	2.22	0.9-1.7 (8H)[e]		3.71	-
4	3.88(2H)[e]		2.32	1.72[i], 2.00-2.25 (3H)[e]	5.48	4.00	-
5	3.84	3.98	2.23	0.8-1.8 (8H)[e]		3.66	2.40
6	3.81	3.86	2.32	1.64[i], 2.05-2.25 (3H)[e]	5.38	3.92	2.39

[a] At 250 MHz, δ_{TMS} = 0 ppm, chemical shifts in ppm, coupling constants in Hz, $CDCl_3$ solution, for 2a in DMSO-d_6 solution. Multiplets for aromatic hydrogens; H^p (NPh), dt(1H): 6.8 (3 and 4), $H^{o,m}$ (NPh), m(4H): 7.15 (3 and 4); H-3',5' (A or B part of the AA'BB' type m of Ar group, J(A,B): 7.8-8.5), 7.95 (1a), 7.81 (1b), 7.85 (2a), 7.80 (2b), ~7.35 (3 and 4), 7.24 (5), 7.23 (6); $H^{m,p}$ (CPh), m(3H)[h]: ~7.50 (3 and 4), ~7.45 (5 and 6), H-2',6'/H^o (overlapping m's of B or A part of the AA'BB' spectrum of the Ar and of H^o of CPh groups), m(4H): 7.35 (1a), 7.15 (1b), 7.45 (2a), 7.14 (2b), ~7.65 (3, 4 and 6), ~7.70 (5). [b] AB part of an ABX spin system. (In case of 4 simplified to a d, J(A,X) + J(B,X) = 15.2. Approximate values of the coupling constants J(A,B), J(A,X) and J(B,X) are as follows: 10.6, 4.7 and 3.4 (1a,b); 10.6, 5.6 and 3.2 (2a); 10.6, 7.2 and 4.1 (2b); 11.6, 10.4 and 5.8 (3); 11.7, 11.3 and 4.6 (5); 11.6, 11.6 and 3.5 (6). [c] Approximate singlets (2H) for 2a,b, 4 and 6, m or m's of 4H total intensity for 1a,b, 3 and 5. [d] Approximate quartet for 1a,b and 2a,b, J: 4.6 (1a,b), ~6 (2a), 6.3 (2b), dt for 3 and 5, J: 12.8, 5.2 and 5.2, ddd for 4 and 6, J: 10, 8 and 5. [e] Overlapping signals. [f] Overlapping with the CHD_2 signal of the light isotope contamination of the solvent. [g] Further split to ddd by ca. 1.2 Hz. [h] Approximate dd, probably the signal of H-9 (quasi-axial) coplanar with the C_9-N_1 bond. [i] H-6(axial), d (1H), $^2J \cong 17$.

to the conformational change, C-6 assumes a sterically more favourable position and its signal is shifted downfield (by 3.9 and 3.2 ppm, respectively).

The unsaturated compounds 4 and 6 also have analogous stereostructures. For 4 the AB multiplet of the ABX spin system of H-5,5',5a is simplified to a doublet, and in the spectrum of 6 the lines of the AB multiplet are also partially coalesced. Thus, the value of the coupling constant J(B,X), which is of crucial importance as concerns the conformation, can not be determined. Since the lines in the H-9a multiplet are also partially merged, the 9,9a coupling constants can not be determined exactly either. Nevertheless, the unaltered band-width (~25 Hz) of the H-9a signal as compared to those of the analogous 3 and 5, and the nearly identical chemical shifts of the three protons in question, render an analogous steric structure probable. Additionally, the fact that the carbon resonances display changes identical in direction and extent as compared to those for starting compounds (in the case of cycloadducts 4 or 6 the C-5 and C-9 lines undergo upfield shifts of 6.6 or 4.5, and 2.6 or 2.7 ppm, respectively, and the C-6 signal undergoes a downfield shift of 2.2 or 2.7 ppm, respectively) prove the analogous trans-aryl configuration deduced for the saturated pairs 3 and 5, i.e. the S^* and R^* relative configuration of C-3a for 4 and 6, respectively, and the analogous conformation, as well.

X-ray analysis of 4. The final relative atomic coordinates for non-hydrogen atoms and the relevant torsion angles are given in Tables 3 and 4. The geometry of 4 is shown in the Figure. The oxazine ring bearing the p-chlorophenyl moiety in the axial position exhibits a flattened chair form characterized by a puckering ampli-

Table 2. ^{13}C n.m.r. chemical shifts for compounds 1a,b, 2a,b and 3-6[a]

Compound	1a	1b	2a[b]	2b	3	4	5	6
C-1	-	-	-	-	149.9	149.8	157.9	157.7
C-3a	153.7	154.4	154.0	154.7	103.3	103.4	113.7	113.6
C-5	69.0	68.8	69.4	67.6	61.8	62.8	62.3	63.1
C-5a	32.3	32.6	32.7	31.2	32.6	30.9	33.4	31.3
C-6	24.9[c]	24.9[c]	25.4	24.8	28.1[c]	27.6[c]	27.6[c]	26.7
C-7	24.2[c]	24.4[c]	126.1	124.4	20.3	124.2	20.5	123.8
C-8	21.7	21.8	125.2	123.9	25.3	124.8	25.4	123.9
C-9	31.7	31.8	29.1	28.4	27.8[c]	26.5[c]	27.4[c]	25.7
C-9a	51.1	51.0	49.7	48.8	53.1	50.1	53.9	50.5
CH_3(Ar)	-	21.3	-	21.3	-	-	21.1	21.0
C^s Ph(1)	-	-	-	-	140.1	140.4	139.2	139.2
C^s Ar	132.7	131.7	134.2	131.5	129.5	129.6	125.8	125.4
C^s N(3)-Ph	-	-	-	-	142.0	141.9	-	-
C^{o,m}	128.1	127.1	129.5	127.2	117.1[d] 127.7 128.0 128.6	117.0[d] 127.7 128.2[e]	127.5 128.2	127.3 128.0
	128.5	128.6	130.0	128.6	128.8 129.2	128.7[f] 129.1	128.9[e]	128.9[e]
C^p Ph(1)	-	-	-	-	134.3	134.5	134.9	135.2
C^p Ar	136.3	140.1	136.8	140.2	128.9	128.7[f]	130.5	130.5
C^p N(3)-Ph	-	-	-	-	120.7	120.8	-	-

[a] In $CDCl_3$ solution at 20 MHz, δ_{TMS} = 0 ppm. [b] Data (measured in DMSO-d_6 solution) are also given in Ref. 3. [c] Reversed assignments may also be possible. [d] N(3)-Phenyl group. [e,f] Two overlapping lines.

tude[15] of Q = 0.515(6) Å. The same sign (-) of the endocyclic torsion angles (Table 4) pertaining to the C(3a)-N(10) bond indicates a *cis* fusion of the 1,3-oxazine and 1,2,4-triazoline rings. This substantiates the conclusions inferred from the ^1H and ^{13}C n.m.r. spectra for the compound containing a saturated carbocyclic ring, and extended analogously to the corresponding unsaturated ones, such as compound 4. N(10) has a pronounced pyramidality,[16] with χ_{N_3} = 0.69 rad., indicating its $sp^3 > sp^2$ hybridization, bearing a lone pair of electrons eclipsed with C(31). The shape of the triazoline ring with its C(1)-N(2) double bond 1.276(4) Å is a transitional conformation between an *envelope* and a *half-chair*, with a rather low puckering amplitude: Q = 0.149(5) Å. The neighbourhood of N(3) is practically coplanar, in accordance with its sp^2 hybridization (its pyramidality is only 0.11 rad.). The N(3)-phenyl ring lies practically in the best plane of the N(2),N(3),C(3),C(21) moiety, while the C(1)-ring makes a dihedral angle of 67.0(1)° with the least-squares plane of N(2),C(1),N(10),C(11). The di-

Table 3. Final fractional coordinates for non-hydrogen atoms*

Atom	x/a	y/b	z/c
Cl	0.42113(9)	0.36471(9)	0.54123(8)
O(4)	-0.2193(1)	0.1613(1)	0.7217(1)
N(2)	-0.2219(2)	-0.0478(2)	0.9736(1)
N(3)	-0.1263(2)	-0.0118(2)	0.8505(1)
N(10)	-0.2226(2)	0.1769(2)	0.9155(1)
C(1)	-0.2764(2)	0.0634(2)	1.0054(2)
C(3a)	-0.1395(2)	0.1332(2)	0.8002(2)
C(5)	-0.2981(3)	0.2930(3)	0.7087(2)
C(5a)	-0.3981(3)	0.3191(3)	0.8334(2)
C(6)	-0.4877(3)	0.4572(4)	0.8212(3)
C(7)	-0.4118(4)	0.5703(3)	0.8095(3)
C(8)	-0.2966(4)	0.5553(3)	0.8294(3)
C(9)	-0.2185(3)	0.4234(3)	0.8647(2)
C(9a)	-0.3103(3)	0.3079(2)	0.9102(2)
C(11)	-0.3764(2)	0.0724(2)	1.1320(2)
C(12)	-0.3299(2)	0.1130(2)	1.2064(2)
C(13)	-0.4214(3)	0.1155(3)	1.3267(2)
C(14)	-0.5552(3)	0.0806(3)	1.3717(2)
C(15)	-0.6031(3)	0.0425(3)	1.2984(2)
C(16)	-0.5121(3)	0.0377(3)	1.1784(2)
C(21)	-0.0442(2)	-0.1122(2)	0.7907(2)
C(22)	-0.0272(3)	-0.2425(3)	0.8596(2)
C(23)	0.0592(4)	-0.3416(3)	0.8016(3)
C(24)	0.1299(4)	-0.3146(3)	0.6750(3)
C(25)	0.1114(3)	-0.1871(3)	0.6070(2)
C(26)	0.0262(3)	-0.0858(2)	0.6622(2)
C(31)	0.0021(2)	0.1907(2)	0.7315(2)
C(32)	0.0868(2)	0.1836(2)	0.7965(2)
C(33)	0.2149(2)	0.2357(3)	0.7399(2)
C(34)	0.2594(3)	0.2979(2)	0.6150(2)
C(35)	0.1786(3)	0.3059(3)	0.5476(2)
C(36)	0.0506(2)	0.2526(2)	0.6058(2)

* E.s.d.'s are in parentheses.

hedral angle formed by the best planes of these phenyl rings is 84.9(1)°. The unsaturated carbocyclic ring is cis-fused to the oxazine ring assumes a half-chair conformation, as described by the puckering parameters: Q = 0.426(7) Å, Θ = 131.(1), Ψ = 145(1)°.

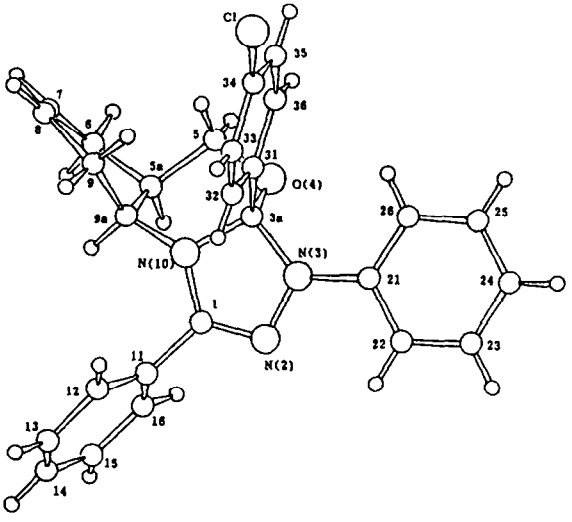


Fig. A perspective view of the molecular structure of 4, showing atomic numbering.

Table 4. Relevant torsion angles (°)*

C(1)-N(2)-C(3)-C(3a)	=	-8.4(5)
N(2)-N(3)-C(3a)-N(10)	=	14.6(4)
N(3)-C(3a)-N(10)-C(1)	=	-15.0(4)
C(3a)-N(10)-C(1)-N(2)	=	12.0(5)
N(10)-C(1)-N(2)-N(3)	=	-2.4(5)
C(3a)-O(4)-C(5)-C(5a)	=	-55.5(6)
O(4)-C(5)-C(5a)-C(9a)	=	59.5(5)
C(5)-C(5a)-C(9a)-N(10)	=	-54.4(5)
C(5a)-C(9a)-N(10)-C(3a)	=	48.3(5)
C(9a)-N(10)-C(3a)-O(4)	=	-42.5(5)
N(10)-C(3a)-O(4)-C(5)	=	44.8(5)
C(1)-N(10)-C(3a)-O(4)	=	98.3(5)
N(3)-C(3a)-N(10)-C(9a)	=	-155.7(6)
C(3a)-N(10)-C(9a)-C(9)	=	-78.2(6)
N(10)-C(9a)-C(5a)-C(6)	=	-177.9(7)
C(5a)-C(6)-C(7)-C(8)	=	-12.2(9)
C(6)-C(7)-C(8)-C(9)	=	1.4(8)
C(7)-C(8)-C(9)-C(9a)	=	-16.2(7)
C(8)-C(9)-C(9a)-C(5a)	=	42.2(7)
C(9)-C(9a)-C(5a)-C(6)	=	-53.0(6)
C(9a)-C(5a)-C(6)-C(7)	=	36.7(7)
C(3a)-N(10)-C(1)-C(11)	=	-174.7(7)
N(10)-C(1)-C(11)-C(12)	=	-64.1(6)
N(10)-C(3a)-N(3)-C(21)	=	-171.5(7)
C(3a)-N(3)-C(21)-C(22)	=	168.9(7)
N(2)-N(3)-C(3a)-C(31)	=	133.9(6)
N(3)-C(3a)-C(31)-C(32)	=	-64.2(6)

*E.s.d.'s are in parentheses.

EXPERIMENTAL

The n.m.r. spectra were recorded in $CDCl_3$ solution in 5 or 10 mm tubes at room temperature, on a Bruker WM-250 (^1H) and a WP-80 SY (^{13}C) FT-spectrometer controlled by an Aspect 2000 computer at 250.13 (^1H) and 20.14 (^{13}C) MHz, with the deuterium signal of the solvent as the lock and TMS as internal standard. The most important measuring parameters of the spectra were as follows: sweep width 5 kHz, pulse width 1 and 3.5 μs (~20 and 30° flip angle), acquisition time 1.64 s, number of scans 16 or 32 (^1H) and 1-6 K (^{13}C), computer memory 16 K. Lorentzian exponential multiplication for signal-to-noise enhancement (LB: 0.7 and 1.0 Hz) and for ^{13}C n.m.r. spectra proton noise decoupling (~1.5 W) was applied.

Preparation of 1,3-oxazino-1,2,4-triazolines 3 and 4

A mixture of 1a or 2a (2.6 g, 0.01 mol), N-(α-chlorobenzylidene)phenylhydrazine (2.3 g, 0.01 mol) and triethylamine (3.0 ml) was refluxed for 3 h in dry benzene (20 ml). After removal of the solid, the filtrate was washed with water (3x10 ml), dried (Na_2SO_4) and evaporated. The residue was transferred to a silica gel column, and eluted with benzene and then with ethanol. The residue of the ethanolic eluate was crystallized from benzene—petroleum ether. Data on the obtained compounds 3 and 4 are given in Table 5.

Table 5. Physical and analytical data on compounds 3-6

Compd.	M.p. °C	Yield %	Found C	Found H	Found N	Formula	Required C	Required H	Required N
3	176-178	68	72.85	5.76	9.27	$C_{27}H_{26}ClN_3O$	73.04	5.90	9.46
4	211-212	50	73.54	5.61	9.49	$C_{27}H_{24}ClN_3O$	73.37	5.47	9.51
5	131-133	46	75.76	6.81	8.10	$C_{22}H_{24}N_2O_2$	75.83	6.94	8.04
6	165-167	43	76.14	6.31	8.05	$C_{22}H_{22}N_2O_2$	76.27	6.40	8.09

Preparation of 1,3-oxazino-1,2,4-oxadiazolines 5 and 6

To a dry ethereal (20 ml) solution of 1b or 2b (2.3 g, 0.01 mol), triethylamine (1.0 g, 0.01 mol) and a solution of chlorobenzaldoxime (1.6 g, 0.01 mol) in dry ether (10 ml) were added dropwise. After stirring at ambient temperature (1 h), the mixture was washed with water (2x10 ml), dried (Na_2SO_4) and evaporated. The residue was transferred to a silica gel column and eluted with benzene. The residue of the eluate was crystallized from benzene—petroleum ether. Data on compounds 5 and 6 are given in Table 5.

Crystal structure and crystal data for compound 4

$C_{27}H_{24}ClN_3O$, M = 441.96, triclinic, a = 10.372(1), b = 10.495(1), c = 12.239(1) Å, α = 72.37(1), β = 65.48(1), γ = 76.99(1)°, V = 1147.6(1) Å^3 (by least-squares refinement) on diffractometer angles for 25 automatically centred reflexions (λ = 1.54184 Å), space group $P\bar{1}$ (from successful structure refinement), Z = 2, D_x = 1.28 g.cm^{-3}, F(000) = 464. Crystal dimensions: 0.10x0.25x0.30 mm^3, μ(Cu-K$_\alpha$) = 16.6 cm^{-1}.

Data collection, structure determination and data refinement were carried out with a CAD-4 diffractometer and its PDP-11/34 minicomputer unit, $\omega/2\Theta$ scan in the range $1.5 < \Theta < 75°$, with scan width 0.5+0.14 tan Θ, using graphite monochromated CuK$_\alpha$ radiation. Three standard reflexions ($\bar{4}03$, $\bar{5}1\bar{5}$, $02\bar{6}$) were monitored every hour and showed no significant deviation. 3932 unique observations were recorded with h = 0 → 12, k = −13 → 13, l = −15 → 15, of which - after correction for Lorentz and polarization effects (L_p) - 2973 with $I > 3.0\sigma(I)$ were used for the structure analysis and refinement. An empirical absorption correction of the data set was performed with the DIFABS[17] program. Relative transmission coefficients ranged from 0.604 to 1.522, with an average value of 0.999.

The structure was solved by MULTAN[18], using 361 E > 1.78 normalized structure factors. The full-matrix least-squares refinement minimized $\Sigma w(\Delta F)^2$; 289 parameters were refined. Final R = 0.049, R_w = 0.044, S = 0.63, $w = 4F_o^2/\sigma^2(F_o^2)$. The largest parameter shift in the final cycle of refinement was Δ/σ = 0.61, while the highest peak in the final diff. map was 0.18(4) e.Å^{-3}. Hydrogen positions were located in a difference Fourier calculation and added to the structure factor calculations with a mean isotropic temperature factor ($B_{iH} = B_{iC} + 1$ in Å^2). Atomic scattering factors were taken from Cromer and Waber[19].

REFERENCES

1. Stereochemical Studies, 131. Saturated Heterocycles, 133. Parts 130/132: F. Fülöp, K. Pihlaja, J. Mattinen, G. Bernáth, Tetrahedron, 43, 1863 (1987).
2. G. Bernáth, F. Fülöp, L. Gera, L. Hackler, A. Kálmán, Gy. Argay and P. Sohár, Tetrahedron, 35, 799 (1979).
3. G. Bernáth, G. Stájer, A. E. Szabó, F. Fülöp and P. Sohár, Tetrahedron, 41, 1353 (1985).
4. G. Stájer, A. E. Szabó, G. Bernáth and P. Sohár, Tetrahedron, 43, 1931 (1987).
5. P. Sohár, G. Stájer and G. Bernáth, Magn. Reson. Chem., 25, 635 (1987).
6. R. Huisgen, M. Seidel, G. Wallbillich and H. Knupfer, Tetrahedron, 17, 3 (1962).
7. Houben-Weyl, Methoden der Organischen Chemie, Vol. 8, p. 691, Thieme, Stuttgart (1952).
8. R. Huisgen, Pure and Applied Chemistry, Vol. 53. p. 171-187, Pergamon Press, Great Britain (1981).
9. M. Karplus, J. Chem. Phys., 30, 11 (1959); 33, 1842 (1960).
10. P. Sohár, L. Gera and G. Bernáth, Org. Magn. Reson., 14, 204 (1980).
11. P. Sohár, F. Fülöp and G. Bernáth, Org. Magn. Reson., 22, 575 (1984).
12. P. Sohár, Nuclear Magnetic Resonance Spectroscopy, Vol. 1, pp. 35-38, CRC Press, Boca Raton, Florida (1983).
13. D. M. Grant and B. V. Cheney, J. Am. Chem. Soc., 89, 5315 (1967).
14. P. Sohár and G. Bernáth, Org. Magn. Reson., 5, 159 (1973).
15. D. Cremer and J. A. Pople, J. Am. Chem. Soc., 97, 1354 (1975).
16. J. D. Dunitz and F. K. Winkler, Acta Cryst., B31, 251 (1975).
17. N. Walker and D. Stuart, Acta Cryst., A39, 158 (1983).
18. P. Main, S. E. Hull, L. Lessinger, G. Germain, P. J. Declercq and M. M. Woolfson, A System of Computer Programs for Automatic Solution of Crystal Structures from X-ray Diffraction Data (MULTAN), Universities of York and Louvain (1978).
19. D. T. Cromer and J. T. Waber, International Tables for X-ray Crystallography, Vol. 4, Table 2.2B, Kynoch Press, Birmingham (1974).