

similar, the only difference being a rotation of approximately 17 (3)° around the bond C(8)–C(9) of ring II. The molecules are not planar. The packing of the molecules is illustrated in Fig. 3. No intermolecular distances are less than the sum of the van der Waals radii of the atoms involved.

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References

BLIVOET, J. M., PEERDEMAN, A. F. & VAN BOMMEL, A. J. (1951). *Nature (London)*, **168**, 271–272.

BURKE-LAING, M. & LAING, M. (1976). *Acta Cryst.* **B32**, 3216–3224.
 FONSECA, I., MARTÍNEZ-CARRERA, S. & GARCÍA-BLANCO, S. (1979). *Acta Cryst.* **B35**, 2643–2646.
International Tables for X-ray Crystallography (1974). Vol. IV. Birmingham: Kynoch Press.
 JOHNSON, C. K. (1965). *ORTEP*. Report ORNL-5138. Oak Ridge National Laboratory, Oak Ridge, Tennessee.
 MAIN, P., LESSINGER, L., WOOLFSON, M. M., GERMAIN, G. & DECLERCQ, J. P. (1977). *MULTAN 77. A System of Computer Programs for the Automatic Solution of Crystal Structures from X-ray Diffraction Data*. Univs. of York, England, and Louvain, Belgium.
 MARTÍNEZ-RIPOLL, M. & CANO, F. H. (1975). *PESOS*. Instituto Rocasolano, Serrano 119, Madrid, Spain.
 MARTÍNEZ-RIPOLL, M. & FAYOS, J. (1980). *Z. Kristallogr.* **152**, 189–194.

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The Structure of 2',3'-O-(Tetraisopropyl-1,3-disiloxanediyl)cytidine at 97 K*

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Abstract. C₂₁H₃₉N₃O₆Si₂, orthorhombic, *P*2₁2₁2₁, *a* = 8.649 (2), *b* = 23.301 (4), *c* = 26.902 (8) Å at 293 K and *a* = 8.630 (4), *b* = 23.082 (5), *c* = 26.301 (9) Å at 97 K; *Z* = 8, *D*_c = 1.23 Mg m⁻³ at 293 K; *R*_w(*R*) = 0.028 (0.045) for 2830 reflexions [2323 with *I* > 2σ(*I*)]. The structure was solved by direct methods. The two independent ribose rings display a C(2')-endo conformation; pseudorotation angles *P* = 160.3 (2) and 163.2 (1)° and φ_{max} = 40.5 (3) and 41.0 (3)°, respectively. Both O(5') atoms are *gauche-gauche* oriented with respect to O(1') and C(3'). The two cytosine bases are *anti* with respect to the sugar rings: χ_{CN} = 39.9 (5) and 55.6 (5)°. The two independent molecules form dimeric units by means of hydrogen bonds N(3A)⋯H–N(4B) [2.992 (5) Å] and N(4A)–H⋯N(3B) [2.967 (5) Å]. The cytosine carbonyl oxygens serve as acceptors in hydrogen bonds O(5'A)–H⋯O(2A) [2.696 (4) Å] and O(5'B)–H⋯O(2B) [2.718 (4) Å] connecting neighbouring molecules in the direction [100].

Introduction. As a follow-up to the structure determination of 3',5'-O-(tetraisopropyl-1,3-disiloxanediyl)-

cytidine (Verdegaal, de Kok, Westerink, van Boom & Romers, 1981) we now report the crystal structure of 2',3'-O-(tetraisopropyl-1,3-disiloxanediyl)cytidine (TIS). The disiloxane group is introduced in order to protect two of the three hydroxyl functions during the synthesis of oligonucleotides (Verdegaal, Jansse, de Rooij & van Boom, 1980). Crystals were grown by evaporation of a solution of TIS in a 1:1 acetonitrile/acetone mixture. A crystal with dimensions 0.35 × 0.15 × 0.15 mm was sealed in a glass capillary and mounted on a Nonius CAD-4 diffractometer. A total of 2830 symmetry-independent reflexions were collected at 97 K, using graphite-monochromated Mo *K*α radiation (λ = 0.71069 Å) and scanning in the range of 2° < θ < 20°. 2323 reflexions had *I* > 2σ(*I*). The intensities were corrected for loss of scattering power (12%) during the exposure period. No absorption correction was applied.

The structure was solved by direct methods using the *MULTAN* 78 program system (Main, 1978). The missing heavy atoms and H atoms were found in Fourier and difference Fourier maps. Full-matrix refinement with anisotropic heavy atoms and isotropic H atoms resulted in *R*_w = [Σ w(*F*_o – |*F*_c|)²/Σ w*F*_o²]^{1/2} = 0.028 and *R* = Σ |*F*_o – |*F*_c||/Σ *F*_o = 0.045 for 2830 reflexions. The weights used are *w* = 1/σ²(*F*_o), the variance σ²(*F*_o) being derived from the measurements.

* Nucleic Acid Constituents. XXII. Part XXI: Mellema, Haasnoot, van Boom & Altona (1981).

Table 1. Positional parameters ($\times 10^4$) and B_{eq} values ($\text{\AA}^2 \times 10$) of the non-hydrogen atoms

Estimated standard deviations in the least significant digit are given in parentheses. $B_{eq} = \frac{2}{3}\pi^2 \text{trace } \bar{U}$.

	x	y	z	B_{eq}
Si(1A)	-11473 (2)	7426 (1)	1504 (1)	19 (1)
C(7A)	-13966 (6)	8056 (2)	1907 (2)	34 (2)
C(8A)	-13263 (6)	7873 (2)	1396 (2)	28 (2)
C(9A)	-14512 (6)	7577 (2)	1059 (2)	33 (2)
C(10A)	-8452 (7)	7539 (2)	1883 (2)	50 (2)
C(11A)	-9788 (6)	7875 (2)	1680 (2)	28 (2)
C(12A)	-9242 (6)	8256 (2)	1233 (2)	45 (2)
O(4A)	-11090 (3)	7035 (1)	1003 (1)	19 (1)
Si(2A)	-10796 (2)	6344 (1)	896 (1)	20 (1)
C(13A)	-12736 (7)	6374 (2)	34 (2)	42 (2)
C(14A)	-12487 (6)	6057 (2)	546 (2)	33 (2)
C(15A)	-12506 (7)	5409 (2)	478 (2)	43 (2)
C(16A)	-8441 (8)	6715 (2)	231 (3)	58 (2)
C(17A)	-8907 (6)	6215 (2)	570 (2)	34 (2)
C(18A)	-7587 (6)	6023 (3)	926 (2)	54 (2)
C(1'A)	-11170 (5)	5799 (2)	2328 (2)	14 (1)
O(1'A)	-12350 (3)	5906 (1)	2683 (1)	15 (1)
C(2'A)	-11842 (5)	5956 (2)	1815 (2)	14 (1)
O(2'A)	-10665 (3)	6009 (1)	1449 (1)	17 (1)
C(3'A)	-12769 (5)	6497 (2)	1951 (2)	15 (1)
O(3'A)	-11753 (3)	6980 (1)	1987 (1)	16 (1)
C(4'A)	-13392 (5)	6343 (2)	2476 (2)	13 (1)
C(5'A)	-15025 (5)	6107 (2)	2477 (2)	19 (1)
O(5'A)	-15121 (3)	5654 (1)	2112 (1)	20 (1)
N(1A)	-10680 (4)	5197 (1)	2359 (1)	12 (1)
C(2A)	-9146 (5)	5053 (2)	2254 (2)	14 (1)
O(2A)	-8175 (3)	5451 (1)	2235 (1)	20 (1)
N(3A)	-8755 (4)	4502 (2)	2171 (1)	17 (1)
C(4A)	-9824 (6)	4087 (2)	2213 (2)	17 (1)
N(4A)	-9408 (4)	3549 (1)	2092 (1)	22 (1)
C(5A)	-11372 (5)	4209 (2)	2381 (2)	19 (1)
C(6A)	-11751 (5)	4771 (2)	2427 (2)	18 (1)
Si(1B)	-3403 (2)	387 (1)	1011 (1)	16 (1)
C(7B)	-5658 (6)	-516 (2)	1011 (2)	32 (1)
C(8B)	-4833 (5)	-66 (2)	1350 (2)	18 (1)
C(9B)	-4196 (6)	-360 (2)	1826 (2)	26 (1)
C(10B)	-427 (6)	-46 (2)	1312 (2)	29 (2)
C(11B)	-1470 (6)	58 (2)	854 (2)	24 (1)
C(12B)	-1629 (6)	-486 (2)	531 (2)	40 (2)
O(4B)	-4140 (3)	627 (1)	482 (1)	16 (1)
Si(2B)	-4615 (1)	1268 (1)	260 (1)	16 (1)
C(13B)	-1738 (6)	1374 (2)	-245 (2)	31 (2)
C(14B)	-3516 (5)	1385 (2)	-339 (2)	22 (1)
C(15B)	-3958 (6)	929 (2)	-740 (2)	40 (2)
C(16B)	-7232 (6)	1935 (2)	-1 (2)	35 (2)
C(17B)	-6756 (5)	1326 (2)	171 (2)	19 (1)
C(18B)	-7630 (5)	1141 (2)	656 (2)	38 (2)
C(1'B)	-3806 (5)	2159 (2)	1507 (2)	15 (1)
O(1'B)	-2659 (3)	2136 (1)	1891 (1)	15 (1)
C(2'B)	-3076 (5)	1911 (2)	1037 (2)	14 (1)
O(2'B)	-4226 (3)	1770 (1)	677 (1)	17 (1)
C(3'B)	-2144 (5)	1422 (2)	1271 (2)	12 (1)
O(3'B)	-3113 (3)	945 (1)	1389 (1)	13 (1)
C(4'B)	-1551 (5)	1687 (2)	1766 (2)	15 (1)
C(5'B)	47 (5)	1942 (2)	1754 (2)	18 (1)
O(5'B)	129 (3)	2379 (1)	1376 (1)	21 (1)
N(1B)	-4324 (4)	2764 (1)	1476 (1)	12 (1)
C(2B)	-5867 (6)	2904 (2)	1587 (2)	16 (2)
O(2B)	-6831 (3)	2514 (1)	1619 (1)	21 (1)
N(3B)	-6233 (4)	3469 (1)	1666 (1)	16 (1)
C(4B)	-5166 (5)	3880 (2)	1601 (2)	18 (2)

Table 1 (cont.)

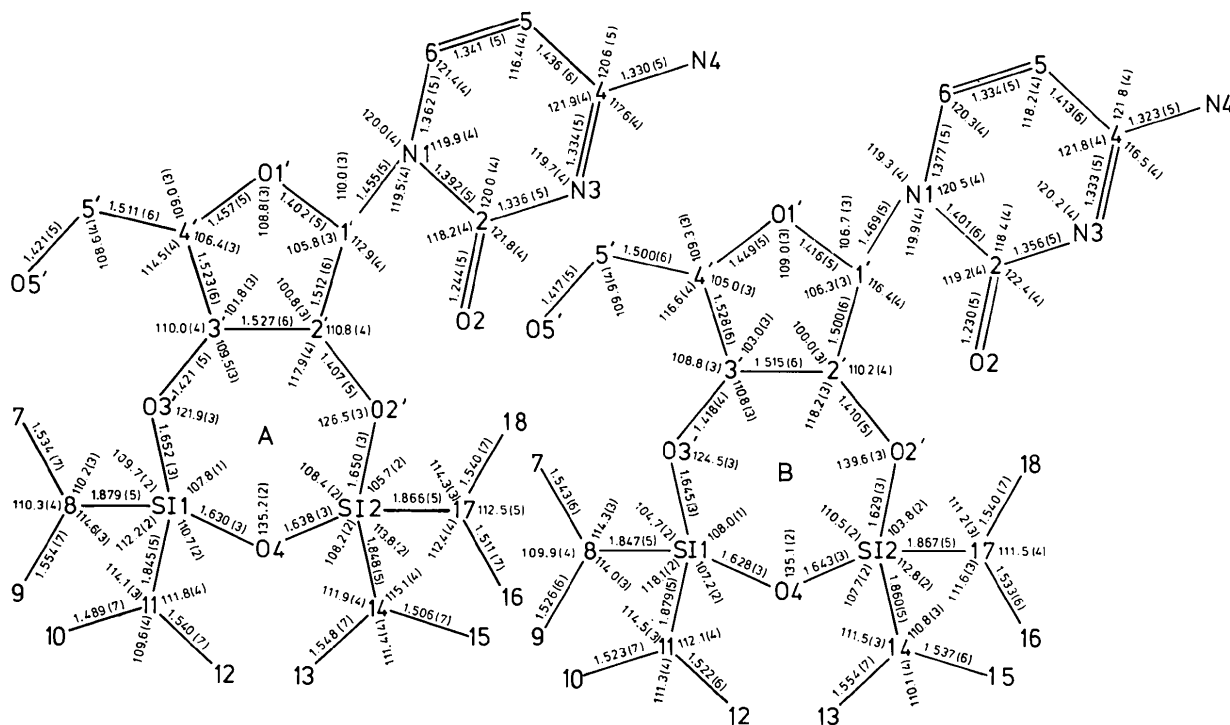
	x	y	z	B_{eq}
N(4B)	-5598 (4)	4417 (1)	1706 (1)	23 (1)
C(5B)	-3653 (5)	3749 (2)	1432 (2)	18 (1)
C(6B)	-3248 (5)	3194 (2)	1392 (2)	17 (1)

Scattering factors for C, H, N, O and Si were adopted from *International Tables for X-ray Crystallography* (1974). The anisotropic temperature factors are defined as $\exp(-2\pi^2 \sum_i \sum_j a_i^* a_j^* h_i h_j U_{ij})$, $i, j = 1, 2, 3$. The positional parameters, their standard deviations and B_{eq} values of the heavy atoms are tabulated in Table 1.†

Discussion. Bond lengths and valency angles of molecules *A* and *B* are given in Fig. 1. The cytosine bases (see Fig. 2) are linked by two hydrogen bonds N(3A)···H—N(4B) [2.992 (5) Å] and N(4A)—H···N(3B) [2.967 (5) Å]. Apparently the structure consists of dimeric units *A* + *B*. Two strong hydrogen bonds (see Fig. 2), *i.e.* O(5'A)—H···O(2A) [2.696 (4) Å] and O(5'B)—H···O(2B) [2.718 (4) Å] connect the dimeric units along [100]. Fig. 2 shows that cytosine *A* and *B* are related by a local pseudocentre of symmetry. Similar dimeric units are observed in the structures of 2'-deoxycytidine (Young & Wilson, 1975) and 1-methylcytosine (Rossi & Kistenmacher, 1977). In these cases (see the least-squares planes, Table 4, in the deposited material) the bases are more or less distorted and bent into the shape of hammocks.

In particular the non-planarity of the two cytosines in TIS is quite significant: N(1A), C(5A), N(4B) and O(2B) are displaced by 0.1 Å or more from their least-squares planes, whereas the displacement of C(1'A) and C(1'B) from these planes amounts to 0.4 Å. Relevant torsion angles are listed in Table 2. Both sugar rings have an envelope conformation with C(2') *endo*. The values of the pseudorotation parameters [molecule *A*: $\varphi_{\max} = 40.5 (3)^\circ$, $P = 160.3 (2)^\circ$; molecule *B*: $\varphi_{\max} = 41.0 (3)^\circ$, $P = 163.2 (1)^\circ$ (Altona, Geise & Romers, 1968)] agree well with the average values ($\varphi_{\max}^{\text{av}} = 38.0$, $P_{\text{av}} = 168^\circ$) for β -pyrimidine nucleotides in the C(2')-*endo* form (Altona & Sundaralingam, 1972). Inspection of Table 2 indicates that the orientation of the bonds C(5')—O(5') with respect to C(3') and O(1') is *gauche-gauche* in both molecules. The cytosine moieties are orientated *anti* with respect to the sugar rings [$\chi_{\text{CN}} = 39.9 (5)$ and

† A list of observed and calculated structure factors, anisotropic vibrational parameters, positional parameters and B values of H atoms and a number of least-squares planes (Table 4) have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 36914 (16 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.



C(8A) - Si(1A) - O(4A) 110.4(2)

C(11A) - Si(1A) - O(3'A) 105.8(2)

C(17A) - Si(2A) - O(4A) 111.7(2)

C(14A) - Si(2A) - O(2'A) 108.9(2)

C(8B) - Si(1B) - O(4B) 110.2(2)

C(11B) - Si(1B) - O(3'B) 108.3(2)

C(17B) - Si(2B) - O(4B) 110.8(2)

C(14B) - Si(2B) - O(2'B) 111.3(2)

Fig. 1. Bond distances (Å) and bond angles (°). The numbering of the atoms is indicated. Estimated standard deviations in the least significant digit are given in parentheses.

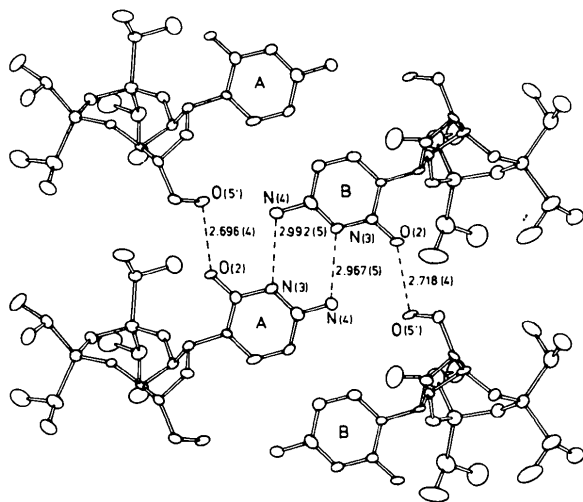


Fig. 2. Projection of a part of the structure along [001]. The hydrogen bonds are indicated by dashed lines. The numbers refer to distances in Å.

55.6(5)°, respectively (Sundaralingam, 1969)]. The disiloxane parts of the seven-membered rings are nearly planar; the r.m.s. values for the least-squares planes

Table 2. Some torsion angles (°) of the sugar rings

Estimated standard deviations in the least significant digit are given in parentheses.

Notation	Designation	Angle	Conformation
Molecule A			
τ_0	C(1')-C(2')-C(3')-C(4')	-37.1(4)	S-type
τ_1	C(2')-C(3')-C(4')-O(1')	23.5(4)	C(2')-endo
τ_2	C(3')-C(4')-O(1')-C(1')	0.8(4)	$P = 160.3(2)^\circ$
τ_3	C(4')-O(1')-C(1')-C(2')	-25.4(4)	$\phi_{max} = 40.5(3)^\circ$
τ_4	O(1')-C(1')-C(2')-C(3')	39.3(4)	
χ_{C-N}	O(1')-C(1')-N(1)-C(6)	39.9(5)	anti
ψ	C(3')-C(4')-C(5')-O(5')	50.4(5)	g^* (gauche-gauche)
	O(1')-C(4')-C(5')-O(5')	-68.7(5)	
Molecule B			
τ_0	C(1')-C(2')-C(3')-C(4')	-38.3(4)	S-type
τ_1	C(2')-C(3')-C(4')-O(1')	25.4(4)	C(2')-endo
τ_2	C(3')-C(4')-O(1')-C(1')	-1.2(4)	$P = 163.2(1)^\circ$
τ_3	C(4')-O(1')-C(1')-C(2')	-24.1(4)	$\phi_{max} = 41.0(3)^\circ$
τ_4	O(1')-C(1')-C(2')-C(3')	38.9(4)	
χ_{C-N}	O(1')-C(1')-N(1)-C(6)	55.6(5)	anti
ψ	C(3')-C(4')-C(5')-O(5')	57.7(5)	g^* (gauche-gauche)
	O(1')-C(4')-C(5')-O(5')	-61.1(5)	

through the five atoms of the disiloxane moieties (marked with an asterisk in Table 3) are 0.095 Å for A and 0.006 Å for B. Apparently the disiloxane moieties possess an appreciable double-bond character due to $d_{\pi}-p_{\pi}$ overlap (Eaborn, 1960).

Table 3. *Least-squares planes through the disiloxane moieties and the distances (Å) to the plane of the atoms of the seven-membered ring*

The atoms defining the plane are marked with an asterisk. Estimated standard deviations in the least significant digit are given in parentheses.

	Molecule A Plane (i)	Molecule B Plane (ii)
O(3')	0.109 (1)*	-0.007 (1)*
Si(1)	-0.098 (2)*	0.006 (2)*
O(4)	-0.007 (2)*	0.001 (2)*
Si(2)	0.107 (2)*	-0.007 (2)*
O(2')	-0.112 (1)*	0.007 (1)*
C(2')	0.721 (5)	0.598 (6)
C(3')	1.187 (5)	0.993 (5)

The least-squares planes with respect to orthogonal axes *X*, *Y* and *Z* are described by:

- (i) $-0.9648 (2)X + 0.1935 (9)Y + 0.1784 (12)Z + 4.6283 (33) = 0$
 (ii) $0.9208 (3)X + 0.1017 (11)Y - 0.3764 (9)Z + 3.6205 (34) = 0$.

References

ALTONA, C., GEISE, H. J. & ROMERS, C. (1968). *Tetrahedron*, **24**, 13–32.

- ALTONA, C. & SUNDARALINGAM, M. (1972). *J. Am. Chem. Soc.* **94**, 8205–8212.
 EABORN, C. (1960). *Organosilicon Compounds*, pp. 94–103. London: Butterworth.
International Tables for X-ray Crystallography (1974). Vol. IV. Birmingham: Kynoch Press.
 MAIN, P. (1978). *Computing in Crystallography*, edited by H. SCHENK, R. OLTHOF-HAZEKAMP, H. VAN KONINGSVELD & G. C. BASSI, pp. 93–107. Delft Univ. Press.
 MELLEMA, J. R., HAASNOOT, A. G., VAN BOOM, J. H. & ALTONA, C. (1981). *Biochim. Biophys. Acta*, **655**, 256–264.
 ROSSI, M. & KISTENMACHER, T. J. (1977). *Acta Cryst.* **B33**, 3962–3965.
 SUNDARALINGAM, M. (1969). *Biopolymers*, **7**, 821–860.
 VERDEGAAL, C. H. M., JANSSE, P. L., DE ROOIJ, J. F. M. & VAN BOOM, J. H. (1980). *Tetrahedron Lett.* **21**, 1571–1574.
 VERDEGAAL, C. H. M., DE KOK, A. J., WESTERINK, H. P., VAN BOOM, J. H. & ROMERS, C. (1981). *Acta Cryst.* **B37**, 1924–1926.
 YOUNG, D. W. & WILSON, H. R. (1975). *Acta Cryst.* **B31**, 961–965.

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2-Methyl-4,5,6,7-tetrahydropyrazolo[3,4-*c*]pyridin-3-ol Monohydrate, a Structural Analogue of THIP (4,5,6,7-Tetrahydroisoxazolo[5,4-*c*]pyridin-3-ol)

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Abstract. $C_7H_{11}N_3O \cdot H_2O$, $M_r = 171.21$, monoclinic, $P2_1/c$, $a = 8.204 (4)$, $b = 7.352 (3)$, $c = 15.320 (7)$ Å, $\beta = 118.52 (5)^\circ$, $V = 811.9 (6)$ Å³, D_m (floatation) = 1.40, $D_c = 1.401$ Mg m⁻³, $Z = 4$. The structure was solved by direct methods and refined by full-matrix least-squares methods. The final *R* value for 1309 observed reflections is 0.044. The molecule is a zwitterion, and the crystal structure is stabilized by a system of hydrogen bonds.

Introduction. Muscimol [5-(aminomethyl)-3-isoxazolol] is a very active and selective GABA (γ -aminobutyric acid) agonist (Johnston, Curtis, DeGroat & Duggan, 1968; Curtis, Duggan, Felix & Johnston, 1971; Krogsgaard-Larsen, Johnston, Curtis, Game & McCulloch, 1975). Using muscimol as a model

compound, a comprehensive series of heterocyclic GABA analogues has been developed (Krogsgaard-Larsen, 1978; Krogsgaard-Larsen, Honoré & Thyssen, 1979; Brehm, Krogsgaard-Larsen & Jacobsen, 1979) and studied with respect to various GABA synaptic processes (Krogsgaard-Larsen, Johnston, Curtis, Game & McCulloch, 1975; Krogsgaard-Larsen & Johnston, 1975, 1978). Some muscimol analogues including THIP are very potent GABA agonists *in vivo* and *in vitro* (Krogsgaard-Larsen, Johnston, Lodge & Curtis, 1977). However, 2-methyl-4,5,6,7-tetrahydropyrazolo[3,4-*c*]pyridin-3-ol (2), which is a structural analogue of THIP in which the 3-isoxazolol moiety has been replaced by a related heterocyclic ring, showed no affinity for the GABA receptors *in vitro* (Krogsgaard-Larsen & Roldskov Christiansen, 1979).