thermostated to ±0.05 °C using a Haake F3 circulator. First-order rate constants were determined by the Guggenheim method.[14] Activation parameters were determined by a least-squares plot of log (rate constant) vs. $1/T$ comprising at least 6 points over ~20-deg range. However, the low reactivity of the ethers in 100% EtOH (half-life > 48 h at 336 K) precluded accurate determination over a 20-deg range.

Solvents. Ethanol was dried by the method of Lund and Bjerrum[15] and trifluoroethanol distilled from 4A molecular sieves.

Product Analyses. The 2,4-dinitrophenyl ethers were alcoholyzed for ~1 half-life, and the reaction mixture was analyzed directly by GLC (12-ft AP-L packed column, t = 150 °C).

---

(14) Guggenheim, E. A. *Philos. Mag.* **1926**, *7* (2), 538.
(15) Lund, H.; Bjerrum, J. *Chem. Ber.* **1931**, *64*, 210.

Trimethyl[(4*r*)-tetrahydro-*trans*-2,6e-diphenyl-*cis*-3,5e-dimethyl-2*H*-pyran-4-yl]ammonium Iodide and Trimethyl[(4*r*)-tetrahydro-*cis*-2,6e-diphenyl-*cis*-3,5e-dimethyl-2*H*-pyran-4-yl]ammonium Iodide. Evidence for a Twist-Boat Form in Each Isomer in Solution and the Solid State

Kondareddiar Ramalingam and K. Darrell Berlin*

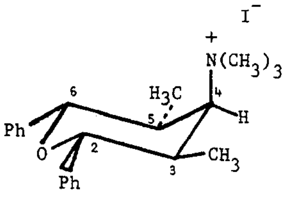
Department of Chemistry, Oklahoma State University, Stillwater, Oklahoma 74078

Douglas R. Powell and Dick van der Helm*

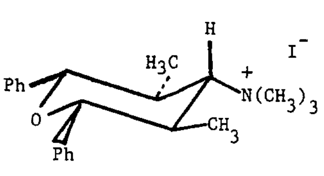
Department of Chemistry, University of Oklahoma, Norman, Oklahoma 73109

Received August 18, 1986

Substituted oxanes (tetrahydropyrans) and, in particular, aminooxanes are known but are relatively rare.[1] The title compounds 1 and 2, respectively, have been subjected to NMR analysis,[1e] with the proton NMR data strongly indicating that both isomers exist in solution in a nonchair form. Indeed, it was suggested that each salt probably assumed a twist form in solution. We now present X-ray diffraction results on single crystals of 1 and 2 that clearly demonstrate that both systems are twisted boat conformers in the *solid state.*



1



2

Table I. Conformational Angles (deg) for the Tetrahydropyran Ring[a]

	1	2A	2B
C(6)-O(1)-C(2)-C(3)	72.1 (3)	73.2 (2)	67.8 (2)
O(1)-C(2)-C(3)-C(4)	-39.0 (3)	-26.1 (3)	-23.6 (2)
C(2)-C(3)-C(4)-C(5)	9.2 (4)	-41.8 (3)	-42.9 (2)
C(3)-C(4)-C(5)-C(6)		68.3 (3)	71.0 (2)
C(4)-C(5)-C(6)-O(1)		-23.2 (3)	-28.7 (3)
C(5)-C(6)-O(1)-C(2)		-43.3 (3)	-36.8 (3)

[a] In this and succeeding tables the estimated standard deviation is given in parentheses for the least significant digit.

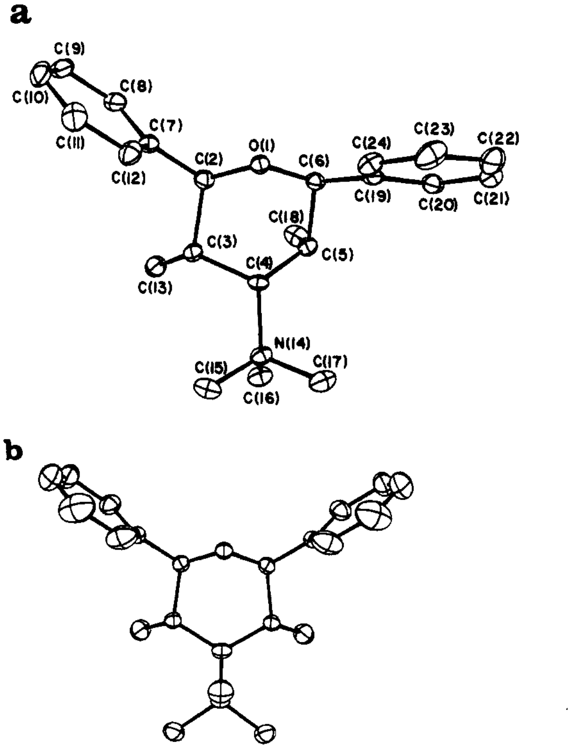
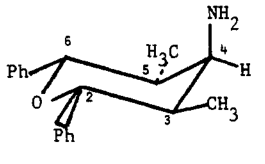
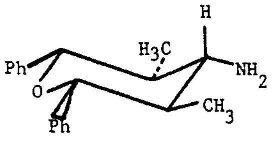


Figure 1. Perspective view of 2 and numbering of atoms (a) and perspective view of 1 (b).

It had been observed in 1 that $^3J_{H(3)H(4)}$ was 4.8 Hz with a $w_{1/2}$ of 11.25 Hz, while $^3J_{H(2)H(3)}$ was 5.15 Hz.[1e] In comparison, 2 had values of 3.68, 7.87, and 8.60 Hz, respectively. Noteworthy are the differences in these same values when there is an amino group at C(4), as in 3 and 4.[1a]



3



4

These values were, respectively, for 3 and 4, multiplet, 8 and 11 Hz; 10, 20, and 11 Hz. Unfortunately, it was not possible to resolve the multiplet in the spectrum of 3 to determine $^3J_{H(3)H(4)}$. Nevertheless, the ^3J couplings appear to be more normal for near-chair forms in these latter compounds and, in contrast, strongly suggested to us that 1 and 2 were probably flattened at or near the oxygen end of the molecule, which in turn reduced the dihedral angle for H(2)-C(2)-C(3)-H(3) where the H-C bonds are axial. This flattening or twisting effect is not unknown in certain heterocyclics.[2,3]

---

(1) (a) Chandrasekara, N.; Ramalingam, K.; Herd, M. D.; Berlin, K. D. *J. Org. Chem.* **1980**, *45*, 4352. (b) Ziriakus, W.; Haller, R. *Arch. Pharm. (Weinheim, Ger.)* **1972**, *305*, 493. (c) Chandrasekara, N.; Ramalingam, K.; Berlin, K. D. *Spectrosc. Lett.* **1981**, *14*, 11. (d) Subramanian, P. K.; Chandrasekara, N.; Ramalingam, K.; Zan, P. M.; Levy, G. C.; Satyamurthy, N.; Berlin, K. D. *J. Org. Chem.* **1982**, *47*, 1933. (e) Chandrasekara, N.; Ramalingam, K.; Satymurthy, N.; Berlin, K. D. *J. Org. Chem.* **1983**, *48*, 1591. (f) Chandrasekara, N.; Subramanian, P. K.; Ramalingam, K.; Satymurthy, N.; Berlin, K. D. *J. Org. Chem.* **1983**, *48*, 1597. (g) Subramanian, P. K.; Chandrasekara, N.; Ramalingam, K.; Berlin, K. D. *Indian J. Chem., Sect. B* **1983**, *22B*, 410.

(2) Subramanian, P. K.; Ramalingam, K.; Pantaleo, N. S.; van der Helm, D.; Satymurthy, N.; Berlin, K. D. *Phosphorus Sulfur* **1983**, *17*, 343.

0022-3263/87/1952-2108$01.50/0

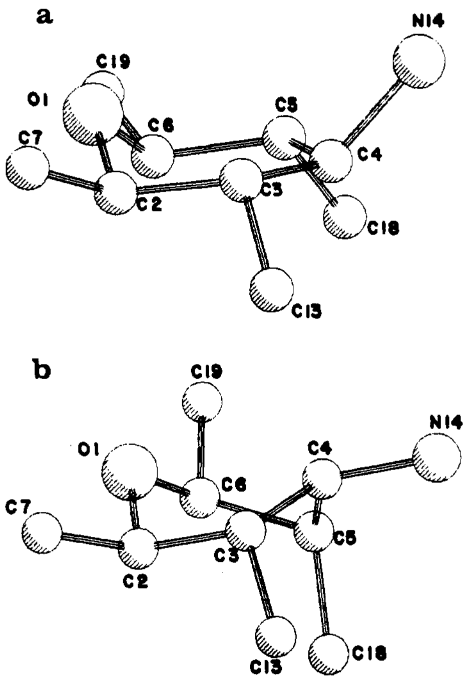


Figure 2. Conformation of the tetrahydropyran ring in 1 (a) and 2 (b).

Table II. Bond Distances and Angles

	1	2A	2B
	(a) Bond Distances (Å)		
O(1)–C(2)	1.429 (3)	1.436 (3)	1.425 (3)
C(2)–C(3)	1.537 (4)	1.562 (3)	1.569 (4)
C(3)–C(4)	1.556 (3)	1.538 (4)	1.531 (4)
C(4)–C(5)		1.544 (3)	1.541 (3)
C(5)–C(6)		1.569 (3)	1.562 (3)
C(6)–O(1)		1.434 (3)	1.438 (3)
C(2)–C(7)	1.507 (4)	1.513 (3)	1.512 (4)
C(7)–C(8)	1.379 (4)	1.389 (4)	1.390 (4)
C(8)–C(9)	1.392 (5)	1.391 (4)	1.391 (4)
C(9)–C(10)	1.363 (6)	1.378 (4)	1.382 (4)
C(10)–C(11)	1.380 (6)	1.381 (4)	1.389 (5)
C(11)–C(12)	1.383 (6)	1.392 (4)	1.389 (4)
C(12)–C(7)	1.386 (4)	1.396 (4)	1.398 (3)
C(3)–C(13)	1.540 (4)	1.541 (4)	1.535 (4)
C(4)–N(14)	1.567 (5)	1.539 (3)	1.538 (3)
N(14)–C(15)	1.516 (4)	1.507 (3)	1.505 (3)
N(14)–C(16)	1.492 (5)	1.501 (4)	1.498 (3)
N(14)–C(17)		1.510 (4)	1.505 (4)
C(5)–C(18)		1.535 (4)	1.538 (4)
C(6)–C(19)		1.511 (4)	1.512 (4)
C(19)–C(20)		1.396 (3)	1.400 (4)
C(20)–C(21)		1.384 (5)	1.382 (6)
C(21)–C(22)		1.383 (4)	1.385 (6)
C(22)–C(23)		1.383 (5)	1.369 (5)
C(23)–C(24)		1.385 (5)	1.386 (6)
C(24)–C(19)		1.399 (4)	1.387 (4)
	(b) Bond Angles (deg)		
C(6)–O(1)–C(2)	107.9 (2)	111.9 (2)	115.2 (2)
O(1)–C(2)–C(3)	110.8 (2)	110.0 (2)	110.6 (2)
C(2)–C(3)–C(4)	113.7 (2)	105.3 (2)	105.6 (2)
C(3)–C(4)–C(5)	118.3 (3)	112.9 (2)	112.8 (2)
C(4)–C(5)–C(6)		103.9 (2)	103.2 (2)
C(5)–C(6)–O(1)		111.8 (2)	111.7 (2)
O(1)–C(2)–C(7)	107.1 (2)	107.3 (2)	105.5 (2)
C(3)–C(2)–C(7)	112.8 (2)	112.0 (2)	112.4 (2)
C(2)–C(7)–C(8)	120.5 (2)	120.3 (2)	120.8 (2)
C(2)–C(7)–C(12)	120.4 (3)	120.1 (2)	120.0 (2)
C(12)–C(7)–C(8)	119.0 (3)	119.6 (2)	119.2 (2)
C(7)–C(8)–C(9)	120.8 (3)	119.9 (3)	120.3 (3)
C(8)–C(9)–C(10)	119.9 (3)	120.5 (3)	120.2 (3)
C(9)–C(10)–C(11)	119.7 (4)	119.8 (3)	119.9 (3)
C(10)–C(11)–C(12)	120.9 (4)	120.5 (3)	120.0 (3)
C(11)–C(12)–C(7)	119.6 (3)	119.6 (3)	120.3 (3)
C(2)–C(3)–C(13)	107.7 (2)	108.7 (2)	109.5 (2)
C(4)–C(3)–C(13)	111.0 (3)	120.7 (2)	120.5 (2)
C(3)–C(4)–N(14)	109.9 (2)	115.9 (2)	117.0 (2)
C(5)–C(4)–N(14)		115.0 (2)	114.5 (2)
C(4)–N(14)–C(15)	109.6 (2)	109.8 (2)	109.7 (2)
C(4)–N(14)–C(16)	114.0 (3)	115.3 (2)	115.2 (2)
C(4)–N(14)–C(17)		108.5 (2)	108.3 (2)
C(15)–N(14)–C(16)	108.7 (2)	109.2 (2)	109.3 (2)
C(15)–N(14)–C(17)		105.7 (2)	106.5 (2)
C(16)–N(14)–C(17)		107.9 (2)	107.5 (2)
C(4)–C(5)–C(18)		119.6 (2)	119.2 (2)
C(6)–C(5)–C(18)		110.1 (2)	110.9 (2)
C(5)–C(6)–C(19)		113.3 (2)	113.2 (2)
O(1)–C(6)–C(19)		107.7 (2)	105.8 (2)
C(6)–C(19)–C(20)		118.9 (2)	119.5 (2)
C(6)–C(19)–C(24)		122.8 (2)	121.9 (2)
C(24)–C(19)–C(20)		118.3 (3)	118.6 (3)
C(19)–C(20)–C(21)		121.3 (3)	120.2 (3)
C(20)–C(21)–C(22)		119.8 (3)	120.0 (4)
C(21)–C(22)–C(23)		119.6 (3)	120.2 (4)
C(22)–C(23)–C(24)		120.9 (3)	120.0 (3)
C(23)–C(24)–C(19)		120.1 (3)	120.7 (3)

Single-crystal X-ray diffraction analyses have now been completed for 1 and 2, which differ only in arrangement of the trimethylammonium group. If we consider only 1, the methyl groups and the trimethylammonium group appear to occupy pseudoaxial positions, while the phenyl groups assume pseudoequatorial positions. The tetrahydropyran ring, however, is highly distorted, as can be seen from examination of the torsional angles in Table I. The numbering of atoms is given in Figure 1. The ring is highly puckered around the oxygen atom O(1) but is nearly flat at the opposite end (C(4)). Compound 1 crystallizes in a halfboat or "sofa" conformation in which the mirror plane of the molecule coincides with the crystallographic mirror plane of the space group. The methyl groups and the trimethylammonium group "bend" away from perfect axial positions. This strained conformation is also reflected in the long bond distances for C(3)–C(4) (1.556 Å) and C(4)–N(14) (1.567 Å) and several bond angles: C(2)–C(3)–C(4) (113.7°), C(3)–C(4)–C(5) (118.3°), and C(4)–N(14)–C(16) (114.0°) as shown in Table II. Short intramolecular distances involve primarily the hydrogen atoms on the ring with the methyl groups on the nitrogen atom. A perspective view is shown in Figure 1b, and a detailed view of the conformation of the tetrahydropyran ring is shown in Figure 2a. A conformational change could put all five substituents in axial positions or put them in equatorial positions, and it is remarkable that the latter conformation is *not* observed in the crystal structure.

Salt 2 crystallizes with two molecules in the asymmetric unit, and two independent observations are thus obtained. The conformations of both individual molecules are quite similar. Each is a highly twisted boat conformation, which is shown in Figures 1a and 2b and described by the torsion angles in Table I. Figure 2b details the pyran ring in 2 (molecule A), while Figure 1a shows the perspective veiw of molecule A in the unit cell. Again, the phenyl rings are equatorially bonded and the methyl groups are in pseudoaxial positions, but the trimethylammonium group in 2 is in a pseudoequatorial position. The twist arrangement reduces the close contacts between the pseudoaxial methyl groups. Nevertheless, this molecule is highly strained, which is reflected in long bond distances for C(2)–C(3) (1.562, 1.569 Å) and for C(5)–C(6) (1.569, 1.562 Å) as well as in large bond angles for C(3)–C(4)–N(14) (115.9, 117.0°),

---

(3) Lambert, J. B. *Acc. Chem. Res.* **1971**, *4*, 87. See also, discussions in: Armarego, W. L. F. *Stereochemistry of Heterocyclic Compounds*, Parts I and II; Wiley-Interscience: New York, 1977. Parker, W. *Aliphatic, Alicyclic, and Saturated Heterocyclic Chemistry*; The Chemical Society: London, 1973–present.

Table III. Crystal Data

formula	$C_{22}H_{30}NO^{+}I^{-}$ (**1**)	$C_{22}H_{30}NO^{+}I^{-}$ (**2**)
fw	451.39	451.39
crystal size, mm	0.12 × 0.18 × 0.38	0.12 × 0.15 × 0.32
space group, *Z*	*Pnam*, 4	$P\bar{1}$, 4
cell (138 (2) K)		
a, Å	11.110 (7)	14.862 (9)
b, Å	11.098 (8)	15.124 (7)
c, Å	17.016 (13)	10.134 (4)
α, deg	90.0	96.67 (3)
β, deg	90.0	109.82 (3)
γ, deg	90.0	74.67 (4)
V, Å^3	2098.1	2065.8
cell (25 °C)		
a, Å	11.2105 (5)	14.877 (2)
b, Å	11.0650 (3)	15.464 (2)
c, Å	17.2148 (6)	10.182 (1)
α, deg	90.0	96.419 (8)
β, deg	90.0	109.942 (8)
γ, deg	90.0	75.128 (11)
V, Å^3	2135.4	2127.5
ρ_{obsd}, g cm^{-3} (25 °C)	1.399	1.401
ρ_{calcd}, g cm^{-3} (25 °C)	1.404	1.409
μ, cm^{-1}	14.15	14.37
no. of unique data	2227	8509
no. of obsd data ($I \geq 2\sigma(I)$)	1870	7037
R	0.028	0.028
R_w ($w = 1/\sigma(F)^2$)	0.036	0.032
N_v (parameters)	186	452
S (goodness of fit)	1.31	1.06
min/max esd in diff Fourier, e/Å^3	+0.56/−0.81	+0.56/−0.72

C(5)–C(4)–N(14) (115.0, 114.5°), C(4)–N(14)–C(16) (115.3, 115.2°), C(4)–C(5)–C(18) (119.6, 119.2°), and C(4)–C(3)–C(13) (120.7, 120.5°). There are more short intramolecular distances and presumably more strain in **2** than in **1**. In **2**, these short distances are between the methyl groups and hydrogen atoms on the ring and the methyl groups on the nitrogen atom.

The iodide atom in **1** is positionally disordered over two sites (90:10). The sites are only 0.362 Å apart, and for the remainder of this discussion, only the principally occupied site is used. In both compounds, the iodides interact with two *different* molecules. If the nitrogen atoms are considered as the center of tetrahedra with bonded carbons at the corners, then the iodide atoms interact with the nitrogen atoms through the C(15)–C(16)–C(17) face (A) and the C(4)–C(15)–C(16) face (B). In **1**, the I···N ($^1/_2 + x$, $^1/_2 - y$, z) distance through face A is 4.439 (2) Å and the I···N distance through face B is 4.447 (2) Å. In **2**, I(1) is bonded to molecule B through N($1 - x$, $1 - y$, $-z$) (face A; 4.620 Å) and N(x, $y - 1$, z) (face B; 4.485 (2) Å). Iodides I(2) and I(3) coordinate to molecule A through I(3)–N($x - 1$, y, $z - 1$) (face A; 4.471 (2) Å) and through I(2)–N($x - 1$, y, $z - 1$) (face B; 4.383 (2) Å).

In summary, the ^{1}H NMR data[1e] are consistent with a distorted molecule for both **1** and **2**, which are now demonstrated to exist as twist-boat forms in the solid state. Of course, in solution there may be rapidly equilibrating boat or pseudoboat forms present to minimize repulsive forces and to accommodate solvation parameters. The two examples reported herein are rare cases in this heterocyclic family.[3]

Experimental Section

General Procedures. Compounds **1** and **2** were prepared by the method reported[1e] and characterized. All NMR data have been recorded in Me$_2$SO-d_6[1e] on a Bruker WH 270 NMR spectrometer with a Bruker Model B-NC 12 data system (with a Nicolet NIC Model 294 disk memory coupler). The chemical shifts are in δ relative to internal $(H_3C)_4Si$. The values follow.

1: δ 1.46 [d, 6 H, C*H*$_3$(3,5), J = 7.0 Hz], 2.63–2.80 [m, 2 H, H(3,5)], 3.17 [s, 9 H, C*H*$_3$N], 4.03 [t, 1 H, H(4), J = 4.8 Hz, $w_{1/2}$ = 11.25 Hz], 4.61 [d, 2 H, H(2,6), J = 5.15 Hz], 7.34–7.62 [m, 10 H, Ar*H*].

2: δ 1.23 [d, 6 H, C*H*$_3$(3,5), J = 7.0 Hz], 2.33–2.50 [m, 2 H, H(3,5)], 3.10 [s, 9 H, C*H*$_3$N], 3.73 [t, 1 H, H(4), J = 3.68 Hz, $w_{1/2}$ = 7.87 Hz] 4.40 [d, 2 H, H(2,6), J = 8.60 Hz], 7.31–7.51 [m, 10 H, Ar*H*].

Crystallographic Experimental Data. Pertinent experimental details for the single-crystal diffraction studies of **1** and **2** are given in Table III. Intensity data at 138 (2) K for both compounds were collected on an Enraf-Nonius CAD-4 diffractometer equipped with a nitrogen-streaming, low-temperature device. Cell constants were determined by a least-squares fit to the ±2θ values of 48 intensity maxima distributed throughout reciprocal space. Density measurements were made by flotation in mixtures of hexane and in 1,1,2,2-tetrabromoethane. Structure **1** was solved by heavy-atom methods and refined by full-matrix, least-squares techniques.[4] Structure **2** was solved by the use of Patterson superposition methods. The occupancy of two iodine sites was determined from a difference Fourier and not further refined. Instead, the anisotropic thermal parameters of the major site and isotropic parameter for the minor site were refined. The least-squares refinement was blocked with one molecule in each block, while the iodine positions were included in both blocks. The hydrogen positions in both compounds were determined from difference Fouriers and refined with isotropic thermal parameters, while all other atoms were refined anisotropically. The bond distances involving hydrogen atoms varied between 0.92 and 1.08 Å in **1** and between 0.85 and 1.03 Å in compound **2**. The major residual peaks in the final difference Fourier were found to be close to the iodine positions.

Acknowledgment. We acknowledge support by the College of Arts and Sciences at the Oklahoma State University in the form of salary (K.D.B.). The study was supported in part by a grant from the DDHS, National Cancer Institute, CA 17562 (D.v.d.H.). Acknowledgment is also due the University of Oklahoma computing center for providing computing facilities and services.

Supplementary Material Available: Tables of final atomic positional and thermal parameters (10 pages). Ordering information is given on any current masthead page.

---

[4] Sheldrick, G. M. *SHELX 76, Program for Crystal Structure Determination*; University Chemical Laboratory: Cambridge, England, 1976.

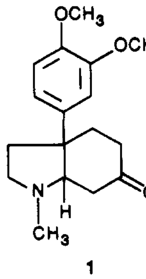
α-Arylation of Pyrrolidinones[1]

Jon D. Stewart, Stephen C. Fields, Kanwarpal S. Kochhar, and Harold W. Pinnick*

Department of Chemistry, Bucknell University, Lewisburg, Pennsylvania 17837

Received August 14, 1986

The total synthesis of alkaloids such as mesembrine (**1**) caused us to investigate the α-arylation of lactams, because



1

0022-3263/87/1952-2110$01.50/0