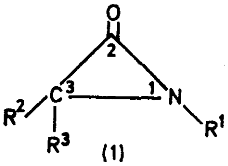
X-Ray Crystallographic Structure Determination of an Aziridinone. Demonstration of a Non-Planar Arrangement at Nitrogen in an α-Lactam

By Andrew H.-J. Wang and Iain C. Paul*
(*W. A. Noyes Chemical Laboratory, University of Illinois, Urbana, Illinois,* 61801)
and Erach R. Talaty and Aubry E. Dupuy, Jun.
(*Departments of Chemistry, Wichita State University, Wichita, Kansas,* 67208; *and Louisiana State University in New Orleans, New Orleans, Louisiana,* 70122)

Summary The *X*-ray crystal-structure analysis of 1,3-diadamantylaziridinone (1b) demonstrates that the configuration at nitrogen is pyramidal (N lying 0·534 Å from the plane defined by its three substituents) and that the adamantyl groups are *trans* to each other.

Stable α-lactams, or aziridinones, have been prepared where there are bulky substituents on the 1- and one of the 3-positions, *e.g.*, (1a and b).[1,2] While various factors have been considered important in determining the stability,[3] no structural information on the dimensions of the aziridinone ring has been available. We now report the results of an *X*-ray study on (1b) which provides the geometry of this ring system although the accuracy of the results has been reduced by the presence of crystallographic disorder.



(1)

a; $R^1 = R^2 = Bu^t$

b; $R^1 = R^2 =$ 1-adamantyl

White crystals of (Ib) were stable in air, and upon irradiation with *X*-rays. *Crystal Data:* $C_{22}H_{31}NO$, $M = 325{\cdot}5$, monoclinic, $a = 24{\cdot}739$ (9), $b = 6{\cdot}672$ (2), $c = 22{\cdot}560$ (5) Å, $\beta = 98{\cdot}90$ (2)°, $V = 3679$ Å^3, $Z = 8$, $D_c = 1{\cdot}175$ g cm^{-3}. Space-group $C2/c$ or Cc. A total of 1645 non-zero structure amplitudes was collected on a Picker FACS-1 computer-controlled diffractometer using Cu-K_α radiation. The structure was solved in the space-group $C2/c$ by the symbolic addition method[4] and has been refined, including anisotropic temperature factors on the non-hydrogen atoms and isotropic temperature factors on the hydrogen atoms, by full-matrix least-squares methods to an R factor of 0·074 on the observed data.

While the positions of the carbon atoms in the adamantyl groups and the general location of the aziridinone ring were readily apparent from the initial E map, the exact positions of the N(1) and C(3) atoms in the ring could not be readily established from this map or earlier Fourier maps. After an i.r. spectrum had indicated the purity of the compound being examined, we were able to rationalize our electron-density maps and obtain a suitable model for refinement in terms of a disorder, consisting of unequal numbers of the two enantiomorphic forms of (1b) at each molecular site in the crystal. Such a disorder is not unexpected as the crystal packing will be largely determined by the positions of the bulky adamantyl groups which are essentially invariant in the two molecular orientations, as are the two atoms of the carbonyl group. Refinement of the occupancy of the two different sites for both N(1) and C(3) (Figure 1) indicates that these sites are occupied approximately in the ratio 65:35. This particular model for the disorder is presented over several others considered, on the basis of the respective lengths of the C(2)–C(3) and N(1)–C(2) bonds and the very clear location of the hydrogen atom on C(3). The model with N(1) and C(3) interchanged on the minor isomer, however, cannot be definitely rejected, although such a disorder would still involve enantiomorphic molecules. While the molecular dimensions obtained from the two sites are in agreement within the low accuracy of the results on the minor isomer, the discussion will be based only on those obtained from the major occupied site (65%).

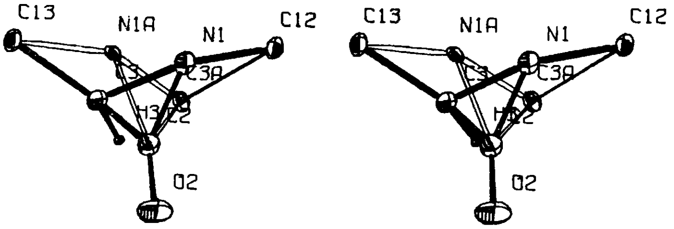


Figure 1. *Stereoscopic view of the two orientations of the aziridinone ring. The major isomer* [N(1) *and* C(3)] *is shown with the bonds shaded, the minor isomer* [N(1A) *and* C(3A)] *with the bond outlines only.* C(12) *and* C(13) *are carbon atoms in the adamantyl groups.*

The bond lengths and angles in the aziridinone ring are shown in Figure 2. The four atoms, N(1), C(2), C(3), and O(2), are very close to being planar with the two adamantyl groups being disposed *trans* with respect to the three-membered ring. The nitrogen atom is pyramidal, lying 0·534 Å from the plane defined by its three substituents. Despite the non-planarity at nitrogen, the N(1)–C(2) bond length suggests some double-bond character. The u.v. spectra of aziridinones have been interpreted in terms of interaction of the lone-pair electrons on nitrogen with the carbonyl group.[5,6] Absorption maxima at 210 nm[7] and at 250 nm[5-7] have been reported in aziridinones. These spectra correspond to higher energy $n \rightarrow \pi^*$ transitions than are found in cyclopropanones (λ 310 nm)[8] and suggest that some feature (presumably involving the nitrogen atom) is operative in aziridinone molecules that is absent in the simple ketones. The non-planar nitrogen atom in the α-lactam is in marked contrast to the exactly planar arrangement found in γ-lactams.[9,10] The nitrogen atom was 0·087 Å from the plane defined by its three bonded neighbours in the β-lactam, 1-(*p*-chlorophenyl)-3-isopropyl-4-phenylazetidin-2-one,[11] while a distance of 0·243 Å was found in a fused β-lactam in cephaloridine hydrochloride monohydrate, and this feature was related to biological activity by the authors.[12]

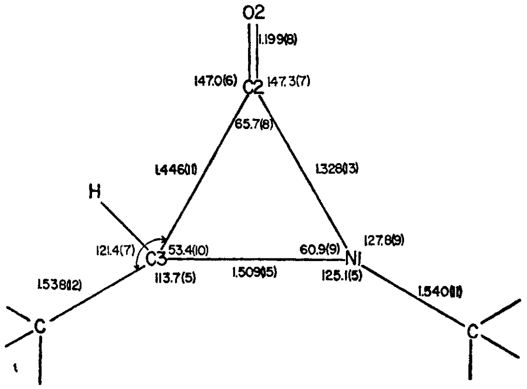


Figure 2. *Bond lengths and angles in the aziridinone ring for the major isomer. Standard deviations shown in parentheses.*

C(3) lies 0·690 Å from the plane of its three non-hydrogen substituents, a value which agrees well with the comparable distances in cyclopropane-1,1-dicarboxylic acid.[13] The disorder involves unequal numbers of molecules of the two enantiomorphic forms of (1b) at each site in the crystal (Figure 1). A rather similar disorder involving (+) and (−)-dihydrothymine molecules in the crystal has been reported by Furberg and Jensen.[14] Some of the thermal ellipsoids of the carbon atoms in the adamantyl groups were very large. It is unlikely that these properly represent real vibrations, but rather that they are manifestations of some comparatively small positional disorder of the carbon atoms in these groups. This is borne out by the comparison of the root-mean-square deviation for the C–C lengths in the adamantyl groups (1·518 ± 0·026 Å) with the standard deviations obtained from the least-squares results (0·008—0·021, avg. 0·011 Å).

(*Received, July* 23*rd,* 1971; *Com.* 1278.)

---

[1] J. C. Sheehan and J. H. Beeson, *J. Amer. Chem. Soc.*, 1967, **89**, 362.

[2] E. R. Talaty, A. E. Dupuy, jun., and A. E. Cancienne, jun., *J. Heterocyclic Chem.*, 1967, **4**, 657.

[3] I. Lengyel and J. C. Sheehan, *Angew. Chem.*, 1968, **80**, 27; *Angew. Chem. Internat. Edn.*, 1968, **7**, 25.

[4] J. Karle and I. L. Karle, *Acta Cryst.*, 1966, **21**, 849.

[5] J. C. Sheehan and M. Mehdi Nafissi-V., *J. Amer. Chem. Soc.*, 1969, **91**, 1176.

[6] E. R. Talaty, A. E. Dupuy, jun., and T. H. Golson, *Chem. Comm.*, 1969, 49.

[7] S. Sarel, B. A. Weissman, and Y. Stein, *Tetrahedron Letters*, 1971, 373.

[8] N. J. Turro and W. B. Hammond, *J. Amer. Chem. Soc.*, 1966, **88**, 3672.

[9] J. A. Molin-Case, E. Fleischer, and D. W. Urry, *J. Amer. Chem. Soc.*, 1970, **92**, 4728.

[10] K. B. Birnbaum, *Acta Cryst.*, 1970, **B26**, 722.

[11] J. L. Luche, H. B. Kagan, R. Parthasarathy, G. Tsoucaris, C. de Rango, and C. Zelwer, *Tetrahedron*, 1968, **24**, 1275; R. Parthasarathy, *Acta Cryst.*, 1970, **B26**, 1283.

[12] R. M. Sweet and L. F. Dahl, *J. Amer. Chem. Soc.*, 1970, **92**, 5489.

[13] M. A. M. Meester, H. Schenk, and C. H. MacGillavry, *Acta Cryst.*, 1971, **B27**, 630.

[14] S. Furberg and L. H. Jensen, *J. Amer. Chem. Soc.*, 1968, **90**, 470.