

- International Tables for X-ray Crystallography* (1974). Vol. IV. Birmingham: Kynoch Press. (Present distributor Kluwer Academic Publishers, Dordrecht.)
- JOHNSON, C. K. (1976). *ORTEPII*. Report ORNL-5138. Oak Ridge National Laboratory, Tennessee, USA.
- KOWALIK, J. (1985). PhD thesis. Institute of Organic and Physical Chemistry, Technical Univ. of Wrocław, Poland.
- KOWALIK, J., SAWKA-DOBROWOLSKA, W. & GŁOWIAK, T. (1984). *J. Chem. Soc. Chem. Commun.* pp. 446–447.
- LEJCZAK, B., STARZEMSKA, H. & MASTALERZ, P. (1981). *Experientia*, **37**, 461–462.
- NEUZIL, S. & CASSAIGNE, A. (1980). *Expo. Annu. Biochim. Med. Ser. No. 34*, pp. 165–210.
- SAWKA-DOBROWOLSKA, W. (1980). PhD thesis. Institute of Chemistry, Univ. of Wrocław, Poland.
- SAWKA-DOBROWOLSKA, W. (1985). *Acta Cryst.* **C41**, 84–86.
- SAWKA-DOBROWOLSKA, W., GŁOWIAK, T., KOWALIK, J. & MASTALERZ, P. (1985). *Acta Cryst.* **C41**, 1773–1776.
- SAWKA-DOBROWOLSKA, W., GŁOWIAK, T., SIATECKI, Z. & SOROKA, M. (1985). *Acta Cryst.* **C41**, 453–456.
- Syntax (1976). *XTL/XTLE Structure Determination System*. Syntax Analytical Instruments, Cupertino, California, USA.

Acta Cryst. (1988). **C44**, 1627–1629

Adamantylideneadamantane Epoxide

BY WILLIAM H. WATSON* AND ANTE NAGL†

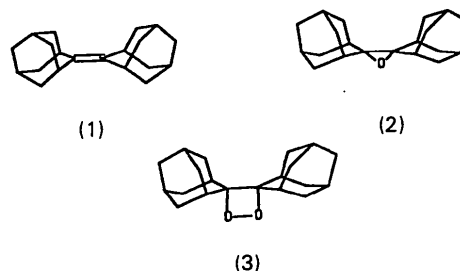
Department of Chemistry, Texas Christian University, Fort Worth, Texas 76129, USA

(Received 2 November 1987; accepted 25 April 1988)

Abstract. 2-(Tricyclo[3.3.1.1^{3,7}]dec-2-ylidene)tricyclo[3.3.1.1^{3,7}]decane 2,2'-epoxide (2), C₂₀H₂₈O, *M_r* = 284.45, monoclinic, *P*_{2₁}/*n*, *a* = 6.539 (1), *b* = 21.002 (2), *c* = 11.195 (1) Å, β = 93.68 (1)°, *V* = 1534.3 (3) Å³, *Z* = 4, *D_x* = 1.23 g cm⁻³, λ(Mo *K*α) = 0.71073 Å, μ = 0.68 cm⁻¹, *F*(000) = 624, *T* = 293 K, *R* = 0.0427 for 1548 reflections. The title compound has approximate *mm* symmetry. The bonds in the adamantane moieties average 1.524 (8) Å and the angles 109.4 (5)° indicating little bond or angle strain except in the three-membered epoxide ring.

Introduction. The reaction of singlet oxygen with olefins has been postulated to occur *via* a perepoxide intermediate with subsequent rearrangement into a dioxetane or to an allylic hydroperoxide *via* an ene mechanism. Compounds such as (1) are of interest because the flanking bridgehead hydrogen atoms cannot participate in the ene reaction and are classified as Bredt's rule protected olefins. Reaction of (1) with ¹O₂ leads to the formation of a relatively stable dioxetane (3) which decomposes slowly at room temperature to adamantanone (Wieringa, Strating, Wijnberg & Adam, 1972). The reaction of (1) with singlet oxygen generated chemically or photogenetically leads to the formation of both (2) and (3) with the ratio of the two products dependent upon solvent and sensitizer (Jefford & Boschong, 1977). These authors postulate that the production of the epoxide occurs *via* loss of a hydroperoxy radical while the dioxetane is

formed most likely *via* a radical cation reaction of (1) (Bartlett, 1978; Nelsen, Kapp, Akaba & Evans, 1986). A number of theoretical and experimental investigations of (1) and other Bredt's rule protected olefins have been reported (e.g. Clark, Teasley, Nelsen & Wynberg, 1987). Molecular-mechanics calculations have been reported for (1) and a number of its derivatives to evaluate strain energies and conformational changes due to short intramolecular contacts across the double bond (Lenoir & Frank, 1978; Cordt, Frank & Lenoir, 1979; Lenoir, Frank, Cordt, Gieren & Lamm, 1980). In order to provide additional structural data for this series of compounds, we report the structure of adamantylideneadamantane epoxide (2).



Experimental. Compound (2) prepared by peracid oxidation of (1); colorless, transparent crystal from CHCl₃, recrystallizations, 0.43 × 0.33 × 0.30 mm; Nicolet *R3M/μ* update of *P*_{2₁} diffractometer; data collected in Wyckoff mode (2θ fixed, ω varied, 3° ≤ 2θ ≤ 45°), variable scan rate (4 to 29.3° min⁻¹), graphite-monochromated Mo *K*α radiation; lattice parameters from a least-squares refinement of 15

* Author to whom correspondence should be addressed.

† On leave from Faculty of Technology, University of Zagreb, Zagreb, Yugoslavia.

Table 1. Atomic coordinates ($\times 10^4$) and equivalent isotropic thermal parameters ($\text{\AA}^2 \times 10^3$)

	x	y	z	U_{eq}^*
O	640 (2)	3072 (1)	3902 (1)	42 (1)
C(1)	294 (3)	2723 (1)	2780 (2)	32 (1)
C(2)	2193 (3)	2417 (1)	2309 (2)	40 (1)
C(3)	1666 (3)	2210 (1)	1009 (2)	46 (1)
C(4)	-92 (3)	1736 (1)	964 (2)	46 (1)
C(5)	-1959 (3)	2051 (1)	1447 (2)	42 (1)
C(6)	-1476 (3)	2260 (1)	2738 (2)	35 (1)
C(7)	2755 (3)	1831 (1)	3078 (2)	48 (1)
C(8)	503 (3)	1155 (1)	1727 (2)	52 (1)
C(9)	-865 (3)	1683 (1)	3508 (2)	44 (1)
C(10)	994 (3)	1363 (1)	3027 (2)	47 (1)
C(11)	22 (3)	3424 (1)	2822 (2)	33 (1)
C(12)	1602 (3)	3892 (1)	2420 (2)	42 (1)
C(13)	969 (3)	4116 (1)	1151 (2)	46 (1)
C(14)	-1122 (3)	4435 (1)	1133 (2)	47 (1)
C(15)	-2692 (3)	3963 (1)	1544 (2)	45 (1)
C(16)	-2074 (3)	3736 (1)	2826 (2)	38 (1)
C(17)	1698 (4)	4462 (1)	3264 (2)	56 (1)
C(18)	-1016 (3)	5005 (1)	1983 (2)	54 (1)
C(19)	-1954 (3)	4309 (1)	3662 (2)	51 (1)
C(20)	-385 (4)	4789 (1)	3244 (2)	55 (1)

* Equivalent isotropic U defined as one third of the trace of the orthogonalized U_{ij} tensor.

reflections ($18.32^\circ \leq 2\theta \leq 23.39^\circ$), systematic absences ($h0l, h+l=2n+1; 0k0, k=2n+1$) and Laue symmetry $2/m$ consistent with space group $P2_1/n$; monitored reflections $08\bar{4}$ and $2\bar{7}1$ showed only statistical variations in intensities; 1996 independent reflections measured ($-7 \leq h \leq 7, 0 \leq k \leq 22, 0 \leq l \leq 12$), 1568 with $I \geq 3.0\sigma(I)$; Lorentz and polarization corrections, ψ -scan empirical absorption correction (transmission factors 0.886 to 0.985), $R_{\text{merge}} = 0.0147$; structure solved by direct methods, block-cascade least-squares refinement, H atoms refined with a single refined isotropic temperature factor of 0.050 \AA^2 for all atoms; $R = 0.0427, wR = 0.0243$ for 275 parameters and 1548 reflections, $S = 1.684, (\Delta/\sigma)_{\text{max}} = 0.025, (\Delta/\sigma)_{\text{avg}} = 0.006$; largest peaks in the final difference map of $+0.13$ and -0.13 e \AA^{-3} ; $\sum w(|F_o| - |F_c|)^2$ minimized with $w = [1/\sigma^2(F_o)]$. All computer programs supplied by Nicolet (Nicolet Instrument Corporation, 1986) for Desktop 30 Microclipse and Nova 4/C configurations; atomic scattering factors and anomalous-dispersion corrections from *International Tables for X-ray Crystallography* (1974). Table 1 lists atomic positional parameters while Table 2 gives bond lengths and valence angles.*

Discussion. Fig. 1 is a drawing of adamantylideneadamantane epoxide. The molecular parameters may be compared with those of the parent hydrocarbon (1)

* Lists of H-atom coordinates, anisotropic thermal parameters and structure factors have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 44983 (16 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 2. Bond lengths (\AA) and angles ($^\circ$)

O—C(1)	1.460 (2)	O—C(11)	1.452 (2)
C(1)—C(2)	1.522 (3)	C(1)—C(6)	1.509 (3)
C(1)—C(11)	1.484 (2)	C(2)—C(3)	1.536 (3)
C(2)—C(7)	1.533 (3)	C(3)—C(4)	1.520 (3)
C(4)—C(5)	1.518 (3)	C(4)—C(8)	1.526 (3)
C(5)—C(6)	1.524 (3)	C(6)—C(9)	1.526 (3)
C(7)—C(10)	1.513 (3)	C(8)—C(10)	1.533 (3)
C(9)—C(10)	1.518 (3)	C(11)—C(12)	1.516 (3)
C(11)—C(16)	1.520 (2)	C(12)—C(13)	1.527 (3)
C(12)—C(17)	1.523 (3)	C(13)—C(14)	1.522 (3)
C(14)—C(15)	1.520 (3)	C(14)—C(18)	1.527 (3)
C(15)—C(16)	1.541 (3)	C(16)—C(19)	1.524 (3)
C(17)—C(20)	1.524 (3)	C(18)—C(20)	1.515 (3)
C(19)—C(20)	1.532 (3)		
C(1)—O—C(11)	61.3 (1)	O—C(1)—C(2)	115.1 (1)
O—C(1)—C(6)	115.2 (1)	C(2)—C(1)—C(6)	111.0 (1)
O—C(1)—C(11)	59.1 (1)	C(2)—C(1)—C(11)	122.1 (2)
C(6)—C(1)—C(11)	123.1 (2)	C(1)—C(2)—C(3)	108.0 (1)
C(1)—C(2)—C(7)	108.4 (2)	C(3)—C(2)—C(7)	109.7 (2)
C(2)—C(3)—C(4)	109.8 (2)	C(3)—C(4)—C(5)	109.1 (2)
C(3)—C(4)—C(8)	109.9 (2)	C(5)—C(4)—C(8)	109.3 (2)
C(1)—C(5)—C(6)	109.9 (1)	C(1)—C(6)—C(5)	109.1 (1)
C(1)—C(6)—C(9)	108.8 (1)	C(5)—C(6)—C(9)	109.7 (2)
C(2)—C(7)—C(10)	110.2 (2)	C(4)—C(8)—C(10)	109.5 (2)
C(6)—C(9)—C(10)	109.7 (2)	C(7)—C(10)—C(8)	109.5 (2)
C(7)—C(10)—C(9)	108.9 (2)	C(8)—C(10)—C(9)	109.8 (2)
O—C(11)—C(1)	59.7 (1)	O—C(11)—C(12)	114.8 (1)
C(1)—C(11)—C(12)	123.3 (2)	O—C(11)—C(16)	114.8 (1)
C(1)—C(11)—C(16)	122.6 (2)	C(12)—C(11)—C(16)	110.6 (1)
C(11)—C(12)—C(13)	109.1 (1)	C(11)—C(12)—C(17)	109.1 (2)
C(13)—C(12)—C(17)	109.5 (2)	C(12)—C(13)—C(14)	109.7 (2)
C(13)—C(14)—C(15)	109.4 (2)	C(13)—C(14)—C(18)	109.4 (2)
C(15)—C(14)—C(18)	109.1 (2)	C(14)—C(15)—C(16)	110.0 (2)
C(11)—C(16)—C(15)	108.3 (1)	C(11)—C(16)—C(19)	109.4 (1)
C(15)—C(16)—C(19)	109.1 (2)	C(12)—C(17)—C(20)	110.1 (2)
C(14)—C(18)—C(20)	110.2 (2)	C(16)—C(19)—C(20)	109.9 (2)
C(17)—C(20)—C(18)	109.8 (2)	C(17)—C(20)—C(19)	108.4 (2)
C(18)—C(20)—C(19)	109.5 (2)		

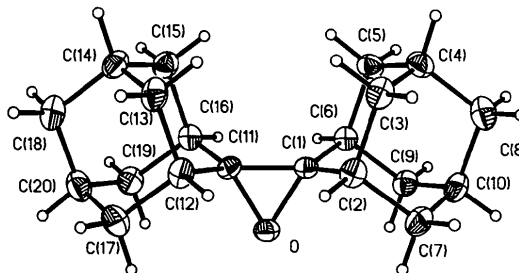


Fig. 1. Drawing of compound (2) with thermal ellipsoids at 35% probability level. H atoms are represented by spheres of arbitrary size.

(Swen-Walstra & Visser, 1971) and with those of the dioxetane derivative (3) (Hess & Vos, 1977). The parent hydrocarbon has approximate mmm symmetry. The epoxide loses one plane of symmetry upon epoxidation but maintains approximate mm symmetry. The four-membered ring of the dioxetane derivative is twisted, resulting in a total loss of mirror-plane symmetry. In the parent hydrocarbon the short bond connecting the adamantane systems and the planarity of this double-bond system lead to short H...H contacts of 1.90 \AA . In the epoxide the two adamantane

moieties are bent away from the epoxide oxygen, tilting the H atoms on C(2) and C(6) away from those on C(12) and C(16), e.g. $H(2)\cdots H(12) = 2.01(3) \text{ \AA}$. The planes defined by C(1)C(2)C(6) and C(11)C(12)C(16) make an angle of $35.0(3)^\circ$. In the dioxetane derivative the same planes make an angle of 62.4° , leading to an increased separation of the $H(2)\cdots H(12)$ type atoms (2.18 \AA). Because of the greater bending in the dioxetane derivative, the $H(3)\cdots H(13)$ type interactions are reduced to 2.01 \AA as compared with a value of $2.48(3) \text{ \AA}$ in the epoxide.

Except for the epoxide functionality, there is little bond-length or valence-angle strain in adamantylideneadamantane epoxide. Bonds within the adamantane system range from 1.509 to 1.541 \AA with an average value of $1.524(8) \text{ \AA}$. This is equivalent to the $1.528(5) \text{ \AA}$ value reported for cyclohexane determined by gas-phase electron diffraction (Davis & Hassel, 1963). The valence angles, excluding those at C(1) and C(11), average $109.4(5)^\circ$ with a range of 108.0 to 110.2° . The strain energy for (2) is calculated to be 46.5 kJ mol^{-1} greater than that in (1) (Allinger & Yuh, 1980).

We thank the Welch Foundation (P-074) and the TCU Research Foundation for their financial support.

Acta Cryst. (1988). **C44**, 1629–1632

Structure of (Z)-4-Methylthiotamoxifen

BY G. M. BLACKBURN, J. GOODMAN AND A. J. SMITH

Department of Chemistry, University of Sheffield, Sheffield S3 7HF, England

(Received 10 November 1987; accepted 23 May 1988)

Abstract. $C_{27}H_{31}NOS$, $M_r = 417.61$, orthorhombic, $Pna2_1$, $a = 16.720(18)$, $b = 13.741(19)$, $c = 10.527(14) \text{ \AA}$, $V = 2419 \text{ \AA}^3$, $Z = 4$, $D_x = 1.15 \text{ g cm}^{-3}$, $\lambda(\text{Mo } K\alpha) = 0.71069 \text{ \AA}$, $\mu = 1.44 \text{ cm}^{-1}$, $F(000) = 894.88$, room temperature, final $R = 0.0449$ for 1454 unique observed reflexions. 4-Methylthiotamoxifen (1) is a second-generation analogue of the antioestrogen tamoxifen (2). Only one of the diastereoisomers of (1) shows antioestrogenic activity whilst the other is a mild oestrogen. The unambiguous identification of the Z-geometry of one diastereoisomer of the alkene (3) by X-ray diffraction confirms a provisional assignment based on NMR and establishes that the antioestrogenic isomer of (1) has the same relative geometry as tamoxifen.

Introduction. Tamoxifen (2) is the drug most commonly used for the treatment of advanced disseminated

- ### References
- ALLINGER, H. L. & YUH, Y. H. (1980). *MM2* with *MMPI* subroutines for IBM PC. Updated by L. C. ROHREN (1984). Adapted by J. J. GAJEWSKI & K. E. GILBERT from copy supplied by O. NELSON & C. SCOTT OWEN. Obtained from Serena Software, 489 Serena Lane, Bloomington, IN 47401, USA.
- BARTLETT, P. D. (1978). *Organic Free Radicals*, edited by W. A. PRYOR, pp. 26–28. Washington, DC: American Chemical Society.
- CLARK, T., TEASLEY, M. F., NELSEN, S. F. & WYNBERG, H. (1987). *J. Am. Chem. Soc.* **109**, 5719–5724.
- CORDT, F., FRANK, R. M. & LENOIR, D. (1979). *Tetrahedron Lett.* pp. 505–508.
- DAVIS, M. & HASSEL, O. (1963). *Acta Chem. Scand.* **17**, 1181.
- HESS, J. & VOS, A. (1977). *Acta Cryst.* **B33**, 3527–3530.
- International Tables for X-ray Crystallography* (1974). Vol. IV. Birmingham: Kynoch Press. (Present distributor Kluwer Academic Publishers, Dordrecht.)
- JEFFORD, C. W. & BOSCHONG, A. F. (1977). *Helv. Chim. Acta.* **60**, 2673–2685.
- LENOIR, D. & FRANK, R. (1978). *Tetrahedron Lett.* pp. 53–56.
- LENOIR, D., FRANK, R. M., CORDT, F., GIEREN, A. & LAMM, V. (1980). *Chem. Ber.* **113**, 739–749.
- NELSEN, S. F., KAPP, D. L., AKABA, R. & EVANS, D. H. (1986). *J. Am. Chem. Soc.* **108**, 6863–6871.
- Nicolet Instrument Corporation (1986). *SHELXTL* for Desktop 30 (Microclipse), PN-269-1040340, April.
- SWEN-WALSTRA, S. C. & VISSER, G. J. (1971). *Chem. Commun.* pp. 82–83.
- WIERINGA, J. H., STRATING, J., WUNBERG, H. & ADAM, W. (1972). *Tetrahedron Lett.* pp. 169–172.

breast cancer (Legha & Carter, 1976). It is a powerful antioestrogen. One of its metabolites, 4-hydroxytamoxifen (4), is 100 times more potent than tamoxifen in antitumour assays *in vitro*, but cannot be used *in vivo* because of its rapid O-glucuronidation and subsequent excretion (Kemp, Adam, Wakeling & Slater, 1983; Jordan, Collins, Rowsby & Prestwich, 1977). Tamoxifen analogues intended as second-generation antioestrogens are therefore designed to block this rapid metabolic oxidation while retaining the enhanced potency associated with a polar group at position 4 of tamoxifen.

The geometry at the central alkene is a key feature of the biological activity of the tamoxifen class of compounds. In general those compounds derived from Z-tamoxifen (2) show antioestrogenic activity whereas E-tamoxifen (5) and its derivatives are oestrogens (Harper & Walpole, 1966, 1967). The configuration of