2·801 (6) and 2·59 (1) Å and O—H···O angles of 171 (4) and 163 (6)° for acetone molecules with s.o.f. 0·71 (1) and 0·29 (1), respectively. The inclusion of the solvent results in a packing that is different from that observed in anhydrous CA I and CA II, where the steroid molecules are hydrogen bonded head-to-tail [O(17)→O(3′)] and head-to-head [O(17)→O(22′)], respectively (Kanters *et al.*, 1985). The packing can be described as $M\,a_9b_9c_5\,211$ (Duax & Norton, 1975) indicating that the molecules are packed two thick, one wide and one long, with the steroid length parallel to **c**.

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The Structure of a Thioxanthodaunomycinone

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Abstract. 8-Acetyl-7,8,9,10-tetrahydro-6,11-dimethoxy-12*H*-5-thianaphthacen-12-one, $C_{21}H_{20}O_4S$, $M_r = 368{\cdot}45$, monoclinic, $P2_1/c$, $a = 9{\cdot}4586\ (6)$, $b = 9{\cdot}4246\ (5)$, $c = 20{\cdot}0674\ (9)$ Å, $\beta = 95{\cdot}361\ (5)°$, $V = 1781\ (1)$ Å^3, $Z = 4$, $F(000) = 776$, $D_x = 1{\cdot}375$ g cm^{-3}, Cu $K\alpha$, $\lambda = 1{\cdot}54178$ Å, Ni filter, $\mu = 17{\cdot}8$ cm^{-1}, 293 K, $R = 0{\cdot}043$, $wR = 0{\cdot}063$, 3195 observed reflections. The introduction of a sulfur atom in the *C* ring of the heteroanthracycline molecule buckles the xanthone skeleton. Owing to steric interactions with the heteroatoms on the *C* ring and the hydrogen atoms of the *A* ring, the methoxy groups on ring *B* are twisted out of the average molecular plane by approximately 90°. The conformation of the cyclohexene ring is distorted from a stable half-chair conformation towards a 1,2 diplanar or sofa conformer.

Introduction. A number of natural and synthetic anthracyclines have been successfully used as antitumor treatments; however, many of these products are cardiotoxic and prolonged administration leads to congestive heart failure. The antitumor effect of these compounds arises from their interaction with double-stranded DNA; the complex of one of these anthracyclines, daunomycin (1), and a DNA fragment has been structurally characterized by Quigley, Wang, Ughetto, Van der Marel, Van Boom & Rich (1980). In the complex, the daunomycin chromophore intercalates between base pairs and forms hydrogen bonds to the bases through the hydroxyl and acetyl groups on the cyclohexene ring. In contrast, the cardiotoxic effects of these compounds may arise from portions of the molecule that do not participate in binding to DNA; these effects are thought to be due to superoxide generation *via* the electron-accepting quinone portion of the molecule. It therefore seems reasonable that the intercalating properties of these molecules can be

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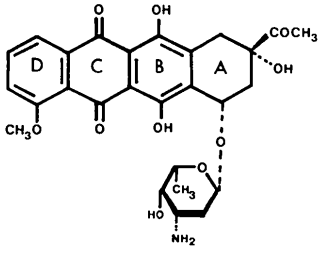
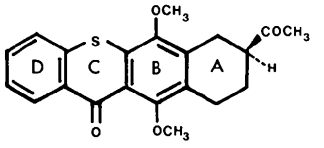
separated from the cardiotoxic effects. Synthetic heteroanthracyclines have been prepared to examine the origins of the cardiotoxic effects in anthracyclines (Wong, Haque, Lam, Marat, Bock & Mi, 1983). The crystal structure of a thioxanthodaunomycinone derivative (2) has been determined to ascertain whether the replacement of a carbonyl group with a sulfur atom, with concomitantly longer bonds, distorts the geometry of the xanthone and to probe the effect on the molecular conformation of methoxy group substituents on an interior ring of the tetracyclic system. If the basic structure of the heteroatomic chromophore is unchanged, these new heteroanthracyclines may lead to safer antitumor agents.



(1)



(2)

Experimental. The title compound was synthesized by Dr C.-M. Wong of the University of Manitoba. Hexagonal orange crystals from 3:1 methanol/methylene chloride, 0·20 × 0·20 × 0·15 mm; Enraf–Nonius CAD-4F diffractometer; $\theta_{max} = 70°$; θ range for 25 reflections that define orientation matrix and cell: 31·51–58·87°; no absorption correction; *hkl* range: $\pm h$, $+k$, $\pm l$; standards 060, 600, 0,0,10, variation <2·0%; 8038 reflections measured and averaged ($R_{int} = 0·020$), 3365 unique, 3195 with $I > 2·5\sigma(I)$; direct methods [*MULTAN*78 (Germain, Main & Woolfson, 1971)]; function minimized $\sum w(|F_o| - |F_c|)^2$; weights defined as $w^{-1} = [\sigma^2(F_o) + 0·002F_o^2]$; $R = 0·043$, $wR = 0·063$, $S = 0·88$; max. shift/e.s.d. = 0·10; max./min. difference Fourier peaks were $\pm 0·30$ e Å^{-3} and were equal to the estimated error; programs: *XRAY*76 (Stewart, 1976); scattering factors from Cromer & Mann (1968) except for H [from Stewart, Davidson & Simpson (1965)].

The H atoms were located in difference Fourier syntheses. The final refinement cycles varied all of the atomic coordinates, the anisotropic thermal parameters of the non-hydrogen atoms, the isotropic thermal parameters of the hydrogen atoms and the isotropic extinction parameter, $g = 1·1\ (1)\ \times 10^{-3}$ (Larson, 1967). The 3284 reflections used for the refinement were the observed reflections and those unobserved reflections with $|F_c| > 2·5\sigma(F_o)$.

Discussion. The molecular conformation and atomic labeling scheme are shown in Fig. 1. The atomic coordinates for the non-hydrogen atoms are in Table 1.* The conformation of this heteroanthracycline differs from those found for the naturally-occurring anthracyclines. Differences are found in the conformation of the cyclohexene ring *A*, the orientation of the methoxy groups, and the overall nonplanarity of the xanthone.

The *A* ring in this structure is distorted from the stable half-chair conformer towards a 1,2 diplanar (sofa) form (Bucourt, 1974). Atoms C(9) and C(8) in turn deviate from the average plane of the other five atoms in the ring by 0·70 (6) and −0·6 (1) Å. The torsion angles of the *A* ring (Table 2) show that the torsion angle about the double bond, C(10)–C(10a)–C(6a)–C(7), is nonzero and that the torsion angle about the C(6a)–C(7) bond is less than the value of 15° that is expected for a half-chair conformer. The occurrence of this alternative conformer may be due to the lack of an intramolecular hydrogen bond to stabilize the half-chair form; such a bond between an axial hydroxyl group at C(9) and an ether oxygen atom at C(7) was found for both carminomycin I (Von Dreele & Einck, 1977) and daunomycin (Neidle & Taylor, 1977). This distortion of the *A* ring could affect how the anthracycline binds to DNA since, in the complex, the substituents on C(9) of this ring bind to DNA above and below the mean plane of the chromophore (Quigley *et al.*, 1980).

* Lists of structure factors, anisotropic thermal parameters, least-squares planes, hydrogen-atom parameters and all bond distances and bond angles have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 43323 (20 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

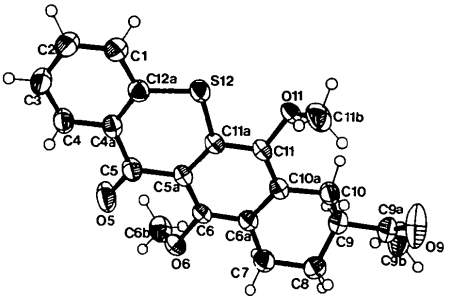


Fig. 1. The molecular conformation and atomic labeling scheme. The drawing was made with the computer program *ORTEP* (Johnson, 1976). The thermal ellipsoids were drawn at the 50% probability level.

The methoxy groups on the *B* ring are not coplanar with the ring and consequently cannot be part of the π system. The torsion angles in Table 2 show that in each case the bond between the O atom and the methyl C atom is perpendicular to the plane of the *B* ring; thus, the terminal methyl C atoms are 0·96 (5) [C(11b)] and −1·39 (5) Å [C(6b)] from the plane of the *B* ring. The orientation of the methoxy groups may be due to steric hindrance of the methoxy groups with the lone pairs of the S atom and of the carbonyl O atom, O(5), on one side and, on the other side, with the H atoms of the cyclohexene ring, *A*. When the methoxy substituent is on the *D* ring the steric constraints are removed and the group is nearly coplanar with the anthracycline fragment: in daunomycin, the terminal methyl C atom was within 0·26 Å of the plane (Neidle & Taylor, 1977); and in a daunomycin–butanol complex the methoxy group is coplanar with the chromophore (Courseille, Busetta, Geoffre & Hospital, 1979). The nonplanar nature of these methoxy groups precludes intercalation between the base pairs in DNA and suggests that active derivatives of this molecule should have hydroxyl groups in these positions as found in the active anthracyclines.

Table 1. *The fractional coordinates* ($\times 10^4$, $\times 10^5$ *for* S) *and* B_{eq} *values* ($\times 10^2$) *for the non-hydrogen atoms of the heteroanthracycline*

$$B_{eq} = \tfrac{8}{3}\pi^2 \sum_i \sum_j U_{ij} a_i^* a_j^* \mathbf{a}_i.\mathbf{a}_j.$$

	x	*y*	*z*	B_{eq}(Å^2)
C(1)	−11483 (2)	−1381 (2)	776 (1)	406 (8)
C(2)	−12690 (2)	−1453 (2)	1111 (1)	467 (9)
C(3)	−13691 (2)	−2507 (2)	949 (1)	458 (9)
C(4)	−13492 (2)	−3461 (2)	452 (1)	386 (7)
C(4a)	−12283 (2)	−3405 (2)	92 (1)	307 (6)
C(5)	−12200 (2)	−4464 (2)	−453 (1)	335 (6)
C(5a)	−10973 (1)	−4401 (2)	−876 (1)	274 (5)
C(6)	−10877 (2)	−5347 (2)	−1419 (1)	279 (5)
C(6a)	−9732 (2)	−5333 (2)	−1809 (1)	295 (6)
C(7)	−9713 (2)	−6385 (2)	−2375 (1)	385 (7)
C(8)	−8341 (2)	−6369 (2)	−2725 (1)	409 (8)
C(9)	−7842 (2)	−4844 (2)	−2819 (1)	340 (6)
C(10)	−7463 (2)	−4190 (2)	−2133 (1)	337 (6)
C(10a)	−8659 (2)	−4307 (2)	−1689 (1)	286 (5)
C(11)	−8756 (2)	−3346 (2)	−1173 (1)	281 (5)
C(11a)	−9871 (1)	−3391 (2)	−763 (1)	273 (5)
S(12)	−97534 (4)	−20873 (4)	−1413 (2)	356 (2)
C(12a)	−11282 (2)	−2350 (2)	263 (1)	311 (6)
O(5)	−13123 (2)	−5337 (2)	−549 (1)	627 (8)
O(6)	−11916 (1)	−6334 (1)	−1588 (1)	344 (5)
C(6b)	−13133 (2)	−5755 (2)	−1975 (1)	424 (8)
C(9a)	−6601 (2)	−4824 (2)	−3249 (1)	380 (7)
O(9)	−5404 (1)	−4716 (3)	−3015 (1)	715 (10)
C(9b)	−6956 (2)	−4853 (3)	−3987 (1)	601 (11)
O(11)	−7831 (1)	−2206 (1)	−1087 (1)	349 (5)
C(11b)	−6471 (2)	−2489 (2)	−738 (1)	486 (9)

Table 2. *Selected torsion angles* (°)

C(1)–C(2)–C(3)–C(4)	−0·9 (3)	
C(2)–C(3)–C(4)–C(4a)	0·1 (2)	
C(3)–C(4)–C(4a)–C(12a)	0·6 (2)	*D* ring
C(4)–C(4a)–C(12a)–C(1)	−0·1 (2)	
C(4a)–C(12a)–C(1)–C(2)	−0·9 (2)	
C(12a)–C(1)–C(2)–C(3)	1·4 (3)	
C(4a)–C(5)–C(5a)–C(11a)	1·8 (2)	
C(5)–C(5a)–C(11a)–S(12)	0·5 (2)	
C(5a)–C(11a)–S(12)–C(12a)	−0·7 (1)	*C* ring
C(11a)–S(12)–C(12a)–C(4a)	0·8 (2)	
S(12)–C(12a)–C(4a)–C(5)	0·4 (2)	
C(12a)–C(4a)–C(5)–C(5a)	−1·7 (2)	
C(5a)–C(6)–C(6a)–C(10a)	−3·2 (2)	
C(6)–C(6a)–C(10a)–C(11)	1·2 (2)	
C(6a)–C(10a)–C(11)–C(11a)	1·4 (2)	*B* ring
C(10a)–C(11)–C(11a)–C(5a)	−2·2 (2)	
C(11)–C(11a)–C(5a)–C(6)	0·2 (2)	
C(11a)–C(5a)–C(6)–C(6a)	2·5 (2)	
C(6a)–C(7)–C(8)–C(9)	−41·4 (2)	
C(7)–C(8)–C(9)–C(10)	64·4 (2)	
C(8)–C(9)–C(10)–C(10a)	−53·7 (2)	*A* ring
C(9)–C(10)–C(10a)–C(6a)	21·7 (2)	
C(10)–C(10a)–C(6a)–C(7)	1·6 (2)	
C(10a)–C(6a)–C(7)–C(8)	8·7 (2)	
C(10a)–C(11)–O(11)–C(11b)	−82·1 (2)	
C(6a)–C(6)–O(6)–C(6b)	−100·0 (2)	

The heteroanthraquinone moiety is nonplanar; the largest distortion occurs in the *B* ring. The torsion angles (Table 2) indicate that the distortions from planarity in the *B* ring are due to the positions of the C atoms that have methoxy substituents; these distortions could be due to the steric crowding mentioned above. The longer C—S bonds in the *C* ring cause little distortion from planarity for that ring; however, the *C* ring is bent with respect to the planar *D* ring by 2·8 (2)°. The angle between the planes of the *C* and *B* rings is only 0·8 (2)° yet this bend adds to that between rings *D* and *C* so that the angle between the two ends of the aromatic tricycle, rings *D* and *B*, is 3·6 (2)°. The major effect of the heteroatom substitution is therefore to buckle slightly the xanthone skeleton.

The introduction of the S atom in place of the carbonyl group usually found in anthracyclines has little effect on bond distances. The distances in the *B* and *D* rings are nearly aromatic with averages of 1·403 (12) and 1·391 (13) Å, respectively. In the *C* ring the double bond is more localized so the C=O distance is short, 1·199 (3) Å, and the average C—C distance is long, 1·449 (46) Å. A similar trend in distances was observed in the carminomycin I structure (von Dreele & Einck, 1977). In summary, the substitution of a sulfur atom in the quinone fragment of an anthracycline has little effect on the conformation of the ring system and so may be a useful modification to these compounds if lower cardiotoxicity can be demonstrated for thioxanthodaunomycinone derivatives. This structure also indicates that methoxy substitution on the *B* ring may inhibit intercalation of an anthracycline derivative into DNA.

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Structure of Bis(diphenyl iodonium *I*-oxide) Diacetate Trihydrate

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Abstract. $2C_{12}H_{10}IO^+.2C_2H_3O_2^-.3H_2O$, $M_r = 766{\cdot}36$, triclinic $P\bar{1}$, $a = 12{\cdot}401$ (2), $b = 12{\cdot}058$ (2), $c = 11{\cdot}074$ (1) Å, $\alpha = 106{\cdot}32$ (2), $\beta = 109{\cdot}67$ (1), $\gamma = 94{\cdot}65$ (1)°, $V = 1467{\cdot}9$ Å^3, $Z = 2$, $D_m = 1{\cdot}729$, $D_x = 1{\cdot}733$ Mg m^{-3}, λ(Mo $K\alpha$) = 0·71069 Å, $\mu = 2{\cdot}22$ mm^{-1}, $F(000) = 756$, $T = 298$ K, final $R = 0{\cdot}056$ for 3868 independent non-zero reflections. The coordination around each I atom is distorted octahedral comprising two normal I–C_{ar} [2·13–2·15 (1) Å], one normal I–O [both 1·84 (1) Å] and three secondary I···O bonds [2·45–2·93 (1) Å]. Secondary and H bonds bridge two $C_{14}H_{13}IO_3$ units to form a dimer, which is further linked to a centrosymmetrically equivalent one to form a tetramer. Finally, H bonds link tetramers together into columns along **c**.

Introduction. Diaryliodosyl salts, $Ar_2I^+O.X^-$, constitute a class of little known hypervalent organoiodine compounds in contrast to the well known diaryliodonium salts $Ar_2I^+.X^-$ (Koser, 1983). The hydrated diphenyl iodonium *I*-oxide acetate (DPIA hereafter) is, so far as we know, the only crystalline representative of this structurally unexplored class of compounds. Since spectroscopic data (Beringer & Bodlaender, 1968) could not distinguish among several alternative formulae, a detailed structure investigation was considered necessary.

Experimental. Colourless crystals, 0·5 × 0·3 × 0·25 mm, m.p. 387–389 K. D_m measured by flotation in 1,2-dibromoethane/carbon tetrachloride. Philips PW 1100 computer-controlled single-crystal diffractometer. Cell constants by least-squares analysis of θ angles of 140 strong reflections within the range 9–20°. Graphite-monochromated Mo $K\alpha$, θ–2θ scan mode. Three standard reflections exhibiting the same percentage linear decrease in intensity (20%). 6716 measured reflections, $\theta = 3$–30°, max. $hkl = 16, \pm16, \pm13$, 3868 with $I > 2\sigma(I)$, $R_{int} = 0{\cdot}059$ from merging 1184 symmetry-equivalent reflections. Correction for intensity drop, no absorption correction. Space group $P\bar{1}$ from intensity statistics. I atoms located by Patterson synthesis, remaining non-H atoms by Fourier synthesis. Full-matrix least-squares refinement using *F*, *XRAY*72 (Stewart, Kruger, Ammon, Dickinson & Hall, 1972). H atoms at calculated positions with isotropic temperature factors equal to those of the atoms to which they are bonded, $w = 1/\{1 + [(F_o - B)/A]^2\}$ with $A = 10$, $B = 50$; final $R = 0{\cdot}056$, $wR = 0{\cdot}056$, $S = 1{\cdot}03$, $(\Delta/\sigma)_{max} = 0{\cdot}28$, $(\Delta/\sigma)_{mean} = 0{\cdot}02$, $\Delta\rho = -0{\cdot}85$ to $1{\cdot}00$ e Å^{-3}. Atomic scattering factors and anomalous-dispersion correction from *International Tables for X-ray Crystallography* (1974).

Discussion. Final positional parameters and equivalent isotropic temperature coefficients for the non-H atoms are given in Table 1.* Selected interatomic distances and angles are in Table 2. A clinographic projection of

* Lists of structure amplitudes, anisotropic thermal parameters, H-atom parameters, C–H bond distances, least-squares-plane calculations, selected short intra- and intermolecular distances and bond angles have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 43274 (33 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

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