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Structure of 5-(1-Hydroxy-2-oxo-1,2-diphenylethyl)-6-(2-oxo-1,2-diphenylethoxy)acenaphthene

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Abstract. $C_{40}H_{30}O_4$, $M_r = 574\cdot67$, orthorhombic, $Pna2_1$, $a = 21\cdot930\,(2)$, $b = 12\cdot444\,(1)$, $c = 21\cdot823\,(3)$ Å, D_m(flotation) = $1\cdot28_1$, $D_x = 1\cdot28_2$ Mg m^{-3}, $Z = 8$, μ(Mo $K\alpha$) = $0\cdot076$ mm^{-1}, $R = 0\cdot079$ for 4744 reflexions (Mo $K\alpha$). The title compound is a novel product of the reaction of the 5,6-dilithioacenaphthene–*N*,*N*,*N*′,*N*′-tetramethyl-1,2-ethanediamine complex with benzil. The absolute configurations at the two benzoin α-carbon atoms are either (*R*,*S*) or (*S*,*R*). The two crystallographically independent molecules have similar molecular geometries. The OH group of the α-substituted benzoin group forms intramolecular bifurcated hydrogen bonds with the two O atoms of the O-substituted benzoin group.

Introduction. In the course of studies on the reactions of the 5,6-dilithioacenaphthene–TMEDA† complex with α-diketones, two of the authors have found that the reaction with benzil followed by hydrolysis gives an unexpected, novel product. Elemental analysis and ^{1}H NMR, IR, and mass spectra indicated that the product may be an acenaphthene derivative possessing two benzoin skeletons, but there remained some ambiguities in interpretation of the spectral data. To determine the structure, an X-ray analysis has been performed.

A crystal of dimensions $0\cdot15 \times 0\cdot5 \times 0\cdot6$ mm was used for the data collection on a Rigaku automatic four-circle diffractometer with graphite-monochromated Mo $K\alpha$ radiation ($\lambda = 0\cdot71073$ Å). The unit-cell dimensions were determined with 41 high-angle reflexions. Intensities were measured in the ω–2θ scan mode with a scan width of 1·2° (in ω) plus α_1–α_2 divergence, and a scan speed of 8° (2θ) min^{-1}. Five reference reflexions showed no intensity deterioration throughout the data collection. Of 5388 independent reflexions in the range $2 \leq 2\theta \leq 50°$, 1272 weak reflexions below background were considered zero reflexions, the threshold value, $F_{\rm llm}$, being 5·00. The standard deviations were estimated by the equation $\sigma^2(F_o) = \sigma_P^2(F_o) + qF_o^2$, where $\sigma_P(F_o)$ was evaluated by counting statistics and q ($7\cdot66 \times 10^{-5}$) was derived from the variations of the monitored reflexions (McCandlish, Stout & Andrews, 1975). The data were corrected for Lorentz and polarization factors but not for absorption effects.

The structure was solved using *MULTAN* (Germain, Main & Woolfson, 1971). Although normalized structure factor statistics strongly indicated the centrosymmetric space group *Pnam*, a reasonable solution was obtained only when the non-centrosymmetric space group $Pna2_1$ was assumed. The structural parameters were refined by the block-diagonal least-squares technique. All the H atoms, found on a difference map, were included. The quantity minimized was $\sum w(|F_o| - |F_c|)^2$, with $w = 1/\sigma^2(F_o)$. The zero reflexions, for which $|F_c| \geq F_{\rm llm}$, were included in the least-squares calculations by assuming $F_o = F_{\rm llm}$ and $w = 1/\sigma^2(F_{\rm llm})$. Sixteen weak reflexions, backgrounds of which measured before and after the peak scan were considerably different, were omitted. The final R was 0·079 for 4744 reflexions with $F_o > 3\sigma(F_o)$; the maximum shift of the parameters in the last cycle was $0\cdot55\sigma$ for C, $0\cdot69\sigma$ for O, and $0\cdot72\sigma$ for H atoms. Atomic scattering factors were taken from *International Tables for X-ray Crystallography* (1974). Atomic parameters for non-hydrogen atoms are listed in Table 1,† and the bond distances and angles are

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† *N*,*N*,*N*′,*N*′-Tetramethyl-1,2-ethanediamine.

† Lists of structure factors, anisotropic thermal parameters, and atomic parameters for H atoms, and tables of weighted least-squares-plane equations, deviations of atoms from these planes, and the dihedral angles, have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 35703 (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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Table 1. *Atomic coordinates* (×10⁴) *and equivalent isotropic temperature factors* (Å²)

	x	y	z	B_{eq}		x	y	z	B_{eq}
O(1A)	2343(2)	-307(3)	5264(2)	3.0	O(1B)	181(2)	4589(3)	2485(2)	2.9
O(2A)	1262(2)	129(3)	4099(2)	3.2	O(2B)	1236(2)	5177(3)	3670(2)	3.3
O(3A)	1908(2)	-1888(3)	4389(2)	2.8	O(3B)	601(2)	3086(3)	3366(2)	2.8
O(4A)	2921(2)	-2376(3)	5012(2)	4.1	O(4B)	-395(2)	2564(3)	2685(2)	4.1
C(1A)	3387(3)	-913(6)	2317(3)	4.9	C(1B)	-847(3)	4148(6)	5449(3)	4.9
C(2A)	3566(3)	229(6)	2527(3)	4.5	C(2B)	-1030(3)	5285(6)	5225(3)	4.4
C(3A)	3278(3)	1189(5)	3550(3)	3.8	C(3B)	-745(3)	6212(5)	4186(3)	3.7
C(4A)	2904(3)	1120(5)	4067(3)	3.3	C(4B)	-373(3)	6128(5)	3652(3)	3.2
C(5A)	2527(3)	268(5)	4202(3)	2.6	C(5B)	-2(3)	5241(5)	3525(3)	2.8
C(6A)	2245(3)	-1660(5)	3847(3)	3.2	C(6B)	267(3)	3302(5)	3899(2)	2.6
C(7A)	2265(3)	-2413(5)	3386(3)	3.5	C(7B)	209(3)	2557(5)	4353(3)	3.3
C(8A)	2616(3)	-2221(5)	2860(3)	4.0	C(8B)	-127(3)	2754(5)	4904(3)	3.5
C(9A)	3258(3)	373(6)	3147(3)	3.7	C(9B)	-726(3)	5403(5)	4607(3)	3.4
C(10A)	2530(3)	-647(4)	3807(3)	2.7	C(10B)	-25(3)	4343(4)	3944(3)	2.6
C(11A)	2947(3)	-1307(5)	2804(3)	3.4	C(11B)	-428(3)	3707(5)	4950(3)	3.4
C(12A)	2896(3)	-534(5)	3264(3)	2.9	C(12B)	-374(2)	4476(5)	4479(3)	2.7
C(13A)	2109(2)	349(5)	4776(3)	2.7	C(13B)	401(3)	5280(5)	2948(3)	2.9
C(14A)	2075(3)	1512(4)	5025(3)	3.1	C(14B)	434(3)	6413(5)	2670(3)	3.0
C(15A)	1747(3)	2292(5)	4713(3)	3.7	C(15B)	764(3)	7229(5)	2975(3)	4.3
C(16A)	1690(3)	3330(5)	4945(3)	4.4	C(16B)	817(4)	8225(6)	2693(4)	5.8
C(17A)	1973(4)	3584(5)	5487(3)	5.9	C(17B)	548(4)	8446(6)	2150(4)	7.3
C(18A)	2325(4)	2836(5)	5798(3)	5.6	C(18B)	223(4)	7656(6)	1850(4)	6.7
C(19A)	2363(3)	1812(5)	5564(3)	4.3	C(19B)	151(3)	6634(5)	2115(3)	4.1
C(20A)	1446(3)	53(5)	4625(3)	3.0	C(20B)	1070(2)	5005(4)	3134(3)	2.5
C(21A)	1015(3)	-287(5)	5118(3)	3.3	C(21B)	1526(2)	4630(5)	2679(2)	2.5
C(22A)	1026(3)	155(5)	5704(3)	4.6	C(22B)	1529(3)	4969(5)	2075(3)	3.8
C(23A)	568(4)	-138(6)	6119(3)	6.0	C(23B)	2001(3)	4670(6)	1679(3)	4.7
C(24A)	122(4)	-848(7)	5952(4)	6.5	C(24B)	2450(3)	4003(6)	1902(3)	5.2
C(25A)	115(3)	-1301(7)	5377(4)	5.9	C(25B)	2444(3)	3623(6)	2502(3)	5.0
C(26A)	561(3)	-1029(5)	4947(3)	4.1	C(26B)	1972(3)	3947(5)	2890(3)	3.7
C(27A)	1983(3)	-2984(4)	4606(3)	2.5	C(27B)	544(3)	1990(5)	3140(3)	2.9
C(28A)	1565(2)	-3177(4)	5142(2)	2.3	C(28B)	974(3)	1802(5)	2611(3)	2.8
C(29A)	1660(3)	-2708(5)	5730(3)	3.8	C(29B)	918(3)	2326(5)	2064(3)	3.1
C(30A)	1266(3)	-2938(5)	6204(3)	4.3	C(30B)	1318(3)	2116(5)	1578(3)	3.7
C(31A)	788(3)	-3632(6)	6127(3)	4.4	C(31B)	1771(3)	1344(5)	1653(3)	4.2
C(32A)	694(3)	-4113(5)	5573(3)	4.3	C(32B)	1826(3)	820(6)	2211(3)	4.5
C(33A)	1077(3)	-3875(5)	5076(3)	3.4	C(33B)	1428(3)	1042(5)	2687(3)	3.6
C(34A)	2654(3)	-3124(5)	4798(3)	3.2	C(34B)	-126(3)	1819(5)	2944(3)	2.8
C(35A)	2955(3)	-4189(4)	4703(3)	2.7	C(35B)	-409(3)	759(5)	3037(3)	3.4
C(36A)	3485(3)	-4389(5)	5021(3)	4.1	C(36B)	-958(3)	557(5)	2717(3)	4.6
C(37A)	3799(3)	-5324(6)	4931(4)	6.0	C(37B)	-1266(3)	-403(6)	2815(4)	6.2
C(38A)	3590(3)	-6087(6)	4522(4)	5.5	C(38B)	-1050(3)	-1148(6)	3224(4)	5.2
C(39A)	3064(3)	-5878(5)	4202(3)	4.5	C(39B)	-518(3)	-968(5)	3543(4)	4.8
C(40A)	2745(3)	-4949(5)	4287(3)	3.5	C(40B)	-196(3)	1(5)	3442(3)	4.3

The e.s.d.'s given in parentheses refer to the least significant digit. $B_{eq} = \frac{8}{3}\pi^2(U_1 + U_2 + U_3)$ where U_1, U_2 and U_3 are the principal components of the mean-square displacement matrix **U**.

shown in Fig. 1 with the atom-numbering scheme. Fig. 2 (the structures of the two independent molecules *A* and *B*), Fig. 3 (the intramolecular bifurcated hydrogen bonds), and Fig. 4 (packing diagram) were drawn with the *TSD:XTAL* system (Takenaka & Sasada, 1980).

Discussion. The structures of the crystallographically independent molecules, *A* and *B*, are described as 5-(1-hydroxy-2-oxo-1,2-diphenylethyl)-6-(2-oxo-1,2-diphenylethoxy)acenaphthene, in which the two benzoin groups are attached to the *peri* positions of the acenaphthene nucleus in the different modes as shown in Fig. 2; one is α-substituted benzoin and the other O-substituted benzoin. In each of the molecules, the stereochemistry of the two asymmetric C atoms, C(13) and C(27),* is (*R*,*S*) or its mirror image (*S*,*R*). In both molecules *A* and *B*, the O(1)—H(O) group of the α-substituted benzoin group forms intramolecular bifurcated hydrogen bonds with the ether O(3) atom and the carbonyl O(4) atom of the O-substituted benzoin group (Fig. 3), so that the relative orientations of these groups with respect to the acenaphthene nuclei are almost the same in the two molecules. The molecule *A* at the original coordinates and *B* at $\frac{1}{2} + x, \frac{1}{2} - y, z$ are related by a pseudo inversion about 0·377 (1), 0·003 (3), 0·387 (2), as shown in Fig. 4, and their molecular geometries resemble each other so closely that the normalized structure factor statistics strongly

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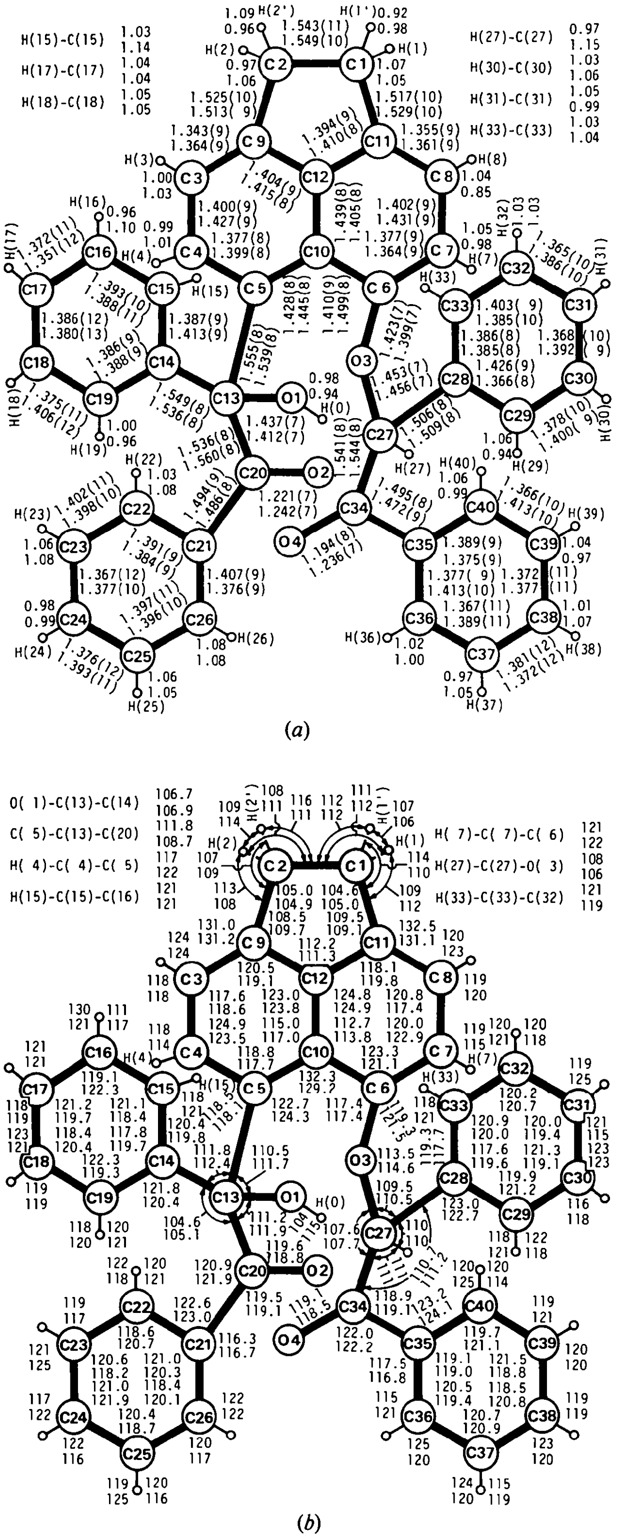
* In discussions of the common features of molecules *A* and *B*, '*A*' and '*B*' in the atom-numbering scheme are omitted.



(a)

(b)

Fig. 1. (*a*) Bond distances (Å) and (*b*) bond angles (°) of the independent molecules. The upper value of each pair is for molecule *A*, the lower for *B*. E.s.d.'s for bond distances are 0·05–0·08 Å for H atoms and, for bond angles, are 0·4–0·8° for non-hydrogen atoms, and 2–5° for H atoms. The atom-numbering scheme is also shown.

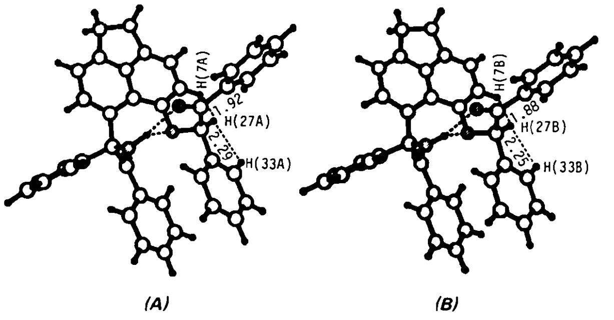


Fig. 2. Structures of molecules *A* and *B*. Some close H—H contacts (Å) are also shown. E.s.d.'s are 0·06–0·08 Å.

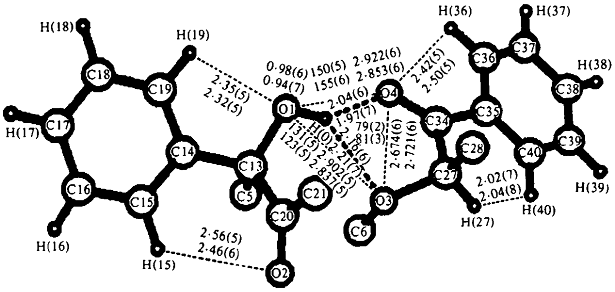


Fig. 3. Common partial molecular structure of molecules *A* and *B* showing intramolecular bifurcated hydrogen-bond distances (Å) and angles (°), and some other H—H and H—O contacts (Å). The upper value of each pair is for molecule *A*, the lower for *B*. The acenaphthene nucleus at C(5) and C(6) and benzene rings at C(21) and C(28) are omitted for clarity.

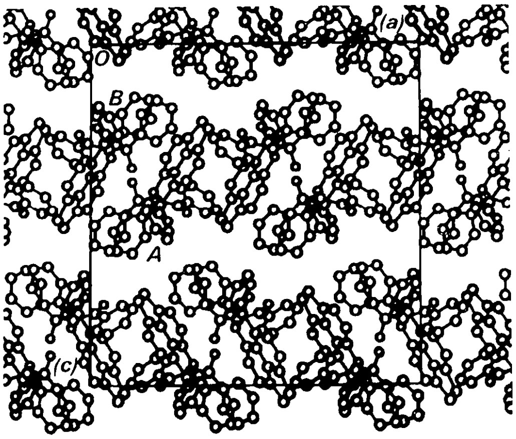


Fig. 4. Packing diagram projected down the *b* axis. H atoms are omitted for clarity.

indicated the centrosymmetric space group. Detailed examination indicates, however, that half the bond distances and angles involving non-hydrogen atoms show differences greater than 2σ between *A* and *B*; the dihedral angles between the planar parts also show large differences between the two molecules. Such differences may be caused by packing forces.

From the out-of-plane displacements of the acenaphthene nuclei, it is clear that the twisting modes of the ethylene bridges, C(1*A*)–C(2*A*) and C(1*B*)–C(2*B*), differ from those of 5,6-dichloro-, 5-bromo-6-chloro-, and 5,6-diphenylacenaphthenes (Avoyan & Struchkov, 1961, 1964; Clough, Kung, Marsh & Roberts, 1976). The bond angles of C(6) also differ from those of these acenaphthene *peri* derivatives, in which the angles *X*–C(5)–C(10) and *X*–C(6)–C(10) are expanded, where *X* is a carbon or halogen atom of the *peri* substituent. In the present structures, however, O(3)–C(6)–C(10) is smaller than O(3)–C(6)–C(7). This may be due to the intramolecular hydrogen bonds mentioned above. C(7)–C(6)–C(10), however, is larger than C(4)–C(5)–C(10). This can be understood by the difference in electronegativities between the substituted atoms, O(3) and C(13), in terms of the valence-shell electron-pair repulsion theory (Domenicano, Vaciago & Coulson, 1975).

Interpretation of the unusual ^{1}H NMR spectra of the present compound (Tanaka & Kasai, to be published) is now possible on the basis of the anomalous configurations causing the shortenings of some H–H distances shown in Figs. 2 and 3.

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Structure of Trichostatin A, a Primary Hydroxamate Antibiotic

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Abstract. $C_{17}H_{22}N_2O_3$, $M_r = 302{\cdot}4$, orthorhombic, $P2_12_12_1$, $Z = 8$; $a = 10{\cdot}446$ (3), $b = 41{\cdot}277$ (16), $c = 7{\cdot}669$ (2) Å, $V = 3307$ (2) Å^3 at 138 (2) K; $a = 10{\cdot}499$ (4), $b = 41{\cdot}528$ (24), $c = 7{\cdot}753$ (2) Å, $V = 3380$ (3) Å^3 at 295 (1) K; Cu $K\alpha_1$ radiation, $\lambda = 1{\cdot}5405$ Å; μ(Cu $K\alpha$) = $0{\cdot}67$ mm^{-1}; $D_c = 1{\cdot}188$, $D_m = 1{\cdot}12$ (1) Mg m^{-3} [295 (1) K]; recrystallized from ethyl acetate–methanol. Trichostatin A is a primary hydroxamic acid and antifungal antibiotic produced by *Streptomyces hygroscopicus* Y-50. The structure was determined from 3886 intensity measurements at 138 (2) K by direct methods and difference Fourier syntheses, and refined to an *R* factor of 0·097 for 3284 data (0·117 for all reflections). The two molecules in the asymmetric unit are closely similar; the unsaturated side chain is all-*trans* and exhibits a significant degree of in-plane bending, while the intermolecular hydrogen-bonded hydroxamate group is planar *cis*.

Introduction. The crystal structure and absolute configuration of naturally occurring biologically active hydroxamic acids [R_1–C(=O)–N(–OH)–R_2], both linear and cyclic, and their ferric chelates, are of interest because of their ability to sequester selectively and facilitate the transport of ferric ions across cell membranes. Trichostatin A is a member of a group of relatively lipophilic hydroxamic acids isolated and identified from the mycelia of *Streptomyces hygroscopicus* Y-50 (Tsuji, Kobayashi, Nagashima, Wakisaka & Koizumi, 1976; Tsuji & Kobayashi, 1978). It is a primary hydroxamic acid (R_2 = H), coordinates ferric ion as a 3:1 complex, and exhibits anti-*Trichophyton* activity. The antibiotic activity of the hydroxamic acid diminishes substantially (by a factor of 4 or 8) as either the tris ferrate(III) complex or as the β-glycopyranosyl derivative. Its ability to act as a ferric ionophore (siderophore) in *S. hygroscopicus* has not yet been confirmed. The present communication confirms the chemical structure postulated by Tsuji *et al.* (1976).

The title compound was obtained as a gift from Dr Naoki Tsuji, Shionogi Research Laboratory, Shionogi

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