Structure of 6-Diethylamino-3-methoxy-11*H*-isoindolo[2,1-*a*]indol-11-one, C$_{20}$H$_{20}$N$_2$O$_2$

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Abstract. $M_r = 320 \cdot 4$, triclinic, $P\bar{1}$, $a = 10 \cdot 510$ (2), $b = 12 \cdot 906$ (1), $c = 13 \cdot 157$ (2) Å, $\alpha = 99 \cdot 75$ (1), $\beta = 107 \cdot 45$ (1), $\gamma = 96 \cdot 06$ (1)°, $V = 1654 \cdot 5$ (9) Å^3, $Z = 4$, $D_m = 1 \cdot 29$, $D_x = 1 \cdot 286$ Mg m^{-3}, λ(Cu $K\alpha$) = $1 \cdot 54178$ Å, $\mu = 0 \cdot 632$ mm^{-1}, $F(000) = 680$, $T = 298$ K. Final $R = 0 \cdot 048$ for 3422 unique significant reflections. Both of the independent molecules in the asymmetric unit are highly planar and have only one of the two *N*-ethyl groups projecting from the aromatic plane.

Introduction. In an attempt to prepare a series of isatogens containing salt-forming groups (Foster, Hooper, Imam, Lovett, Nicholson, Swain, Sweetman & Weetman, 1983), 2-[(diethylamino)methyl]phenylacetylene was reacted with 4-substituted 2-nitroiodobenzenes. These reactions yielded intensely purple compounds rather than the expected orange–red isatogens. Spectroscopic and analytical data were consistent with the isoindoloindole structures (1*a–d*) which could arise by a novel intramolecular rearrangement (Hooper & Imam, 1983). The structure of 1(*c*) has been verified here by crystallographic analysis.

(a) R = H
(b) R = CH$_3$
(c) R = CH$_3$O
(d) R = CH$_3$N ... N(CH$_2$)$_3$O

(1)
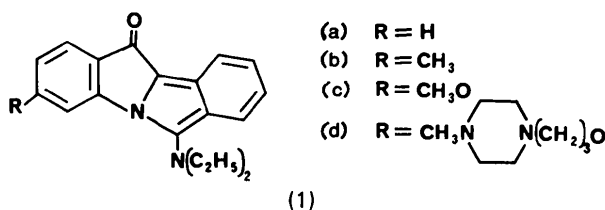
The planarity of this isoindoloindole structure suggests that this type of compound may have DNA-intercalating ability but DNA-binding studies on the most water-soluble derivative, 1(*d*), did not confirm this hypothesis.

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Experimental. Red plate-like crystals grown from ethanol solution, density measured by flotation; X-ray photographs taken to determine crystal class, accurate cell dimensions determined by least-squares analysis of 25 θ values. Enraf–Nonius CAD-4 diffractometer, Ni-filtered Cu $K\alpha$ radiation, ω–2θ scan mode up to $\theta = 60°$ ($0 \le h \le 11$, $-14 \le k \le 14$, $-14 \le l \le 14$), crystal approximately $0 \cdot 31 \times 0 \cdot 20 \times 0 \cdot 02$ mm; three standard reflections monitored at intervals of 3600 s, no crystal decay observed during data collection; 5224 reflections recorded, 3422 with $I \ge 1 \cdot 5\sigma(I)$ used for refinement. Structure solved by direct methods (*MULTAN*80, Main, Fiske, Hull, Lessinger, Germain, Declercq & Woolfson, 1980) and refined on F by full-matrix least-squares procedures. There are two independent molecules per asymmetric unit. All H atoms were clearly revealed in a difference Fourier map and kept fixed during refinement. Final difference map did not show any peaks $>0 \cdot 17$ e Å^{-3}. $R = 0 \cdot 048$, $w = 1$; zero shift/error in final least-squares cycle. Atomic scattering factors from *International Tables for X-ray Crystallography* (1974). An empirical absorption correction was applied using a computer program written by Walker (Walker & Stuart, 1983). All calculations performed on a PDP 11/34a computer using the *SDP* program system (Frenz, 1980).

Discussion. The final atomic parameters are listed in Table 1.† The two independent molecules, molecules (I) and (II), have very similar structures as shown in their bond lengths and angles (see Table 2). The structure of molecule (I) is shown in Fig. 1 with the numbering scheme employed. Chromophores of the two molecules

† Tables of structure factors, H-atom coordinates, C—H distances, anisotropic thermal parameters and Fig. 2 have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 39047 (23 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

are highly planar, although molecule (II) is more puckered with an eight-times larger χ^2 statistic compared with molecule (I). The methoxy groups lie in the chromophore planes. One of the two N-ethyl groups is almost in the plane of the chromophore [deviations from the planes are: molecule (I), C(18) 0·261, C(20) 0·741; molecule (II), C(18) 0·174, C(20) 0·556 Å] whereas the other group projects from the plane [deviations are: molecule (I), C(17) 1·615, C(19) 2·737; molecule (II), C(17) 1·758, C(19) 2·849 Å]. The dimensions of the chromophore are similar to those of ellipticine which shows antitumour activity.
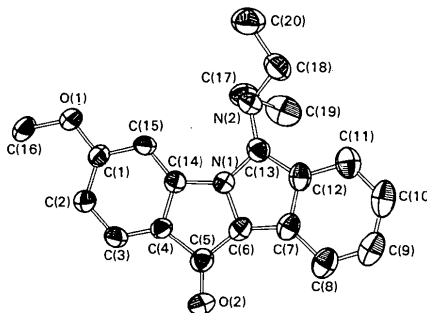

Fig. 1. Plan view of 1(c).

Table 1. *Positional and equivalent isotropic thermal parameters for the non-H atoms with e.s.d.'s in parentheses*

	Molecule (I)				Molecule (II)			
	x	y	z	$B_{eq}*(Å^2)$	x	y	z	$B_{eq}*(Å^2)$
O(1)	1·2361 (2)	0·4176 (2)	0·3088 (2)	4·21 (6)	0·5292 (2)	0·7395 (2)	0·0799 (2)	4·12 (6)
O(2)	0·6219 (2)	0·4943 (2)	0·2731 (2)	4·81 (6)	−0·1077 (2)	0·6738 (2)	0·0418 (2)	4·83 (7)
N(1)	0·8504 (3)	0·3602 (2)	0·4335 (2)	3·20 (6)	0·1493 (3)	0·8974 (2)	0·1314 (2)	3·23 (6)
N(2)	0·9746 (3)	0·2478 (2)	0·5360 (2)	3·71 (7)	0·3045 (3)	1·0599 (2)	0·2029 (2)	3·65 (7)
C(1)	1·1082 (3)	0·4336 (3)	0·3039 (3)	3·33 (8)	0·3989 (3)	0·7278 (3)	0·0779 (3)	3·24 (8)
C(2)	1·0307 (4)	0·4872 (3)	0·2321 (3)	3·63 (8)	0·3120 (4)	0·6309 (3)	0·0447 (3)	3·62 (8)
C(3)	0·9004 (4)	0·4977 (3)	0·2320 (3)	3·51 (8)	0·1784 (4)	0·6274 (3)	0·0419 (3)	3·56 (8)
C(4)	0·8494 (3)	0·4533 (3)	0·3025 (3)	3·06 (8)	0·1333 (3)	0·7198 (3)	0·0738 (3)	3·10 (8)
C(5)	0·7163 (3)	0·4533 (3)	0·3217 (3)	3·51 (8)	−0·0044 (3)	0·7413 (3)	0·0705 (3)	3·56 (8)
C(6)	0·7262 (3)	0·3951 (3)	0·4069 (3)	3·37 (8)	0·0132 (3)	0·8550 (3)	0·1059 (3)	3·48 (8)
C(7)	0·6584 (3)	0·3578 (3)	0·4735 (3)	3·28 (8)	−0·0552 (4)	0·9420 (3)	0·1153 (3)	3·55 (8)
C(8)	0·5307 (4)	0·3676 (3)	0·4845 (3)	3·88 (9)	−0·1927 (4)	0·9494 (3)	0·0992 (3)	4·25 (9)
C(9)	0·4924 (4)	0·3201 (3)	0·5576 (3)	4·7 (1)	−0·2274 (4)	1·0484 (3)	0·1147 (3)	5·0 (1)
C(10)	0·5760 (4)	0·2605 (3)	0·6223 (3)	4·7 (1)	−0·1306 (4)	1·1416 (3)	0·1486 (3)	5·0 (1)
C(11)	0·6997 (4)	0·2489 (3)	0·6127 (3)	4·24 (9)	0·0036 (4)	1·1372 (3)	0·1661 (3)	4·34 (9)
C(12)	0·7442 (4)	0·2980 (3)	0·5388 (3)	3·40 (8)	0·0440 (4)	1·0366 (3)	0·1492 (3)	3·49 (8)
C(13)	0·8641 (4)	0·2993 (3)	0·5095 (3)	3·34 (8)	0·1733 (4)	1·0059 (3)	0·1614 (3)	3·47 (8)
C(14)	·0·9296 (3)	0·3985 (3)	0·3731 (3)	3·08 (8)	0·2239 (3)	0·8162 (3)	0·1084 (3)	3·00 (8)
C(15)	1·0592 (3)	0·3889 (3)	0·3772 (3)	3·33 (8)	0·3547 (3)	0·8230 (3)	0·1103 (3)	3·17 (8)
C(16)	1·2903 (4)	0·4571 (3)	0·2324 (3)	4·6 (1)	0·5785 (4)	0·6428 (3)	0·0456 (3)	4·7 (1)
C(17)	0·9756 (4)	0·1615 (3)	0·4474 (3)	4·53 (9)	0·3816 (4)	1·0393 (3)	0·3096 (3)	4·7 (1)
C(18)	1·0203 (4)	0·2254 (3)	0·6466 (3)	4·13 (9)	0·3272 (4)	1·1706 (3)	0·1898 (3)	4·6 (1)
C(19)	0·8590 (6)	0·0715 (3)	0·4153 (4)	6·6 (1)	0·3167 (6)	1·0645 (4)	0·3962 (3)	6·7 (1)
C(20)	1·1737 (4)	0·2340 (3)	0·6877 (3)	5·2 (1)	0·4634 (5)	1·1983 (4)	0·1779 (4)	6·0 (1)

$$* B_{eq} = \tfrac{4}{3}(a^2B_{11} + b^2B_{22} + c^2B_{33} + abB_{12}\cos\gamma + acB_{13}\cos\beta + bcB_{23}\cos\alpha).$$

Table 2. *Bond lengths (Å) and angles (°) with e.s.d.'s in parentheses*

	Molecule (I)	Molecule (II)		Molecule (I)	Molecule (II)		Molecule (I)	Molecule (II)		Molecule (I)	Molecule (II)
C(1)—C(2)	1·382 (5)	1·387 (5)	C(6)—C(7)	1·397 (5)	1·405 (5)	C(11)—C(12)	1·408 (5)	1·412 (5)	O(1)—C(16)	1·433 (5)	1·455 (5)
C(2)—C(3)	1·390 (7)	1·390 (5)	C(6)—N(1)	1·390 (4)	1·394 (4)	C(12)—C(13)	1·424 (5)	1·427 (5)	C(13)—N(2)	1·382 (5)	1·379 (5)
C(3)—C(4)	1·374 (5)	1·376 (5)	C(7)—C(8)	1·409 (5)	1·412 (5)	C(13)—N(1)	1·357 (4)	1·364 (4)	N(2)—C(17)	1·473 (5)	1·479 (5)
C(4)—C(5)	1·495 (5)	1·492 (5)	C(7)—C(12)	1·434 (5)	1·429 (5)	N(1)—C(14)	1·418 (4)	1·417 (4)	N(2)—C(18)	1·478 (4)	1·471 (5)
C(4)—C(14)	1·397 (5)	1·400 (5)	C(8)—C(9)	1·358 (5)	1·365 (6)	C(14)—C(15)	1·367 (5)	1·361 (5)	C(17)—C(19)	1·501 (7)	1·502 (6)
C(5)—O(2)	1·232 (4)	1·233 (4)	C(9)—C(10)	1·415 (6)	1·403 (6)	C(15)—C(1)	1·397 (5)	1·404 (5)	C(18)—C(20)	1·525 (6)	1·499 (6)
C(5)—C(6)	1·436 (5)	1·436 (5)	C(10)—C(11)	1·364 (6)	1·368 (6)	C(1)—O(1)	1·366 (4)	1·354 (4)			

	Molecule (I)	Molecule (II)		Molecule (I)	Molecule (II)		Molecule (I)	Molecule (II)
O(1)—C(1)—C(2)	124·2 (4)	124·1 (3)	C(6)—C(7)—C(12)	107·4 (3)	107·2 (3)	C(13)—N(1)—C(6)	112·5 (3)	112·4 (3)
O(1)—C(1)—C(15)	114·0 (3)	114·8 (3)	C(12)—C(7)—C(8)	119·6 (4)	120·1 (4)	C(6)—N(1)—C(14)	110·5 (3)	110·7 (3)
C(15)—C(1)—C(2)	121·8 (3)	121·1 (3)	C(6)—C(7)—C(8)	133·0 (4)	132·7 (4)	C(13)—N(1)—C(14)	136·9 (3)	136·6 (3)
C(1)—C(2)—C(3)	119·8 (4)	119·9 (4)	C(7)—C(8)—C(9)	118·7 (4)	118·2 (4)	N(1)—C(14)—C(4)	106·8 (3)	106·7 (3)
C(2)—C(3)—C(4)	119·4 (3)	119·9 (4)	C(8)—C(9)—C(10)	122·2 (4)	122·0 (4)	C(4)—C(14)—C(15)	122·6 (3)	122·8 (3)
C(3)—C(4)—C(14)	119·4 (3)	118·9 (3)	C(9)—C(10)—C(11)	120·4 (4)	121·2 (4)	N(1)—C(14)—C(15)	130·6 (3)	130·4 (3)
C(3)—C(4)—C(5)	131·3 (3)	131·5 (4)	C(10)—C(11)—C(12)	119·4 (4)	118·8 (4)	C(14)—C(15)—C(1)	116·9 (3)	117·4 (3)
C(14)—C(4)—C(5)	109·3 (3)	109·4 (3)	C(11)—C(12)—C(13)	132·6 (4)	132·1 (4)	C(1)—O(1)—C(16)	117·0 (3)	116·5 (3)
C(4)—C(5)—O(2)	126·2 (4)	125·9 (4)	C(11)—C(12)—C(7)	119·8 (4)	119·6 (4)	C(13)—N(2)—C(17)	113·8 (3)	113·8 (3)
C(4)—C(5)—C(6)	104·1 (3)	104·3 (3)	C(7)—C(12)—C(13)	107·6 (3)	108·3 (3)	C(13)—N(2)—C(18)	117·8 (3)	117·1 (3)
O(2)—C(5)—C(6)	129·8 (4)	129·8 (4)	C(12)—C(13)—N(1)	105·9 (3)	105·6 (3)	C(17)—N(2)—C(18)	115·3 (3)	115·9 (3)
C(5)—C(6)—N(1)	109·2 (3)	108·9 (3)	C(12)—C(13)—N(2)	133·8 (3)	134·3 (3)	N(2)—C(17)—C(19)	113·9 (4)	113·9 (4)
N(1)—C(6)—C(7)	106·4 (3)	106·5 (3)	N(2)—C(13)—N(1)	120·1 (3)	119·8 (3)	N(2)—C(18)—C(20)	110·5 (3)	110·9 (4)
C(5)—C(6)—C(7)	144·4 (4)	144·2 (4)						

A difference in chromophore geometry of the present compound from that of ellipticines is that the isoindoloindole has a linear chromophore with the terminal six-membered rings parallel to each other, due to the two fused five-membered rings in the centre of the chromophore. Using standard techniques (Bennett, Sharples & Brown, 1982), the melting profile of DNA was found to be the same in the presence of 1(d) as in its absence, suggesting that the compound does not interact with DNA. This was confirmed by the finding that DNA has no effect on the light-absorption properties of 1(d). This lack of DNA interaction may be due to the projecting N-ethyl group of the isoindoloindole which may hamper the intercalation of the chromophore between the DNA base pairs. To investigate the geometrical feature of the molecule, empirical energetic calculations were used with the aid of molecular graphics using the program system MOLEC (Islam & Neidle, 1983). The self-complementary dimer of d(CpG) was adopted as a DNA model structure and the coordinates were taken from the known intercalating structure of d(CpG).proflavine (Shieh, Berman, Dabrow & Neidle, 1980). The coordinates of 1(c) were those determined in this work and those of a side chain of 1(d) were generated assuming a standard geometry. The d(CpG) geometry was held invariant throughout the study and the molecules 1(c) and 1(d) were restricted to rotational and translational movements. The non-bonded energy component was arbitrarily taken as the interaction energy between d(CpG) and isoindoloindoles in this approximate study. Full intercalation of the molecule into the docking site of d(CpG) exhibits high energy due to short distances between O(6GI) and C(19) (typically 1·5–1·9 Å). It was found that a partial intercalation with some overlapping of DNA base and isoindoloindole chromophore planes is possible both for 1(c) and 1(d). The geometry of an energy minimum is shown in Fig. 2.* Therefore the total

lack of interaction with DNA cannot be attributed to the N-ethyl groups. This was further confirmed by the DNA-binding study with a diketone (2), which was synthesized by hydrolysis of 1(c) in conc. HCl/CH₃OH. Again compound (2) was found to have no stabilizing effect on the thermal-denaturation profile of DNA.

(2)
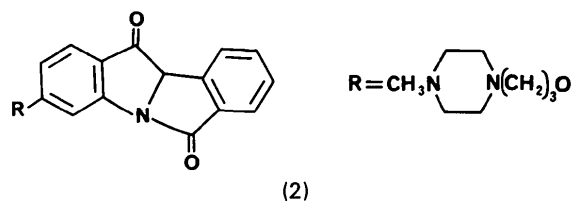
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Structure of 1,1'-Dimethylsilanediylbis(acetone phenylhydrazone), C₂₀H₂₈N₄Si

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Abstract. $M_r = 352\cdot6$, monoclinic, $C2/c$, $a = 20\cdot788\,(3)$, $b = 7\cdot525\,(1)$, $c = 13\cdot200\,(2)$ Å, $\beta = 102\cdot62\,(1)°$, $U = 2015\cdot0$ Å³, $Z = 4$, $D_x = 1\cdot162$ Mg m⁻³, $\lambda(\text{Mo }K\alpha) = 0\cdot71069$ Å, $\mu = 0\cdot12$ mm⁻¹, $F(000) = 760$, $T = 291$ K, $R = 0\cdot094$ for 971 observed reflections. The molecule, with a crystallographic twofold axis through Si, contains essentially single N—N and double N=C bonds in the hydrazone