X-RAY CRYSTALLOGRAPHIC INVESTIGATION OF THE ADDUCT OF 1-DIMETHYLAMINO-2-(4-BROMOPHENYL)-2H-ISOINDOLE WITH N-PHENYLMALEIMIDE

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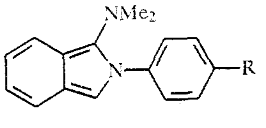
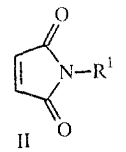
An unusual path for the reaction of 2-aryl-1-dimethylamino-2H-isoindoles with N-R-maleimides, leading to the imides of 1,2-dihydronaphthalene-2,3-dicarboxylic acids, was established by x-ray crystallographic analysis.

1-Dimethylamino-2-arylisoindoles (I) were described in 1971 [1]. Our interest in the addition of maleimide derivatives to these compounds has not diminished since that time [2-4]. This interest is governed by an endeavor to find the fullest correlation between the various spectral characteristics of the obtained adducts and their structures. In the first investigation [2] the ease of cycloaddition was demonstrated, and the exo structure (III) was assigned to the products from the reaction of compounds (I) with (II) on the basis of the PMR spectra. In this paper questions arose in connection with the anomalously high value of the spin—spin coupling constant $^3J_{56}$ of 13.5 Hz for this structure, and this was subsequently explained by means of a wide range of subjects [3] as resulting from transoid fusion of the rings in the adduct (IV), where the 5-H and 6-H protons lie at an angle of 156-158° in relation to the C—C bond.



I



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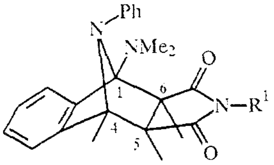

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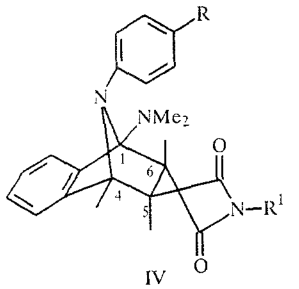

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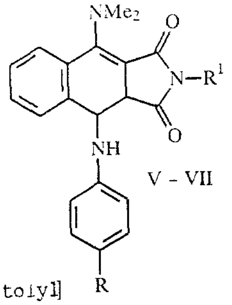

V - VII

VI [V, R=Br, R^1=Ph];
VII [V, R=Br, R^1= p-tolyl]

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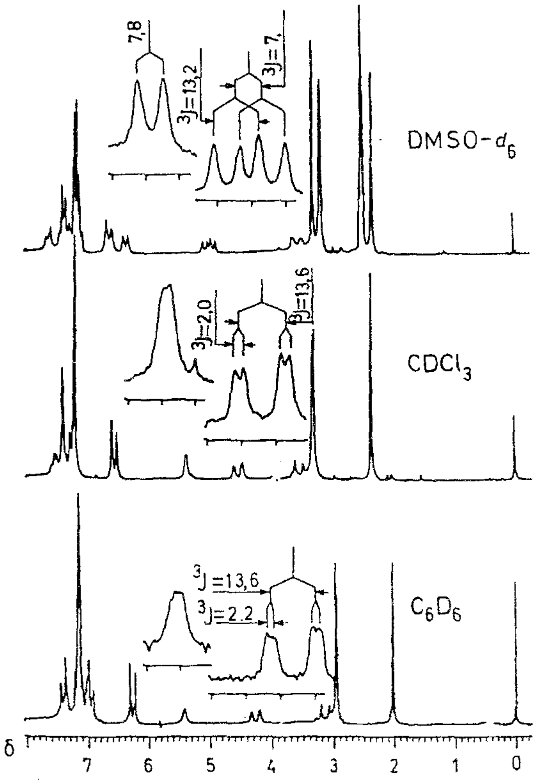


Fig. 1. The PMR spectra of compound (VII).

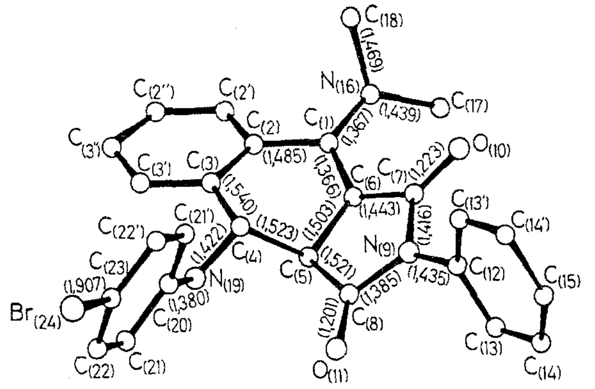


Fig. 2. The general appearance of the molecule of (VI).
(The hydrogen atoms are not shown.)

The last explanation led to the hypothesis that cycloaddition in the 1-dimethylamino-2R-isoindole system was nonsynchronous in nature [3]. In a subsequent paper [4] we returned to these interesting adducts. On the basis of 1-dimethylamino-2-(4-bromophenyl)isoindole we synthesized new adducts and carried out more detailed investigations into their structures by the NMR method [4]. As a result we detected the presence of a mobile structural fragment, containing a proton that exchanges in the presence of D_2O, in their structure, and we also observed certain special features of their solvation and complexation (Fig. 1) [4].

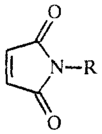
It is not possible to explain the obtained results in terms of the previously proposed structure (VI). It was suggested that 1,2-dihydronaphthalene-2,3-dicarboximides (V) are formed as a result of addition of the maleimide derivatives (II) to 1-dimethylamino-2-arylisoindoles (I) [4].

TABLE 1. The Bond Angles ω (Å) in the Molecule of (VI)

Angle	ω	Angle	ω
$C_{(7)}N_{(9)}C_{(8)}$	112,9 (4)	$N_{(9)}C_{(8)}C_{(5)}$	107,1 (3)
$C_{(7)}N_{(9)}C_{(12)}$	124,3 (3)	$N_{(9)}C_{(12)}C_{(13)}$	118,9 (4)
$C_{(8)}N_{(9)}C_{(12)}$	122,8 (3)	$N_{(19)}C_{(4)}C_{(3)}$	112,9 (3)
$C_{(1)}N_{(16)}C_{(17)}$	121,9 (4)	$N_{(19)}C_{(4)}C_{(5)}$	114,6 (4)
$C_{(1)}N_{(16)}C_{(18)}$	122,9 (4)	$C_{(3)}C_{(4)}C_{(5)}$	107,0 (3)
$C_{(17)}N_{(16)}C_{(18)}$	114,3 (4)	$C_{(4)}C_{(5)}C_{(6)}$	109,1 (3)
$C_{(4)}N_{(19)}C_{(20)}$	127,7 (4)	$C_{(4)}C_{(5)}C_{(8)}$	113,2 (3)
$N_{(16)}C_{(1)}C_{(2)}$	120,0 (3)	$C_{(6)}C_{(5)}C_{(8)}$	104,0 (3)
$N_{(16)}C_{(1)}C_{(6)}$	123,2 (4)	$C_{(1)}C_{(6)}C_{(5)}$	120,9 (3)
$C_{(2)}C_{(1)}C_{(6)}$	116,7 (3)	$C_{(1)}C_{(6)}C_{(7)}$	127,6 (3)
$C_{(1)}C_{(2)}C_{(2')}$	122,1 (5)	$C_{(5)}C_{(6)}C_{(7)}$	108,4 (4)
$C_{(1)}C_{(2)}C_{(3)}$	119,4 (3)	$O_{(10)}C_{(7)}N_{(9)}$	121,2 (3)
$C_{(2)}C_{(3)}C_{(4)}$	119,7 (4)	$O_{(10)}C_{(7)}C_{(6)}$	131,5 (3)
$C_{(3')}C_{(3)}C_{(4)}$	120,6 (4)	$N_{(9)}C_{(7)}C_{(6)}$	107,2 (3)
$N_{(9)}C_{(12)}C_{(13')}$	120,0 (4)	$O_{(11)}C_{(8)}N_{(9)}$	125,3 (4)
		$O_{(11)}C_{(8)}C_{(5)}$	127,6 (4)

In the present work the previously proposed structure (V) was demonstrated unambiguously for the adduct of 1-dimethylamino-2-(4-bromophenyl)-2H-isoindole with N-phenylmaleimide [compound (VI)] by the x-ray crystallographic method. The general appearance of the molecule of N-phenyl-1-(4-bromophenyl)amino-4-dimethylamino-1,2-dihydronaphthalene-2,3-dicarboximide (VI) is shown in Fig. 2, and the bond angles are given in Table 1.

The central cyclohexadiene ring $C_{(1\text{-}6)}$ is substantially nonplanar [the departures of the atoms from the mean-square plane amount to 0.351(5) Å] and has a conformation close to a "half-chair." (The modified Cremer—Pople parameters [5] Q, θ, and $\psi 2$ are 0.71, 126.1, and 309.4° respectively.) The torsion angles in the ring are as follows: $C_{(1)}C_{(2)}C_{(3)}C_{(4)}$, 3.8(7); $C_{(2)}C_{(3)}C_{(4)}C_{(5)}$, 34.9(6); $C_{(3)}C_{(4)}C_{(5)}C_{(6)}$, 56.8(5); $C_{(4)}C_{(5)}C_{(6)}C_{(1)}$, 46.6(6); $C_{(5)}C_{(6)}C_{(1)}C_{(2)}$, 6.6(7); $C_{(6)}C_{(1)}C_{(2)}C_{(3)}$, 19.8(7)°. The pyrrolidine heterocycle $N_{(9)}C_{(5\text{-}8)}$ and the benzene ring $C_{(2,2',2'',3,3',3'')}$ form dihedral angles of 32.7(3) and 17.6(5)° with the mean-square plane of the cyclohexadiene system. The five-membered heterocycle $N_{(9)}C_{(5\text{-}8)}$ is planar within 0.036(5) Å, and the $O_{(10)}$ and $O_{(11)}$ atoms do not lie exactly in this plane but project from it by −0.121(4) and 0.101(4) Å. The benzene ring $C_{(12\text{-}15,\ 14',13')}$ is rotated by 69.5(2)° in relation to the plane of the five-membered ring. Such a mutual orientation rules out the possibility of effective conjugation between the unshared electron pair (UEP) of the $N_{(9)}$ atom and the π system of the benzene ring, while the $N_{(9)}—C_{(12)}$ bond length of 1.435(5) Å is close to the value of 1.45 Å typical of a "purely single" $N(sp^2)—C(sp^2)$ bond [6]. On the other hand, the $N_{(16)}—C_{(1)}$ bond of 1.367(5) Å is greatly shortened. Together with this the $C_{(1)}—C_{(6)}$ bond of 1.366(5) is noticeably elongated in comparison with the typical value of 1.333 Å for a $C(sp^2)—C(sp^2)$ double bond [7]. This is probably due to conjugation between the UEP of the $N_{(16)}$ atom and the π system of the $C_{(1)}{=}C_{(6)}$ double bond. In fact, their mutual orientation is favorable for such conjugation; the dihedral angle between the plane of the amino group and the plane of the double bond is only 35.7(3)°. The $N_{(19)}—C_{(20)}$ bond of 1.380(5) Å is also noticeably shortened, and this indicates conjugation between the almost parallel π system (within 2-3°) of the benzene ring $C_{(20\text{-}23,\ 22',\ 21')}$ and the UEP of the $N_{(19)}$ atom. Attention is drawn to the substantial nonequivalence of the lengths of the $C_{(5)}—C_{(8)}$ [1.521(5)] and $C_{(6)}—C_{(7)}$ [1.443(6) Å] bonds. The shortening of the $C_{(6)}—C_{(7)}$ bond both in comparison with the value of 1.476 Å typical of a single $C(sp^2)—C(sp^2)$ bond [7] and in comparison with the range of 1.491-1.535 Å, obtained for the corresponding bond in previously investigated molecules [8-11] containing a pyrrolidine fragment (A),



may be due to conjugation between the π systems of the $C_{(1)}{=}C_{(6)}$ and $C_{(7)}{=}O_{(10)}$ double bonds. This suggestion agrees well with the increase in the length of the $C_{(7)}{=}O_{(10)}$ bond to 1.223(5) Å in comparison with the $C_{(8)}{=}O_{(11)}$ bond of 1.201(5) Å.

TABLE 2. The Coordinates of the Nonhydrogen Atoms

Atom	x	y	z	Atom	x	y	z
$Br_{(24)}$	-0,0026 (1)	-0,32840 (4)	-0,5035 (5)	$C_{(7)}$	0,5305 (5)	0,0704 (3)	-0,2246 (4)
$O_{(10)}$	-0,5466 (4)	0,1040 (2)	-0,1385 (3)	$C_{(8)}$	0,3957 (5)	0,0187 (3)	-0,4012 (4)
$O_{(11)}$	0,2949 (4)	0,0060 (2)	-0,4888 (3)	$C_{(12)}$	0,2658 (5)	0,0911 (3)	-0,3145 (4)
$N_{(9)}$	0,394 (3)	0,0619 (2)	-0,315 (4)	$C_{(13)}$	0,1945 (6)	0,1401 (3)	-0,3957 (5)
$N_{(16)}$	0,8510 (4)	0,0493 (3)	-0,0922 (4)	$C_{(13')}$	0,2129 (6)	0,0680 (3)	-0,2373 (5)
$N_{(19)}$	0,4797 (4)	-0,1282 (2)	-0,4342 (3)	$C_{(14)}$	0,0686 (7)	0,1671 (3)	-0,4001 (8)
$C_{(1)}$	0,7640 (5)	0,0104 (3)	-0,1832 (4)	$C_{(14')}$	0,0855 (6)	0,0958 (4)	-0,2422 (6)
$C_{(2)}$	0,8171 (5)	-0,0550 (3)	-0,2126 (4)	$C_{(15)}$	0,0141 (6)	0,1442 (4)	-0,3210 (7)
$C_{(2')}$	0,9637 (6)	-0,0696 (3)	-0,1737 (5)	$C_{(17)}$	0,8402 (6)	0,1233 (3)	-0,0913 (5)
$C_{(2'')}$	1,0087 (6)	-0,1309 (4)	-0,2015 (5)	$C_{(18)}$	0,9429 (8)	0,0190 (4)	0,0192 (5)
$C_{(3)}$	0,7187 (5)	-0,1033 (3)	-0,2849 (4)	$C_{(20)}$	0,3683 (5)	-0,1718 (2)	-0,4460 (4)
$C_{(3')}$	0,7674 (7)	-0,1647 (3)	-0,3112 (5)	$C_{(21)}$	0,3034 (6)	-0,2075 (3)	-0,5492 (4)
$C_{(3'')}$	0,9111 (7)	-0,1798 (3)	-0,2691 (6)	$C_{(21')}$	0,3191 (6)	-0,1826 (3)	-0,3606 (5)
$C_{(4)}$	0,5588 (5)	-0,0857 (3)	-0,3382 (4)	$C_{(22)}$	0,1939 (6)	-0,2530 (3)	-0,5664 (4)
$C_{(5)}$	0,5467 (5)	-0,0085 (3)	-0,3636 (4)	$C_{(22')}$	0,2093 (6)	-0,2294 (4)	-0,3773 (5)
$C_{(6)}$	0,6293 (5)	0,0302 (2)	-0,2542 (4)	$C_{(23)}$	0,1469 (5)	-0,2640 (3)	-0,4811 (5)

The $N_{(9)}$, $N_{(16)}$, and $N_{(19)}$ nitrogen atoms have a planar trigonal configuration of the bonds — the sums of the bond angles are 360.0(3), 359.1(4), and 360(6)° respectively.

In the crystal of compound (VI) there is a short intermolecular contact $N_{(19)}\cdots O_{(10)}$ (x, −y, −0.5+z) of 2.973(5), which probably corresponds to a hydrogen bond of the N—H···O type [$N_{(19)}—H_{(19)}$ 0.82(5), $O_{(10)}\cdots H_{(19)}$ 2.16(5) Å, $N_{(19)}H_{(19)}O_{(10)}$ 175(4)°].

EXPERIMENTAL

The unit cell parameters and the intensities of 2446 unique reflections were measured at 20°C on an Enraf—Nonius CAD-4 four-circle automatic diffractometer (λ MoK_α, graphite monochromator, $\omega:\theta = 1.2:1$, $\theta_{max} = 26°$). The crystals of the compound were monoclinic with $a = 10.260(1)$, $b = 19.366(4)$, $c = 12.683(3)$ Å, $\beta = 113.70(2)°$, $V = 2307.5$ Å^3, $Z = 4$, $d_{calc} = 1.41$ g/cm^3, space group Cc. In the structural calculations we used 1742 reflections with $F_{det} \geq 3\sigma$. The structure was interpreted by the heavy atom method and refined in anisotropic full-matrix approximation. All the hydrogen atoms were revealed in the electron density difference synthesis and refined isotropically with fixed B_{iso} values. The final divergence factors were $R = 0.044$ and $R_w = 0.055$. The calculations were conducted on a PDP-11/23 computer using the SDP-PLUS software [12]. The coordinates of the nonhydrogen atoms are given in Table 2.

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