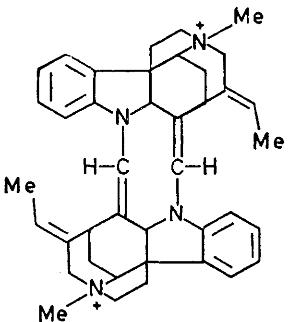
Crystal and Molecular Structure of 2,6-Bis(bromomethyl)-1,4-diphenylpiperazine

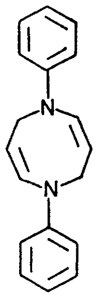
By **B. Morosin** * and **J. Howatson**, Sandia Laboratories, Albuquerque, New Mexico, 87115, U.S.A.

The crystal structure and molecular configuration of the title compound (IV) have been determined by a single crystal *X*-ray diffraction study. The crystals are monoclinic, space group $P2_1/n$, with $Z = 4$, $a = 10{\cdot}717$, $b = 17{\cdot}955$, $c = 9{\cdot}124$, and $\beta = 91{\cdot}28°$. The structure was solved by both Fourier and direct methods and refined by least-square techniques to R 0·074 for 1562 observed reflections. Most bond distances and angles are as expected. However, the chair form of the central piperazine ring is distorted with one interior C–N–C angle of 120°.

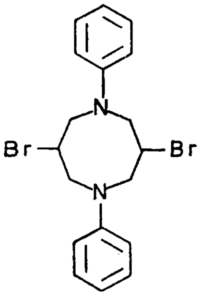
In studies of the photochemical behaviour of the curare alkaloid dehydrotoxiferine (I) the central ring system appears to be of importance.[1] In an attempt to synthesize[2] this central ring system as the compound 1,2,5,6-tetrahydro-1,5-diphenyl-1,5-diazocine (II), the first step was to attempt to replace the hydroxy-groups of 3,7-dihydroxy-1,5-diphenyl-1,5-diazocine by bromine atoms using the reagent phosphorus tribromide to yield the corresponding dibromide (III). Since the initial bromination reaction could conceivably produce various products other than the desired product, a solution n.m.r. spectrum of the intermediate compound was obtained which, unfortunately, did not distinguish unequivocally between the desired product (III) and any of a variety of suggested alternatives. Since this brominated intermediate could be isolated as a colourless crystalline product, an *X*-ray structure determination was undertaken and the compound proved to be an undesired product 2,6-bis(bromomethyl)-1,4-diphenylpiperazine (IV).



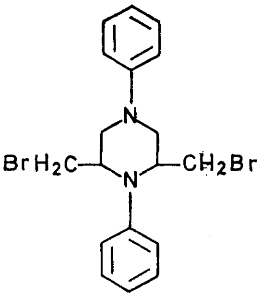
(I)



(II)



(III)



(IV)

EXPERIMENTAL

The compound crystallizes as colourless prisms which reversibly darken upon exposure to *X*-radiation. Preliminary precession photographs were used to determine the space group. Unit-cell parameters were obtained from diffractometer data.

Crystal Data.—$C_{18}H_{20}Br_2N_2$, Monoclinic, $a_0 = 10{\cdot}717(5)$, $b_0 = 17{\cdot}955(9)$, $c_0 = 9{\cdot}124(5)$ Å, $\beta = 91{\cdot}28(1)°$, $U = 1755{\cdot}2$ Å^3, $D_m = 1{\cdot}58$, $Z = 4$, $D_c = 1{\cdot}60$, $F(000) = 848$. Space group $P2_1/n$ from systematic absences: $h + l$ odd for $h0l$, and k odd for $0k0$. Mo-K_α *X*-radiation, $\lambda = 0{\cdot}7107$ Å; μ(Mo-K_α) = 30·5 cm^{-1}.

2142 intensities were measured on a Picker diffractometer equipped with a scintillation counter and pulse-height discriminator by use of the θ—2θ scan technique. Of the data 580 were measured $<3\sigma$, determined from counting statistics, and were considered to be unobserved in subsequent calculations. These data were measured on two crystal specimens (*ca.* 0·36 × 0·42 × 0·25 and *ca.* 0·26 × 0·38 × 0·22 mm, both mounted on the shortest direction, [010]); absorption corrections were applied to data from both crystals.

TABLE 1

Positional parameters for hydrogen atoms

Atom	*x*	*y*	*z*
H(1)	0·640	0·880	0·40
H(2)	0·880	0·680	0·38
H(31)	0·450	0·790	0·32
H(32)	0·536	0·764	0·50
H(41)	0·690	0·600	0·33
H(42)	0·661	0·653	0·52
H(6)	0·510	0·530	0·50
H(7)	0·260	0·490	0·50
H(8)	0·110	0·515	0·34
H(9)	0·160	0·645	0·16
H(10)	0·340	0·720	0·16
H(12)	0·770	0·910	0·36
H(13)	0·920	0·995	0·35
H(14)	1·180	0·935	0·31
H(15)	1·200	0·790	0·30
H(16)	1·020	0·710	0·32
H(171)	0·580	0·770	0·12
H(172)	0·700	0·850	0·09
H(181)	0·670	0·670	0·13
H(182)	0·810	0·730	0·09

Serving as a ' student problem,' the structure was solved by both Fourier (Patterson and subsequent Fourier and difference synthesis) and direct methods. Positional and thermal parameters were refined by the full-matrix, least-squares method, with the function $\Sigma w(F_o - F_c)^2$ minimized (weights were assigned from counting statistics or, for unobserved reflections, set to zero when $|F_o| > |F_c|$). Scattering factors and bromine dispersion corrections were

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[1] A. R. Battersby and H. F. Hodson, *Quart. Rev.*, 1960, XIV, 77.

[2] D. A. Nelson, J. J. Worman, and B. Keen, *J. Org. Chem.*, 1971, **36**, 3361.

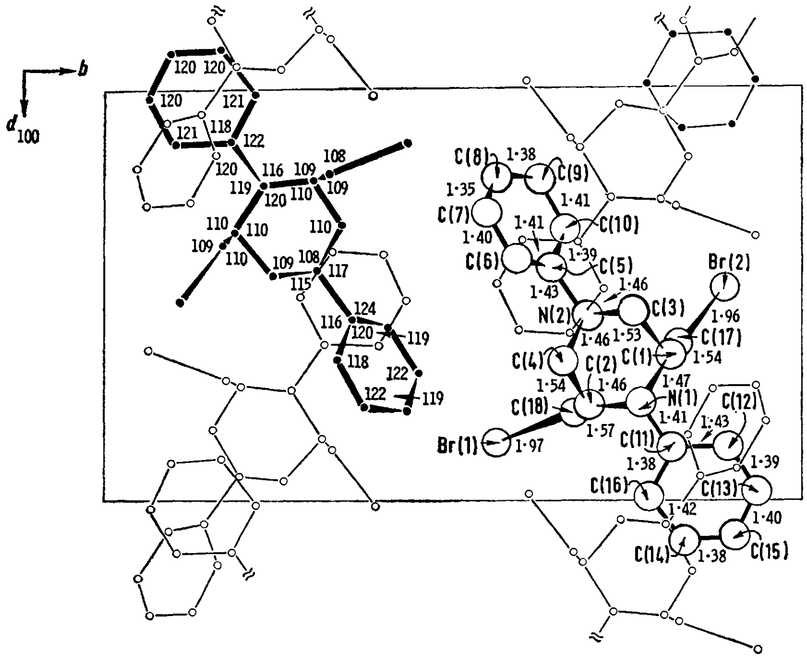
taken from ref. 3. Before the last four cycles of least-squares refinement, hydrogen atoms determined from a difference synthesis were located (Table 1) and included (B = 4·0 Å^2) as fixed atom contributions in subsequent structure-factor calculations. The final reliability index, R, is 0·074; final atomic positional and thermal parameters are listed in Table 2. The numbering system used is shown in the Figure; hydrogen atoms are labelled H(Xi), where X is the number of the carbon atom to which the hydrogen is attached and i is either blank or an index.*

TABLE 2

Positional and thermal parameters *

Atom	x	y	z	B_{11}	B_{22}	B_{33}	B_{12}	B_{13}	B_{23}
Br(1)	0·8662(1)	0·5789(1)	0·1363(2)	5·14(8)	4·88(8)	11·0(1)	1·20(2)	0·45(1)	−1·92(4)
Br(2)	0·4823(2)	0·8975(1)	0·1366(2)	6·58(9)	4·67(8)	9·5(1)	1·93(2)	−1·06(2)	0·19(5)
N(1)	0·7638(9)	0·7741(5)	0·348(1)	3·9(4)	3·1(4)	5·6(6)	−0·1(5)	0·5(4)	−0·0(3)
N(2)	0·5457(8)	0·6888(5)	0·326(1)	2·9(4)	4·1(4)	5·6(6)	0·1(5)	1·6(4)	0·9(3)
C(1)	0·643(1)	0·8114(6)	0·325(1)	4·3(6)	3·5(6)	5·3(6)	0·3(5)	0·2(6)	−0·1(4)
C(2)	0·775(1)	0·6937(6)	0·326(1)	4·3(6)	3·7(6)	5·3(6)	−0·2(5)	1·2(6)	0·9(4)
C(3)	0·538(1)	0·7636(6)	0·387(1)	5·1(6)	3·8(6)	5·3(6)	0·4(5)	1·9(6)	0·2(4)
C(4)	0·660(1)	0·6537(7)	0·386(1)	4·4(7)	4·1(6)	6·3(7)	0·3(5)	1·5(6)	1·2(5)
C(6)	0·413(1)	0·5892(7)	0·436(1)	5·4(7)	4·6(7)	6·8(7)	1·0(6)	2·0(6)	1·7(5)
C(7)	0·301(1)	0·5500(7)	0·431(2)	5·1(7)	3·7(6)	10·1(9)	0·1(6)	0·8(6)	1·2(5)
C(8)	0·209(1)	0·5666(8)	0·334(2)	6·7(8)	3·7(6)	8·4(9)	−0·5(6)	1·3(6)	−0·4(5)
C(9)	0·226(1)	0·6251(9)	0·238(2)	4·2(7)	10·6(9)	6·3(7)	0·6(6)	−0·7(6)	−0·9(5)
C(10)	0·339(1)	0·6657(8)	0·234(2)	3·8(6)	6·6(7)	8·3(9)	0·0(6)	0·1(6)	1·3(5)
C(11)	0·874(1)	0·8160(7)	0·337(1)	5·0(6)	4·2(6)	4·5(6)	−1·0(6)	−0·9(6)	−0·2(5)
C(12)	0·870(1)	0·8954(8)	0·347(1)	5·1(6)	6·2(7)	5·6(6)	−1·6(7)	−0·1(6)	0·1(5)
C(13)	0·978(2)	0·9376(8)	0·341(2)	7·1(8)	6·3(7)	6·4(7)	−2·2(7)	−1·1(7)	−0·1(5)
C(14)	1·101(4)	0·8257(9)	0·322(1)	5·0(7)	6·4(7)	6·8(7)	−1·3(7)	0·1(7)	0·6(5)
C(15)	1·094(1)	0·9025(9)	0·331(2)	6·4(8)	7·7(8)	6·0(7)	−2·9(7)	−0·1(6)	1·7(5)
C(16)	0·990(1)	0·7828(7)	0·321(1)	3·8(6)	5·5(7)	5·4(6)	−0·1(5)	0·1(6)	0·2(4)
C(17)	0·619(1)	0·8261(6)	0·160(1)	4·6(6)	3·7(6)	5·5(6)	0·7(5)	−0·5(6)	0·9(4)
C(18)	0·785(1)	0·6767(6)	0·159(1)	4·0(6)	3·1(6)	6·9(6)	1·2(6)	0·5(6)	0·2(4)
C(5)	0·433(1)	0·6466(6)	0·333(1)	3·7(6)	4·1(7)	4·3(6)	0·4(6)	0·3(6)	−0·5(4)

* Thermal parameters in the form: $\exp(-0{\cdot}25\sum_{i}^{3}\sum_{j}^{3}B_{ij}h_ih_ja_i^*a_j^*$.



A representation of the structure of 2,6-bis(bromomethyl)-1,4-diphenylpiperazine viewed along the c axis. Two molecules appear darker so as to clarify packing arrangement. Labelling of atoms used in the text is also indicated

DESCRIPTION AND DISCUSSION

The bond angles and bond lengths for the molecule are given in the Figure. The standard deviations for the C–Br lengths are 0·01 Å, for the other bond lengths 0·02 Å, and for the bond angles 1°. These values are typical of those found in organic molecules containing

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* Observed and calculated structure factors are listed in Supplementary Publication No. SUP 20372 (3 pp., 1 microfiche). For details see Notice to Authors No. 7 in *J. Chem. Soc.* (*A*), 1970, Issue No. 20 (items less than 10 pp. are sent as full size copies).

[3] 'International Tables for X-Ray Crystallography,' vol. III, Kynoch Press, Birmingham, 1962, pp. 202, 213.

atoms of high atomic number. The intramolecular contact separations include C(18) $\cdots$ C(17) 3·22, C(1) $\cdots$ C(12) 2·87, C(2) $\cdots$ C(16) 2·81, C(4) $\cdots$ C(6) 2·92, and C(3) $\cdots$ C(10) 3·08 Å.

The central piperazine ring is in a distorted chair configuration. All interior angles of this heterocyclic ring are approximately tetrahedral, except the C(1)–N(1)–C(2) angle which is 120°, as has been found in other structure studies (piperazine hexahydrate,[4] piperazine-1,4-dibutyric acid,[5] and piperazine dihydrochloride monohydrate[6]. The least-squares plane through C(1), C(2), C(3), and C(4) intersects the plane through N(1), C(1), and C(2) and through N(2), C(3), and C(4) by 51·7 and 61·4°, respectively. The combination of the latter 120° value along with the exterior angles involving N(1) [C(1)–N(1)–C(11) 119°, and C(2)–N(1)–C(11) 116°] is consistent with sp^2 hybridization for this nitrogen atom. The phenyl ring attached to N(1) is essentially coplanar with the plane described by C(1), N(1), and C(2) and forms an angle of 18·0° with it [an angle of 20·8° is formed with respect to the C(1), C(2), C(3), and C(4) plane]. This provides for maximum interaction between the π electrons of the phenyl ring and the unhybridized p electron pair of N(1). The shortening of the N(1)–C(11) bond to 1·41 Å compared to the accepted N–C single-bond value of 1·47 Å is consistent with such interaction. This bond length comparison is suspect, however, in view of the high standard deviation observed. In other piperazine structure studies [4-6] the N–C bond lengths range from 1·46 to 1·51 Å and the C–N–C bond angles range from 109·3 to 110·6°. We are aware of only one piperazine compound, piperazine-2,5-dione,[7] in which the 126° C–N–C bond angle is greater than the tetrahedral value; however, in this compound, the keto-groups force an essentially planar ring configuration.

Inspection of a space-filling molecular model of the molecule reveals that the phenyl ring attached to N(1) is not free to rotate around the N(1)–C(11) bond. Free rotation is prevented by intramolecular hydrogen–hydrogen van der Waals repulsions in which the C(16) hydrogen on one side of the phenyl ring is restricted by the piperazine C(2) hydrogen and one of the methyl C(18) hydrogens and the C(12) hydrogen on the other side of the phenyl ring is restricted by the piperazine C(1) hydrogen and one of the methyl C(17) hydrogens. The molecular model further reveals that a second rotation-restricted orientation of this phenyl ring at 90° to that observed is also possible. Presumably this would be a higher-energy configuration, not being favourable for π-bonding to the nitrogen.

The phenyl group attached to the other nitrogen atom, N(2), is tilted substantially out of the plane fixed by C(3), N(2), C(4) and forms an angle of 61·4° with it [an angle of 51·4° is formed with respect to the C(1), C(2), C(3), and C(4) plane]. Intramolecular hydrogen–hydrogen repulsion also prevents free rotation of this ring.

There are no exceptionally short intermolecular contacts. The five shortest intermolecular C–C separations are: C(18) $\cdots$ C(14) 3·62, C(7) $\cdots$ C(17) 3·64, C(10) $\cdots$ C(11) 3·67, C(13) $\cdots$ C(13) 3·69, and C(8) $\cdots$ C(17) 3·70 Å, in which one mentioned carbon atom resides on a symmetry related molecule.

We thank Dr. D. A. Nelson for suggesting the investigation and for providing the crystals, and R. Trudo for laboratory assistance. We also thank the U.S. Atomic Energy Commission for financial support of this work, and Associated Western Universities for financial support (to J. H.).

[1/2144 *Received, 15th November*, 1971]

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