The Structure, Absolute Configuration, and Chemistry of Nogalose[1]

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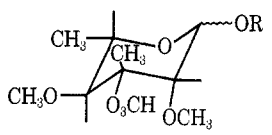
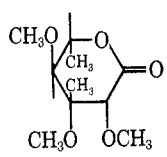
The structure of nogalose, $C_{10}H_{20}O_5$, the sugar portion of the antibiotic nogalamycin, has been determined and certain aspects of its chemistry have been investigated. Deductions primarily from nmr data on the native sugar and several derivatives indicated the gross structure. An X-ray crystal structure study of *N*-(*p*-bromobenzyl)-nogalonamide gave the absolute configuration of nogalose except for C-1. These studies show that nogalose has the structure represented by I. The configuration is that of L-rhamnose. X-Ray and nmr results are discussed in detail.

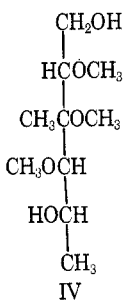
Nogalose (I) is a neutral sugar which has been obtained by acid hydrolysis of the antibiotic nogalamycin.[1,2] The present report discusses the determination of the total structure of I as derived from physical, chemical, and crystallographic data, as well as discussing some of the chemistry of I.



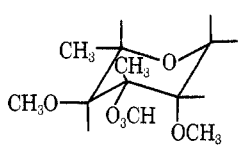
I, R = H
II, R = CH_3



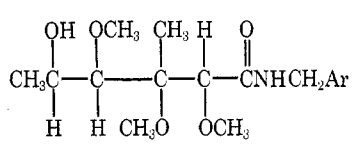
III



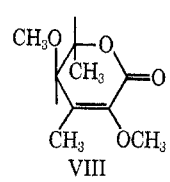
IV



V



VI, Ar = C_6H_5
VII, Ar = *p*-BrC_6H_4

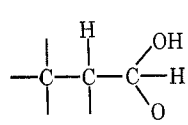


VIII

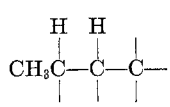
Nogalose is a colorless, crystalline, neutral compound which was shown to have a molecular formula of $C_{10}H_{20}O_5$ by analyses and a mass spectral molecular weight determination. The nmr spectrum ($CDCl_3$) showed the presence of three CH_3O groups (three singlets, each representing 3 H, at δ 3.20, 3.40, and 3.45) and two CH_3C groups (a doublet representing 3 H centered at δ 1.14 and a singlet representing 3 H at δ 1.30). Although nogalose is only very weakly reducing, its composition and source were suggestive of a sugar. The infrared spectrum of I showed the absence of carbonyl and the presence of one or more hydroxyl groups and considerable C–O bonding. The nmr spectrum of I has a doublet of doublets due to 1 H centered at δ 5.15, which is a strong indication of anomeric hydrogen. Treatment of I with methanolic hydrogen chloride gave a methyl glycoside (II) as evidenced by an nmr signal due to a fourth methoxyl (δ 3.36) and disappearance of hydroxyl bands from the infrared spectrum. I was readily oxidized by treatment with Jones reagent to give a lactone III, as shown by absence of infrared bands due to hydroxyl and appearance of a carbonyl band at 1765 cm^{-1}. These four lines of evidence leave little doubt that nogalose is a sugar. Reduction of nogalose to nogalitol (IV) also occurs as would be expected of a sugar, but vigorous conditions are required.[3] Attempted preparation of the *p*-tosyl derivative of IV resulted in cyclization to the corresponding pyran V. A similar reaction has been reported by Rabinsohn and Fletcher,[4] and, in their case, the stereochemistry of the carbon bearing the secondary hydroxyl group was retained. Reasoning from analogy and from theory, it seems likely that the stereochemistry of the pyran is as indicated in V.

The lactone III reacts readily with benzylamines to form amides (VI and VII), the second of which was used for crystallographic studies. Treatment of III with piperidine resulted in elimination of methanol rather than amide formation, giving rise to an unsaturated lactone VIII.

The gross structure of nogalose and part of the stereochemistry was deduced from the nmr data. The anomeric hydrogen of nogalose is coupled with an exchangeable hydrogen (δ 6.30, J = 4 Hz) and a hydrogen on carbon (δ 3.25, J = 2 Hz). The hydrogen on C-2 is not coupled with a hydrogen at C-3, indicating the system



in which the adjacent protons on carbon are *ee* or *ae*. A doublet attributable to a methyl group has already been mentioned. The protons on the methyl group are coupled (J = 6 Hz) with a hydrogen which gives rise to a multiplet centered at δ 3.7. The single proton is again coupled with a single hydrogen (d, δ 2.98, J = 9 Hz), and the coupling constant indicates a diaxial arrangement. The second hydrogen has no other proton on an adjacent carbon. Such data suggest the presence of a moiety



(1) A preliminary report of a portion of this work has already been published: see P. F. Wiley, F. A. MacKellar, E. L. Caron, and R. B. Kelly, *Tetrahedron Lett.*, 663 (1968). This study was supported in part by Contract PH43-68-1023, Cancer Chemotherapy National Service Center, National Cancer Institute, NIH, Bethesda, Md.

(2) (a) B. K. Bhuyan and A. Dietz, *Antimicrob. Ag. Chemother.*, 836 (1965); (b) B. K. Bhuyan, R. B. Kelly, and R. M. Smith, U. S. Patent 3,183,157 (May 11, 1965).

(3) W. Keller-Schierlein and G. Roncari, *Helv. Chim. Acta*, **45**, 138 (1962).

(4) Y. Rabinsohn and H. G. Fletcher, Jr., *J. Org. Chem.*, **32**, 3452 (1967).

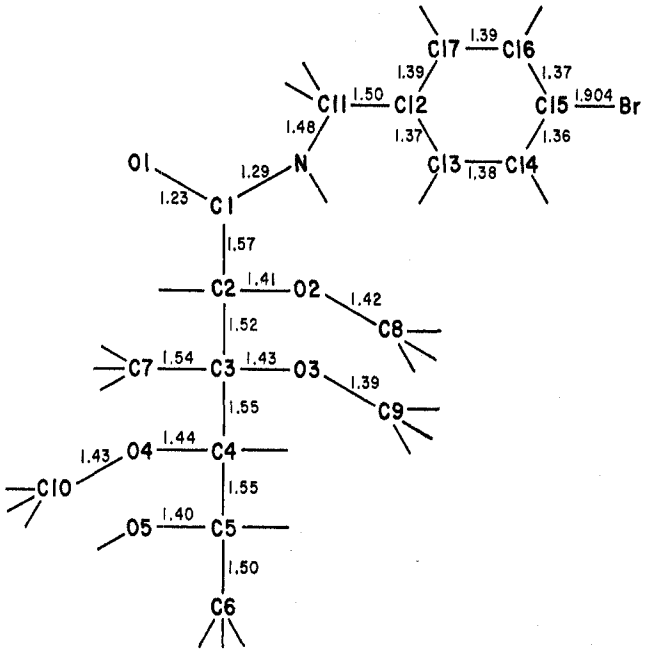


Figure 1.—Interatomic distances of *N*-(*p*-bromobenzyl)-nogalonamide. Drawing of the sugar fragment is in the correct absolute configuration and in the usual Fischer projection. Standard deviations in the bond distances are about 0.015 Å. Distances shown are the average over the two molecules.

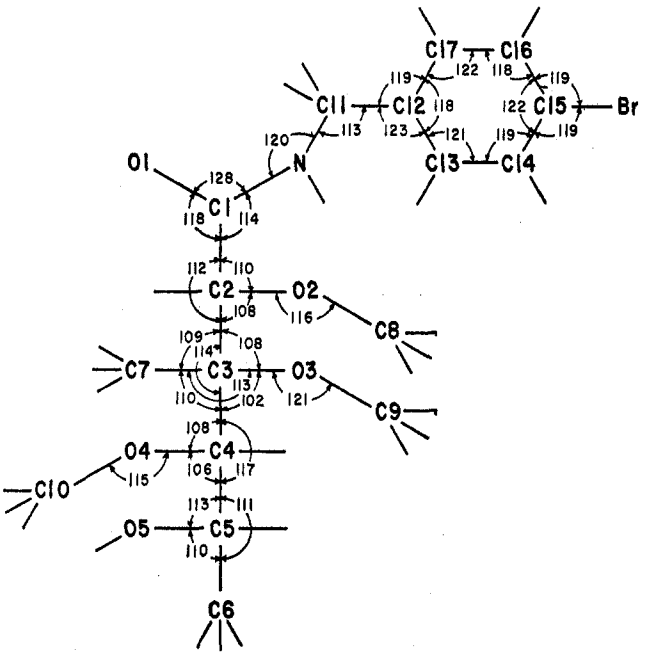


Figure 2.—Bond angles of *N*-(*p*-bromobenzyl)nogalonamide. Angles shown are the average over the two molecules. Standard deviations in the bond angles are about 1°.

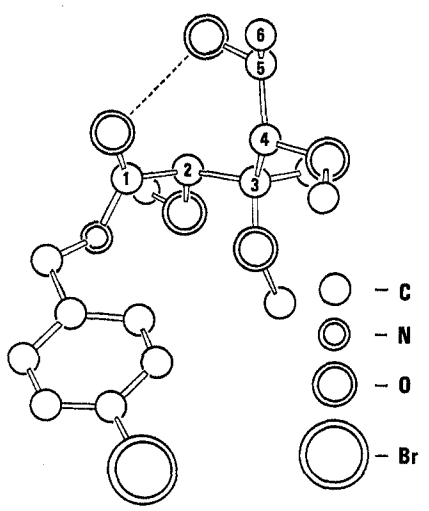


Figure 3.—Computer drawing of molecule 2 of *N*-(*p*-bromobenzyl)nogalonamide from crystallographic data. Projection is in an arbitrary direction in the unit cell.

Combining the two portions of the molecule and considering the methyl and methoxyl groups known to be present, nogalose must have the gross structure (although not necessarily the stereochemistry) indicated in I or the isomeric furanose structure with a methoxyl group at C-5. It is clear from the nmr of III that the pyranose structure is correct, since the proton giving rise to a multiplet, which indicates it is on C-5, shifts substantially downfield in the spectrum of III, as compared with its chemical shift in the spectrum of I.

Crystal structure results on VII are shown in Figures 1, 2, and 3. These results confirm the nmr deductions and show clearly that nogalose has the configuration of L-rhamnose (6-deoxy-L-mannose). L-Rhamnose is known to occur widely in nature.[5] The average bond distances and angles for the two molecules in the crystallographic asymmetric unit, shown in Figures 1 and 2, do not differ significantly from those found previously in other sugars.[6] Figure 3 shows the conformation of one of the molecules; the conformation of the other is very similar. The folding of the sugar is dominated by a strong intramolecular hydrogen bond from the hydroxyl group (O5) to the carbonyl (O1). The O1–O5 distances in molecules 1 and 2 are 2.65 and 2.75 Å, respectively. Intermolecularly, N of molecule 1 is hydrogen bonded to O5 of molecule 2 (d = 2.94 Å), and N of molecule 2 is in turn hydrogen bonded to O5 of molecule 1 translated one unit in the x direction (d = 2.90 Å), thus forming an infinite chain in the x direction.

The determination of the configuration of nogalose by the use of VII gives no indication of conformation. However, the conformation indicated in I is that expected and is that indicated by the nmr spectrum of nogalose. The coupling constant of 9.09 Hz exhibited by H-4 and H-5 quite conclusively indicates a diaxial relationship which would necessitate the conformation indicated. The configuration of C-1 is not established in the present work, but the nmr indicates that only one isomer is present, and the equatorial hydroxyl conformation seems probable in the total antibiotic in view of crowding in the axial isomer. If such were the case, the configuration would be β.

(5) L. Glaser, *Physiol. Rev.*, **43**, 215 (1963).

(6) (a) H. S. Kim, G. A. Jeffrey, and R. D. Rosenstein, *Acta Crystallogr., Sect. B*, **25**, 2223 (1969); (b) H. M. Berman, S. S. C. Chu, and G. A. Jeffrey, *Science*, **157**, 1576 (1967).

Experimental Section

Nogalose (I).—Nogalamycin (5 g) was dissolved in 100 ml of 0.4 *N* HCl, and the solution was boiled under reflux for 0.5 hr. The cooled reaction mixture was extracted with four 50-ml portions of chloroform. The combined extracts were dried ($MgSO_4$) and evaporated to dryness under reduced pressure. The residue was sublimed at 60° (0.02 mm), yield 0.83 g, mp 110°. A portion (400 mg) was recrystallized twice from ethyl acetate and sublimed again: yield 190 mg; mp 115–121°; $[\alpha]^{25}D$ −10.6°

(c 1, CH_3OH); $[\alpha]^{25}D$ +15.5° (c 1, H_2O); ν_{max}^{Nujol} 3400, 1195, 1175, 1155, 1110, 1085, 1060, and 1035 cm^{-1}.

Anal. Calcd for $C_{10}H_{20}O_5$: C, 54.52; H, 9.15; O, 36.32; mol wt, 220.26. Found: C, 54.72; H, 9.28; O, 35.87; mol wt (mass spectrum), 220.

Methyl Nogaloside (II).—A solution of 200 mg of nogalose in 10 ml of 5% methanolic HCl was allowed to stand at room temperature for 36 hr. The reaction mixture was poured into 40 ml of 5% $NaHCO_3$ solution which was extracted with four 10-ml portions of chloroform. The combined extracts were dried ($MgSO_4$) and concentrated under reduced pressure. The residue was sublimed four times at 35° (0.02 mm): mp 41–43°; $[\alpha]^{25}D$ −48.4° (c 1, CH_3OH); nmr ($CDCl_3$) δ 1.28 (3 H, d, J = 6.3 Hz), 1.31 (3 H, s), 3.07 (1 H, d, J = 9.5 Hz), 3.28 (3 H, s), 3.36 (3 H, s), 3.49 (3 H, s), 3.53 (3 H, s), 3.63 (1 H, m), and 4.72 (1 H, d, J = 2 Hz). The ir spectrum showed no band in the OH region.

Anal. Calcd for $C_{11}H_{22}O_5$: C, 56.38; H, 9.47; O, 34.14. Found: C, 55.93; H, 9.34; O, 33.38.

Nogalolactone (III).—A solution of 1.10 g (5 mmol) of nogalose in 30 ml of acetone was stirred while adding 2.4 ml (6.6 mmol) of Jones reagent dropwise. The solution was allowed to stand at room temperature for 4 hr, followed by addition of 100 ml of water and concentration under reduced pressure until the acetone was removed. The residue was extracted with five 100-ml portions of chloroform. The combined chloroform extracts were dried ($MgSO_4$) and evaporated under reduced pressure until a light-brown liquid remained, wt 0.97 g. Distillation under reduced pressure gave 236 mg; bp 76° (0.1 mm); $[\alpha]^{25}D$ +15.9° (c 1, $CHCl_3$); ν_{max}^{neat} 1765, 1195, 1170, 1140, 1100, 998, 955, 934, 860, and 804 cm^{-1}; nmr ($CDCl_3$) δ 1.37 (3 H, s), 1.48 (3 H, d, J = 6 Hz), 3.20 (1 H, d, J = 7 Hz), 3.33 (3 H, s), 3.52 (3 H, s), 3.58 (3 H, s), 3.83 (1 H, s), and 4.21 (1 H, m, J = 6 and 7 Hz).

Anal. Calcd for $C_{10}H_{18}O_5$: C, 55.06; H, 8.31; O, 36.66. Found: C, 54.99; H, 8.77; O, 34.69.

Nogalitol (IV).—A mixture of 0.8 g of nogalose, 0.8 g of lithium aluminum hydride, and 120 ml of anhydrous dioxane was boiled under reflux for 6 hr. The cooled reaction mixture was acidified by the addition of 20 ml of 6 N HCl. The aqueous layer was removed and the dioxane layer was dried (KOH). The solvent was removed by evaporation under reduced pressure, leaving a colorless syrup, wt 0.52 g. The residue (0.3 g) was chromatographed on 15 g of silica gel, using a chloroform–methanol (95:5) system, and collecting 5-ml fractions. Fractions 3–15 were combined on the basis of weight analysis. The yield of clear, colorless oil was 0.26 g: $[\alpha]^{25}D$ −13° (c 1, CH_3OH); significant ir bands at 3340 and 1115 cm^{-1}; nmr ($CDCl_3$) δ 1.18 (3 H, d, J = 6 Hz), 1.31 (3 H, s), 2.97 (1 H, d, J = 7 Hz), 3.35 (3 H, s), 3.53 (6 H, s), 3.42–3.85 (3 H, m), and 4.1 (1 H, m, J = 6 and 7 Hz). Two exchangeable H's appear as broad peaks at δ 3.12 and 3.78.

Anal. Calcd for $C_{10}H_{22}O_5$: C, 54.03; H, 9.97. Found: C, 53.81; H, 10.05.

2*S*,3*S*,4*S*,5*S*-2,4-Dimethyl-3,4,5-trimethoxytetrahydropyran (V).—A solution of 222 mg (1 mmol) of nogalitol and 192 mg (1.12 mmol) of p-tosyl chloride in 10 ml of dry pyridine was allowed to stand at room temperature for 6 days. The solvent was removed by distillation under reduced pressure at 35°. The residue was chromatographed on 20 g of silica gel using chloroform as the solvent and collecting fifty 5-ml fractions. Fractions 32–38 were combined on the basis of a weight analysis and only one spot in tlc (silica gel, cyclohexane–ethyl acetate–ethanol, 5:3:2). Evaporation of the combined fractions under reduced pressure gave 66 mg of colorless liquid. The ir spectra showed no bands in the OH region, and the only strong band was at 1110 cm^{-1}: nmr ($CDCl_3$) δ 1.22 (3 H, s), 1.28 (3 H, d, J = 5 Hz), 3.02 (1 H, d, J = 7 Hz), 3.1 and under the methoxyl signals, 3.27 (3 H, s), 3.41 (3 H, s), 3.51 (3 H, s), 4.02 (1 H, d of d, J = 2 and 13 Hz).

Anal. Calcd for $C_{10}H_{20}O_4$: C, 58.78; H, 9.87; mol wt, 204.1361. Found: C, 58.31; H, 10.23; mol wt (mass spectrum), 204.1357.

***N*-Benzylnogalonamide (VI).**—A solution of 1.45 g (6.6 mmol) of nogalolactone and 1.4 g (13.2 mmol) of benzylamine in 15 ml of methanol was allowed to stand at room temperature for 3 days. The residue remaining after removal of the solvent under reduced pressure was mixed with 10 ml of water, and the solution was adjusted to pH 2.0 with 1 N HCl. The acidic solution was extracted with three 10-ml portions of chloroform which were combined and dried ($MgSO_4$). The dried solution was concentrated under reduced pressure, and the residue was recrystallized three times from Skellysolve B: yield 0.55 g; mp 91–93°; $[\alpha]^{25}D$ +28° (c 1, $CHCl_3$); ν_{max}^{Nujol} 3250, 1635, and 1530 cm^{-1}; nmr ($CDCl_3$) δ 1.26 (3 H, d, J = 6.2 Hz), 1.41 (3 H, s), 3.07 (1 H, d, J = 8.5 Hz), 3.35 (3 H, s), 3.37 (3 H, s), 3.70 (1 H, m), 4.18 (1 H, s), 4.32 (1 H, exch, broad), 4.42 (2 H, d of d), 7.17 (1 H, exch, broad), 7.3 (5 H, s).

Anal. Calcd for $C_{17}H_{27}NO_5$: C, 62.74; H, 8.36; N, 4.31; O, 24.59. Found: C, 62.37; H, 8.18; N, 4.71; O, 24.42.

***N*-(*p*-Bromobenzyl)nogalonamide (VII).**—A solution of 1.09 g (5 mmol) of nogalolactone and 0.976 g (5.3 mmol) of p-bromobenzylamine in 12 ml of methanol was allowed to stand at room temperature for 4 days. The solvent was removed by evaporation under reduced pressure. The residue was mixed with 10 ml of water, and the mixture was adjusted to pH 2.0 with 1 N HCl. The precipitate which formed was removed by filtration and recrystallized from methanol: yield 0.44 g; mp 120–121°; ν_{max}^{Nujol} 3150, 1640, 1550, 1280, 1175, 1106, 1082, 1030, 1015, 965, 838, 820, and 803 cm^{-1}.

Anal. Calcd for $C_{17}H_{26}BrNO_5$: C, 50.45; H, 6.58; N, 3.66; Br, 19.96. Found: C, 50.54; H, 6.49; N, 3.47; Br, 19.78.

(4*S*,5*S*)-2,4-Dimethoxy-3-methyl-2-hexen-5-olide (VIII).—A solution of 2.20 g (10 mmol) of nogalolactone and 1.70 g (20 mmol) of piperidine in 35 ml of methanol was allowed to stand at room temperature for 3 days. The methanol was removed by evaporation under reduced pressure. The residue was mixed with 16 ml of water, and the mixture was adjusted to pH 3.5 with 1 N HCl. The aqueous system was extracted with three 16-ml portions of chloroform. The combined chloroform extracts were dried ($MgSO_4$) and evaporated under reduced pressure. Distillation under reduced pressure [bath temperature, 100–110° (0.3 mm)] gave a colorless liquid: yield 0.90 g; λ_{max}^{EtOH} 210 mμ (ε 7720), 224 (6050); ν_{max}^{neat} 1710, 1650, 1270, 1215, 1185, 1155, 1105, 1080, 1040, 980, 938, 908, 882, 787, and 762 cm^{-1}; nmr ($CDCl_3$) δ 1.42 (3 H, d, J = 5 and 6 Hz), 1.95 (3 H, s), 3.46 (3 H, s), 3.63 (1 H, s), 3.72 (3 H, s), 4.48 (1 H, m).

Anal. Calcd for $C_9H_{14}O_4$: C, 58.05; H, 7.58; O, 34.37. Found: C, 58.06; H, 7.96; O, 34.28.

X-Ray Structure Studies on VII. Experimental.—Crystals of *N*-(p-bromobenzyl)nogalonamide (VII) were monoclinic with lattice parameters: a = 12.862 ± 0.001 Å, b = 9.402 ± 0.001 Å, c = 16.139 ± 0.002 Å, and β = 96.21 ± 0.01°. Systematic absences for $0k0$ reflections with k odd indicated space group $P2_1$: X = 1940 Å^3, d_m = 1.379 g/cm^3, Z = 4, d_c = 1.384 g/cm^3. The linear absorption coefficient (μ) for Cu Kα radiation is 34.0 cm^{-1}.

Three-dimensional X-ray intensity data were gathered on an automated diffractometer using nickel filtered Cu K radiation; the θ–2θ scan technique was used with 3.5° scans at 4°/min and 20-sec background counts at each end of the scan. Two crystals were used, the first being replaced by the second after a deterioration of 15–20% in intensity of check reflections had occurred. Orientations of both crystals were correlated carefully since anomalous dispersion work was contemplated. For scaling purposes, 21 selected reflections taken at the beginning of data collection of the first crystal were retaken using the second crystal. Lorentz and polarization corrections[7] and separate absorption corrections[8] were applied to data from both crystals prior to scaling the two sets together. Standard deviations were assigned by the equation[9]

$$\sigma^2(I) = \sigma^2_{\text{counting statistics}} + (0.03\,I)^2$$

and were scaled by propagation of error techniques through all corrections. The data (3427 reflections) were placed on an approximate absolute scale by a Wilson plot.

Trial Structure.—An attempt was made to obtain a trial structure by the heavy atom method. Trial positions for the two bromine atoms were found easily from a three-dimensional Patterson function. The positions, however, were separated by 0.50 in y and just off pseudo special positions in the other directions. Structure factors, calculated from the heavy atoms only, gave R = 0.498. After extensive analyses of several three-dimensional electron density maps failed to yield a trial structure,

(7) All computer calculations were done on the IBM 360 computer using programs of the CRYM system written by D. J. Duchamp.

(8) W. R. Busing and H. A. Levy, *Acta Crystallogr.*, **10**, 180 (1957).

(9) S. W. Peterson and H. A. Levy, *ibid.*, **10**, 70 (1957).

TABLE I

ATOMIC PARAMETERS (× 10^5) AND THEIR STANDARD DEVIATIONS[a]

	Molecule 1			Molecule 2		
	X	Y	Z	X	Y	Z
Br	44048 (7)	100077 (0)	8596 (6)	−1022 (8)	4423 (19)	53089 (6)
N	81861 (39)	52852 (92)	25807 (36)	30767 (42)	24896 (83)	23530 (34)
C1	89332 (52)	47096 (119)	22314 (42)	39992 (61)	30042 (108)	25860 (42)
C2	88625 (52)	30417 (102)	21644 (45)	40987 (50)	46474 (101)	24421 (41)
C3	85588 (52)	25192 (101)	12910 (44)	40043 (49)	54816 (109)	32509 (40)
C4	93850 (58)	28875 (106)	6735 (43)	47394 (49)	49822 (105)	40084 (39)
C5	105397 (66)	24202 (124)	9681 (56)	59215 (55)	50503 (123)	39823 (49)
C6	111874 (73)	24839 (143)	2417 (62)	65020 (65)	44350 (144)	47495 (54)
C7	84066 (62)	9053 (113)	12845 (50)	41436 (71)	70819 (123)	30714 (52)
C8	84189 (64)	21455 (137)	34894 (49)	35782 (62)	50501 (149)	10061 (46)
C9	66673 (60)	28317 (132)	10626 (53)	21077 (71)	59644 (146)	32420 (62)
C10	86961 (94)	30904 (148)	−7790 (57)	39989 (75)	51561 (153)	53308 (49)
C11	81870 (61)	68881 (123)	27110 (52)	28227 (60)	10436 (110)	25457 (51)
C12	72441 (55)	75867 (105)	22490 (45)	20579 (57)	9190 (105)	31779 (48)
C13	67950 (62)	71615 (115)	14562 (50)	14105 (67)	−2031 (134)	32030 (53)
C14	59835 (65)	78446 (122)	10568 (48)	7640 (61)	−3652 (130)	38695 (69)
C15	55646 (55)	90042 (110)	14290 (46)	7955 (60)	6406 (121)	44589 (51)
C16	59627 (59)	94711 (101)	22283 (46)	14082 (67)	17922 (120)	44554 (51)
C17	68005 (55)	87262 (106)	26359 (48)	20641 (59)	18960 (110)	38211 (52)
O1	96794 (36)	52902 (75)	19570 (34)	47562 (39)	23489 (71)	29248 (30)
O2	80763 (36)	25666 (65)	26519 (29)	33288 (33)	51364 (77)	18288 (25)
O3	76654 (36)	32911 (76)	9196 (30)	28886 (32)	51528 (73)	34829 (28)
O4	90639 (43)	21419 (77)	−988 (32)	45352 (41)	58228 (71)	47119 (30)
O5	110009 (36)	32678 (82)	16044 (34)	62548 (34)	44204 (74)	32594 (31)

[a] Coordinates are given for a left-handed coordinate system.

we turned to statistical phasing. The phases from structure factors calculated from the two bromine atoms were used as input to a tangent formula phase refinement and extension.[10] By using 136 input phases for reflections with $E > 1.6$, a set of refined phases for 875 reflections with $E > 1.15$ was obtained. An E map calculated using these phases gave positions for 15 possible lighter atoms. These trial atoms were used to phase another cycle of tangent formula refinement. The resulting E map yielded positions of 23 lighter atoms. Two subsequent electron density maps served to correctly extend this set to all 46 lighter atoms. The resultant trial structure gave $R = 0.275$.

Refinement and Absolute Configuration.—The trial structure and a scale factor were refined by multiple-matrix least squares.[7] The function minimized was $\Sigma w(|F_o|^2 - |F_c|^2)^2$ where initially the Hughes $1/F_o$ weighting scheme was used. Form factors to calculate structure factors were from the literature.[11] After two cycles of refinement with all lighter atoms designated as carbon, analysis of interatomic distances and large reductions in certain isotropic temperature factors allowed assignment of N and O atoms. Refinement continued; anisotropic thermal parameters were added at the appropriate time. Hydrogen atoms, located in a difference Fourier, were used in the calculations but not refined. When hydrogens were added, the weighting scheme was shifted to

$$w = 1/\sigma(F_o^2)$$

where $\sigma(F_o^2)$ is that assigned in the data reduction.

When refinement without anomalous dispersion had converged ($R = 0.073$), a computer search was made to find those reflections most affected by anomalous dispersion. From a list of 50, 18 were selected for checking by Bijvoet's method.[12] Accurate diffractometer scans showed that 17 are in agreement with the assigned absolute configuration; the one which does not agree has the second-to-weakest calculated difference.

Refinement was continued with anomalous dispersion effects included in the calculations. Convergence was obtained at $R = 0.071$ (all reflections including the very weak included). At this point, all shifts were less than one-third the corresponding standard deviations. The final goodness of fit

$$= \left[\frac{\Sigma w(|F_o|^2 - F_c|^2)^2}{m - s}\right]^{1/2}$$

was 1.6, indicating a good fit of the data.

Final atomic coordinates and their standard deviations are given in Table I for both independent molecules in the unit cell.[13]

Registry No.—I, 30319-19-8; II, 30319-20-1; III, 30319-21-2; IV, 30319-22-3; V, 30319-23-4; VI, 30319-24-5; VII, 30319-48-3; VIII, 30319-49-4.

(10) J. Karle, *Acta Crystallogr., Sect. B*, **24**, 182 (1968).

(11) Atomic form factors are from "International Tables for X-Ray Crystallography," Vol. III, Kynoch Press, Birmingham, England, 1959; anomalous dispersion factors are from D. T. Cromer, *Acta Crystallogr.*, **18**, 17 (1965).

(12) J. M. Bijvoet, *Endeavour*, **14**, 71 (1955).

(13) Tables of hydrogen parameters, anisotropic temperature factors, and observed and calculated structure factors will appear following these pages in the microfilm edition of this volume of the journal. Single copies may be obtained from the Reprint Department, ACS Publications, 1155 Sixteenth St., N.W., Washington, D. C. 20036, by referring to author, title of article, volume, and page number. Remit $4.00 for photocopy or $2.00 for microfiche.