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DETERMINATION OF THE ABSOLUTE CONFIGURATION OF 1,1'-BINAPHTHYL AND ITS DERIVATIVES BY X-RAY DIFFRACTION

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Various investigations[1] have been reported on the stereochemistry of optically active compounds resulting from restricted rotation, especially in the biaryl system. Nevertheless, their absolute configurations have been proposed mainly by stereochemical mechanisms[2], optical properties[2] and thermal analysis[2]. An unequivocal determination of the absolute configurations of the biaryl system has not been hitherto reported and it should be pointed out that the clear establishment of such absolute configurations is, in fact, impossible by known methods except X-ray diffraction.

The purpose of the present communication is the assignment of an absolute configuration of a binaphthyl derivative by X-ray diffraction, followed by chemical correlations of it with some other binaphthyl derivatives. Optically active (+)-2,2'-dihydroxy-1,1'-binaphthyl-3,3'-dicarboxylic acid dimethyl ester (II) was chosen as the standard substance for the binaphthyl system and its absolute configuration was determined by X-ray diffraction.

<u>X-ray study</u> —— The (+)-ester (II) [m.p. 239-240°, $[\alpha]_D^{25}$ +159° (c=1.0, THF)], prepared from the (+)-acid (I) [m.p. >300°, $[\alpha]_D^{25}$ +190° (c=1.0, THF)][3] by way of the acid chloride, was recrystallized from bromobenzene.

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The crystals which contain one equivalent mole of bromobenzene are pale yellow plates with well developed (100) faces.

Crystal data.

$C_{24}H_{18}O_6 \cdot C_6H_5Br$ Mol.wt. 559.4
Monoclinic.
Space group $P2_1$
$a=15.78$Å $b=9.22$Å $c=9.12$Å $\beta=97.0°$
$V=1327$Å^3
$Dm=1.42 g \cdot cm^{-3}$ $Dc=1.40 g \cdot cm^{-3}$ for $Z=2$
(Density was measured by the flotation method.)

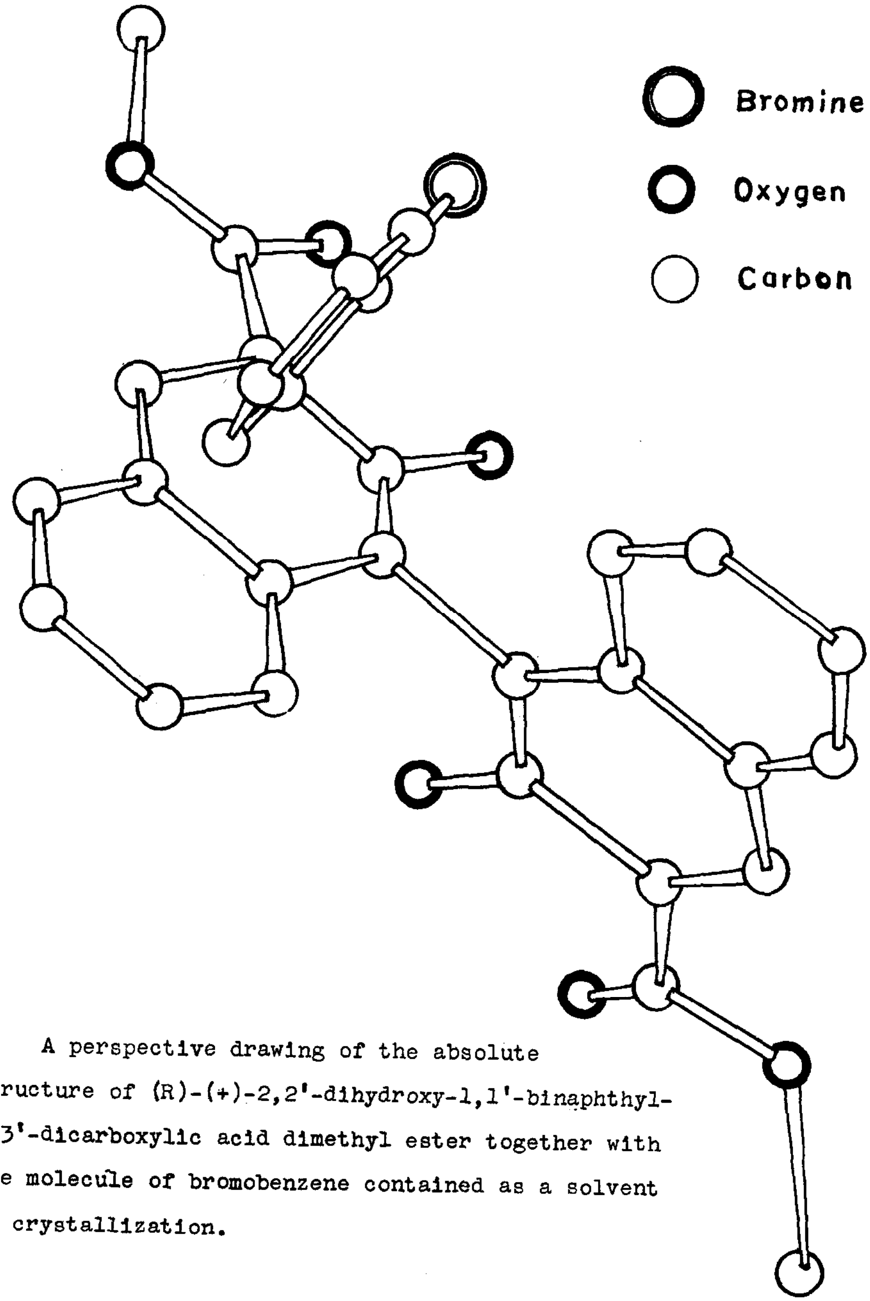
From Weissenberg photographs taken with Cu-Kα radiation, intensities of 1213 independent reflexions were estimated visually. The crystal structure was solved by the heavy atom method using three-dimensional Fourier and difference Fourier syntheses, and refined by the method of least squares. The final R value was 0.113. The bond distances and angles were normal values. The dihedral angle between two naphthalene nuclei was about 77°.

The absolute configuration of (+)-II was determined as in the Figure by the comparison of the observed and calculated intensity differences of 22 (hkl) and $(h\bar{k}l)$ pairs in the c-axis Weissenberg photographs, taking into account the anomalous dispersion effect of the bromine atom for Cu-Kα radiation.

Chemical correlations ——— Positive rotatory II has been shown by X-ray study to have the (R)-configuration and correlations of (+)-II with some binaphthyl derivatives are shown in the Chart.

Treatment of (R)-(+)-I [m.p. >300°, $[\alpha]_D^{25}$ +190° (c=1.0, THF)][3] with diazomethane in a mixture of ether-methanol gave the tetramethyl derivative, which was hydrolyzed to dicarboxylic acid with methanolic potassium hydroxide. The resulting dicarboxylic acid was submitted to Curtius rearrangement by way of acid chloride and acid azide to afford the (+)-diamine (III) [m.p. 95-97°, $[\alpha]_D^{25}$ +9.3° (c=0.64, THF)]. This compound, after deamination by hypophosphorous acid reduction of tetrazotised solution, was demethylated with boron tribromide in a cold solution of methylene chloride to yield the (+)-diol (IV) [m.p. 199-201°, $[\alpha]_D^{26}$ +43.0° (c=0.90, THF)].

Figure



A perspective drawing of the absolute structure of (R)-(+)-2,2'-dihydroxy-1,1'-binaphthyl-3,3'-dicarboxylic acid dimethyl ester together with the molecule of bromobenzene contained as a solvent of crystallization.

The sequence of the above reaction establishes the absolute configuration of(+)-III and (+)-IV as the (R)-series.

The transformation of the other (-)-diamine (VI) [m.p. 215°, $[\alpha]_D^{26}$ -95.5° (c=1.1, benzene)] correlated to (-)-dicarboxylic acid (V) by K. Mislow et al[4], to the diol (IV), was accomplished by the treatment of its tetrazotised solution with dilute hot sulfuric acid. The diol obtained was negative rotatory [m.p. 190-193°, $[\alpha]_D^{24}$ -19.0° (c=0.20, THF)].

Hence, the absolute configuration of (-)-V and (-)-VI proved to belong to the (S)-series.

An attempt to synthesize 1,1'-binaphthyl (VIII), from the diamine (VI), was reported to be unsuccessful by F. Bell and W.H.D. Morgan[5], but later A.S. Cooke and M.M. Harris[6] succeeded in obtaining (+)-VIII by the deamination of (+)-IX.

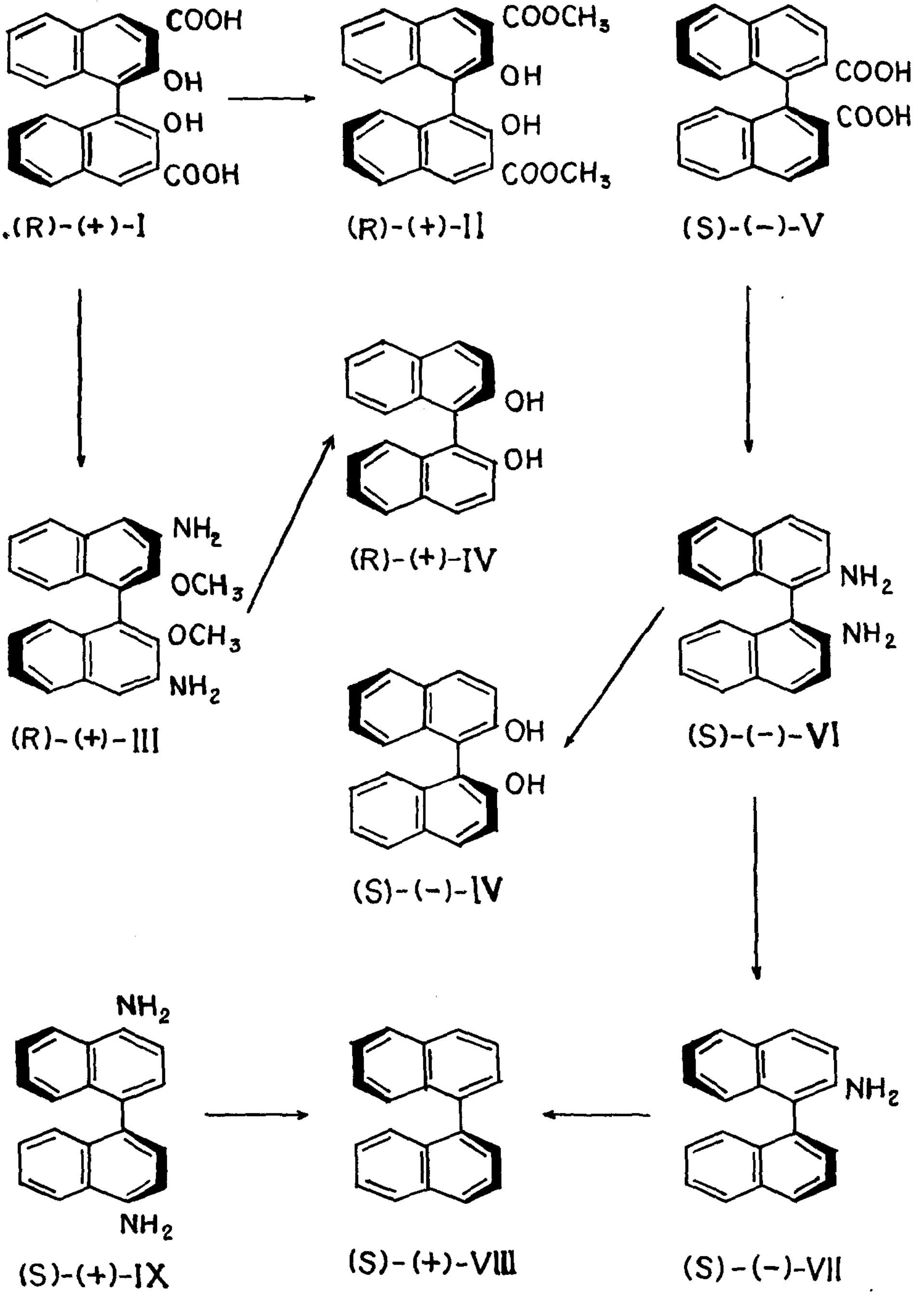
Chemical correlation between optically active binaphthyls, (VI) and (VIII), was attempted according to the following scheme. Monoacetyl derivative of the diamine, prepared from (S)-(-)-VI [m.p. 215°, $[\alpha]_D^{26}$ -95.5° (c=1.1, benzene)], was submitted to deamination with nitrous acid and hypophosphorous acid to yield, after hydrolysis, the (-)-monoamine (VII) [m.p. 189-190°, $[\alpha]_D^{25}$ -51.4° (c=1.2, THF)]. The stepwise deamination of (-)-VII by the same procedure as above gave (+)-VIII, which was purified through chromatography on alumina to give the pure (+)-VIII [m.p. 153-154°, $[\alpha]_D^{10}$ +104° (c=1.0, THF)].[7]

Accordingly the absolute configuration of (-)-VII, (+)-VIII and (+)-IX proved to belong to the (S)-series.

In conclusion, the absolute configuration of 1,1'-binaphthyl (VIII), the simplest model in this system has been clearly established and the absolute configurations of V and its derivatives, which were previously proposed by K. Mislow et al, were demonstrated to be correct. All the absolute configurations of binaphthyl derivatives shown in the Chart have been elucidated by chemical correlations of them with (R)-(+)-II.

Studies on CD and ORD of these binaphthyl derivatives are in progress in our laboratory.

Chart


COOH
OH
OH
COOH
(R)-(+)-I
COOCH$_3$
OH
OH
COOCH$_3$
(R)-(+)-II
COOH
COOH
(S)-(−)-V
OH
OH
(R)-(+)-IV
NH$_2$
OCH$_3$
OCH$_3$
NH$_2$
(R)-(+)-III
NH$_2$
NH$_2$
(S)-(−)-VI
OH
OH
(S)-(−)-IV
NH$_2$
NH$_2$
(S)-(+)-IX
(S)-(+)-VIII
NH$_2$
(S)-(−)-VII

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REFERENCES

(1) K. Mislow, M.A.W. Glass, R.E. O'Brien, P. Rutkin, D.H. Steinberg, J. Weiss, and C. Djerassi, J. Amer. Chem. Soc., **84**, 1455 (1962).

K. Mislow, and A.J. Gordon, J. Amer. Chem. Soc., **85**, 3521 (1963).

A.S. Cooke, and M.M. Harris, J. Chem. Soc. (C), 988 (1967).

(2) K. Mislow, Angew. Chem., **70**, 683 (1958).

(3) W.M. Stanley, and R. Adams, Rec. trav. chim., **48**, 1035 (1929).

(4) K. Mislow, and P.A. Grasemann, J. Org. Chem., **23**, 2027 (1958).

(5) F. Bell, and W.H.D. Morgan, J. Chem. Soc., 1963 (1950).

(6) A.S. Cooke (née Mellor), and M.M. Harris, J. Chem. Soc., 2365 (1963).

(7) Spectral and analytical data on all crystalline intermediates are in agreement with the assigned structures.