spectrometer. The infrared spectrum was taken in potassium bromide with a Perkin-Elmer Model 221 spectrophotometer. The ultraviolet spectrum was taken in ethanol with a Cary Model 14 spectrophotometer.

Acknowledgment.—The author wishes to thank Professor H. Rapoport for advice and encouragement. This investigation was carried out during the tenure of a fellowship from the U. S. Public Health Service.

Configuration Assignments in Symmetrical Alkyl–Aryl Pinacols[1]

WILLIAM A. MOSHER AND NED D. HEINDEL[2]

Department of Chemistry, University of Delaware, Newark, Delaware

Received March 8, 1963

In a study of the mechanism of the pinacol–pinacolone rearrangement it became necessary to synthesize and characterize pure diastereoisomeric forms of PhRC(OH)C(OH)RPh where R = methyl, ethyl, and *n*-propyl. These diols previously have been reported as dimeric reduction products of their respective ketones—acetophenone,[3] propiophenone,[4] and *n*-butyrophenone[5]—or by appropriate Grignard additions to benzil.[3,6] In only one case has a configurational assignment of the *dl* and *meso* isomers been established and that by a synthesis of optically active and inactive 2,3-diphenyl-2,3-butanediol from (−)-methylbenzoin.[7]

Chiurdoglu and others have reported that hydrogen bonding studies could distinguish *threo* and *erythro* isomers in a series of aliphatic 1,2-diols and we have found such studies can provide information upon which to base reliable configurational assignments in aryl–alkyl diols.

By examination of the hydrogen bonding patterns of the three isomeric pairs (see Table I), it is possible to divide the diols into two sets. One member of each pair (II, IV, and VI) shows only a free hydroxyl peak in the 3605–3611-cm.$^{-1}$ region with an attendant shoulder while the other member shows a sharp, distinct pair of free and bonded peaks (in addition to the concentration dependent intermolecular bands).

Steric considerations dictate that in order to exhibit intramolecular hydrogen bonding between hydroxyls the *meso* isomers would have to exist in an unfavored conformation in which the bulky phenyl groups on adjacent carbons would be in close proximity.[9] The *dl*-diastereoisomers can intramolecularly bond their hydroxyls when the phenyls are in a favored *trans* orientation. Hence I, III, and V might be assigned the *dl*-configuration, and II, IV, and VI the *meso*.

TABLE I

HYDROGEN BONDING IN PhRC(OH)RPh

R	M.p., °C.	Free –OH (cm.$^{-1}$)	Bonded –OH (cm.$^{-1}$)	Δν	Position of C–O (cm.$^{-1}$)		Assignment
Methyl							
I	122–123[a]	3615	3580 (s)	35	1143	1191	*dl*
II	117–118[a]	3605	3570 (sh)[e]	35	1126	1167	*meso*
Ethyl							
III	113[b]	3616	3572 (s)	46	1143	1182	*dl*
IV	138–139[b]	3609	3570 (w)[e]	39	1125	1164	*meso*
n-Propyl							
V	95–96[c]	3615	3569 (s)	46	1144	1180	*dl*
VI	128–129[d]	3611	3561 (m)[e]	50	1124	1159	*meso*

[a] Prepared as in ref. 3. [b] Prepared as in ref. 4. [c] Prepared as in ref. 5. [d] Prepared as in ref. 6. [e] The characterization of the position of the bonded peak is approximate since it appears as a shoulder or broad weak band.

The same conclusion might be reached by considering that in *dl* isomers the intramolecularly bonding hydroxyls can attain a perfect *cis* orientation without the severe phenyl–phenyl eclipsing that would be necessary in the *meso* form.

This conclusion is strengthened by examination of the bands associated with C–OH stretching modes for the tertiary hydroxyl which appear at 1140 to 1190 cm.$^{-1}$. Each of the diols II, IV, and VI shows double absorption peaks in this region which shift to higher frequencies in those diols which show strong intramolecular hydrogen bonding, I, III, and V.[10] The shift is exactly in the direction predicted for increased rigidity imparted to the C–O bond by intramolecular associations.[11]

It is also possible that the C–O bond shifts in going from *meso* to *dl* isomers are due to differences in dipole–dipole interactions in the two configurational species. Support for this possibility arises from the fact that the peak displacements show a remarkable constancy, between 16 and 20 cm.$^{-1}$, in the various isomers (see Table I).

If the C–O bond shifts were solely due to increased rigidity imparted to the bond by increased intramolecular association in the *dl* forms then one might expect a proportional increase in the C–O shift differences (between *dl* and *meso* forms of the same compound) as the hydrogen bond becomes tighter. Such a correlation is not observed.

The constancy of the C–O peak displacements suggests that they might possibly serve as qualitative and quantitative tools for identifying such compounds in mixtures.[12]

It also has been observed that the small amount of intramolecular hydrogen bonding which occurs in the *meso* forms increases as one proceeds from methyl to ethyl to *n*-propyl. This is explained by the conformational consideration that the unfavored rotomer for intramolecular bonding in *meso* becomes less and less

(1) Presented at the Fourth Delaware Valley Regional Meeting, American Chemical Society, January, 1962.

(2) A portion of this work is taken from the M.S. thesis of Ned D. Heindel, National Science Foundation Predoctoral fellow, 1959–63.

(3) Ramart-Lucas and M. Salmon-Legagneur, *Bull. soc. chim. France*, (4) **45**, 718 (1929).

(4) G. Ciamician and P. Silber, *Atti Accad. Nazl. Lincei, Mem. Classe Sci. Fis. Mat. Nat. Sez.*, (5) **23-I**, 860 (1914).

(5) I. Nazarov, *Ann. Leningrad State U. Chem. Ser.*, **1**, 123 (1935); *Chem. Abstr.*, **31**, 6617 (1937).

(6) E. Chu and J. Chu, *J. Chinese Chem. Soc.*, **10**, 11 (1943).

(7) D. Cram and K. Kopecky, *J. Am. Chem. Soc.*, **81**, 2748 (1959).

(8) G. Chiurdoglu, R. de Groote, W. Masschelein, and M. H. van Risseghem, *Bull. soc. chim. Belges*, **70**, 342 (1961); *Chem. Abstr.*, **56**, 8185 (1962).

(9) E. Eliel, "Stereochemistry of Carbon Compounds," McGraw-Hill Book Co., Inc., New York, N. Y., 1962, pp. 132–133.

(10) Similar shifts of this kind have been previously reported and correlated with hydrogen bonding. H. E. Zimmerman and J. English, Jr., *J. Am. Chem. Soc.*, **75**, 2368 (1953).

(11) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," John Wiley and Sons, Inc., New York, N. Y., 1958, pp. 108–110.

(12) Cram and Kopecky, ref. 7, have observed but not explained these differences in the 8.8-μ region for the diastereoisomeric acetophenone pinacols and have employed them for quantitative analysis purposes.

unfavored as the increasing bulk of the R groups approaches that of the phenyl.

The increase in the strength of the hydrogen bond, as reflected in $\Delta\nu$,[13] from 35 in the *meso*-methyl to 50 cm.$^{-1}$ in *meso*-*n*-propyl is expected in light of previous observations that replacement by increasingly bulky alkyl groups on the carbons bearing the hydroxyl and phenyl reduces the O–C–C angle and brings the hydroxyls into closer proximity. This is in accord with the Thorpe–Ingold deformation hypothesis that says when steric repulsions increase one of the angles at a carbon atom, the opposite angle is decreased.[13,14]

While these observations support the conclusion that in this series simple intramolecular bonding between hydroxyls is occurring, it is impossible to eliminate completely the possibility of –OH to π bonding involving the electrons of the phenyl ring. The $\Delta\nu$'s obtained in this work are of the approximate order of magnitude as those observed for the –OH to π bonding in β-phenyl ethanols,[15] and the diols measured herein might be considered structural analogs of the β-phenyl ethanols with suitable changes in substitution on the α and β carbons.

The possibility of –OH to π bonding in the PhRC(OH)C(OH)RPh series has been tested by employing the known sensitivity of such bonding to the basicity of the acceptor.[15,16] A tighter hydrogen bond is obtained when electron release into the aromatic system is facilitated.

Synthesis and spectral examination of the *dl* forms of *p*-methyl and *p*-methoxyacetophenone pinacols gave $\Delta\nu$ values of 36 and 35 cm.$^{-1}$, respectively, and a strong intramolecular bonding peak. Since these values are in perfect agreement with the unsubstituted *dl*-acetophenone pinacol (see Table I), it appears that bonding between hydroxyls is favored.

The diols I, III, and V can be assigned the *dl*-configuration, and II, IV, and VI, the *meso*. In the case of I and II this is in agreement with the results obtained by Cram and Kopecky.[7]

Experimental

The bonding measurements were performed in these laboratories on a Perkin-Elmer 421 grating spectrophotometer and by P. von R. Schleyer of Princeton University on a Perkin-Elmer Model 21 spectrophotometer with lithium fluoride optics. All diols were examined as dilute solutions in spectral grade carbon tetrachloride according to standard procedures.

The diols were prepared according to the procedure in the references noted (see Table I) and recrystallized to constant melting point. With the exception of the high melting isomer of 4,5-diphenyl-4,5-octanediol (VI), all had melting points in agreement with those reported. Diol VI was obtained after several recrystallizations from 1:1 hexane–benzene as white microneedles of m.p. 128–129°, as reported.

Anal. Calcd. for $C_{20}H_{26}O_2$: C, 80.49; H, 8.78. Found: C, 80.47; H, 8.88.

The *dl* isomer of 2,3-di-*p*-tolyl-2,3-butanediol was prepared as described by Backer, Stevens, and Van der Bij.[17] The configurational assignments provided by the authors, on the basis of relative oxidation rates with lead tetraacetate, are confirmed by the bonding study.

The *dl* isomer of 2,3-di-*p*-anisyl-2,3-butanediol was prepared by a method employing Cram's rule of asymmetric induction.[7] To an ice-cooled solution containing 0.40 mole of *p*-anisylmagnesium bromide in 700 cc. of anhydrous ether was added 0.10 mole of 2,3-butanedione in 20 cc. of ether. After addition was complete, the mixture was stirred 12 hr. and hydrolyzed with ice–ammonium chloride solution. The ethereal extracts were concentrated to an oil and steam distilled to remove unchanged diketone and other volatiles. The organic portion of the nonvolatiles was dried and chromatographed on alumina with hexane–benzene elutants. A total of 7.1 g. (23%) of the *dl*-diol was obtained, m.p. 122–123°, (lit.[18] m.p. 122–123°).

Acknowledgment.—Appreciation is expressed to Dr. P. von R. Schleyer, Princeton University, for confirming a portion of the bonding measurements and suggesting the possibility of –OH to π bonding and to Dr. Harold C. Beachell, this institution, for helpful discussions and interpretation.

(13) L. P. Kuhn, *J. Am. Chem. Soc.*, **74**, 2493 (1952).

(14) L. P. Kuhn, *ibid.*, **80**, 5950 (1958).

(15) P. von R. Schleyer, C. Wintner, D. S. Trifan, and R. Bacskai, *Tetrahedron Letters*, **14**, 1–7 (1959).

(16) M. Oki and H. Iwamura, *Bull. Chem. Soc. Japan*, **32**, 1135 (1959).

(17) H. J. Backer, W. Stevens, and J. R. Van der Bij, *Rec. trav. chim.*, **59**, 1146 (1940).

(18) C. C. Price and G. P. Mueller, *J. Am. Chem. Soc.*, **66**, 634 (1944).

Preparation of 2-Bromopyrimidines

HENRY BADER[1] AND NORMAN SPIERE

Division of Organic Chemistry, Ortho Research Foundation, Raritan, New Jersey

Received January 28, 1963

Conversion of 2-amino- to 2-chloropyrimidines is usually effected by diazotization in concentrated hydrochloric acid. The yields by this procedure rarely exceed 30%.[2] Alternatively, the amine may be diazotized in the presence of sulfuric acid, giving the 2-hydroxy compound which subsequently is chlorinated with phosphorus oxychloride; the over-all yield in this process is likewise about 30%. In our own experience, application of the first method to 2-amino-4,5-diethoxypyrimidine gave the 2-chloro derivative in 38% yield.

We have observed that significantly better results can be obtained in the analogous preparation of 2-bromopyrimidines, by diazotization in hydrobromic acid after formation of a perbromide. This method, introduced by Craig[3] for application to 2-aminopyridines, seems not to have been used hitherto in the pyrimidine series. Thus, 2-amino-4,5-diethoxypyrimidine gave 2-bromo-4,5-diethoxypyrimidine in 79% yield, and 2-amino-4-chloro-5-ethoxypyrimidine gave 2-bromo-4-chloro-5-ethoxypyrimidine in 67% yield.

However, the utility of this reaction is circumscribed by the possibility of side reactions; in particular, it appears that the ease of electrophilic 5-bromination of the pyrimidine ring[4a] will limit the use of the Craig reaction to 5-substituted pyrimidines. From 2-amino-4-methoxypyrimidine the major product was 2-

(1) American Cyanamid Company, Bound Brook, N. J.

(2) (a) N. Sperber, D. Papa, E. Schwenk, M. Sherlock, and R. Fricano, *J. Am. Chem. Soc.*, **73**, 5752 (1951), reported a 52% yield of 2-chloropyrimidine from 2-aminopyrimidine; however, (b) I. C. Kogon, R. Minin, and C. G. Overberger, *Org. Syn.*, **35**, 34 (1955), obtained yields of only 26–27% in this same preparation; (c) K. L. Howard, U. S. Patent 2,477,409 (July 26, 1949), quotes only one yield, 26.8% in the conversion of 2-amino-5-chloropyrimidine to 2,5-dichloropyrimidine.

(3) L. C. Craig, *J. Am. Chem. Soc.*, **56**, 231 (1934).

(4) (a) G. W. Kenner and Sir A. Todd in R. C. Elderfield, "Heterocyclic Compounds," Vol. VI, John Wiley and Sons, Inc., New York, N. Y., 1957, pp. 290–295; (b) p. 301.