stirred with 35.0 mL of 50% NaOH (660 mmol) in the presence of 1.21 g of NBu_4HSO_4 (3.55 mmol) at 75 °C and 1000 rpm. In experiments 1-3 and 8, 1.19 g of durene (8.88 mmol) was also present as NMR internal standard. Samples were taken for NMR analysis at regular intervals. Conversions were determined by integration band area ratio between the methyl doublet (1.70 ppm, J = 6.5 Hz) or the durene methyl singlet (2.09 ppm) and the ring methyl singlet (2.17 ppm). The styrene vinyl hydrogens (5.0–6.7 ppm) were used as a double check.

Synthesis of 4-Bromostyrene. 4-Bromo(1-chloroethyl)benzene (11 g, 0.05 mol), 20 g of solid sodium hydroxide (0.5 mol), and 1.15 g of aliquat 336 (2.5 mmole) were placed in a 50-mL flask equipped with a magnetic stirrer and a distillation condenser under 1 mmHg of vacuum. The mixture was heated by an oil bath at 70 °C and the material distilled at 42–45 °C was collected. Product (6.3 g) was obtained, which by ^1H NMR spectrum was found to contain 94% of 4-bromostyrene and 6% of the starting material (yield 64%).

^1H NMR: [4-bromo(1-chloroethyl)benzene] 7.18 (AB, J = 8 Hz, 4 H, Ar), 4.87 (qt, J = 6 Hz, 1 H), 1.78 (db, J = 6 Hz, 3 H), [4-bromostyrene] 7.12 (AB, J = 8 Hz, 4 H, Ar), 6.20–6.66 (m, 1 H, vinylbenzyl), 5.35–5.63 (m, 1 H, vinyl cis to ring), 5.00–5.17 (m, 1 H, vinyl trans to ring) ppm.

Dehydrobromination of (2-Bromoethyl)benzene. The reaction vessel consisted of 100-mL three-necked round-bottomed flask equipped with an rpm-calibrated mechanical stirrer, a thermometer (immersed in the reaction mixture during agitation), and a sampling port. The reaction vessel was immersed in a stirred thermoregulated bath (contract thermometer ±0.5 °C. A solution of 12.30 g of 1 (66.5 mmol) and 840 mg of toluene (9.12 mmol) as internal GC standard as mixed with 35.0 mL of 50% NaOH (660 mmol) for 15 min. GC analysis showed no conversion. NEt_3BzBr (181 mg, 0.665 mmol) was then added and the time taken, and samples taken at regular intervals were injected into a GC column: 15% DEGS on Chromosorb P, 2 m, $^1/_{64}$ in. copper tube operating at 95 °C (N_2 flow 1 cm^3/s). Conversions were determined by a calibration graph. Clear resolution of the peaks was obtained with retention times of 1.1 min (toluene), 1.5 min (styrene), and 4.9 min (1).

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The Synthesis and Ionization Constants of Some Derivatives of 1-Biphenylenol[1]

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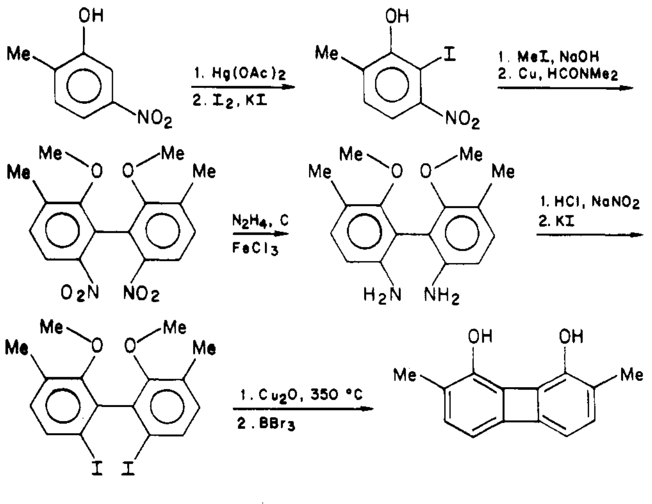
2,7-Dimethyl-1,8-biphenylenediol has been synthesized from 2-methyl-5-nitrophenol in nine steps. 1,5-Biphenylenediol has been prepared by dimerization of 3-methoxybenzyne, separation of isomers, and demethylation. 8-Methoxy-1-biphenylenol has been made by the partial demethylation of 1,8-dimethoxybiphenylene. Ionization constants (pK_1 8.04, pK_2 11.47, pK_1 8.35, pK_2 9.97, and pK 9.15, respectively) have been determined for these compounds and for 1,8-biphenylenediol (pK_1 8.01, pK_2 11.00) and 1-biphenylenol (pK 8.64) by ultraviolet spectrophotometric measurements in aqueous solution.

As part of our study of double hydrogen bonding by 1,8-biphenylenediol[2,3] and its derivatives, we have synthesized some new derivatives of 1-biphenylenol and determined their ionization constants and also the ionization constants of some known 1-biphenylenol derivatives.

The synthesis of 2,7-dimethyl-1,8-biphenylenediol was carried out, as shown in Scheme I, by a method similar to that used previously to synthesize 1,8-biphenylenediol itself.[4,5] The overall yield was 3.9%, based on 6-methyl-3-nitrophenol, similar to the 4.4% of the 1,8-diol itself in nine analogous steps. The previously used method for reduction of the nitro groups by tin and hydrochloric acid was replaced by a hydrazine reduction method.[6]

The 1,5-biphenylenediol was made by a method in which 3-methoxybenzyne is presumably dimerized and the mixture of dimethoxybiphenylenes separated, as shown in Scheme II. The 10% yield of dimethoxybiphenylenes consisted of about 80% 1,5-isomer and 20% 1,8-isomer.

Scheme I



The 8-methoxy-1-biphenylenol was obtained by stopping the cleavage of 1,8-dimethoxybiphenylene by boron tribromide, which was already being carried out as part of the synthesis of 1,8-biphenylenediol, when the maximum amount of a previously unknown intermediate, as measured by TLC, was present.

All the ionization constants were obtained by ultraviolet measurements on aqueous solutions of known concentrations of the 1-biphenylenol derivative of various measured pHs. Most of the aqueous solutions contained buffers and

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[1] This research was supported in part by NSF Grant CHE-8114770. Abstracted in part from the Ph.D. Dissertations of David E. Miles and Soonkap Hahn, The Ohio State University, Columbus, OH, 1982 and 1985, respectively.

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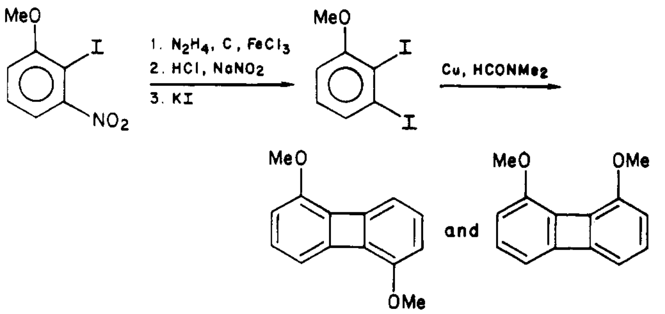
Table I. Determination of Ionization Constants of Derivatives of 1-Biphenylenol[a]

phenol	$10^3\epsilon_{H_2A}$	$10^3\epsilon_{HA}$	$10^3\epsilon_A$	10^9K_1	$10^{12}K_2$
1,8-biphenylenediol[b]					
260 nm	64.6 (1.3)	33.7 (0.8)	17.9 (1.0)	9.2 (1.5)	8.8 (2.6)
272 nm	5.70 (1.15)	29.0 (0.6)	27.4 (1.0)	12.6 (2.3)	2.81 (5.8)
277 nm	3.30 (0.80)	15.3 (0.5)	30.5 (0.6)	11.8 (3.1)	12.6 (2.5)
282 nm	2.10 (0.63)	9.59 (0.5)	34.6 (0.5)	7.4 (2.5)	10.1 (1.0)
2,7-dimethyl-1,8-biphenylenediol					
260 nm	45.7 (0.3)	29.3 (0.1)	17.3 (0.2)	9.5 (0.7)	3.20 (0.20)
265.3 nm	61.6 (0.4)	35.6 (0.1)	21.4 (0.1)	10.7 (0.5)	3.57 (0.18)
270 nm	2.10 (0.09)	12.2 (0.3)	32.7 (1.3)	6.7 (0.6)	2.86 (0.45)
1,5-biphenylenediol					
253 nm	47.5 (0.3)	28.4 (0.7)	16.4 (0.1)	5.38 (0.66)	103 (12)
261 nm	49.4 (0.3)	30.4 (0.6)	25.8 (0.1)	4.49 (0.48)	58 (18)
277 nm	4.74 (0.06)	13.8 (1.0)	42.0 (0.3)	3.80 (0.71)	125 (11)
285 nm	2.77 (0.07)	9.24 (1.31)	23.8 (0.3)	3.91 (1.28)	143 (29)
1-biphenylenol					
249 nm		58.4 (0.3)	35.7 (0.1)	2.29 (0.11)	
252 nm		45.6 (0.1)	24.4 (0.05)	2.19 (0.05)	
294 nm		1.43 (0.03)	21.1 (0.1)	2.46 (0.06)	
8-methoxy-1-biphenylenol					
254 nm		54.7 (0.2)	33.5 (0.1)	0.775 (0.031)	
262 nm		79.0 (0.3)	35.8 (0.1)	0.692 (0.019)	
270.4 nm		11.2 (0.2)	34.7 (0.3)	0.711 (0.041)	

[a] In water at 26 °C unless otherwise noted. All extinction coefficients in M^{-1} cm^{-1}. The parenthesized figures are estimated standard deviations. [b] At 25 °C.

Scheme II



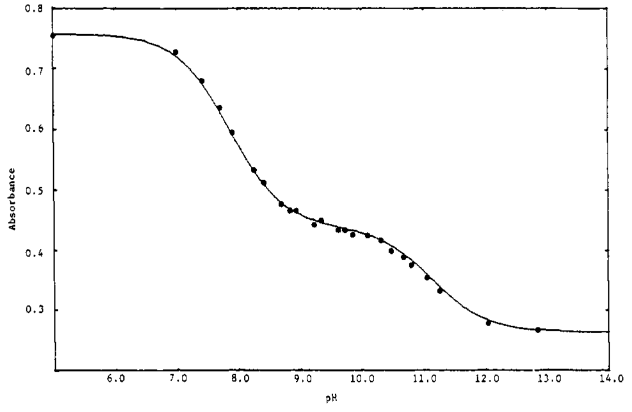


Figure 1. Plot of apparent extinction coefficient of 2,7-dimethyl-1,8-biphenylenediol at 265 nm vs. pH in water at 26 °C.

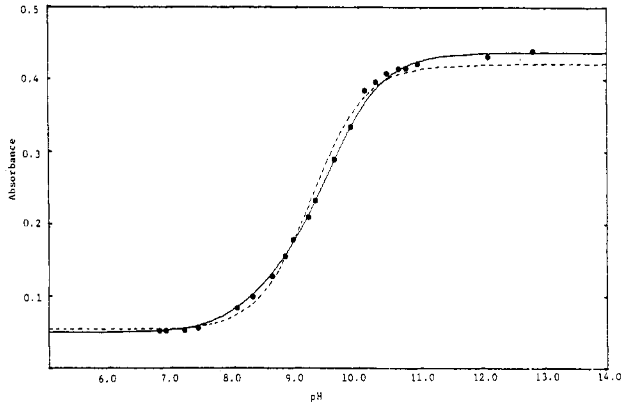


Figure 2. Plot of apparent extinction coefficient of 1,5-biphenylenediol at 277 nm vs. pH in water at 26 °C. The solid line was calculated from the K values in Table II and the ϵ values in Table I. The dashed line was calculated by assuming only one ionization occurred, $K = 4.52 \times 10^{-10}$, $\epsilon_{H_2A} = 5140$ M^{-1} cm^{-1}, and $\epsilon_{HA} = 40\,400$ M^{-1} cm^{-1}.

their ionic strengths ranged from 0.0001 to 0.19. Activity coefficients were assumed to obey the Davies equation[7] (eq 1), in which γ is the activity coefficient of a singly charged

$$-\log \gamma = 0.51(\mu^{1/2}/(1 + \mu^{1/2}) - 0.2\mu) \qquad (1)$$

ion (for a double charge log γ_2 is four times as large), and μ is the ionic strength. For a dibasic acid, such as a biphenylenediol, the total absorbance A is given by eq 2, in

$$A = \frac{C(\epsilon_{H_2A}a_H{}^2\gamma^4 + \epsilon_{HA}a_H\gamma^3K_1 + \epsilon_AK_1K_2)}{a_H{}^2\gamma^4 + a_H\gamma^3K_1 + K_1K_2} \qquad (2)$$

which C is the total concentration of the acid in all states of protonation, a_H is the hydrogen ion activity, K_1 and K_2 are the thermodynamic first and second ionization constants, and ϵ_{H_2A}, ϵ_{HA}, and ϵ_A are the extinction coefficients of the neutral, monoionic, and diionic forms of the acid, respectively. From 21 to 31 absorbance values obtained from around pH 6 to above 12 were fit to eq 2 by the method of nonlinear least squares, for each of three or four wavelengths. The results obtained for 1,8-biphenylenediol, 2,7-dimethyl-1,8-biphenylenediol, and 1,5-biphenylenediol are listed in Table I. The plot of the apparent extinction coefficient A/C of the 2,7-dimethyl 1,8-diol vs. pH in Figure 1 shows a clear break between the two ionization constants. The break for 1,8-biphenylenediol itself was somewhat less pronounced. But for the 1,5-diol, where the ratio of K_1 to K_2 is much smaller, no such break can be seen. The plot of A/C vs. pH for the 1,5-diol is shown in Figure 2. In this figure, as in Figure 1, the solid line is calculated from eq 2, the parameter values in Table I, and γ values at an ionic strength of 0.1. Some of the experimental points are slightly closer to or further from the line than they would be if they had been run at ionic strength 0.1. Also shown in Figure 2 is a dashed line calculated from

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(7) Davies, C. W. *J. Chem. Soc.* 1938, 2093–2098.

Table II. pK Values for Derivatives of 1-Biphenylenol[a]

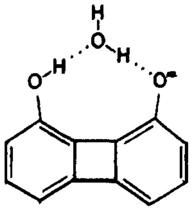
phenol	pK_1	pK_2
1,8-biphenylenediol[b]	8.01 (0.12)	11.00 (0.16)
2,7-dimethyl-1,8-biphenylenediol	8.04 (0.09)	11.47 (0.05)
1,5-biphenylenediol	8.35 (0.08)	9.97 (0.14)
1-biphenylenol	8.64 (0.03)	
8-methoxy-1-biphenylenol	9.15 (0.03)	

[a] In water at 26 °C unless otherwise noted. The parenthesized figures are estimated standard deviations. [b] At 25 °C.

the assumption that there is only one ionization constant. A calculation assuming that K_1 is equal to $4K_2$ and that ϵ_{HA} is the arithmetic mean of ϵ_{H_2A} and ϵ_A gives a line identical with the dashed line. The least-squares best values of the single ionization constant K (4.52×10^{-10}), ϵ_{H_2A} (5140 M^{-1} cm^{-1}), and ϵ_{HA} (40400 M^{-1} cm^{-1}) at 277 nm give a sum of the squares of the pH_{obsd} minus pH_{calcd} values that is four times as large as that which the parameter values from Table I gave.[8,9] This supports our belief that there are two ionization constants for the 1,5-diol and that K_1 is larger than $4K_2$. However, the dashed line is close enough to the experimental points to convince us that the experimental uncertainty in our pK_1, pK_2, and ϵ_{HA} values is considerably larger than the estimated standard deviations, which were obtained by using standard statistical procedures.

The ionization constants of the monobasic acids, 1-biphenylenol and 8-methoxy-1-biphenylenol, were obtained from about 16 absorbance values at a given wavelength using a simplified version of eq 2. The resulting extinction coefficients and ionization constants are also listed in Table I, from which it may be seen that the estimated standard deviations are smaller than for the diols, mainly because pK_1 and pK_2 for a diol are correlated with each other. The average pK values obtained are shown in Table II.

The electronic effect of the methoxy substituent is usually quite similar to that of the hydroxy substituent, with methoxy being less electron donating or more electron withdrawing according to five common sets of substituent constants.[10] It is therefore interesting that 1,8-biphenylenediol is about six times as acidic, per hydroxy group, as 8-methoxy-1-biphenylenol. Apparently there are significant proximity effects. The oxygen atoms in 1,8-biphenylenediol are about 4.2 Å apart,[2] which is too far apart to permit any significant amount of direct internal hydrogen bonding in the monoanion of the diol. However, the monoanion could be stabilized by hydrogen bonding via an intervening solvent molecule as shown in structure 1. A water molecule that is hydrogen bonded to a phenolic hydrogen atom should thereby be made more acidic. It will therefore be an improved solvator of a phenoxide anion. The unusual structure of 1,8-biphenylenediol permits this to be done with nearly optimum stereochemistry. The amount of extra stabilization arising from the hydrogen bonding illustrated in 1 is certainly much smaller than that which can arise from direct internal hydrogen bonding in the monoanion of a diol. 1,8-Naphthalenediol,[11] in which the molecular geometry is relatively favorable for such hydrogen bonding, is more acidic per hydroxy group than 1-naphthol[12] by about 200-fold. Similar large effects have been found with 2,2′-dihydroxybiphenyl and some of its derivatives,[11] but catechol,[12] in which the molecular geometry is not very good for direct or for solvent-mediated hydrogen bonding in the monoanion, is only about twice as acidic per hydroxy group as its monomethyl ether is.[12]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It is also possible that the 8-methoxy substituent is sterically interfering with solvation of the phenoxide ion, but this should be important for only one of the two possible coplanar conformations of the methoxy group. Such steric hindrance of solvation in the case of 2,7-dimethyl-1,8-biphenylenediol has not made the compound significantly less acidic than the unmethylated 1,8-diol. The two methyl substituents should decrease the local effective dielectric constant and thereby increase the substituent effect of the O^- group on K_2. It is therefore not surprising that K_1/K_2 is more than twice as large as for the unmethylated 1,8-diol.

In 1,5-biphenylenediol the hydroxy groups are further apart and have no net effect on each other's acidity. The acidity of the 1,5-diol per hydroxy group is within the experimental uncertainty of the acidity of 1-biphenylenol itself. Similarly the ratio K_1/K_2 is less than $^1/_{20}$ of the corresponding ratio for the 1,8-diol.

Experimental Section

Melting points, determined on a Reichert apparatus, are uncorrected. Ultraviolet spectra were measured on a Varian DMS 100 or a Cary 1605 spectrophotometer. NMR spectra were obtained from Varian EM-360 and EM-390 spectrometers and a Bruker WP-200 instrument. Mass spectra were obtained from an AEI MS-9 spectrometer at 70 eV. Chromatography was carried out on silica gel using 1- or 2-ft columns. 1-Biphenylenol was prepared by a literature method.[13]

2-Iodo-3-nitro-6-methylphenol. A solution of 17.75 g (0.116 mol) of sublimed 2-methyl-5-nitrophenol (Pfaltz and Bauer) and 3.6 g (0.09 mol) of sodium hydroxide in 200 mL of water was stirred while a solution of 3.6 g (0.113 mol) of mercuric acetate and 3.3 mL of acetic acid in 200 mL of water was added. After 30 min at 100 °C the solution was cooled and filtered to obtain yellow crystals, which were washed with 500 mL of water and 200 mL of ether and dried in a vacuum oven. The 48 g (100% yield) of crude acetoxymercury compound (mp 209 °C dec) was not purified, but 38 g (0.092 mol) was suspended in 230 mL of 10% aqueous potassium iodide. To the suspension 230 mL of 20% aqueous potassium triiodide was added dropwise with stirring during 3 h. After 3 h more of stirring the reaction mixture was extracted with three 200-mL portions of dichloromethane. The combined extracts were washed with 40 mL of 10% aqueous sodium bisulfite and concentrated to give 19 g of crude solid. Chromatography, eluting with 1:8 chloroform–hexane, gave 9.5 g (37% yield) of 2-iodo-3-nitro-6-methylphenol: mp 37–40 °C; after crystallization from methylene chloride–hexane, mp 43–45 °C; ^1H NMR ($CDCl_3$, 90 MHz) δ 2.30 (s, 3 H, CH_3), 5.98 (s, 1 H, OH), 7.10 (d, $J_{4,5}$ = 7.8 Hz, 1 H, Ar H), 7.34 (d, 1 H, Ar H).

Anal. Calcd for $C_7H_6O_3NI$: C, 30.13; H, 2.17; N, 5.02; I, 45.48. Found: C, 30.22; H, 2.23; N, 4.99; I, 45.47.

2-Iodo-3-nitro-6-methylanisole. A solution of 9 g (0.032 mol) of 2-iodo-3-nitro-6-methylphenol in 100 mL of 1.8% aqueous sodium hydroxide was added dropwise over 3 h to a mixture of

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[8] Hamilton, W. C. "Statistics in Physical Sciences"; Ronald Press: New York, 1964; Sections 4.1, 5.3.

[9] The pH_{calcd} values were obtained using the appropriate ionic strength, of course, not the average value of 0.1.

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[11] Musso, H.; Mathies, H. G. *Chem. Ber.* **1961**, *94*, 356–368.

[12] Serjeant, E. P.; Dempsey, B. "Ionization Constants of Organic Acids in Aqueous Solution"; Pergamon: New York, 1979.

[13] Boulton, A. J.; Chadwick, J. B.; Harrison, C. R.; McOmie, J. F. W. *J. Chem. Soc. C* **1968**, 328–330.

30 mL (0.482 mol) of methyl iodide and dicyclohexano-18-crown-6 at 50 °C. After 3 h more of reflux the cooled reaction mixture was extracted with three 100-mL portions of dichloromethane. Removal of solvent from the combined extracts gave 10.1 g of crude yellow solid. Chromatography, eluting with 1:4 chloroform–hexane, gave 9.1 g (96% yield): mp 34–40 °C of 2-iodo-3-nitro-6-methylanisole; after recrystallization from methylene chloride-hexane, mp 41–42 °C; ^{1}H NMR ($CDCl_3$, 60 MHz) δ 2.39 (s, 3 H, CH_3C), 3.77 (s, 3 H, CH_3O), 7.13 (d, $J_{3,4}$ = 8.2 Hz, 1 H, Ar H), 7.36 (d, 1 H, Ar H).

Anal. Calcd for $C_8H_8O_3NI$: C, 32.79; H, 2.75; N, 4.78; I, 43.30. Found: C, 32.94; H, 2.81; N, 4.70; I, 43.27.

2,2′-Dimethoxy-3,3′-dimethyl-6,6′-dinitrobiphenyl. To a stirred solution (0.078 mol) of 2-iodo-3-nitro-6-methylanisole in 120 mL of dimethylformamide was added 28 g of activated copper.[14] After the mixture was stirred 3 h at 154 °C under argon another 28 g of activated copper was added. When the mixture had been stirred for 3 h more it was cooled and poured into 1 L of water. The resulting precipitate was extracted with acetone for 24 h in a Soxhlet extractor. Removal of acetone gave 12.8 g of green solid, which was recrystallized to give 10.5 g (81% yield) of yellow platelets: mp 141–143 °C; ^{1}H NMR ($CDCl_3$, 60 MHz) δ 2.36 (s, 6 H, CH_3C), 3.36 (s, 6 H, CH_3O), 7.30 (d, $J_{4,5}$ = 8.0 Hz, 2 H, H-4 and H-4′), 7.83 (d, 2 H, H-5 and H-5′); exact mass of the parent ion, calcd 332.1009, obsd 332.1000.

Anal. Calcd for $C_{16}H_{16}O_6N_2$: C, 57.83; H, 4.85; N, 8.43. Found: C, 57.80; H, 4.94; N, 8.32.

2,2′-Dimethoxy-3,3′-dimethyl-6,6′-diaminobiphenyl. A mixture of 12 g (0.036 mol) of 2,2′-dimethoxy-3,3′-dimethyl-6,6′-dinitrobiphenyl, 200 mg (0.74 mmol) of ferric chloride hexahydrate, and 2 g of activated carbon in 100 mL of methanol was refluxed for 10 min. The 11 mL (0.228 mol) of hydrazine hydrate was added dropwise over 1 h, while reflux continued. After 17 h more at reflux the methanol was removed at reduced pressure and the residue crystallized from methanol to give 7.1 g (72% yield) of white crystals: mp 175–178 °C; ^{1}H NMR ($CDCl_3$, 60 MHz) δ 2.27 (s, 6 H, CH_3C), 3.48 (s, 6 H, CH_3O), 3.70 (br s, 4 H, NH_2), 6.50 (d, $J_{4,5}$ = 8.0 Hz, 2 H, H-5 and H-5′), 7.02 (d, 2 H, H-4 and H-4′).

Anal. Calcd for $C_{16}H_{20}O_2N_2$: C, 70.56; H, 7.40; N, 10.29. Found: C, 70.24; H, 7.42; N, 10.24.

2,2′-Dimethoxy-3,3′-dimethyl-6,6′-diiodobiphenyl. A solution of 4.0 g (14.7 mmol) of 2,2′-dimethoxy-3,3′-dimethyl-6,6′-diaminobiphenyl in 15.7 mL of concentrated hydrochloric acid and 20 mL of water was cooled in an ice–water bath, and a solution of 2.24 g (32.5 mmol) of sodium nitrite was added dropwise with stirring over 30 min. After the mixture was stirred 20 min more 20 mL of 10.3 g (6.20 mmol) of potassium iodide in water was added dropwise over 30 min. The mixture was heated at 80 °C for 2 h, cooled, and extracted three times with dichloromethane. The combined extracts were washed with 50 mL of 4% aqueous sodium bisulfite, and the solvent was removed to give 6.5 g (90% yield) of brown solid. Chromatography, eluting with 4:1 hexane–methylene chloride, gave white crystalline 2,2′-dimethoxy-3,3′-dimethyl-6,6′-diiodobiphenyl: mp 101–103 °C; ^{1}H NMR ($CDCl_3$, 90 MHz) δ 2.30 (s, 6 H, CH_3C), 3.48 (s, 6 H, CH_3O), 6.96 (d, $J_{4,5}$ = 8.1 Hz, 2 H, H-4 and H-4′), 7.61 (d, 2 H, H-5 and H-5′).

Anal. Calcd for $C_{16}H_{16}O_2I_2$: C, 38.89; H, 3.26; I, 51.37. Found: C, 38.91; H, 3.30; I, 51.61.

1,8-Dimethoxy-2,7-dimethylbiphenylene. Cuprous oxide (20 g) and 1.1 g (2.2 mmol) of crude brown 2,2′-dimethoxy-3,3′-dimethyl-6,6′-diiodobiphenyl were ground together, and the mixture was placed in a 50-mL round-bottomed flask that was attached to two consecutive bump traps. The reaction mixture was heated, by using a salt bath, at 350 °C for 10 min while being rotated and kept at reduced pressure in a Rotavap. The product in the two traps was removed with 100 mL of acetone, which was then evaporated. The residue was chromatographed, eluting with 1:5 dichloromethane–hexane, to give 165 mg (31% yield) of yellow liquid, which was crystallized from hexane to give yellow crystals: mp 56–57 °C; ^{1}H NMR ($CDCl_3$, 90 MHz) δ 2.07 (s, 6 H, CH_3C), 3.88 (s, 6 H, CH_3O), 6.24 (d, $J_{3,4}$ = 6.6 Hz, 2 H, Ar H), 6.55 (d, 2 H, Ar H).

Anal. Calcd for $C_{16}H_{16}O_2$: C, 79.97; H, 6.71. Found: C, 79.99; H, 6.82.

2,7-Dimethyl-1,8-biphenylenediol. A solution of 230 mg (0.96 mmol) of 1,8-dimethoxy-2,7-dimethylbiphenylene in 25 mL of dry benzene was treated with 3 mL of 1 M boron tribromide in *n*-hexane at 70 °C. After 40 h the mixture was poured carefully into 20 mL of stirred ice–water. The resulting 180 mg of green solid was crystallized from chloroform to give 138 mg (68%) of pale yellow crystals: mp 215–218 °C; ^{1}H NMR ($CDCl_3$, 200 MHz) δ 2.10 (s, 6 H, CH_3), 6.06 (d, J = 6.3 Hz, 2 H, Ar H), 6.42 (d, 2 H, Ar H).

Anal. Calcd for $C_{14}H_{12}O_2$: C, 79.22; H, 5.70. Found: C, 78.88; H, 5.66.

2-Iodo-3-aminoanisole. Dropwise addition of 6 g (0.120 mmol) of hydrazine hydrate to 20 g (0.072 mmol) of 2-iodo-3-nitroanisole, 50 mg of ferric chloride hexahydrate, and 2.2 g of activated carbon in 100 mL of methanol was carried out at 70 °C over 1 h. After 47 h of reflux the cooled reaction mixture was filtered, and the solid obtained was extracted with 100 mL of methanol. Removal of the methanol gave 18 g of crude product, which was chromatographed, eluting with 1:7 dichloromethane–hexene, to give 11.7 g (74% yield) of colorless liquid: ^{1}H NMR ($CDCl_3$, 60 MHz) δ 3.73 (s, 3 H, CH_3), 4.10 (br s, 2 H, NH_2), 6.04 (dd, $J_{4,5}$ = 7.4 Hz, $J_{4,6}$ = 1.2 Hz, 1 H, H-4), 6.23 (dd, $J_{5,6}$ = 8.0 Hz, 1 H, H-5), 6.90 (dd, 1 H, H-6).

Anal. Calcd for C_7H_8ONI: C, 33.76; H, 3.24; N, 5.62; I, 50.95. Found: C, 33.91; H, 3.35; N, 5.67; I, 51.07.

2,3-Diiodoanisole. Dropwise addition of 3.5 g (0.051 mol) of sodium nitrite in 30 mL of water to 10 g (0.046 mol) of 2-iodo-3-aminoanisole in 24.5 mL of concentrated hydrochloric acid and 30 mL of water at 5 °C was carried out over 30 min. After the mixture was stirred 20 min more at 5 °C, a solution of 16.1 g (0.097 mol) of potassium iodide in 20 mL of water was added dropwise. The solution was then heated at 80 °C for 2 h, cooled, and extracted with three 100-mL portions of dichloromethane. The combined extracts were washed with 50 mL of 5% aqueous sodium bisulfite and the solvent removed to give 9.5 g (63% yield) of dark brown solid. Chromatography, eluting with 4:1 hexane–methylene chloride, and recrystallization from chloroform–hexane gave white crystals: mp 74–75 °C; ^{1}H NMR ($CDCl_3$, 90 MHz) δ 3.84 (s, 3 H, CH_3), 6.76 (dd, $J_{4,6}$ = 1.5 Hz, $J_{5,6}$ = 8.4 Hz, 1 H, H-6), 7.07 (dd, $J_{4,5}$ = 7.2 Hz, 1 H, H-5), 7.54 (dd, 1 H, H-4).

Anal. Calcd for $C_7H_6OI_2$: C, 23.36; H, 1.68; I, 70.52. Found: C, 23.58; H, 1.80; I, 70.30.

1,5-Dimethoxybiphenylene. A mixture of 40 g of activated copper[14] and 9 g (0.025 mol) of crude brown 2,3-diiodoanisole in 100 mL of dry dimethylformamide was stirred and heated under argon at reflux for 12 h. The cooled solution was poured into 400 mL of water, and the resulting precipitate was extracted with about 150 mL of acetone, which was removed to give 1.2 g of black-brown solid. Chromatography, eluting with 1:12 dichloromethane–hexane, gave 30 mg (1% yield) of 1,8-dimethoxybiphenylene (identical with material produced by the literature method[5]), 95 mg of a mixture of about 20% 1,8-dimethoxybiphenylene and 80% 1,5-dimethoxybiphenylene, and 150 mg (6% yield) of pale yellow crystals of 1,5-dimethoxybiphenylene: mp 153–155 °C; ^{1}H NMR ($CDCl_3$, 90 MHz) δ 3.90 (s, 6 H, CH_3), 6.30 (m, $J_{2,3}$ = 9.0 Hz, $J_{3,4}$ = 6.9 Hz, 4 H, H-2, H-4, H-6, and H-8), 6.70 (dd, 2 H, H-3 and H-7); exact mass of the parent ion, calcd for $C_{14}H_{12}O_2$ 212.0838, obsd 212.0836.

Anal. Calcd for $C_{14}H_{12}O_2$: C, 79.23; H, 5.70. Found: C, 78.95; H, 5.69.

1,5-Biphenylenediol. A solution of 140 mg (0.66 mmol) of 1,5-dimethoxybiphenylene in 20 mL of dry benzene was treated with 2 mL of 1 M boron tribromide in *n*-hexane at 70 °C. After 40 h the solution was poured into cold water with stirring. The resulting 80 mg of green precipitate was sublimed to give 40 mg (33% yield) of pale yellow solid. Three recrystallizations from chloroform gave 3.5 mg of crystals: mp 266–268 °C; ^{1}H NMR (acetone-d_6, 90 MHz) δ 6.25–6.73 (m, 6 H, Ar H), 8.42 (s, 2 H, OH); exact mass of parent ion, calcd for $C_{12}H_8O_2$ 184.0524, obsd 184.0530.

Anal. Calcd for $C_{12}H_8O_2$: C, 78.25; H, 4.38. Found: C, 77.85; H, 4.46.

8-Methoxy-1-biphenylenol. A solution of 100 mg (0.47 mmol) of 1,8-dimethoxybiphenylene[5] in 20 mL of dry benzene was treated

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[14] Vogel, A. I. "Textbook of Practical Organic Chemistry", 4th ed.; Longman: New York, 1978; pp 285–286.

with 0.4 mL of 1 M boron tribromide in *n*-hexane under argon at 70 °C. After 2.5 h the TLC spot (chloroform) for the previously not isolated product reached its maximum size, and 6 mL of cold water was added to the reaction mixture with stirring. The resulting mixture was extracted with ether. Removal of the ether gave 70 mg of gray solid, which was chromatographed, eluting with chloroform, to give 55 mg (59% yield) of yellow crystals, which was recrystallized from hexane to give product: mp 106–106.5 °C; ^{1}H NMR ($CDCl_3$, 60 MHz) δ 3.84 (s, 3 H, CH_3), 5.01 (s, 1 H, OH), 6.11–6.69 (m, 6 H, Ar H).

Anal. Calcd for $C_{13}H_{10}O_2$: C, 78.79; H, 5.09. Found: C, 79.16; H, 5.44.

Determination of Ionization Constants. Buffer solutions were prepared by the method of Kolthoff,[15] with borate buffers being used for the pH range up to 10 and carbonate buffers for the pH range 10–11. Sodium hydroxide solutions were used for higher pHs. In a specific case, 100 μL of 0.003811 M 1-biphenylenol solution was syringed into 25 mL of each of 17 buffer solutions. The UV spectrum of each of the resulting solutions was measured over the range 300–240 nm at 26 °C.

Registry No. 1,8-Bisphenylenediol, 18798-64-6; 2,7-dimethyl-1,8-biphenylenediol, 98991-01-6; 1,5-biphenylenediol, 98991-02-7; 1-biphenylenol, 1078-07-5; 8-methoxy-1-biphenylenol, 98945-48-3; 2-methyl-5-nitrophenol, 5428-54-6; 2-iodo-6-methyl-3-nitrophenol, 98991-03-8; 2-iodo-6-methylanisole, 25922-05-8; 2,2′-dimethoxy-3,3′-dimethyl-6,6′-dinitrobiphenyl, 98991-04-9; 2,2′-dimethoxy-3,3′-dimethyl-6,6′-diaminobiphenyl, 98991-05-0; 2,2′-dimethoxy-3,3′-dimethyl-6,6′-diiodobiphenyl, 98991-06-1; 1,8-dimethoxy-2,7-dimethylbiphenylene, 98991-07-2; 2-iodo-3-nitroanisole, 98991-08-3; 2-iodo-3-aminoanisole, 98991-09-4; 2,3-diiodoanisole, 98991-10-7; 1,5-dimethoxybiphenylene, 98991-11-8; 1,8-dimethoxybiphenylene, 18798-67-9.

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(15) Kolthoff, I. M. "Indicators"; Wiley: London, 1926; pp 135–149.

Double-Hydrogen-Bonding Catalysis of the Reaction of Phenyl Glycidyl Ether with Diethylamine by 1,8-Biphenylenediol[1]

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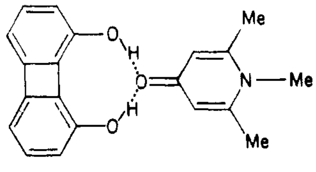
The reaction of phenyl glycidyl ether with diethylamine in butanone gives 3-(diethylamino)-1-phenoxy-2-propanol. Catalysis by phenol and five of its meta- and para-substituted derivatives gives catalysis constants that obey the Brønsted equation well, with an α value of 0.18. The catalysis constants for 1-biphenylenol and 8-methoxy-1-biphenylenol are in good agreement with the Brønsted equation, as is the value for catechol, when the rate constant and acidity constant have been divided by two. The catalysis constant for 1,8-biphenylenediol is about six times as large and hence the value per hydroxy group is about three times as large as calculated from the Brønsted equation. The 1,8-diol, whose adducts with several oxygen bases are known from X-ray crystal structure determinations to have two hydrogen bonds from the hydroxy groups of the diol to the same oxygen atom of the base, is apparently giving double-hydrogen-bonding catalysis. This double-hydrogen-bonding catalysis gives 1,8-biphenylenediol a catalytic activity, per hydroxy group, of a phenol that is 600 times as strong an acid.

1,8-Biphenylenediol has been found to form crystalline complexes with 1,2,6-trimethyl-4-pyridone (1), *N,N,N′,N′,N″,N″*-hexamethylphosphoramide, and 2,6-dimethyl-γ-pyrone in which there are two strong hydrogen bonds from one molecule of the diol to the same oxygen atom of the base.[2] In addition, the 1,8-diol gives equilibrium constants for hydrogen bonding to several oxygen bases in cyclohexane that are larger, by as much as 50-fold, than those for hydrogen bonding of the same bases to *m*-nitrophenol, whose ionization constant per hydroxy group in water is about the same as that of the 1,8-diol.[3] This evidence of the ability of the 1,8-diol to form two hydrogen bonds to the same oxygen atom made us wonder about its ability to act as an acidic catalyst, especially in a reaction where the acid catalyst acts by hydrogen bonding.



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Partansky has studied the reaction of phenyl glycidyl ether with diethylamine[4] at 25 °C in butanone by measuring the extent of reaction after 24 h and after 48 h. He found that the reaction was catalyzed by hydroxy compounds with a crude correlation between catalytic ability and the acidity of the catalyst. Relative catalytic activities were found, for example, to be salicylic acid > *m*-nitrophenol, *p*-chlorophenol > phenol > benzoic acid > methanol. However, the 4% of reaction that occurred after 24 h in the absence of catalyst was increased only to 11.4% by 0.2 M methanol and 33.5% by 0.05 M salicylic acid. The fact that the changes in catalytic activity tend to be so much smaller than the changes in catalyst acidity suggested that there was not a large amount of proton transfer from the catalyst in the transition state of the rate-controlling step. However, the situation must be complicated by hydrogen bonding of the catalyst to the solvent and the amine as well as to the epoxide.

The reaction had already been reported to give 1-(diethylamino)-3-phenoxy-2-propanol[5] (eq 1), on the basis of elemental analysis of the hydrochloride[6] and of analogy

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(1) (a) This investigation was supported in part by NSF Grant CHE-8114770. (b) A preliminary report of the present results was given in: Hine, J.; Linden, S.-M.; Kanagasabapathy, V. M. *J. Am. Chem. Soc.* **1985**, *107*, 1082–1083.

(2) Hine, J.; Ahn, K.; Gallucci, J. C.; Linden, S.-M. *J. Am. Chem. Soc.* **1984**, *106*, 7980–7981.

(3) Hine, J.; Hahn, S.; Miles, D. E. *J. Org. Chem.*, in press.

(4) Partansky, A. M. *Adv. Chem. Ser.* **1970**, *No. 92*, 29–47.

(5) Pyman, F. L. *J. Chem. Soc.* **1917**, *111*, 167–172.

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