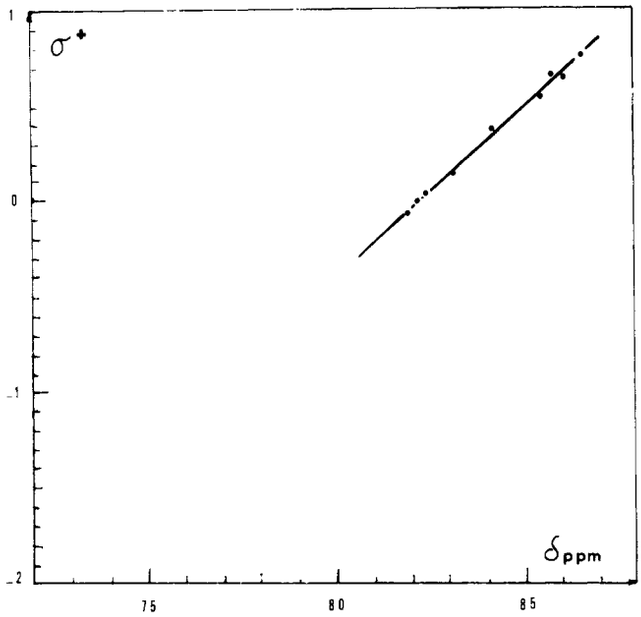


Figure 3. ^{13}C chemical shift for the cyano-bearing cation vs. σ^+ in acetone-d_6 solution: $\sigma^+ = 0.180\delta - 14.812$.

Table II. Sample Values of σ^+ Parameters

Para substituent	Nucleus probe	$\sigma^+(\pm 3\sigma)$
CH=C(CN)$_2$	C-4[8]	0.8[2] ± 0.5
CH=C(CN)$_2$	olef H	0.5[5] ± 0.3
(acetone-d_6)	δ 8.43	
$OCH_2C_6H_5$	olef H	−0.6[6] ± 0.3
(acetone-d_6)	δ 8.09	
OSO_2CH_3	olef H	0.1[6] ± 0.3
(acetone-d_6)	δ 8.32	
OSO_2CH_3	C-8	0.1[5] ± 0.1
(acetone-d_6)	δ 83.11	
$OSO_2C_6H_4CH_3(p)$	olef H	−0.0[6] ± 0.3
(acetone-d_6)	δ 8.26	
$OSO_2C_6H_4CH_3(p)$	C-8	0.1[6] ± 0.1
(acetone-d_6)	δ 83.18	

charge on the α carbon.[11] The empirical finding that either H-7 or C-8[12] have resonances extremely sensitive to σ^+ values for the meta or para ring substituent affords an easy, if not extremely accurate, determination of this important parameter.

Since this note was submitted for publication, Posner and Hall have reported[13] an analogous method for determination of σ^+. Their results, although differing somewhat in the solvents used and in the substituent investigated, are complementary to ours.

Experimental Section

^1H NMR spectra were obtained on a Varian T-60 spectrometer, using tetramethylsilane as internal reference, whereas ^{13}C NMR spectra were determined on a Bruker HFX-90 spectrometer, field locked on deuterium (chloroform-*d* or acetone-d_6) and linked to a Nicolet Fourier transform system. The solvent peak (77.5 ppm) was used as reference for chloroform-*d* solutions, and a trace of internal methylene chloride (54.0 ppm) served as standard for acetone-d_6 solutions.

The substituted benzylidenemalononitriles were prepared from the corresponding substituted benzaldehyde and malononitrile according to the standard procedure of Corson and Stoughton,[4] except for the p-SO_3CH_3 and the p-$SO_3C_6H_4CH_3(p)$ derivatives, which were prepared by reaction between p-hydroxybenzylidenemalononitrile and the corresponding sulfonyl chloride in pyridine solution. All ^1H and ^{13}C NMR spectra were fully compatible with the correct benzylidenemalononitrile structures.

All the compounds were crystallized to constant melting points, in excellent agreement with data in the literature.[3,4] The following values (uncorrected) have not been previously reported (substituent, mp): p-C_6H_5, 142–143 °C; m-CN, 147–148 °C; p-SO_3CH_3, 117.5 °C; p-$SO_3C_6H_4CH_3(p)$, 150.5–151 °C; p-CH=C(CN)$_2$, 274.5–275 °C.

^1H Chemical Shift Data for the Olefinic Proton in Acetone-d_6 Solution [substituent, δ (ppm), σ^+]: p-$N(CH_3)_2$, 7.80, −1.70; p-OH, 8.01, −0.92; p-OMe, 8.08, −0.78; p-Me, 8.17, −0.31; p-C_6H_5, 8.27, −0.17; p-F, 8.24, −0.07; p-H, 8.27, 0.00; p-Cl, 8.29, 0.11; p-Br, 8.35, 0.15; p-CN, 8.45, 0.66; p-NO_2, 8.49, 0.79.

^{13}C Chemical Shift for the Cyano-Bearing Carbon in Chloroform-*d* Solution[14] [substituent, δ (ppm), σ^+]: p-$N(CH_3)_2$, 72.21, −1.70; p-OMe, 78.45, −0.78; p-F, 82.47, −0.07; p-H, 82.67, 0.00; p-Cl, 83.55, 0.11; p-CN, 87.24, 0.66; p-NO_2, 87.47, 0.79.

^{13}C Chemical Shift for the Cyano-Bearing Carbon in Acetone-d_6 Solution[14] [substituent, δ (ppm), σ^+]: p-F, 81.88, −0.07; p-H, 82.21, 0.00; m-OMe, 82.46, 0.05; p-Br, 83.14, 0.15; m-Cl, 84.19, 0.40; m-CN, 85.46, 0.56; p-CN, 86.04, 0.66; m-NO_2, 85.72, 0.67; p-NO_2, 86.61, 0.79.

Acknowledgments. We thank the Fonds de la Recherche Fondamentale Collective for their help in purchasing the Bruker HFX-90 spectrometer used in this study, and Professor Peter Stang (University of Utah) for suggesting application of the method to the mesylate and tosylate groups.

Registry No.—$XC_6H_4CH{=}C(CN)_2$ (X = p-Ph), 26089-09-8; (X = m-CN), 60595-33-7; (X = p-SO_3CH_3), 60595-34-8; (X = p-$SO_3C_6H_4CH_3(p)$), 60595-35-9; (X = p-H=C(CN)$_2$), 17239-69-9; (X = p-NMe_2), 2826-28-0; (X = p-OH), 3785-90-8; (X = p-OMe), 2826-26-8; (X = p-Me), 2826-25-7; (X = p-F), 2826-22-4; (X = p-H), 2700-22-3; (X = p-Cl), 1867-38-5; (X = p-Br), 2826-24-6; (X = p-NO_2), 2700-23-4; (X = m-OMe), 2972-72-7; (X = m-Cl), 2972-73-8; (X = p-CN), 36937-92-5; (X = m-NO_2), 2826-32-6.

References and Notes

(1) H. C. Brown and Y. Okamoto, *J. Am. Chem. Soc.*, **80**, 4979 (1958).
(2) J. M. McKelvey, S. Alexandratos, A. Streitwieser, Jr., J. L. M. Abboud, and W. J. Hehre, *J. Am. Chem. Soc.*, **98**, 244 (1976).
(3) M. A. Weinberger, R. M. Heggie, and H. L. Holmes, *Can. J. Chem.*, **43**, 2585 (1965).
(4) B. B. Corson and R. W. Stoughton, *J. Am. Chem. Soc.*, **50**, 2825 (1928). Melting points are within 1 °C of those reported in the literature: I. Horner and K. Klüpfel, *Justus Liebigs Ann. Chem.*, **591**, 89 (1955); E. Lord, M. P. Naan, and C. D. Hall, *J. Chem. Soc. B*, 213 (1971).
(5) Extrapolation to infinite dilution can be dispensed with, since chemical shifts vary linearly with concentration with an almost uniform slope of ~0.1 ppm mol^{-1} for all substituents.
(6) S. Ehrenson, R. T. C. Brownlee, and R. W. Taft, *Prog. Phys. Org. Chem.*, **10**, 1–80 (1973).
(7) G. J. Bay, R. J. Kurland, and A. K. Colter, *Tetrahedron*, **27**, 735 (1971).
(8) G. L. Nelson, G. C. Levy, and J. D. Cargioli, *J. Am. Chem. Soc.*, **94**, 3089 (1972).
(9) P. J. Stang and A. G. Anderson, *J. Org. Chem.*, **41**, 781 (1976).
(10) W. A. Sheppard, in "The Chemistry of the Cyano Group", Z. Rappoport, Ed., Wiley-Interscience, New York, N.Y., 1970, Chapter 5, pp 209–237.
(11) R. Roberge and S. Fliszàr, *Can. J. Chem.*, **53**, 2400 (1975).
(12) But not C-7, for reasons unclear at present.
(13) T. B. Posner and C. D. Hall, *J. Chem. Soc., Perkin Trans. 2*, 729 (1976).
(14) Owing to the low sensitivity of the resonance of the *gem*-dicyano bearing carbon [M. Acar, A. Cornélis, and P. Laszlo, *Tetrahedron Lett.*, 3625 (1972)], only those substituted benzylidenemalononitriles having sufficient solubility in that solvent were studied.

An Improved Preparation of Phenolic [1.1.1.1]Metacyclophanes

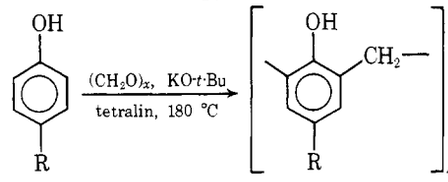
Timothy B. Patrick* and Philip A. Egan

Department of Chemistry, Southern Illinois University, Edwardsville, Illinois 62026

Received July 16, 1976

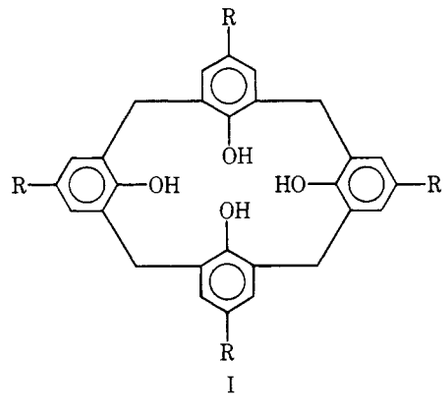
Phenolic [1.1.1.1.]metacyclophanes (I) represent a very interesting and little studied class of compounds. For example, the cuplike structure[1] and strong complexing ability[1,2] of these macrocycles permit these molecules to act as unique models for enzyme–substrate complexes.[3] The macrocyclic structure

Table I



Compd[a]	R	% yield	Mp, °C[b]	Lit. mp, °C	Mol wt	Theor mol wt
1	CH_3	54	370–375	>360[2,6]	480[c]	480
2	$C(CH_3)_3$	53	342–344	330–332[1]	677,[d] 648[e]	696
3	Ph	81	340–350	330–60[2]	741[d]	728
4	OCH_3	92	380–385	*f*	544[c]	544
5	CO_2CH_3	32	380–390	*f*	672[d]	656

[a] All compounds gave satisfactory (C, H) elemental analyses. [b] Decomposition points obtained in sealed capillary tubes. [c] MS. [d] Rast method in camphor. [e] NMR using acetophenone as the internal standard. [f] New compound.



I

has been proven using x-ray analysis,[1] spectroscopy (IR, NMR), and multistep synthesis.[4,5]

Previous preparations of these compounds have been achieved mainly through the two-step method of condensing a para-substituted phenol with formaldehyde and base, and then forming the cyclic tetramer by heating the reaction mixture in linseed oil at 220 °C.[1,2,6] This procedure is cumbersome and furnishes the compounds in low yields.[7]

These phenolic [1.1.1.1]metacyclophanes can now be prepared in good yield (Table I) in a one-flask reaction procedure in which a para-substituted phenol is condensed with formaldehyde (paraformaldehyde) in the presence of potassium *tert*-butoxide. Conducting this reaction in tetralin at 180–200 °C effects both condensation and ring closure; the phenolic [1.1.1.1]metacyclophane precipitates from the reaction mixture in a good state of purity. Although limitations exist, in that, *p*-Cl-, *p*-Br-, and *p*-acetylaminophenols give only amorphous, unworkable materials, this procedure is much more satisfactory than the previously reported two-step sequence.

The phenolic [1.1.1.1]metacyclophane structure was proven through spectroscopic (NMR, IR, MS) and molecular weight determinations, and by comparison with published data for the authentic samples.[1,2]

Experimental Section

Melting points were taken in sealed capillary tubes using a Mel-Temp apparatus and are uncorrected. NMR spectra were obtained in pyridine-d_5 solution on a Varian T60 spectrometer using tetramethylsilane (δ 0.0) as an internal standard. Mass spectra (MS) were obtained at 80 eV on a Varian MAT-111 using a heated direct inlet probe. Infrared spectra (IR) were obtained in KBr on a Perkin-Elmer Model 337 grating spectrometer. Commercial phenols, potassium *tert*-butoxide and tetralin (Aldrich), and paraformaldehyde (Fisher) were used as obtained.

General Procedure. A mixture of para-substituted phenol (0.1 mol), potassium *tert*-butoxide (2–3 g), paraformaldehyde (10 g), and tetralin (200 ml) was placed in a 500-ml round-bottomed flask connected to a Dean-Stark trap and condenser fitted with a drying tube. The mixture was heated slowly to 180–200 °C (thermocouple) for 6–8 h during which the product precipitated as a yellow-white powder. after the mixture had cooled, the powder was collected by suction filtration and washed with isopropyl alcohol. The powder was then dissolved in pyridine and filtered to remove gummy, resinous materials. The phenolic [1.1.1.1]metacyclophane was obtained in pure form on acidification of the pyridine solution with cold dilute hydrochloric acid followed by filtration and drying under vacuum to remove occluded solvent(s).

Spectra, General. The IR spectra of **1–5** all contained strong absorption at 3200–3100 cm^{-1} (broad, OH) and a sharp band at 851–849 cm^{-1} (1,2,4,6 substitution). **5** displayed carbonyl absorption at 1705 cm^{-1}.

The NMR spectra for **1–5** all contained the following absorptions: δ 3.8–4.1 (broad, 2 H, CH_2), 7.0–7.2 (s, 2 H, aromatic), 7.9–8.6 (s, 1 H, OH). The para substituent was observed as a singlet for the correct proton count at δ 4.1 (CH_3), 1.2 [$-C(CH_3)_3$], 7.2 (Ph, m), 3.8 (OCH_3), 3.6 (CO_2CH_3).

The MS of **1** and **5** showed the parent ion as the most intense ion.

Acetone Complex with 2. A mixture of **2** and acetone was allowed to stand until the acetone had completely evaporated and a dry powder complex was obtained. The NMR spectrum of the complex showed acetone at δ 2.0. The complex stoichiometry was obtained from comparison of the integral ratios of acetone (δ 2.0) and the *tert*-butyl peak (δ 1.2) as 1:1.

Acknowledgment. We thank Dr. C. D. Gutsche, Washington University, St. Louis, Mo., for helpful discussions and literature information.

Registry No.—**1**, 53255-02-0; **2**, 60705-62-6; **3**, 60705-63-7; **4**, 60705-64-8; **5**, 60705-65-9; HOC_6H_4-*p*-R (R = CH_3), 106-44-5; HOC_6H_4-*p*-R (R = $C(CH_3)_3$), 98-54-4; HOC_6H_4-*p*-R (R = Ph), 92-69-3; HOC_6H_4-*p*-R (R = OCH_3), 150-76-5; HOC_6H_4-*p*-R (R = CO_2CH_3), 99-76-3.

References and Notes

(1) J. W. Cornforth, P. D'A Hart, G. A. Nicols, R. J. W. Rees, and J. A. Stock, *Br. J. Pharmacol.*, **10**, 73 (1955).
(2) A. Zinke, R. Kretz, E. Leggewie, and H. Hossinger, *Monatsh. Chem.*, **83**, 1213 (1952); A. Zinke, G. Zigeuner, K. Hossinger, and G. Hoffman, *ibid.*, **79**, 438 (1948).
(3) C. D. Gutsche, T. C. Kung, and M.-L. Hse, Abstracts, 11th Midwest Regional Meeting of the American Chemical Society, Carbondale, Ill., Oct 1975, No. 517.
(4) H. Kammerer, G. Happel, and F. Caesar, *Makromol. Chem.*, **162**, 179 (1972).
(5) B. T. Hayes and R. F. Hunter, *J. Appl. Chem.*, **8**, 743 (1958).
(6) A. Zinke and E. Ziegler, *Chem. Ber.*, **77**, 264 (1944).
(7) Acid-catalyzed preparations have been reported also but have received little attention: J. B. Niederland and H. S. Vogel, *J. Am. Chem. Soc.*, **62**, 2512 (1940); H. Erdtman, S. Hogberg, S. Abrahamsson, and B. Nilsson, *Tetrahedron Lett*, 1679 (1968).
(8) Metacyclophane nomenclature:[9] (1) 4,11,18,25-tetramethyl-7,14,21,28-tetrahydroxy[1.1.1.1]metacyclophane; (2) 4,11,18,25-tetra-*tert*-butyl-7,14,21,28-tetrahydroxy[1.1.1.1]metacyclophane; (3) 4,11,18,25-tetraphenyl-7,14,21,28-tetrahydroxy[1.1.1.1]metacyclophane; (4) 4,11,18,-25-tetramethoxy-7,14,21,28-tetrahydroxy[1.1.1.1]metacyclophane; (5) 4,11,18,25-tetracarbomethoxy-7,14,21,28-tetrahydroxy[1.1.1.1]metacyclophane.
(9) B. H. Smith, "Bridged Aromatic Compounds", Academic Press, New York, N.Y., 1964, Chapter 1.