Metacyclophanes and Related Compounds. 1. Preparation and Nuclear Magnetic Resonance Spectra of 8,16-Disubstituted [2.2]Metacyclophanes

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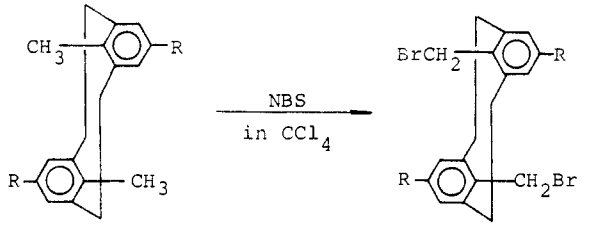
Preparation of 8,16-bis(alkoxymethyl)- (**3a–j**), 8,16-bis(iodomethyl)- (**4a,b**), 8,16-bis(acetylhydroxymethyl)- (**5a,b**), 8,16-dihydroxy- (**6a,b**), and 8,16-bis(pyridiniummethyl)[2.2]metacyclophanes was described. The corresponding 2-substituted 5-*tert*-butyl-*m*-xylenes (BMX) were also prepared as reference materials for the determination of ^1H and ^{13}C NMR spectra of MCP. On the basis of the differences ($\Delta\delta$) of the chemical shifts of the internal protons of the [2.2]metacyclophanes (MCP) from the corresponding protons of BMX, the effect of ring current of the opposite aromatic ring on the internal protons of MCP was judged. The ring current effect on the chemical shifts seems be associated with the distance of the protons from the same side aromatic ring rather than the kind of the groups in positions 8 and 16 in MCP. There was no effect of the ring current on the internal carbons of MCP in the measurement of ^{13}C NMR.

Recently, Boekelheide and his co-workers[1-10] have reported the synthesis of interesting 8-mono- and 8,16-disubstituted [2.2]metacyclophanes (MCP) and found that their internal alkyl protons show upfield shifts due to the ring current of the opposite aromatic ring.[7] Although such upfield shifts might be observed in ^1H NMR spectra of MCP having internal substituents other than alkyl groups there has not been any report concerning the above problem so far. Although Sato and his co-workers have studied ^{13}C NMR spectra of some [2.2]metacyclophanes, the ^{13}C NMR spectra of 8,16-disubstituted [2.2]metacyclophanes[11-14] have not been reported.

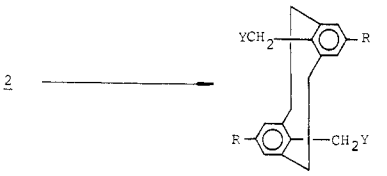
We previously reported that[15] the bromination of 8,16-dimethyl- (**1a**) and 5,13-di-*tert*-butyl-8,16-dimethyl[2.2]-



1 a: R = H b: R = t-Bu 2

metacyclophane (**1b**) with NBS gave the corresponding dibromides **2a** and **2b** in good yields. We now report on the preparation and the ^1H and ^{13}C NMR spectra of some 8,16-disubstituted [2.2]MCP having substituents other than alkyl groups.

Scheme I



Product	R	Y	Yield (%)	Product	R	Y	Yield (%)
3a	H	OCH_3	65	5a	H	OAc	79
3b	H	OC_2H_5	67	5b	t-Bu	OAc	89
3c	H	O-nC_3H_7	71	6a	H	OH	92
3d	H	O-nC_4H_9	64	6b	t-Bu	OH	79
3e	H	$OCH_2CH{=}CH_2$	74	8a	H		78
3f	t-Bu	OCH_3	78	8b	H		48
3g	t-Bu	OC_2H_5	76	8c	H		97
3h	t-Bu	O-nC_3H_7	81	8d	H		65
3i	t-Bu	O-nC_4H_9	83	8e	t-Bu		70
3j	t-Bu	$OCH_2CH{=}CH_2$	77	8f	t-Bu		100
4a	H	I	70	8g	t-Bu		99
4b	t-Bu	I	63	8h	t-Bu		85

Results and Discussion

Preparation. The title compounds were prepared from **2**, and the results are summarized in Scheme I.

When **2a** and **2b** were refluxed with sodium alkoxide in the corresponding alcohols, the expected 8,16-bis(alkoxymethyl)[2.2]metacyclophanes **3** were obtained in good

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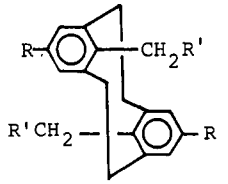
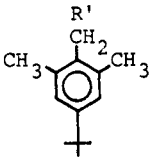
Table I. Chemical Shifts of the Internal CH_2 and CH_3 Protons of MCP[a]



MCP



BMX

R	R'	α-CH_2 $\delta_{MCP}^{CH_2}$	α-CH_2 $\delta_{BMX}^{CH_2}$	α-CH_2 $\Delta\delta(CH_2)$	ω-CH_3 $\delta_{MCP}^{CH_3}$	ω-CH_3 $\delta_{BMX}^{CH_3}$	ω-CH_3 $\Delta\delta(CH_3)$
t-Bu	I	3.01	4.38	1.37			
H	OH	2.94	4.64	1.70			
t-Bu	OH	2.93	4.64	1.71			
t-Bu	CH_3	1.03	2.56	1.53	0.32	1.07	0.75
t-Bu	CH_2CH_3	0.92	2.51	1.63	0.48	1.00	0.52
t-Bu	$CH_2CH_2CH_3$	0.92	2.46	1.59	0.64	0.95	0.31
H	$OCOCH_3$	3.40	5.12	1.72	1.76	2.01	0.25
t-Bu	$OCOCH_3$	3.40	5.12	1.72	1.76	2.01	0.25
H	OCH_3	2.68	4.40	1.72	2.78	3.35	0.57
t-Bu	OCH_3	2.68	4.40	1.72	2.87	3.35	0.48
H	OCH_2CH_3	2.70	4.44	1.74	0.89	1.21	0.32
t-Bu	OCH_2CH_3	2.70	4.44	1.74	0.95	1.21	0.26
H	$OCH_2CH_2CH_3$	2.71	4.44	1.73	0.70	0.92	0.22
t-Bu	$OCH_2CH_2CH_3$	2.70	4.44	1.74	0.72	0.92	0.20
H	$OCH_2CH_2CH_2CH_3$	2.71	4.43	1.72	0.76	0.90	0.14
t-Bu	$OCH_2CH_2CH_2CH_3$	2.68	4.43	1.75	0.77	0.90	0.13
H	$OCH_2CH{=}CH_2$	2.72	4.47	1.75			
t-Bu	$OCH_2CH{=}CH_2$	2.76	4.47	1.71			

a

yields. Compounds **2a** and **2b** reacted with NaI in boiling acetone to give the corresponding diiodides **4a** and **4b** in good yields. Treatment of **2** with $AgOCOCH_3$ in Ac_2O afforded the corresponding diacetates **5** in good yields, and the latter were easily hydrolized with aqueous KOH–EtOH solution to give the corresponding bis(hydroxymethyl)-[2.2]metacyclophanes **6**.

When **2** was refluxed with pyridines **7** for 12 h, the corresponding salts **8** were obtained in good yields, except for **8b**.

2-Substituted 5-*tert*-butyl-*m*-xylenes (BMX) corresponding to the MCP described above were prepared from 2-(chloromethyl)-5-*tert*-butyl-*m*-xylene (**10**) as a standard reference material (Scheme II). Preparation of **10** from *m*-xylene was described in the previous paper.[16]

^{1}H NMR Spectra. The chemical shifts of only the internal α-methylene and ω-methyl protons of the substituents in positions 8 and 16 of MCP are summarized in Table I. The corresponding proton signals of the corresponding substituents in position 2 of BMX and the differences ($\Delta\delta$) of the chemical shifts of MCP from those of BMX are also shown in this table.

The effect of the ring current of the opposite aromatic ring on the internal protons might be judged by the values of the shift differences ($\Delta\delta$) since there is no ring current of the opposite aromatic ring in the BMX system. Although the preparation and NMR spectral data of 8,16-dialkyl[2.2]metacyclophanes have been previously reported,[15] such difference values ($\Delta\delta$) were not calculated. These values are, therefore, included in Table I.

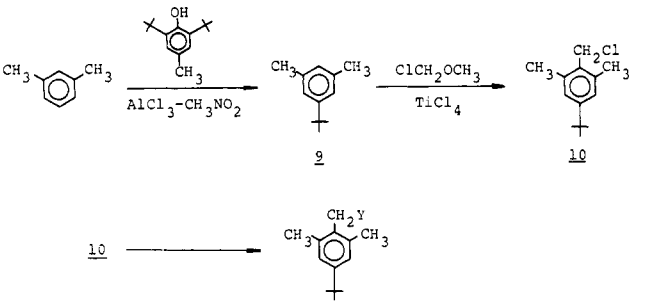
Unfortunately, the ^{1}H NMR spectrum of **4a** could not be measured since its solubility in suitable solvents was very poor.

The data of the Table I show that most of the calculated values of $\Delta\delta(CH_2)$ are in a narrow range of 1.5–1.7 ppm though R′ groups are widely changed. The values of $\Delta\delta(CH_3)$ are affected by the length of the chain of the R′ groups, but not by the kind of R′ groups; that is, the values of $\Delta\delta(CH_3)$ with one, two, three, four, and five atoms removed are 0.75, ca. 0.5, ca. 0.3, ca 0.2, and ca. 0.13, respectively. These results mean that the effect of the ring current of the opposite aromatic ring on the internal ω-methyl protons decreases gradually with increasing distance from the attached aromatic ring. The $\Delta\delta(CH_3)$ values should be almost zero when R′ groups have more than six or seven atoms.

Similar results are observed for the values of $\Delta\delta(CH_2)$ in C_4-MCP as shown in the Table II. That is, the values for one, two, and three atoms removed are ca. 1.7, 0.74, and ca. 0.5, respectively.

The values of $\Delta\delta(\alpha,\beta,\gamma\text{-H})$ and $\Delta\delta(CH_3)$ calculated from chemical shifts of pyridine ring protons and methyl protons

Scheme II



Product	Y	Yield (%)	Product	Y	Yield (%)
11a	OCH_3	95	14	I	83
11b	OC_2H_5	85	15a		71
11c	O-nC_3H_7	81	15b		81
11d	O-nC_4H_9	89			
11e	OCH_2-CH=CH_2	83	15c		97
12	OAc	86			
13	OH	71	15d		34

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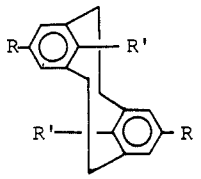
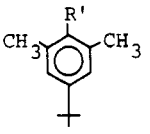
Table II. Chemical Shifts of the Internal α-, β-, and γ-methylene Protons of C_4-MCP[a]



MCP

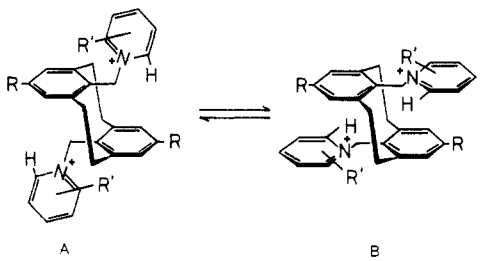


BMX

R	R′	δ(MCP)	δ(BMX)	Δδ[c]
	One Atom Removed			
t-Bu	$CH_2CH_2CH_2CH_3$	0.92	2.46	1.59
H	$CH_2OCH_2CH_3$	2.70	4.44	1.74
t-Bu	$CH_2OCH_2CH_3$	2.70	4.44	1.74
H	CH_2OCOCH_3	3.40	5.12	1.72
t-Bu	CH_2OCOCH_3	3.40	5.12	1.72
	Two Atoms Removed			
t-Bu	$CH_2CH_2CH_2CH_3$	0.68[b]	1.42[b]	0.74
	Three Atoms Removed			
t-Bu	$CH_2CH_2CH_2CH_3$	0.92[b]	1.42[b]	0.50
H	$CH_2OCH_2CH_3$	2.91	3.51[b]	0.60
t-Bu	$CH_2OCH_2CH_3$	2.98	3.51	0.53

[a] Determined in $CDCl_3$ by using $SiMe_4$ as a reference and and given in parts per million. [b] Midpoint values of multiplets. [c] Upfield shift due to ring current.

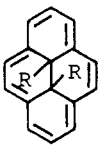
of MCP and BMX pyridinium salts are summarized in Tables III and IV, respectively. It was found that the effect of the ring current of the opposite aromatic ring on the internal pyridine ring protons was determined by the values of Δδ(H) as shown in Table III. It should be noted that the values (0.19–0.20 ppm) of Δδ(α-H) of α-picolinium salts are smaller than those (0.40–0.60 ppm) of the other pyridinium salts. As is shown in Table IV, the values (0.69–0.98 ppm) of $\Delta\delta(\alpha\text{-}CH_3)$ are larger than those (0.12–0.14 ppm) of $\Delta\delta(\beta\text{-}CH_3)$ and of $\Delta\delta(\gamma\text{-}CH_3)$. From the above results, it is concluded that pyridinium salts 8 have the conformers A and B and that **8b** and **8f** might exist



A B

in conformer A because of steric repulsion between the α-methyl groups and the bridged ethylene bonds. Accordingly, the α-methyl protons of the pyridine rings of **8b** and **8f** might be slightly affected by the ring current of the aromatic rings on the same side rather than that of the opposite aromatic rings.

Although proton shielding is markedly influenced by magnetic field induced circulation of π electrons in a closed, conjugated system, the same influences (~5 ppm) are less significant in determining ^{13}C resonance positions.[17] DuVernet and Boekelheide[18] measured ^{13}C chemical shifts for the R groups in dihydropyrenes 11.



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The data of Table V show that the chemical shifts of the 8- and 16-position carbon resonances of MCP are observed at lower field than those of the 2-position carbon resonances of BMX. The values $\Delta\delta_{Ali}{}^{13C}$ seem to be affected by the R groups rather than by the R′ groups. From the data shown in Table VI, it is clear that the chemical shifts of the carbon resonances of the internal carbons of MCP are not affected by the ring current of the opposite aromatic rings. It was also observed that the values $\Delta\delta_{Ali}{}^{13C}$ vary at random. The differences of the chemical shifts of the carbon resonances of internal aliphatic carbons of MCP and the corresponding BMX seem to vary at random too.

Experimental Section

All melting and boiling points are uncorrected. NMR spectra were determined at 100 MHz with a Nippon Denshi JEO FT-100 NMR spectrometer with Me_4Si as an internal reference, and IR spectra were measured as KBr pellets or as a liquid film on NaCl plates in a Nippon Bunko IR-A-102 spectrometer. Mass spectra were obtained on a Nippon Denshi JMS-01SA-2 spectrometer at 75 eV by using a direct inlet system.

Preparation of 8,16-Bis(alkoxymethyl)[2.2]metacyclophanes (3). 8,16-Bis(methoxymethyl)[2.2]metacyclophane (3a). To a solution of 83 mg (3.6 mmol) of sodium in 20 mL of absolute methyl alcohol was added 473 mg (1.2 mmol) of 8,16-bis(bromomethyl)[2.2]metacyclophane (2), and the mixture was refluxed for 12 h. Upon cooling, it was diluted with water and acidified with acetic acid, and the product was extracted with dichloromethane. The dichloromethane solution was dried over Na_2SO_4 and evaporated in vacuo to give 320 mg of white crystals. Recrystallization from methyl alcohol gave 250 mg (64.8%) of **3a**: colorless prisms (methyl alcohol); mp 206–208 °C; IR (KBr) 3060, 2950, 2880, 2810, 1580, 1460, 1380, 1180, 1085, 1055, 1030, 950, 880, 775, 735 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.68 (4 H, s), 2.78 (6 H, s), 2.78–3.07 (8 H, m, CH_2CH_2), 6.92–7.21 (6 H, m); ^{13}C NMR ($CDCl_3$) δ 36.30 (t), 57.36 (q), 66.18 (t), 127.09 (d), 127.62 (d), 137.47 (s), 143.21 (s); mass spectrum, *m/e* 296 (M^+). Anal. Calcd for $C_{20}H_{24}O_2$: C, 81.04; H, 8.16. Found: C, 80.54; H, 8.22.

Similarly, **3b–j** were synthesized in the same manner as described above.

3b: colorless prisms (methyl alcohol); mp 149–151 °C; IR (KBr) 3050, 2980, 2930, 2880, 1580, 1485, 1460, 1440, 1400, 1365, 1350, 1120, 1085, 1010, 895, 870, 775, 735 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.80 (6 H, t, *J* = 7 Hz), 2.70 (4 H, s), 2.91 (4 H, q, *J* = 7 Hz), 2.76–3.05 (8 H, m), 6.90–7.20 (6 H, m); ^{13}C NMR ($CDCl_3$) δ 14.91 (q), 36.21 (t), 64.03 (t), 64.71 (t), 126.80 (d), 127.48 (d), 137.37 (s), 143.41 (s); mass spectrum, *m/e* 324 (M^+). Anal. Calcd for $C_{22}H_{28}O_2$: C, 81.43; H, 8.70. Found: C, 81.04; H, 8.78.

3c: colorless prisms (methyl alcohol); mp 72–74 °C; IR (KBr) 3050, 2980, 2940, 2860, 1580, 1450, 1185, 1105, 1080, 1035, 885, 780, 730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.70 (6 H, t, *J* = 7 Hz), 2.78–3.07 (8 H, m), 6.92–7.23 (6 H, m); ^{13}C NMR ($CDCl_3$) δ 10.48 (q), 22.71 (t), 36.35 (t), 64.37 (t), 71.34 (t), 126.89 (d), 127.53 (d), 137.56 (s), 143.66 (s); mass spectrum, *m/e* 352 (M^+). Anal. Calcd for $C_{24}H_{34}O_2$: C, 81.77; H, 9.15. Found: C, 81.29; H, 9.22.

3d: colorless prisms (methyl alcohol); mp 72–74 °C; IR (KBr) 3050, 2960, 2940, 2860, 1580, 1470, 1450, 1355, 1190, 1095, 1045, 1015, 770, 730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.76 (6 H, t, *J* = 7 Hz), 0.95–1.40 (8 H, m), 2.71 (4 H, s), 2.80 (4 H, t, *J* = 7 Hz), 2.75–3.05 (8 H, m), 6.92–7.24 (6 H, m); ^{13}C NMR ($CDCl_3$) δ 14.23 (q), 19.69 (t), 32.11 (t), 36.89 (t), 64.96 (t), 69.78 (t), 127.38 (d), 128.06 (d), 138.10 (s), 144.19 (s); mass spectrum, *m/e* 380 (M^+). Anal. Calcd for $C_{26}H_{36}O_2$: C, 82.06; H, 9.54. Found: C, 82.04; H, 9.49.

3e: colorless prisms (methyl alcohol); mp 76–79 °C; IR (KBr) 3060, 3020, 2960, 2880, 1580, 1455, 1415, 1280, 1190, 1115, 1140,

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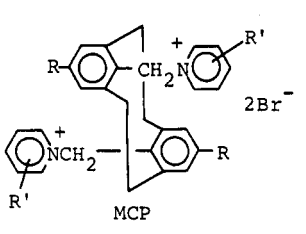
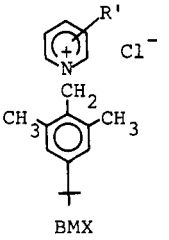
(18) R. DuVernet and V. Boekelheide, *Proc. Natl. Acad. Sci. U.S.A.* 71, 296 (1974).

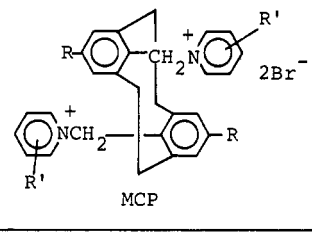
Table III. Chemical Shifts of the Protons of Pyridine Ring

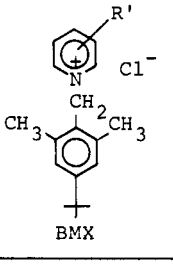




R	R'	α-proton			β-proton			γ-proton		
		$\delta_{MCP}^{\alpha\text{-H}}$	$\delta_{BMX}^{\alpha\text{-H}}$	$\Delta\delta^{\alpha\text{-H}}$	$\delta_{MCP}^{\beta\text{-H}}$	$\delta_{BMX}^{\beta\text{-H}}$	$\Delta\delta^{\beta\text{-H}}$	$\delta_{MCP}^{\gamma\text{-H}}$	$\delta_{BMX}^{\gamma\text{-H}}$	$\Delta\delta^{\gamma\text{-H}}$
H	H	8.38	8.98	0.60	7.90	8.15	0.25	8.44	8.64	0.20
t-Bu	H	8.38	8.98	0.60	7.94	8.15	0.21	8.38	8.64	0.26
H	α-CH_3	8.27	8.46	0.19	7.05, 7.64	7.80, 7.96	0.75, 0.32	7.85	8.19	0.34
t-Bu	α-CH_3	8.26	8.46	0.20	7.42, 7.70	7.80, 7.96	0.38, 0.26	7.86	8.19	0.33
H	β-CH_3	8.24, 8.48	8.64, 8.96	0.41, 0.48	7.77	8.01	0.24	8.01	8.47	0.46
t-Bu	β-CH_3	8.23, 8.40	8.64, 8.96	0.41, 0.56	7.78	8.00	0.23	8.05	8.47	0.42
H	γ-CH_3	8.20	8.75	0.55	7.70	7.94	0.24			
t-Bu	γ-CH_3	8.21	8.75	0.54	7.73	7.94	0.21			

Table IV. Chemical Shifts of Methyl Protons of Pyridinium Salts





R	R'	α-methyl			β-methyl			γ-methyl		
		$\delta_{MCP}^{\alpha\text{-CH}_3}$	$\delta_{BMX}^{\alpha\text{-CH}_3}$	$\Delta\delta^{\alpha\text{-CH}_3}$	$\delta_{MCP}^{\beta\text{-CH}_3}$	$\delta_{BMX}^{\beta\text{-CH}_3}$	$\Delta\delta^{\beta\text{-CH}_3}$	$\delta_{MCP}^{\gamma\text{-CH}_3}$	$\delta_{BMX}^{\gamma\text{-CH}_3}$	$\Delta\delta^{\gamma\text{-CH}_3}$
H	α-CH_3	2.10	3.08	0.98						
t-Bu	α-CH_3	2.41	3.08	0.69						
H	β-CH_3				2.37	2.51	0.14			
t-Bu	β-CH_3				2.37	2.51	0.14			
H	γ-CH_3							2.46	2.59	0.13
t-Bu	γ-CH_3							2.47	2.59	0.12

1050, 1015, 925, 780, 740 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.72 (4 H, s), 2.76–3.06 (8 H, m), 3.31–3.40 (4 H, m), 4.89–5.10 (4 H, m), 5.44–5.82 (2 H, m), 6.96–7.21 (6 H, m); ^{13}C NMR ($CDCl_3$) δ 36.35 (t), 63.50 (t), 70.41 (t), 117.05 (t), 127.04 (d), 127.67 (d), 134.83 (d), 137.56 (s), 143.12 (s); mass spectrum, *m/e* 348 (M^+). Anal. Calcd for $C_{24}H_{28}O_2$: C, 82.72; H, 8.10. Found: C, 82.47; H, 8.20.

3f: colorless prisms (methyl alcohol); mp 235–237 °C; IR (KBr) 3050, 2960, 2880, 2820, 1595, 1480, 1460, 1360, 1195, 1100, 1085, 955, 885, 860, 820, 775, 730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.31 (18 H, s), 2.68 (4 H, s), 2.87 (6 H, s), 2.72–3.04 (8 H, m), 7.10 (4 H, s); ^{13}C NMR ($CDCl_3$) δ 30.99 (q), 33.87 (s), 36.30 (t), 57.60 (q), 66.13 (t), 124.36 (d), 136.73 (s), 140.05 (s), 149.12 (s); mass spectrum, *m/e* 408 (M^+). Anal. Calcd for $C_{28}H_{40}O_2$: C, 82.30; H, 9.87. Found: C, 81.78; H, 9.89.

3q: colorless prisms (methyl alcohol); mp 140–142 °C; IR (KBr) 3040, 2960, 2860, 1590, 1480, 1440, 1370, 1350, 1280, 1120, 1080, 1000, 895, 860, 770, 725, 660 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.95 (6 H, t, J = 7 Hz), 1.31 (18 H, s), 2.70 (4 H, s), 2.76–3.00 (8 H, m), 2.98 (4 H, q, J = 7 Hz), 7.08 (4 H, s); ^{13}C NMR ($CDCl_3$) δ 15.01 (q), 31.33 (q), 34.11 (s), 36.60 (t), 64.23 (t), 65.40 (t), 124.60 (d), 137.08 (s), 140.54 (s), 149.16 (s); mass spectrum, *m/e* 436 (M^+). Anal. Calcd for $C_{30}H_{44}O_2$: C, 82.51; H, 10.16. Found: C, 82.29; H, 10.22.

3h: colorless prisms (methyl alcohol); mp 113–115 °C; IR (KBr) 3080, 2000, 2890, 1600, 1485, 1360, 1280, 1120, 1100, 1040, 965, 870, 820, 830, 660 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.72 (6 H, t, J = 7 Hz), 1.31 (18 H, s), 1.15–1.50 (4 H, m), 2.70 (4 H, s), 2.88 (4 H, t, J = 7 Hz), 2.72–3.03 (8 H, m), 7.08 (4 H, s); ^{13}C NMR ($CDCl_3$) δ 10.48 (q), 22.56 (t), 31.33 (q), 34.11 (s), 36.65 (t), 64.47 (t), 71.97 (t), 124.60 (d), 137.12 (s), 140.73 (s), 149.16 (s); mass spectrum, *m/e* 464 (M^+). Anal. Calcd for $C_{32}H_{48}O_2$: C, 82.70; H, 10.41. Found: C, 82.62; H, 10.49.

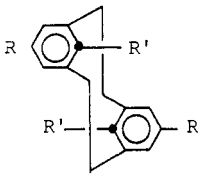
3i: colorless prisms (methyl alcohol); mp 100–102 °C; IR (KBr) 3040, 2960, 2860, 1595, 1470, 1400, 1360, 1125, 1100, 1030, 1010, 885, 860, 810, 770, 720 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.32 (18 H, s), 2.76 (4 H, s), 2.77–3.04 (8 H, m), 3.41–3.49 (4 H, m), 4.90–5.11 (4 H, m), 5.46–5.84 (2 H, m), 7.09 (4 H, s); ^{13}C NMR ($CDCl_3$) δ 31.29 (q), 34.06 (s), 36.50 (t), 63.60 (t), 70.76 (t), 116.61 (t), 124.56 (d), 134.98 (d), 137.03 (s), 140.24 (s), 149.31 (s); mass spectrum, *m/e* 460 (M^+). Anal. Calcd for $C_{32}H_{44}O_2$: C, 83.43; H, 9.63. Found: C, 83.30; H, 9.73.

3j: colorless prisms (methyl alcohol); mp 109–112 °C; IR (KBr) 3100, 3020, 2980, 2850, 1645, 1595, 1450, 1405, 1360, 1280, 1220, 1180, 1120, 1040, 1015, 945, 910, 900, 890, 880, 860, 810, 775, 715, 660 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.32 (18 H, s), 2.76 (4 H, s), 2.77–3.04 (8 H, m), 3.41–3.49 (4 H, m), 4.90–5.11 (4 H, m), 5.46–5.84 (2 H, m), 7.09 (4 H, s); mass spectrum, *m/e* 460 (M^+). Anal. Calcd for $C_{32}H_{44}O_2$: C, 83.43; H, 9.63. Found: C, 83.30; H, 9.73.

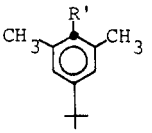
Preparation of 8,16-Bis(iodomethyl)[2.2]metacyclophane (4a). Powdered NaI (11.4 g, 76.1 mmol) was added slowly to a hot solution of 300 mg (0.761 mmol) of **2a** in 100 mL of acetone. After the reaction mixture was refluxed for 6 h, it was evaporated in vacuo to leave a residue which was washed with 50 mL of warmed water to give 260 mg (70.1%) of **4a**: colorless prisms (benzene); mp >300 °C; IR (KBr) 3030, 2940, 1570, 1455, 1440, 1215, 1180, 885, 770, 740, 675 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.80–3.16 (8 H, m), 3.01 (4 H, s), 7.08–7.20 (6 H, m); mass spectrum, *m/e* 488 (M^+). Anal. Calcd for $C_{18}H_{18}I_2$: C, 44.29; H, 3.72. Found: C, 45.10; H, 3.95.

Preparation of 5,13-Di-*tert*-butyl-8,16-bis(iodomethyl)-[2.2]metacyclophane (4b). Powdered NaI 3.32 g (2.2 mmol) was added slowly to a hot solution of 100 mg (0.198 mmol) of **2b** in 50 mL of acetone. After the reaction mixture was refluxed for

Table V. Substituents Effect on Chemical Shifts of the Inner 8- and 16-Position Carbon Resonances of [2.2]Metacyclophanes[a]



MCP



BMX

R	R'	δ(MCP)	δ(BMX)	Δδ[b]
t-Bu	CH_2OH	143.3	133.7	9.6
t-Bu	CH_3	139.6	131.8	7.8
t-Bu	CH_2CH_3	146.5	137.7	8.8
t-Bu	$CH_2CH_2CH_3$	145.0	136.5	8.5
t-Bu	$CH_2CH_2CH_2CH_3$	145.0	136.6	8.4
H	CH_2OCOCH_3	140.5	129.1	11.4
t-Bu	CH_2OCOCH_3	137.5	129.1	8.4
H	CH_2OCH_3	143.2	131.1	12.1
t-Bu	CH_2OCH_3	140.0	131.1	8.9
H	$CH_2OCH_2CH_3$	143.4	131.3	12.1
t-Bu	$CH_2OCH_2CH_3$	140.5	131.3	9.2
H	$CH_2OCH_2CH_2CH_3$	143.7	131.5	12.2
t-Bu	$CH_2OCH_2CH_2CH_3$	140.7	131.5	9.2
H	$CH_2OCH_2CH_2CH_2CH_3$	144.2	131.6	12.6
t-Bu	$CH_2OCH_2CH_2CH_2CH_3$	140.7	131.6	9.1
H	$CH_2OCH_2CH{=}CH_2$	143.1	135.1	8.0
t-Bu	$CH_2OCH_2CH{=}CH_2$	140.2	135.1	5.1
t-Bu	CH_2N^+	135.0	126.6	8.4

[a] Determined in $CDCl_3$ or Me_2SO-d_6 by using $SiMe_4$ as a reference and given in parts per million. [b] Δδ = δ(cyclophane) − δ(BMX).

Table VI. Chemical Shifts of the Internal Carbon of [2.2]Metacyclophanes[a]

R	R'	δ(MCP)	δ(BMX)	Δδ[b]
	One Atom Removed			
t-Bu	$CH_2CH_2CH_2CH_3$	34.1	31.4	−2.7
H	$CH_2OCH_2CH_3$	64.0	65.6	1.6
t-Bu	$CH_2OCH_2CH_3$	64.2	65.6	1.4
H	CH_2OCOCH_3	58.7	61.0	2.3
t-Bu	CH_2OCOCH_3	59.1	61.0	1.9
	Two Atoms Removed			
t-Bu	$CH_2CH_2CH_2CH_3$	24.9	29.2	4.4
	Three Atoms Removed			
t-Bu	$CH_2CH_2CH_2CH_3$	22.8	23.3	0.5
H	$CH_2OCH_2CH_3$	64.7	66.6	1.9
t-Bu	$CH_2OCH_2CH_3$	65.4	66.6	1.2
H	CH_2OCOCH_3	170.2	170.3	0.1
t-Bu	CH_2OCOCH_3	170.3	170.3	0
	Four Atoms Removed			
t-Bu	$CH_2CH_2CH_2CH_3$	13.9	13.9	0
H	$CH_2OCH_2CH_3$	14.9	15.2	0.3
t-Bu	$CH_2OCH_2CH_3$	15.0	15.2	0.2
H	CH_2OCOCH_3	20.8	20.8	0
t-Bu	CH_2OCOCH_3	20.9	20.8	−0.1

[a] Determined in $CDCl_3$ by using $SiMe_4$ as a reference and given in parts per million. [b] Upfield shift due to ring current.

6 h, it was treated as described above to give 75.5 mg (63.4%) of **4b**: colorless prisms (benzene); mp >300 °C; IR (KBr) 3040, 2960, 1585, 1470, 1450, 1360, 1275, 1220, 1145, 880, 860, 805, 760, 660 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.29 (18 H, s), 2.67–3.10 (8 H, m), 3.01 (4 H, s), 7.07 (4 H, s); mass spectrum, *m/e* 600 (M^+). Anal. Calcd for $C_{26}H_{34}I_2$: C, 52.01; H, 5.71. Found: C, 52.30; H, 5.86.

Preparation of 8,16-Bis(acetoxymethyl)[2.2]metacyclophane (5a). A solution of 300 mg (0.761 mmol) of **2a** in 50 mL of glacial acetic acid containing 1.27 g (7.61 mmol) of silver acetate was heated at 85–90 °C for 4 h. The resulting suspension was concentrated and then extracted with dichloromethane. After the dichloromethane solution had been washed successively with an aqueous sodium bicarbonate solution and water, it was dried over Na_2SO_4 and concentrated to give 212.2 mg (79.2%) of **5a**: colorless prisms (methyl alcohol); mp 232–234 °C; IR (KBr) 3040, 2940, 1720, 1365, 1230, 1180, 1010, 945, 780, 740 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.76 (6 H, s), 2.74–3.16 (8 H, m), 3.40 (4 H, s), 8.13–8.27 (6 H, m); ^{13}C NMR ($CDCl_3$) δ 20.81 (q), 36.11 (t), 58.72 (t), 128.01 (d), 128.16 (d), 137.62 (s), 140,48 (s), 170.21 (s); mass spectrum, *m/e* 352 (M^+). Anal. Calcd for $C_{22}H_{24}O_4$: C, 74.97; H, 6.86. Found: C, 74.31; H, 6.90.

Preparation of 5,13-Di-*tert*-butyl-8,16-bis(acetoxymethyl)[2.2]metacyclophane (5b). A solution of 300 mg (0.593 mmol) of **2b** in 50 mL of glacial acetic acid containing 990 mg (5.93 mmol) of silver acetate was heated at 85–90 °C for 4 h. The reaction mixture was treated as described above to give 234 mg (85.1%) of **5b**: colorless prisms (methyl alcohol); mp 246–248 °C; IR (KBr) 3040, 2960, 1725, 1590, 1480, 1375, 1240, 1020, 960, 940, 890, 860, 815, 765, 730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.35 (18 H, s), 1.76 (6 H, s), 2.72–3.06 (8 H, m), 3.40 (4 H, s), 8.16 (4 H, s); ^{13}C NMR ($CDCl_3$) δ 20.86 (q), 31.24 (q), 34.35 (s), 36.35 (t), 59.06 (t), 125.04 (d), 137.37 (s); mass spectrum, *m/e* 464 (M^+). Anal. Calcd for $C_{30}H_{40}O_4$: C, 77.55; H, 8.68. Found: C, 77.30; H, 8.76.

Preparation of 8,16-Bis(hydroxymethyl)[2.2]metacyclophane (6a). A solution of 5.0 g of KOH and 1 mL of H_2O was added to a solution of 1.06 g (3 mmol) of **2a** in 10 mL of ethyl alcohol, and the mixture was refluxed for 12 h. Upon cooling, it was diluted with water and extracted with dichloromethane. The dichloromethane extract was washed with water, dried over Na_2SO_4, and evaporated in vacuo to give 563 mg (70%) of **6a**: colorless plates (benzene); mp >300 °C; IR (KBr) 3400, 3040, 2960, 1460, 1445, 1385, 1185, 995, 875, 870, 775, 755 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.43 (2 H, br s), 2.94 (4 H, s), 2.74–3.14 (8 H, m), 6.94–7.24 (6 H, m); mass spectrum, *m/e* 268 (M^+). Anal. Calcd for $C_{18}H_{20}O_2$: C, 80.56; H, 7.51. Found: C, 80.30; H, 7.45.

Preparation of 5,13-Di-*tert*-butyl-8,16-bis(hydroxymethyl)[2.2]metacyclophane (6b). A solution of 5.0 g of KOH and 1 mL of H_2O was added to a solution of 1.39 g (3 mmol) of **2b** in 10 mL of ethyl alcohol, and the mixture was refluxed for 12 h. The reaction mixture was treated as described above to give 710 mg (62.3%) of **6b**: colorless prisms (benzene–hexane, 3:1); mp >300 °C; IR (KBr) 3200, 3040, 2930, 1585, 1470, 1455, 1355, 1220, 990, 860, 770 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.32 (18 H, s), 2.78–3.06 (8 H, m), 2.93 (4 H, s), 7.11 (4 H, s); ^{13}C NMR ($CDCl_3$) δ 31.29 (q), 34.26 (s), 36.45 (t), 56.72 (t), 125.14 (d), 136.59 (s), 143.27 (s), 149.84 (s); mass spectrum, *m/e* 380 (M^+). Anal. Calcd for $C_{26}H_{36}O_2$: C, 82.06; H, 9.54. Found: C, 81.66; H, 9.60.

Preparation of 8,16-Bis(pyridiniummethyl)[2.2]metacyclophane Dibromide (8). A mixture of 500 mg (1.27 mmol) of **2a** and 20 mL of pyridine was boiled under reflux for 12 h. After the reaction mixture had cooled, 30 mL of benzene was added to give colorless solid. This solid was washied with dichloromethane and hexane to give 580 mg (77.7%) of **8a**: colorless powder; mp >300 °C; IR (KBr) 3040, 3000, 1620, 1575, 1500, 1475, 1460, 1205, 1145, 1100, 780, 760, 740, 680, 675 cm^{-1}; ^1H NMR (Me_2SO-d_6) δ 3.04–3.25 (8 H, m), 4.20 (4 H, s), 7.24–7.56 (6 H, m), 7.90 (4 H, dd, J_{ba} = 6 Hz, J_{bc} = 8 Hz, H_b), 8.38 (4 H, dd, J_{ab} = 6 Hz, J_{ac} = 1 Hz, H_a), 8.44 (2 H, dd, J_{cb} = 8 Hz, J_{ca} = 1 Hz, H_c). Anal. Calcd for $C_{28}H_{28}N_2Br_2{\cdot}2H_2O$: C, 57.15; H, 5.48; N, 4.76. Found: C, 57.14; H, 4.93; N, 4.46.

Similarly, **8b–h** were synthesized in the same manner as described above.

8b: colorless prisms; mp >300 °C; IR (KBr) 3500, 3425, 3050, 2950, 1625, 1500, 1455, 1180, 1150, 780, 730 cm^{-1}; ^1H NMR (Me_2SO-d_6) δ 2.51 (6 H, s), 2.68–3.21 (8 H, m), 3.90 (4 H, s), 7.05 (2 H, m), 7.28–7.52 (6 H, m), 7.85 (2 H, m), 8.27 (2 H, m). Anal. Calcd for $C_{30}H_{32}N_2Br_2{\cdot}3H_2O$: C, 56.79; H, 6.04; N, 4.42. Found: C, 56.30; H, 5.90; N, 4.30.

8c: colorless powder; mp >300 °C; IR (KBr) 3450, 3070, 3050, 1630, 1615, 1505, 1495, 1470, 1150, 815, 790, 730, 690 cm^{-1}; ^1H NMR (Me_2SO-d_6) δ 2.37 (6 H, s), 3.14 (8 H, br s), 4.14 (4 H, s), 7.23–7.57 (6 H, m), 7.77 (2 H, dd, J_{ca} = 6 Hz, J_{cd} = 8 Hz, H_c), 8.01 (2 H, dd, J_{bc} = 6 Hz, J_{bd} = 1 Hz, H_b), 8.24 (2 H, dd, J_{dc} = 8 Hz, J_{db} = 1 Hz, H_d), 8.48 (2 H, br s, H_a). Anal. Calcd for $C_{30}H_{32}N_2Br_2{\cdot}2.5H_2O$): C, 57.61; H, 5.96; N, 4.48. Found: C, 57.60; H, 5.85; N, 4.40.

8d: brown powder; mp >300 °C; IR (KBr) 3040, 2950, 1635,

1515, 1460, 1150, 810, 780, 720 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 2.46 (6 H, s), 3.12 (8 H, br s), 4.08 (4 H, s), 7.16–7.30 (6 H, m), 7.70 (4 H, d, J_{ba} = 6 Hz, H_b), 8.20 (4 H, d J_{ab} = 6 Hz, H_a). Anal. Calcd for $C_{30}H_{32}N_2Br_2{\cdot}2H_2O$: C, 58.45; H, 5.89; N, 4.54. Found: C, 58.80; H, 5.78; N, 4.70.

8e: colorless powder; mp >300 °C; IR (KBr) 3040, 2960, 1620, 1585, 1480, 1220, 1140, 880, 860, 760, 680 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 1.36 (18 H, s), 3.16 (8 H, s), 4.22 (4 H, s), 7.51 (4 H, s), 7.94 (4 H, dd, J_{ba} = 6 Hz, J_{bc} = 8 Hz, H_b), 8.38 (4 H, dd, J_{ab} = 6 Hz, J_{ac} = 1 Hz, H_a), 8.41 (2 H, dd, J_{cb} = 8 Hz, J_{ca} = 1 Hz, H_c); ^{13}C NMR ($CDCl_3$) δ 30.65 (q), 34.26 (s), 35.43 (t), 54.82 (t), 126.80 (d), 127.96 (d), 134.35 (s), 137.95 (s), 143.85 (d), 145.46 (d), 151.84 (s). Anal. Calcd for $C_{36}H_{44}N_2Br_2{\cdot}H_2O$: C, 63.34; H, 6.79; N, 4.10. Found: C, 63.70; H, 6.65; N, 3.91.

8f: colorless powder; mp >300 °C; IR (KBr) 3480, 3400, 3040, 2980, 1630, 1595, 1505, 1480, 1360, 1290, 1230, 1140, 890, 800, 780, 720 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 1.37 (18 H, s), 2.41 (6 H, s), 2.68–3.20 (8 H, m), 3.95 (4 H, s), 7.42 (2 H, m), 7.60 (4 H, s), 7.70 (2 H, m), 7.86 (2 H, m), 8.26 (2 H, m). Anal. Calcd for $C_{38}H_{48}N_2Br_2$: C, 65.89; H, 6.99; N, 4.04. Found: C, 65.35; H, 7.05; N, 3.97.

8g: colorless powder; mp >300 °C; IR (KBr) 3400, 3040, 2980, 1630, 1595, 1505, 1480, 1465, 1365, 1225, 1140, 895, 870, 780, 720, 680 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 1.34 (18 H, s), 7.78 (2 H, dd, J_{ca} = 6 Hz, J_{cd} = 8 Hz, H_c), 8.05 (2 H, dd, J_{bc} = 6 Hz, J_{bd} = 1 Hz, H_b), 8.22 (2 H, dd, J_{dc} = 8 Hz, J_{db} = 1 Hz, H_d), 8.40 (2 H, br s), H_a). Anal. Calcd for $C_{38}H_{48}N_2Br_2{\cdot}H_2O$: C, 64.22; H, 7.09; N, 3.94. Found: C, 64.41; H, 7.04; N, 4.14.

8h: brown powder, mp >300 °C; IR (KBr) 3430, 3020, 2960, 1640, 1590, 1520, 1470, 1360, 1220, 1120, 885, 805, 780, 715 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 1.34 (18 H, s), 2.47 (6 H, s), 3.13 (8 H, s), 4.09 (4 H, s), 7.47 (4 H, s), 7.73 (4 H, d, J_{ba} = 6 Hz, H_b), 8.21 (4 H, d, J_{ab} = 6 Hz, H_a). Anal. Calcd for $C_{38}H_{48}N_2Br_2{\cdot}^4/_3H_2O$: C, 63.68; H, 7.13; N, 3.91. Found: C, 63.68; H, 7.00; N, 3.97.

Preparation of 2,6-Dimethyl-4-*tert*-butylbenzyl Alkyl Ethers (11). 2,6-Dimethyl-4-*tert*-butylbenzyl chloride (**10**; 10.53 g 50 mmol) was added to a solution of 1.73 g (75 mmol) **of** sodium in 80 mL of absolute alcohol, and the mixture was refluxed for 12 h. Upon cooling, it was diluted with water and acidified with acetic acid, and the product was extracted with benzene. Distillation of the benzene extracts yielded 2,6-dimethyl-4-*tert*-butylbenzyl alkyl ethers (**11**).

11a: colorless liquid; bp 93–94 °C (3 mmHg); IR (NaCl) 3060, 2980, 2840, 1610, 1490, 1460, 1360, 1240, 1190, 1120, 1095, 950, 965, 770, 720 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.27 (9 H, s), 2.35 (6 H, s), 3.35 (3 H, s), 4.40 (2 H, s), 7.00 (2 H, s). ^{13}C NMR ($CDCl_3$) δ 19.69 (q), 31.19 (q), 34.11 (s), 57.99 (q), 68.51 (t), 124.99 (d), 131.13 (s), 137.12 (s), 150.48 (s). Anal. Calcd for $C_{14}H_{22}O$: C, 81.50; H, 10.75. Found C, 81.07; H, 10.68.

11b: colorless liquid; bp 92–94 °C (2 mmHg); IR (NaCl) 3060, 2980, 2880, 1610, 1490, 1460, 1445, 1360, 1240, 1130, 1095, 865, 770, 720 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.21 (3 H, t, J = 7 Hz), 1.26 (9 H, s), 2.36 (6 H, s), 3.51 (2 H, q, J = 7 Hz), 4.44 (2 H, s), 6.98 (2 H, s). ^{13}C NMR ($CDCl_3$) δ 15.20 (q), 19.64 (q), 31.14 (q), 34.06 (s), 65.59 (t), 66.57 (t), 124.99 (d), 131.32 (s), 137.03 (s), 150.25 (s). Anal. Calcd for $C_{15}H_{24}O$: C, 81.76; H, 10.98. Found: C, 81.40; H, 11.01.

11c: colorless liquid; bp 101–103 °C (2 mmHg); IR (NaCl) 3060, 2980, 2880, 1610, 1490, 1460, 1360, 1240, 1120, 1095, 1040, 865, 820 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.92 (6 H, t, J = 7 Hz), 1.29 (9 H, s, *t*-Bu), 1.42–1.78 (2 H, m), 2.36 (6 H, s), 3.42 (2 H, t, J = 7 Hz), 4.44 (2 H, s), 6.98 (2 H, s); ^{13}C NMR ($CDCl_3$) δ 10.72 (a), 19.74 (q), 22.95 (t), 31.24 (q), 34.11 (s), 66.86 (t), 72.22 (t), 125.04 (d), 131.52 (s), 137.12 (s), 150.33 (s). Anal. Calcd for $C_{16}H_{26}O$: C, 81.99; H, 11.18. Found: C, 81.74; H, 11.23.

11d: colorless liquid; bp 120–122 °C (2 mmHg); IR (NaCl) 3060, 2980, 2880, 1610, 1490, 1460, 1360, 1240, 1120, 1095, 1050, 870, 720 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.90 (6 H, t, J = 7 Hz), 1.25 (9 H, s), 1.20–1.73 (4 H, m), 2.36 (6 H, s), 3.47 (2 H, t, J = 7 Hz), 4.43 (2 H, s), 6.98 (2 H, s). ^{13}C NMR ($CDCl_3$) δ 13.89 (q), 19.49 (t), 19.83 (q), 31.29 (q), 31.92 (t), 34.21 (s), 66.96 (t), 70.37 (t), 125.14 (d), 131.57 (s), 137.23 (s). Anal. Calcd for $C_{17}H_{28}O$: C, 82.20; H, 11.36. Found: C, 81.86; H, 11.42.

11e: colorless liquid; bp 130–132 °C (2 mmHg); IR (NaCl) 3100, 3060, 2980, 2880, 1610, 1580, 1490, 1460, 1360, 1240, 1120, 1080, 1000, 920, 865, 770, 720 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.28 (9 H, s), 2.38 (6 H, s), 3.97–4.05 (2 H, m), 4.47 (2 H, s), 5.09–5.39 (2 H, m), 5.77–6.16 (1 H, m), 7.00 (2 H, s); ^{13}C NMR ($CDCl_3$) δ 19.88 (q), 31.29 (q), 34.26 (s), 66.22 (t), 71.44 (t), 116.95 (t), 125.19 (d), 131.32 (d), 135.08 (s), 137.32 (s), 150.68 (s). Anal. Calcd for $C_{16}H_{24}O$: C, 82.70; H, 10.41. Found: C, 82.43; H, 10.36.

Preparation of 2,6-Dimethyl-4-*tert*-butylbenzyl Acetate (12). A solution of 8.4 g (40 mmol) of **10** in 200 mL of glacial acetic acid containing 33.4 g (200 mmol) of silver acetate was heated at 85–90 °C for 4 h. The resulting suspension was concentrated and then extracted with benzene. After the benzene solution had been washed with water, it was dried over Na_2SO_4 and concentrated to give 9.3 g of colorless liquid. Distillation of this yielded 2,6-dimethyl-4-butylbenzyl acetate (**12**): colorless liquid; bp 107–109 °C (1 mmHg); IR (NaCl) 3040, 2980, 1745, 1610, 1480, 1460, 1380, 1360, 1230, 1020, 960, 870, 760, 730 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.28 (9 H, s), 2.01 (3 H, s), 2.36 (6 H, s), 5.12 (2 H, s), 7.02 (2 H, s); ^{13}C NMR ($CDCl_3$) δ 19.83 (q), 20.76 (q), 31.24 (q), 34.31 (s), 61.01 (t), 125.28 (d), 129.09 (s), 137.71 (s), 151.40 (s), 170.95 (s). Anal. Calcd for $C_{15}H_{22}O$: C, 76.94; H, 9.46. Found: C, 76.68; H, 9.50.

Preparation of 2,6-Dimethyl-4-*tert*-butylbenzyl Alcohol (13). A solution of 10 g of KOH in 1 mL of water was added to a solution of 22.2 g (95 mmol) of **12** in 30 mL of ethyl alcohol, and the mixture was refluxed for 12 h. Upon cooling, it was diluted with water, and the product was extracted with benzene. After the benzene solution had been washed with water, it was dried over Na_2SO_4 and concentrated to give **13**: colorless needles (hexane); mp 97.5–9.0 °C; IR (KBr) 3370, 3070, 2980, 1610, 1580, 1480, 1460, 1360, 1240, 1000, 865, 775, 720 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.29 (9 H, s), 1.46 (1 H, s, exchanged by D_2O), 2.46 (6 H, s), 4.64 (2 H, s), 7.00 (2 H, s). ^{13}C NMR ($CDCl_3$) δ 19.69 (q), 31.24 (q), 34.26 (s), 59.11 (t), 125.33 (d), 133.66 (s), 136.84 (s), 150,82 (s). Anal. Calcd for $C_{13}H_{20}O$: C, 81.20; H, 10.48. Found: C, 81.36; H, 10.59.

Preparation of 2,6-Dimethyl-4-*tert*-butylbenzyl Iodide (14). Powdered NaI (75.0 g, 0.5 mmol) was added slowly to a hot solution of 10.53 g (50 mmol) of **10** in 300 mL of acetone. After the reaction mixture was refluxed for 6 h, it was evaporated in vacuo to leave a residue which was extracted with benzene. The benzene extracts were washed with water and dried over Na_2SO_4. Distillation of the benzene extracts yielded 12.5 g (82.8%) of **14**: colorless liquid; bp 139–140 °C (2 mmHg); IR (NaCl) 3040, 2950, 1600, 1460, 1410, 1360, 1235, 1140, 1025, 925, 860, 745, 715; ^{1}H NMR ($CDCl_3$) δ 1.27 (9 H, s), 2.31 (6 H, s), 4.38 (2 H, s), 6.97 (2 H, s). Anal. Calcd for $C_{13}H_{19}I$: C, 51.67; H, 6.34. Found: C, 51.75; H, 6.40.

Preparation of Pyridinium Salts (15). Preparation of 15a. A mixture of 1.0 g (4.75 mmol) of **10** and 15 mL of pyridine was boiled under reflux for 12 h. After the reaction mixture had cooled, 30 mL of hexane was added to give colorless solid. This solid was washed with hexane successively to give 1.0 g (71.4%) of **15a**: colorless plates; mp >300 °C; IR (KBr) 3040, 2960, 1650, 1620, 1600, 1570, 1480, 1150, 1140, 865, 765, 755, 715, 680 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 1.27 (9 H, s), 2.28 (6 H, s), 6.07 (2 H, s), 7.16 (2 H, s), 8.15 (2 H, dd, J_{ba} = 6 Hz, J_{bc} = 8 Hz, H_b), 8.64 (1 H, dd, J_{cb} = 8 Ha, J_{ca} = 1 Hz, H_c), 8.98 (2 H, dd, J_{ab} = 8 Hz, J_{ac} = 1 Hz; H_a); ^{13}C NMR (Me_2SO-d_6) δ 19.78 (q), 30.85 (q), 34.06 (s), 57.94 (t), 125.67 (d), 126.41 (s), 128.20 (d), 138.44 (s), 143.99 (d), 145.55 (d), 152.09 (s). Anal. Calcd for $C_{18}H_{24}NCl{\cdot}0.25H_2O$: C, 73.45; H, 8.39. Found: C, 73.51; H, 8.33.

Similarly, **15b–d** were synthesized in the same manner as described above and the yields are summarized in Table IV.

15b: colorless powder; mp >300 °C; IR (KBr) 3500, 3400, 3040, 2980, 1635, 1610, 1510, 1480, 1365, 1240, 1150, 880, 770, 760, 720, 700 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 1.30 (9 H, s), 2.21 (6 H, s), 3.08 (3 H, s), 5.76 (2 H, s), 7.22 (2 H, s), 7.80 (1 H, m), 7.96 (1 H, m), 8.19 (1 H, m), 8.46 (1 H, m). Anal. Calcd for $C_{19}H_{26}NCl{\cdot}^1/_3H_2O$: C, 73.64; H, 8.67; N, 4.52. Found: C, 73.64; H, 8.60; N, 4.56.

15c: colorless powder; mp >300 °C; IR (KBr) 3520, 3450, 3060, 3050, 2980, 1635, 1505, 1490, 1465, 1360, 1240, 1150, 870, 820, 770, 710, 680 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 1.28 (9 H, s), 2.28 (6 H, s), 2.51 (3 H, s), 5.94 (2 H, s), 7.17 (2 H, s), 8.01 (1 H, dd, J_{ca} = 6 Hz, J_{cd} = 8 Hz, H_c), 8.47 (1 H, dd, J_{dc} = 8 Hz, J_{db} = 1 Hz, H_d), 8.64 (1 H, dd, J_{bc} = 6 Hz, J_{bd} = 1 Hz, H_b), 8196 (1 H, br s, H_a). Anal. Calcd for $C_{19}H_{26}NCl{\cdot}^1/_3H_2O$: C, 74.22; H, 8.66, N, 4.56. Found: C, 74.20; H, 8.51; N, 4.52.

15d: colorless powder; mp >300 °C; IR (KBr) 3500, 3430, 3060, 2980, 1645, 1480, 1240, 1140, 875, 850, 840, 820, 780, 715 cm^{-1}; ^1H NMR (Me_2SO-d_6) δ 1.28 (9 H, s), 2.27 (6 H, s), 2.59 (3 H, s), 5.90 (2 H, s), 7.27 (2 H, s), 7.94 (2 H, d, J = 7 Hz, H_b), 8.75 (2 H, d, J = 7 Hz). Anal. Calcd for $C_{19}H_{26}NCl \cdot {}^1/_3H_2O$: C, 73.64; H, 8.67; N, 4.52. Found: C, 73.96; H, 8.47; N, 4.52.

Registry No. 2a, 76497-10-4; **2b**, 76447-50-2; **3a**, 78919-65-0; **3b**, 78919-66-1; **3c**, 78919-67-2; **3d**, 78939-65-8; **3e**, 78919-68-3; **3f**, 78919-69-4; **3g**, 78919-70-7; **3h**, 78919-71-8; **3i**, 78919-72-9; **3j**, 78919-73-0; **4a**, 78919-74-1; **4b**, 78919-75-2; **5a**, 78919-76-3; **5b**, 78919-77-4; **6a**, 78919-78-5; **6b**, 78919-79-6; **8a**, 78919-80-9; **8b**, 78919-81-0; **8c**, 78919-82-1; **8d**, 78919-83-2; **8e**, 78919-84-3; **8f**, 78919-85-4; **8g**, 78919-86-5; **8h**, 78939-66-9; **10**, 19387-83-8; **11a**, 78919-87-6; **11b**, 78919-88-7; **11c**, 78919-89-8; **11d**, 78919-90-1; **11e**, 78919-91-2; **12**, 19387-84-9; **13**, 50849-03-1; **14**, 78919-92-3; **15a**, 78919-93-4; **15b**, 78919-94-5; **15c**, 78919-95-6; **15d**, 78919-96-7; methanol, 67-56-1; ethanol, 64-17-5; butanol, 71-36-3; 2-propenol, 107-18-6; pyridine, 110-86-1; 2-methylpyridine, 109-06-8; 3-methylpyridine, 108-99-6; 4-methylpyridine, 108-89-4; 5,13-di-*tert*-butyl-8,16-diethyl[2.2]metacyclophane, 76447-78-4; 5,13-di-*tert*-butyl-8,16-dipropyl[2.2]metacyclophane, 76447-79-5; 5,13-di-*tert*-butyl-8,16-dibutyl[2.2]metacyclophane, 76466-37-0; 5,13-di-*tert*-butyl-8,16-dimethyl[2.2]metacyclophane, 67691-35-4.

Notes

Manganic Oxidation of 3-Substituted Toluenes

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The oxidation of toluenes that contain an electron-releasing group in the meta position to benzyl esters and benzaldehydes is of interest because such compounds, particularly the 3-phenoxy derivatives, are useful intermediates for the preparation of pyrethroid insecticides.[1,2] The direct oxidation of 3-phenoxytoluene (**1e**) with $Co(OAc)_2/O_2$ or $Co(OAc)_2/O_2$/aldehyde has been reported to give 3-phenoxybenzyl alcohol (or acetate) and 3-phenoxybenzaldehyde in yields of 21% and 29%, respectively, whereas amounts of byproducts were formed (25–50%, respectively).

The two-step oxidation of 3-phenoxytoluene to 3-phenoxybenzaldehyde, involving free-radical-initiated bromination of the methyl group followed by hydrolysis, has been reported.[3] However, bromination of the toluene on a large scale produces significant aryl bromide byproducts. This problem has been overcome by use of *N*-bromosuccinimide as the brominating agent, giving a 77% yield of 3-phenoxybenzaldehyde[3a]. For large-scale industrial preparations, one-step oxidations by metal salts are preferred. We report here studies of the oxidation of meta-substituted toluenes **1a–f** with manganic (Mn^{III}) salts.

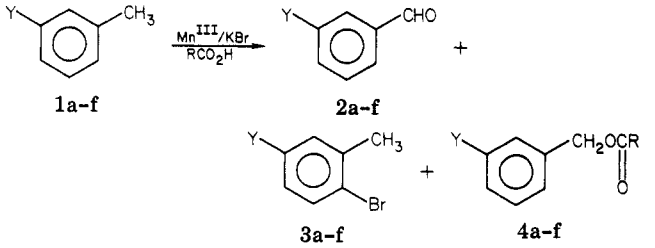
Manganic salts in acetic acid alone[4,5], or with addition of a strong acid[6], are among the most effective reagents for oxidation of 4-halogeno- and 4-alkoxytoluenes. Addition of KBr has been reported to give improved yields[7,8]. We have obtained very low yields (<7%) in using these reagents on the much less reactive meta compounds **1a–f**, presumably because of thermal decomposition of Mn^{III}[7] and reduction of Mn^{III} to Mn^{II} by AcOH and Br^-; accumulation of Mn^{II} in such reactions has been shown to inhibit them.[9,10]

Table I. Oxidation of Substituted Toluenes (Molar Percentages)

1	Y	trans-formed	2a-f	3a-f	4a-f
a	3-Br	58	9	5	85
b	3-Cl	74	8	8	80
c	3-CH_3O	87	4	57	35
d	3-C_2H_5O	69	3	56	38
e	3-C_6H_5O	99	4	53	26
f	3-CH_3CO_2	59	0	38	27

Results

We have found that the inhibiting effect of Mn^{II} can be avoided by carrying out the oxidation with $KMnO_4$ in the presence of an aliphatic acid, its anhydride, and a halide such as KBr. $KMnO_4$ forms the Mn^{III} carboxylate in situ



in a modification of a reported procedure.[4] $KMnO_4$ decarboxyles carboxylic acids and gives $Mn(O_2CR)_3$, RCO_2K, and H_2O, as shown by UV–visible spectra.

The addition of $KMnO_4$ is carried out in portions in order to reoxidize Mn^{II} to Mn^{III} and prevent accumulation of the former. This procedure requires only one-fifth the amount of Mn that must be used with $Mn(OAc)_3$ as the

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