Macro Rings. XXXVII. Multiple Electrophilic Substitution Reactions of [2.2]Paracyclophanes and Interconversions of Polysubstituted Derivatives[1]

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Abstract: Dibromination of [2.2]paracyclophane (I) led to predominantly pseudo-*ortho*[2] (II) and pseudo-*para*[2] (III) disubstituted compounds, and to lesser amounts of pseudo-*meta* (IV) and *para* (V) isomers. Oxidation of these dibromides gave terephthalic acids whose esters were identified by vpc, and whose structures allowed homoannular and transannular bromination to be differentiated. Tetrabromination of I gave compound VI with two *p*-bromines in each ring with a set of pseudo-*ortho* and a set of pseudo-*para* relationships between transannular bromines. This compound by lithiation and methylation of the organometallic gave the known tetramethyl[2.2]paracyclophane, VIII. Dibromination of dibromide II also gave VI. Compound VII was also isolated from the tetrabromination of I and the dibromination of III; it contains two *o*-bromines in each ring with a set of pseudo-*meta* and a set of pseudo-*para* relationships between transannular bromines. Dehalogenation of VII with *n*-butyllithium in the presence of furan gave the bis(furan)benzyne adduct IX, which was converted to the known [2.2]paracyclonaphthane. Dibromide III was converted to dilithium derivative X. Methylation of X gave pseudo-*p*-dimethyl[2.2]-paracyclophane[2] (XI). Oxidation of X produced the pseudo-*p*-dihydroxy derivative, XII, and iodination, the pseudo-*p*-diiodo derivative, XIII. Dibromide II was also lithiated, and the dilithio derivative converted to pseudo-*o*-dihydroxy[2.2]paracyclophane[2] (XVI). Attempts to oxidize diphenols XII and XVI to the corresponding bis quinones failed. Cuprous cyanide cyanation of pseudo-*o*- or pseudo-*p*-dibromo compounds (II or III) at 225° gave, besides a mixture of II and III, four compounds: pseudo-*o*-bromocyano[2.2]paracyclophane (XVIII), pseudo-*p*-bromocyano[2.2]paracyclophane (XIX), pseudo-*o*-dicyano[2.2]paracyclophane (XX), and pseudo-*p*-dicyano[2.2]-paracyclophane (XXI). Thermal isomerization by ring rotation accompanied substitution. The yield pattern showed no difference in activation or deactivation effects between the bromo and cyano groups toward the cyanation reaction. Chlorination of I was less discrete than bromination, and only pseudo-*p*-dichloro[2.2]paracyclophane (XXII) was isolated from a multitude of products. Dinitration of I gave four dinitro derivatives whose yield pattern revealed little evidence of a dominant transannular directive effect of a nitro group in one ring on the position of entry of a second into the transannular ring. The presence of the pseudo-*gem* isomer (XXIII), along with the pseudo-*m*- (XXIV), pseudo-*o*- (XXV), and pseudo-*p*- (XXVI) dinitro[2.2]paracyclophanes, indicates the availability of the special mechanism for proton transfer in the pseudo-*gem* σ complex for introduction of the second nitro group into the system.

In paper XXXV of this series the patterns of transannular directive influences of substituents in 4-substituted [2.2]paracyclophanes on the positions of entry of electrophiles into the system were discussed. Bromination and acetylation reactions were found to substitute predominantly at those positions in the unsubstituted ring pseudo-*gem*[2] to the most basic carbon or substituent in the originally substituted ring.[3a] Proton transfer from a σ complex intermediate appeared to be the rate-limiting and product-determining step. In paper XXXVI, pseudo-*gem*- and pseudo-*meta*-disubstituted [2.2]paracyclophanes were found to equilibrate thermally at 200°, as were pseudo-*ortho* and pseudo-*para* isomers.[3b] Paper XXXVIII reports the determination of structure by nmr and mass spectral techniques[3c] of the large number of disubstituted [2.2]paracyclophanes reported in the three previous papers. Correlations of physical properties with positions of substituents are also reported.[3c]

This paper reports results of multiple halogenation and nitration reactions of [2.2]paracyclophane, and of conversions of halo-substituted [2.2]paracyclophanes into other substituted compounds. This ring system is highly rigid,[4] and can act as a scaffold for placing functional groups in set geometric relationships to one another for systematic studies of transannular and multiple functional group effects on physical and chemical properties. This study is concerned with development of synthetic methods whose ultimate objective is to bring to hand any desired multiply substituted [2.2]paracyclophane. Direct introduction of two or more bromine[5] or chlorine atoms[5a,b] and of two nitro groups[6] has been reported, but without fully distinguishing isomeric structures. Metalation and cyanation of mono and dihalo derivatives of [2.2]paracyclophane have been previously reported.[5a-h]

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(1) The authors wish to thank the National Science Foundation for a grant used in support of this research. H. J. R. also wishes to acknowledge a Woodrow Wilson Fellowship (1964–1965) and a U. S. Rubber Co. tuition grant for 1967.

(2) The colloquial nomenclature is self-evident: pseudo-*gem* denotes two transannularly adjacent positions on the benzene rings; pseudo-*ortho*, pseudo-*meta*, and pseudo-*para* specify *ortho*, *meta*, and *para* relationships displaced from the usual homoannular into a transannular context.

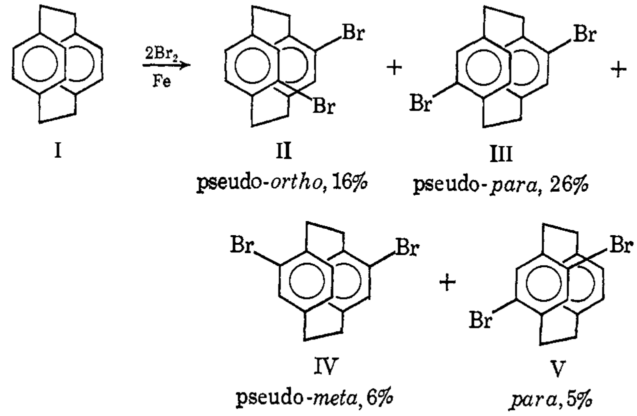
(3) (a) H. J. Reich and D. J. Cram, *J. Am. Chem. Soc.*, **91**, 3505 (1969); (b) H. J. Reich and D. J. Cram, *ibid.*, **91**, 3517 (1969); (c) H. J. Reich and D. J. Cram, *ibid.*, **91**, 3534 (1969).

(4) P. K. Gantzel and K. N. Trueblood, *Acta Cryst.*, **18**, 958 (1965).

(5) (a) W. F. Gorham, Candian Patent 638,335 (1962); (b) Y. L. Yeh, U. S. Patent 3,155,172 (1962); (c) Y. L. Yeh, U. S. Patent 3,349,124 (1967); (d) Y. L. Yeh, Canadian Patent 705,457 (1965); (e) Y. L. Yeh, Canadian Patent 772,189 (1967); (f) Y. L. Yeh, U. S Patent 3,155,712 (1964); (g) W. F. Gorham, U. S. Patent 3,117,168 (1964); (h) Y. L. Yeh and W. F. Gorham, *J. Org. Chem.*, in press; (i) D. J. Cram and A. C. Day, *ibid.*, **31**, 1227 (1966).

(6) D. J. Cram, R. H. Bauer, N. L. Allinger, R. A. Reeves, W. J. Wechter, and E. Heilbronner, *J. Am. Chem. Soc.*, **81**, 5977 (1959).

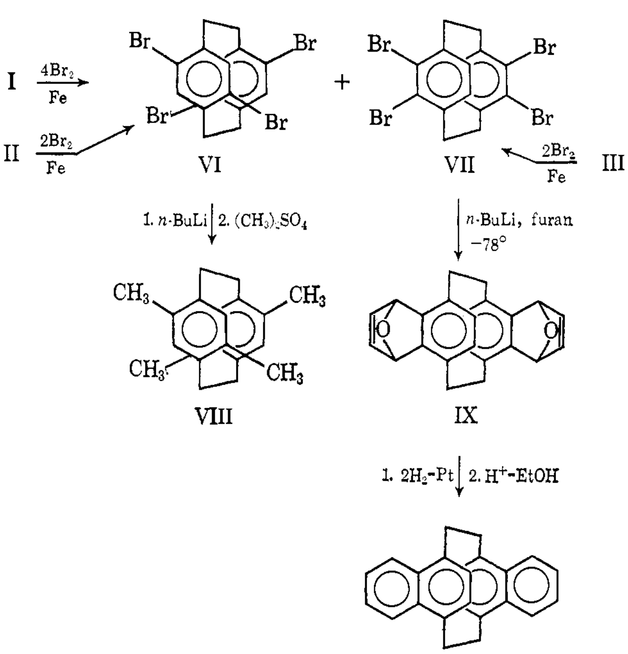
Results and Discussion



Dibromination of [2.2]Paracyclophane (I). Iron-catalyzed bromination of hydrocarbon I with 2 mol of bromine in carbon tetrachloride gave four isomeric dibromides in the isolated yields indicated. The compounds were separated by a combination of chromatographic and crystallization techniques. Although definitive structure determinations of these compounds are reported elsewhere,[3c] the question of distribution of the two bromines between the two rings was settled by degradation experiments. Permanganate oxidation of each of the four dibromides to the substituted terephthalic acids and vpc analysis of the derived dimethyl esters showed that only V had the two bromine atoms in the same ring. Isomers II and III were thermally converted to the same equilibrium mixture of the two (about equal amounts),[3b] whereas IV and V were not appreciably isomerized under the same conditions, as expected. The residue from the dibromides (after separation from mono- and tribrominated material by preparative vpc) contained, apart from pseudo-*meta* and pseudo-*ortho* isomers, a third component detectable by its unique nmr absorption at τ 3.01 (close doublet). Although this nmr signal is consistent with either the pseudo-*gem*- or *o*-dibromo[2.2]paracyclophane structures, the latter is the more probable on steric grounds.

Tetrabromination of [2.2]Paracyclophane (I). Use of excess bromine in the presence of an iron catalyst gave two products after chromatography which comprised over 70% by weight of the chromatographable materials. The faster moving component (VI) (29%) gave correct elemental analysis and nmr integration for a tetrabromo[2.2]paracyclophane. The nmr spectrum of VI consisted of a singlet at τ 2.83 (4 H) and a symmetrical A_2B_2 multiplet centered at τ 6.92 (8 H). This substance was also produced by dibromination of pseudo-*o*-dibromo[2.2]paracyclophane (II). These facts suggested that VI possessed the structure formulated. Proof of the correctness of this assignment was provided by tetralithiation of VI with butyllithium and methylation of the organometallic to give the known tetramethyl derivative VIII.[7]

The second slower moving tetrabromo isomer (VII) was isolated in 28% yield, and exhibited a nmr spectrum which also showed high symmetry: a singlet at τ 3.02 (4 H) and a symmetrical (A_2B_2) multiplet centered at τ 6.78 (8 H). Tetrabromide VII (but no VI) was also produced by dibromination of pseudo-*p*-dibromide III. The symmetry properties of the nmr spectrum of VII[3c] coupled with the normal *ortho* and *para* directing properties of a bromine substituent in a benzene ring point to the bis-*ortho* structure formulated for the substance. Neither VI nor VII underwent thermal isomerization,[3b] which indicates them to be the thermally stable members of their respective isomerizable pairs. This fact is compatible with structural assignments that do not involve two bromine substituents pseudo-*gem* to one another.



Conversion of VII of [2.2]paracyclonaphthane[8a] provides a structure proof for the tetrabromide and a convenient synthetic route to the naphthalene derivative. Treatment of VII with *n*-butyllithium and furan at low temperature gave the bisfuran adduct IX by sequential benzyne–furan Diels–Alder reactions.[8b] Hydrogenation of the double bonds in IX followed by acidic hydrolysis[8c] gave [2.2]paracyclonaphthane.[8a] The nmr spectra of IX and tetrahydro-IX (Experimental Section) were similar to the nmr spectra of other compounds having the 1,4-oxadihydro- and -tetrahydronaphthalene ring system.[8d]

The absence of VI among the products of further bromination of pseudo-*p*-dibromo[2.2]paracyclophane (III) constitutes a test for a hypothetical brominative mechanism in which a positive bromine is donated to a position pseudo-*gem* to a position already carrying a bromine. The resulting σ complex (A) might decompose by donation of the inner proton to the pseudo-*gem* position of the transannular ring to give a new σ complex (B) which decomposes to stable material by loss of positive bromine. Further bromination would then provide tetrabromide VI. Clearly, production of bromides higher than tetra[5b] requires substitution pseudo-*gem* to bromine in the molecule, possibly by some scheme similar to that envisioned here, except that initial attack occurs on a position already

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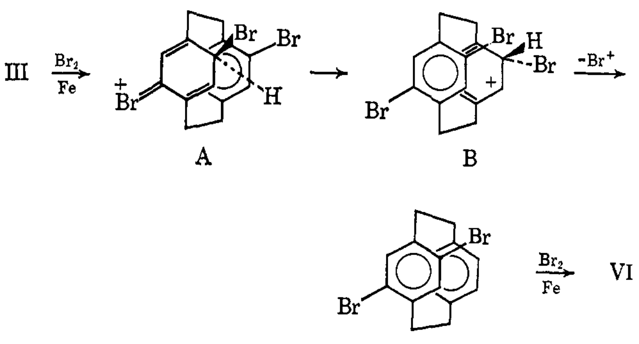
(7) (a) D. T. Longone and C. L. Warren, *J. Am. Chem. Soc.*, **84**, 1507 (1962); (b) D. T. Longone and M. T. Reetz, *Chem. Commun.*, 46 (1967).

(8) (a) D. J. Cram, C. K. Dalton, and G. R. Knox, *J. Am. Chem. Soc.*, **85**, 1088 (1963); (b) E. Wolthius, *J. Org. Chem.*, **26**, 2215 (1961); (c) G. Wittig and L. Pohmer, *Chem. Ber.*, **89**, 1334 (1956); (d) R. W. Franck and K. Yanagi, *Tetrahedron Letters*, 2905 (1966); (e) P. Buck and G. Köbrich, *ibid.*, 1563 (1967).



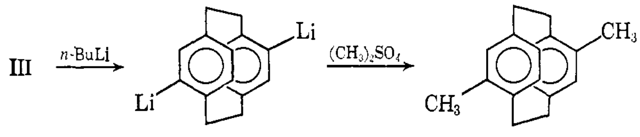
A

B

V

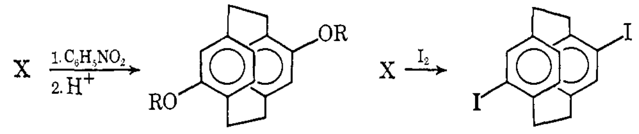
brominated, a positive bromine is transferred from ring to ring, and proton loss provides a pseudo-*gem* positioning of two bromines.

Conversions of Dibromo[2.2]paracyclophanes into Other Disubstituted Derivatives. Dilithiation of pseudo-*p*-dibromide III produced X, which served as an intermediate for preparation of three other pseudo-*para* derivatives. Treatment of X with dimethyl sulfate gave dimethyl derivative XI; with nitrobenzene,[8e] gave dihydroxy derivative XII;[9] and with iodine, gave diiodo derivative XIII. Dihydroxy compound XII, as with paracyclophane phenols,[5c] did not exhibit a sharp melting point, and was therefore characterized as its dimethyl ether (XIV) and diacetate (XV).[9] Attempts to convert XII into the corresponding bis quinone failed.[5c,9]



X

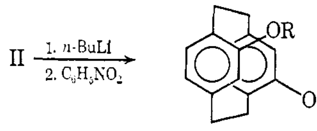
XI



XII, R = H
XIV, R = CH_3
XV, R = Ac

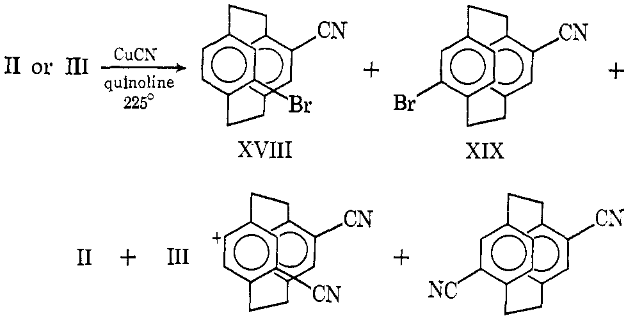
XIII

Similar dilithiation of pseudo-*o*-dibromo[2.2]paracyclophane (II) gave an organometallic, which when treated with nitrobenzene gave pseudo-*o*-dihydroxy-[2.2]paracyclophane (XVI), characterized as its dimethyl ether (XVII).[9] The reaction of aryllithium derivatives with nitrobenzene at low temperature[8e] has proven to be a convenient route to a number of paracyclophane phenols otherwise difficult to prepare.



XVI, R = H
XVII, R = CH_3

Structural interrelations between the dibromides and other disubstituted derivatives[3a] were established through cyanation reactions[5b] with cuprous cyanide at temperatures high enough (225°) to cause isomer equilibration.[3b] Thus, pseudo-*o*- and pseudo-*p*-dibromides (II and III) gave the same mixture from which were separated chromatographically both dibromides (II and III), two bromocyano derivatives (XVIII and XIX), and two dicyano derivatives (XX and XXI). The structural assignments of compounds XVIII and XIX were made based on their spectral properties,[3c] their origins, and on conversion to the corresponding bromocarbomethoxy[2.2]paracyclophanes, prepared from the bromoacetyl[2.2]paracyclophanes.[3a] Both XVIII and XIX also were prepared by bromination of 4-cyano[2.2]paracyclophane.[3a] Interestingly, mixtures of pseudo-*p*-bromonitrile (XIX) and pseudo-*p*-dibromide (III) crystallized together to give well-defined crystals with sharp melting points intermediate between those of the pure components. The structures of the two dicyano derivatives XX and XXI were established from their spectral properties. These substances, although present in the mixture obtained from dibromide III, were isolated only from the mixture obtained from II.



XVIII

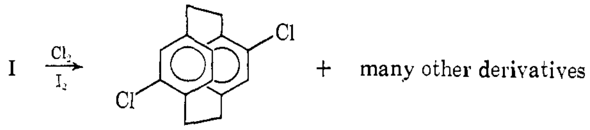
XIX

XX

XXI

Surprisingly the cyanide substitution reactions of the dibromides show no substituent effect. The statistical distribution of products observed (Experimental Section) shows that the bromocyano derivatives react at about the same rate as did the dibromo compounds.

Dichlorination of [2.2]Paracyclophane (I). The iodine-catalyzed dichlorination of [2.2]paracyclophane did not proceed as discretely as the bromination. Substantial amounts of monochloro and trichloro products were generated when 2 mol of chlorine had been consumed. Only the insoluble pseudo-*p*-dichloro derivative (XXII) was isolated (10% yield), and the reaction was not further investigated. The structure of XXII was assigned through use of its spectral properties.[3c]



XXII

Dinitration of [2.2]Paracyclophane (I). Nitration of I with fuming nitric acid in glacial acetic acid for a minimum length of time provides mainly 4-nitro[2.2]-paracyclophane.[10] When the reaction time was extended, a large number of products was generated,[6] among which were the formulated four dinitro[2.2]-

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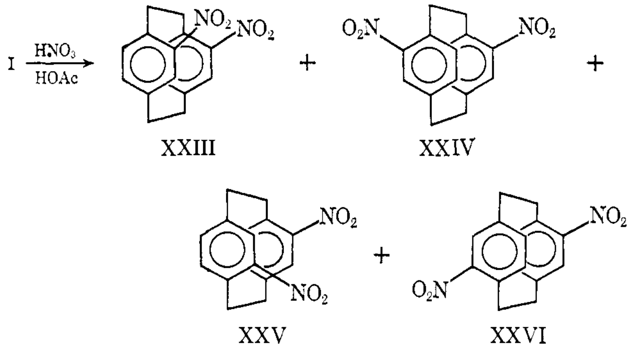
[9] The authors are indebted to Dr. T. J. Leitereg for these experiments.

[10] (a) D. J. Cram and N. L. Allinger, *J. Am. Chem. Soc.*, 77, 6289 (1955); (b) B. E. Norcross, D. Becker, R. I. Cukier, and R. M. Schultz, *J. Org. Chem.*, 32, 220 (1967).

paracyclophanes (XXIII–XXVI). Two of these had been isolated before, but their structures had been misassigned.[6] The present structural assignment rests on spectral and other physical properties[3c] and on the thermal isomerization, XXIII $\rightleftarrows$ XXIV.



The aromatic region of the nmr spectra of the four dinitro[2.2]paracyclophanes[3c] allows only the assignment that they are heteroannularly disubstituted [2.2]paracyclophanes since the nitro group does not give a definite pseudo-*gem* shift. However, the side-chain region allows differentiation of the pseudo-*gem* and pseudo-*meta* isomers (XXIII and XXIV), which show two superimposed symmetric multiplets (τ 6.39 and 6.77 for XXIII, τ 6.40 and 6.77 for XXIV) from the pseudo-*ortho* and pseudo-*para* isomers (XXV and XXVI), which exhibit a much more complex pattern.[3c,11] Compounds XXIII and XXIV can be distinguished by their polarities during thin layer chromatography (R_f 0.33 and 0.60 on silica gel, 0.17 and 0.57 on alumina for XXIII and XXIV, respectively), which require the assignments as shown. Compounds XXV and XXVI can be assigned the pseudo-*ortho* and pseudo-*para* structures on the same basis (R_f 0.39 and 0.64 on silica gel, 0.23 and 0.69 on alumina, respectively). The order of polarities for the dinitro[2.2]paracyclophanes (pseudo-*para* $\leqslant$ pseudo-*meta* $<$ pseudo-*ortho* $<$ pseudo-*gem*) is that expected from simple dipole considerations, and is the same as for the bromonitro[2.2]paracyclophanes.[3c]

The yield pattern was random enough to provide isolable quantities of all four compounds. The pseudo-*gem* derivative, although present, did not dominate in the reaction mixture as it did in bromination of 4-nitro[2.2]paracyclophane.[3a] This fact correlates with the facts that kinetic hydrogen–deuterium isotope effects are little observed in nitrations, but are frequently encountered in brominations (see ref 3a for a review of the literature). The isolation of any pseudo-*gem* dinitro derivative indicates that the special mechanism for proton transfer from ring to ring might operate to a minor extent even in nitration.[3a]

Experimental Section

General Comments. Unless specified otherwise in individual procedures, melting points are uncorrected, and all solvents are reagent grade. Nuclear magnetic resonance (nmr) measurements were made with a Varian A-60 spectrometer on dilute solutions (5–20%) in deuteriochloroform using tetramethylsilane as internal standard. Infrared spectra were run in chloroform solution on a Beckman IR-5 spectrophotometer. Vapor phase chromatography (vpc) was carried out on an F & M Model 720 instrument using 3 ft × 0.25 in. columns packed with 20% SE-30 on 60–80 Firebrick at a flow rate of 60 cc/min. Thin-layer chromatograms (tlc) were run using Brinkmann silica gel G or aluminum oxide G coated on glass or Pyrex plates with appropriate cyclohexane–ethyl acetate mixtures as developer. Iodine vapor or 10% phosphomolybdic acid in ethanol was used to spot the plates. Silica gel for column chromatography was Baker chromatographic grade; alumina was Harshaw catalyst grade activated at 120° for 20 hr.

Dibromination of [2.2]Paracyclophane (I). A solution of 46.2 g (0.288 mol) of bromine in 400 ml of carbon tetrachloride was prepared, and 30 ml of this solution was stirred with 0.4 g of iron filings and 300 ml of dichloromethane for 1 hr. Dichloromethane (500 ml) was added, the solution was brought to reflux, and 30 g (0.144 mol) of I was added. The remainder of the bromine solution was added over a period of 3 hr (progress of the reaction was followed by vpc analysis). After completion of the bromine addition, the mixture was refluxed for 0.5 hr. The reaction mixture was washed several times with 10% sodium bisulfite solution, then with saturated sodium chloride solution, and dried. After removal of solvent the crude product was dissolved in 500 ml of hot chloroform, 300 ml of ether was added, and it was allowed to crystallize. A second crop was obtained and the combined solids were sublimed at 160° (0.03 mm) to give 15.41 g of material. Recrystallization from chloroform–ether gave 12.78 g of pseudo-*p*-dibromo[2.2]paracyclophane (III), mp 248.5–250° (lit.[5c] 250–251°).

The mother liquors from this crystallization were chromatographed on 2 kg of alumina (Woelm neutral, activity I) using 5–20% ether–pentane as eluent. The initial fractions of the chromatogram were a mixture of several compounds, from which a mixture of pseudo-*p*- and *p*-dibromo[2.2]paracyclophanes was crystallized. Several crystallizations from chloroform, ethyl acetate, tetrahydrofuran, benzene, or pyridine failed to produce pure *p*-dibromide. Constant crystallizing mixtures containing 30% pseudo-*para* (III) were formed as shown by infrared analysis.[3c] A sample which had been crystallized three times from ethyl acetate–ethanol had mp 184.5–185°. *Anal.* Calcd for $C_{16}H_{14}Br_2$: C, 52.49; H, 3.85. Found: C, 52.45; H, 3.84.

Further amounts of this mixture were obtained throughout subsequent crystallizations. A total of 4.0 g of mixture was isolated, having absorbance of 0.26 at 1049 cm^{-1} and 0.11 at 1036 cm^{-1} in the infrared. Thus, it contained approximately 2.8 g of *p*-dibromo[2.2]paracyclophane and 1.2 g of pseudo-*p*-dibromo[2.2]paracyclophane.

After some of the *p*- and pseudo-*p*-dibromide mixture had been crystallized, mixtures of these with pseudo-*o*-dibromo[2.2]paracyclophane began to crystallize (from ether and ether–pentane). Occasionally, the pseudo-*ortho* isomer would crystallize separately in chunks and could be manually separated from the other isomers. Most of the pseudo-*o*-dibromide (II) isolated was separated by chromatography on alumina, where it could be obtained pure from the later fractions. One such sample after two recrystallizations from ether gave mp 204–207° (range somewhat dependent on rate of heating). *Anal.* Calcd for $C_{16}H_{14}Br_2$: C, 52.49; H, 3.85. Found: C, 52.69; H, 3.85.

After the bulk of the *p*- and pseudo-*p*-dibromides had been crystallized, further chromatography on alumina gave pseudo-*m*-dibromo[2.2]paracyclophane (IV) contaminated with small amounts of the insoluble isomers in the initial fractions and essentially pure pseudo-*ortho* isomer in the later fractions. The pseudo-*m*-dibromo[2.2]paracyclophane (IV) was separated from the less soluble compounds by dissolving it in ether and decanting. The mother liquor was evaporated, and the residue crystallized three times from pentane containing small amounts of ether to give an analytical sample, mp 123.5–125.5°. *Anal.* Calcd for $C_{16}H_{14}Br_2$: C, 52.49; H, 3.85. Found: C, 52.22; H, 3.72.

The chromatographic separations were conveniently followed by nmr spectroscopy, where the pseudo-*ortho* and pseudo-*meta* isomers could be clearly distinguished.[3c] The total amount of products obtained after three chromatographs, each on 2 to 3 kg of alumina, and numerous crystallizations was as follows: pseudo-*para* (III), 12.78 g, mp 248.5–250°, and 1.2 g in mixture with *para* isomer, total yield, 14.0 g (26.3%); *para* (V, 2.81 g in mixture (5.3%); pseudo-*ortho* (II), 8.35 g, mp 200–207° (15.7%); pseudo-*meta* (IV), 3.38 g, mp 115–122° (6.4%).

The residues from the above separation scheme amounted to 1.42 g. A 0.3-g sample of this material was separated by preparative vpc at 225° on a 1 ft × 0.25 in. column packed with 20% SE-30 on 60–80 Firebrick to give 186 mg of dibromides, 58 mg of tril bromides, and 26 mg of 4-bromo[2.2]paracyclophane. The tota-residue, thus, contained 0.88 g (1.7%) of dibromides, 0.27 g (0.4%)

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[11] The nmr spectrum of XXVI was examined in bromobenzene solution at 135°.

of tribromides, and 0.12 g of monobromide (0.3%). No other compounds could be detected in the vpc.

The dibromide portion consisted of pseudo-*o*- and pseudo-*m*-dibromides and a third component detected by nmr absorption at τ 3.01 (in carbon tetrachloride), possibly *o*-dibromo[2.2]paracyclophane. Several crystallizations from pentane did not change the composition substantially, and since this isomer ran between pseudo-*meta* and pseudo-*ortho* isomers during alumina chromatography, attempts to isolate it were abandoned.

***p*-Dibromo[2.2]paracyclophane** (V). An approximately 1:2 mixture of pseudo-*p*- and *p*-dibromo compounds (0.8 g) was placed in a tube, evacuated, sealed, and heated at 200° for 48 hr. The product was chromatographed on 100 g of alumina using pentane as eluent. The initial fractions were essentially free of pseudo-*o*-dibromo isomer (tlc analysis). These were combined and crystallized from dichloromethane–ether. Repeated crystallizations did not give pure *p*-dibromide (infrared analysis), so 483 mg of material free of pseudo-*o*-dibromide was again heated at 200° for 47 hr. Chromatography on alumina and two recrystallizations of the initially eluted material from dichloromethane–ether gave 160 mg of essentially pure *p*-dibromo[2.2]paracyclophane, mp 194.5–196.5° (the 2:1 eutectic mixture with pseudo-*p*-dibromide has mp 184.5–185°). A further crystallization gave an analytical sample, mp 195–197°. *Anal.* Calcd for $C_{16}H_{14}Br_2$: C, 52.49; H, 3.85. Found: C, 52.65; H, 3.86.

Permanganate Oxidation Reactions. A mixture of 200 mg (0.55 mmol) of dibromo[2.2]paracyclophane, 10 ml of pyridine, and 10 ml of water was refluxed with 0.4 g (2.5 mmol) of potassium permanganate until the violet color had disappeared. Five more portions of 0.4 g of potassium permanganate were added at approximately 1-hr intervals. The reaction was allowed to cool, 30 ml of water, 10 ml of 10% aqueous sodium hydroxide, and 10 ml of chloroform were added, and the precipitated manganese dioxide was filtered. The chloroform was separated and the aqueous layer acidified and extracted by 20 ml of 1:1 chloroform–ethyl acetate five times. The combined extracts were washed with a small portion of water and two portions of saturated sodium chloride solution and dried. Solvent was removed, and the crude acids were esterified by refluxing for 2 days with 25 ml of 1,2-dichloroethane, 3 ml of methanol, and 0.25 ml of sulfuric acid. The usual isolation procedure gave crude ester.

Dimethyl Bromoterephthalate. Oxidation and esterification of 2-bromo-*p*-xylene (Matheson Coleman and Bell, 99+%) by the above procedure followed by one crystallization of the product from ether–pentane gave needles, mp 51–52.5° (lit.[12] 52–53°). The retention time on vpc of this compound at 250° was 2.8 min.

Dimethyl 2,5-Dibromoterephthalate. Oxidation of 2,5-dibromo-*p*-xylene by the above procedure (except that only water was used as solvent and all of the permanganate was added in one portion) followed by esterification of the diacid and crystallization from dichloromethane–ether gave dimethyl 2,5-dibromoterephthalate, mp 143.5–145° (lit.[13] 148.6°). Retention time on vpc at 250° was 5.2 min.

Oxidation of Pseudo-*o*-dibromo[2.2]paracyclophane (II). The oxidation was carried out as above. The crude diester (88 mg) was sublimed at 80° (0.03 mm) to give 70 mg, mp 43–49°. This material was recrystallized from ether–pentane to give needles, mp 52–53°; with authentic dimethyl bromoterephthalate mmp 51–52.5°, vpc retention time 2.8 min.

Oxidation of Pseudo-*p*-dibromo[2.2]paracyclophane (III). Reaction was carried out as above. The crude ester had a retention time of 2.8 min on vpc.

Oxidation of Pseudo-*m*-dibromo[2.2]paracyclophane (IV). Oxidation was carried out as above except that 50 mg of dibromide and six portions of 0.2 g of potassium permanganate were used. The crude ester had a retention time of 2.8 min on vpc. There was a minor peak at 4.8 min, possibly due to dibromoterephthalate ester from a small amount of *p*-dibromo isomer present in the starting material.

Oxidation of the *p*- and Pseudo-*p*-dibromo[2.2]paracyclophane Mixture. The crude mixture of diesters prepared by the above procedure had a vpc chromatogram showing three peaks of approximately equal area with retention times of 1.5, 2.9, and 5.3 min. The retention time of dimethyl terephthalate (Eastman Organic Chemicals) was 1.5 min.

Tetrabromination of [2.2]Paracyclophane (I). Approximately 2 ml of a solution of 3.45 g (1.1 ml, 21.6 mmol) of bromine in 20 ml of dichloromethane was stirred with 0.1 g of iron dust for 15 min. A further 40 ml of dichloromethane was added, the mixture was brought to reflux, 1.0 g of I was added, and the remainder of the bromine solution was added over a period of 0.5 hr. After refluxing for a further 0.5 hr, 50 ml of 10% sodium bisulfite solution was added, and the organic portion was chromatographed on 400 g of alumina, taking 100-ml fractions. Solvent for fractions 1–33 was 1% ether in pentane, for fractions 34–50, 2% ether–pentane. Fractions 12–29 (1.24 g) were combined with the ether-soluble portion of fractions 30–32 and recrystallized from ether to give 0.53 g of 4,7,12,15-tetrabromo[2.2]paracyclophane (VI). The melting point behavior of this compound was anomalous. An analytical sample prepared by recrystallization of the first crop had mp 158–159.5° if the sample was inserted shortly below this temperature. Upon resolidification its melting point was 168–168.5°. A 100-mg sample of VI, mp 163–164°, was heated at 160–165° for 10 min and cooled, when it had mp 165.5–167.5°. The nmr spectrum was identical with that before melting. A second crop of VI (0.45 g) was recrystallized from ether to afford 0.21 g of pure tetrabromo VI for a total yield of 0.74 g (29%). *Anal.* Calcd for $C_{16}H_{12}Br_4$: C, 36.67; H, 2.31. Found: C, 36.76; H, 2.46.

The ether-insoluble portion of fractions 30–32 and fractions 33–49 (0.77 g) were combined and recrystallized from chloroform to give 0.626 g of 4,5,15,16-tetrabromo[2.2]paracyclophane (VII), mp 273.5–276.5° dec. A second crop (0.075 g, mp 270–274° dec) gave a total yield of 0.70 g (28%) of VII. A portion of the first crop was recrystallized from chloroform to give an analytical sample of VII, mp 274.5–278° dec. *Anal.* Calcd for $C_{16}H_{12}Br_4$: C, 36.67; H, 2.31. Found: C, 36.81; H, 2.40.

The total solids which were eluted with up to 5% ether–pentane were 2.01 g. The amounts of tetrabromides VI and VII isolated in a pure state accounted for 73% of this material.

Bromination of Pseudo-*o*-dibromo[2.2]paracyclophane (II). To a solution of 0.2 g (0.55 mmol) of II and 0.24 g (1.5 mmol) of bromine in 20 ml of carbon tetrachloride which had been refluxed with iron filings for 10 hr was added 0.2 ml (0.62 g, 3.9 mmol) of bromine. After refluxing for a further 20 hr, no dibromo or tribromo materials remained (vpc analysis). The reaction mixture was worked up as for the above reaction, and the crude product was chromatographed on 30 g of alumina using 150 ml of 5% ether–pentane as eluent. Eluted was 200 mg (70%) of white solid whose nmr spectrum was essentially superimposable on that for tetrabromide VI. Recrystallization of the material from dichloromethane–ether gave 96 mg (34% yield) of large crystals of VI, initial mp 155–157°; after resolidification, mp 165–166°; initial mixture melting point with authentic VI, 155–157°; after resolidification, mmp 166.5–167.5°.

Bromination of Pseudo-*p*-dibromo[2.2]paracyclophane (III). Approximately 1 ml of a solution of 1.09 g (0.35 ml, 6.85 mmol) of bromine in 10 ml of dichloromethane was stirred with 0.1 g of iron dust for 0.5 hr. Dichloromethane (40 ml) and 1.0 g (2.74 mmol) of pure III were added, the mixture was brought to reflux, and the remainder of the bromine solution was added over a period of 1 hr. Analysis by vpc of a sample of the reaction mixture (4 ft × 0.125 in., packed with 5% SE-30 and 0.5% Atpet on HMDS treated 80–100 Chromosorb W, using an Aerograph 200 at 210°) showed the presence of small amounts of tribrominated material (retention time 9 min), and a large peak corresponding to tetrabromide VII (retention time 21 min). No VI was observed (retention time 14 min, less than 5% of VI would have been detected). A further 0.09 g (0.03 ml) of bromine was added, the mixture was refluxed for 1 hr, and 50 ml of 10% sodium bisulfite solution was added. The organic portion was separated, solvent was removed, and the residue was chromatographed on 25 g of alumina using 5% ether–pentane as eluent to give 0.63 g of solid. This product was crystallized from chloroform to give 420 mg of VII (29% yield), mp 272.5–275.5° dec; mixture melting point with VII obtained above was 273–276° dec.

4,7,12,15-Tetramethyl[2.2]paracyclophane (VIII). To a solution prepared from 7 ml of 1.7 *M* *n*-butyllithium in hexane (12 mmol) and 10 ml of dry ether under nitrogen was added 0.35 g (0.67 mmol) of tetrabromo VI. After the reaction mixture had stirred for 1 hr at room temperature, 1.2 ml (1.62 g, 12.8 mmol) of redistilled dimethyl sulfate was added slowly. The mixture was stirred at room temperature for 2 hr, 10 ml of ammonium hydroxide was added, and the mixture stirred for another 2 hr. More ether was added, and the organic layer was washed twice with water and once with saturated sodium chloride solution and chromatographed on 7 g of alumina

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[13] E. A. Lawton and D. D. McRitchie, *J. Org. Chem.*, **24**, 26 (1959).

with pentane as eluent, 15-ml fractions being taken. Fractions 4–16 crystallized and were combined (126 mg of semisolid). Recrystallization of the material from pentane gave 29 mg, mp 98–100°, and a second crop of 21 mg, mp 97–99°, for a total yield of 50 mg of VIII, yield 28%. The nmr spectrum in carbon tetrachloride of this product had singlets with the expected integrations at τ 3.74 and 8.02 and a symmetric multiplet at τ 7.16 (lit.[7a] τ 3.77, 8.04, and 7.19, respectively). Recrystallization of the above product gave 13 mg, mp 103–104.5° (lit.[7a] 104–105°). The observed ir spectrum (chloroform) gave bands at (cm^{-1}): 3003 (s), 2941 (s), 2865 (s), 1605 (w), 1499 (m), 1477 (m-s), 1376 (m), 1035 (w), 990 (w), and 906 (s). The reported[7a] ir spectrum (chloroform and Nujol) gave bands at (cm^{-1}): 3003 (s), 1605 (w-m), 1499 (m), 1374 (m), 906 (s), and 710 (s).

Conversion of 4,5,15,16-Tetrabromo[2.2]paracyclophane (VII) to the Bisfuran Adduct IX. A solution of 0.8 ml of 1.6 *M n*-butyllithium (1.25 mmol) in 7 ml of dry ether was cooled to −78° under nitrogen, and 8 ml of furan (freshly distilled over lithium aluminum hydride) was added over a period of 10 min. Exactly 200 mg (0.38 mmol) of VII was added; the mixture was stirred at −78° for 2 hr, allowed to warm to −10° over a period of 1.5 hr, and quenched by addition of methanol. The product was dissolved in an ether–dichloromethane mixture, and the solution was washed with water and saturated sodium chloride solution, and dried over potassium carbonate. Solvent was removed, and the residue was crystallized from chloroform–ether to give 72 mg of IX, mp 244° dec. A second crop of 37 mg (pure by nmr) brought the yield to 84%. Compound IX appears to be air and light sensitive, but keeps well under nitrogen at 0°. Recrystallization of the first crop afforded an analytical sample of IX, darkening and decomposition 250–320°. *Anal.* Calcd for $C_{24}H_{20}O_2$: C, 84.68; H, 5.92. Found: C, 84.07; H, 6.05. The nmr spectrum of IX consisted of a sharp singlet at τ 3.89 (4 H, aromatic protons), two identical distorted triplets with splittings of 0.9 Hz at τ 3.05 and 4.37 (4 H each, vinyl and bridgehead protons, respectively), and a closely spaced symmetric multiplet at τ 6.92 (8 H, bridge protons).

Reactions carried out according to the above procedure sometimes gave product contaminated with starting material, which could not be purified by crystallization. Use of double the quantities of ether and furan tripled the amount of *n*-butyllithium, and longer reaction time at −78° (up to 5 hr) gave a lower yield of IX (42%), but no contamination by VII.

Conversion of Furan Adduct IX to [2.2]Paracyclonaphthane. A suspension of 29 mg (0.085 mmol) of IX and 5 mg of platinum oxide (Adam's catalyst, Matheson Coleman and Bell) in 5 ml of benzene and 5 ml of absolute ethanol was hydrogenated at atmospheric pressure. The compound continues to take up hydrogen past the equivalent amount, although at a somewhat reduced rate than before. The catalyst was removed by filtration, and solvent was removed. The residue, an amorphous white solid, had an nmr spectrum consistent with the structure tetrahydro IX, consisting of a sharp singlet at τ 3.71 (4 H, aromatic protons), four proton multiplets at τ 4.74, 8.03, and 8.71 (bridgehead and *endo*/*exo* protons), and a closely spaced symmetrical multiplet at τ 6.95 (8 H bridge protons).

The product from this reaction was refluxed in 20 ml of absolute ethanol containing two drops of hydrochloric acid for 7 hr. Water was added to the reaction mixture, and the product was dissolved in dichloromethane–ether. This solution was washed with 5% sodium carbonate and saturated sodium chloride solution, and dried. Solvent was removed, and the residue was triturated with ether to give 15 mg (58%) of white microcrystalline product, mp 295–297° dec, lit.[8a] for [2.2]paracyclonaphthane 299–301° dec. The nmr spectrum consisted of a singlet at τ 4.26 and symmetrical A_2B_2 multiplets centered at τ 2.46 and 6.67, essentially superimposable on a spectrum of [2.2]paracyclonaphthane prepared by two other independent routes.[8a]

Pseudo-*p*-dimethyl[2.2]paracyclophane (XI). A mixture of 10 ml of ether and 5 ml of 1.6 *N n*-butyllithium in hexane was stirred under nitrogen for 15 min, and 0.50 g (1.37 mmol) of pseudo-*p*-dibromo-[2.2]paracyclophane (III) was added. After the solution had stirred at 25° for 6 hr, 1 ml of redistilled dimethyl sulfate was added slowly, and the reaction mixture was stirred for 15 min. The reaction was then quenched by addition of water and ammonium hydroxide. The organic layer was washed with water, 1 *N* hydrochloric acid, 5% sodium carbonate solution, and saturated sodium chloride solution. A vpc of the crude product showed the presence of approximately 7% bromomethyl compound which could not be removed by crystallization. A second treatment with butyllithium removed this impurity. Crystallization from ether gave 161 mg, mp 179–181.5°. A second crop of 40 mg brought the yield of pseudo-*p*-dimethyl[2.2]paracyclophane (XI) to 64%. Recrystallization of this material from dichloromethane–ether gave an analytical sample, mp 182–182.5°. *Anal.* Calcd for $C_{18}H_{20}$: C, 91.47; H, 8.53. Found: C, 91.42; H, 8.35.

Pseudo-*p*-diiodo[2.2]paracyclophane (XIII). A flask containing 50 ml of anhydrous ether was flushed with nitrogen; 6.0 ml of *n*-butyllithium solution (1.6 *N* in hexane, 9.6 mmol) was added followed by 0.5 g (1.37 mmol) of pseudo-*p*-dibromo[2.2]paracyclophane (III). After the mixture had stirred at room temperature for 1.5 hr, a solution of 2.44 g (9.6 mmol) of iodine in 10 ml of ether was added slowly. After addition of approximately one-half of the iodine solution, all of the organometallics appeared to have reacted since the solution turned brown due to excess iodine. The product was dissolved by addition of excess dichloromethane; the organic layer was washed twice with 10% sodium bisulfite solution, then with saturated sodium chloride solution, and dried. The crude product contained substantial amounts of butylated materials as shown by vpc analysis. Chromatography of the product on alumina using pentane as eluent gave 301 mg of white solid. Crystallization of this material from dichloromethane gave 168 mg (26%) of extremely insoluble crystalline diiodo compound (XIII), mp 267–270°. Recrystallization of the material gave an analytical sample, mp 269.5–270.5°. *Anal.* Calcd for $C_{16}H_{14}I_2$: C, 41.77; H, 3.07. Found: C, 41.78; H, 3.01.

Pseudo-*p*-dihydroxy[2.2]paracyclophane (XII) and Its Dimethyl (XIV) and Diacetyl (XV) Derivatives.[9] Under a dry blanket of pure nitrogen in dry equipment, a cold solution of 30 ml of dry ether and 5.00 ml (8.0 mmol) of 1.6 *M n*-butyllithium in hexane was mixed. To this stirred solution at 0° was added in one portion 0.500 g (1.37 mmol) of pseudo-*p*-dibromide III, and the mixture was stirred for 3 hr and cooled to −78°. A solution of nitrobenzene (0.9 ml or 8.6 mmol) in 5 ml of ether was added dropwise over a 20-min period, and the stirring was continued for 5 hr at −78°. The reaction was quenched with 10 ml of methanol, acidified, and extracted with two 25-ml portions of ether. The ether layers were combined, dried, and evaporated. The crude material was chromatographed on 50 g of silica gel and eluted with 2, 3, 5, 10, 20, 30, 40, and 50% ether–pentane. In this way 0.032 g (11%) of 4-hydroxy[2.2]paracyclophane, 0.041 g (10%) of pseudo-*p*-bromohydroxy[2.2]paracyclophane, and 0.184 g (56%) of pseudo-*p*-dihydroxy[2.2]paracyclophane (XII) were obtained. The latter material was recrystallized several times from ether–methylene chloride, mp >300° dec (turns brown at 240°). The ir spectrum (KBr, Perkin-Elmer 421 spectrophotometer) showed an intense hydroxyl absorption at 3260 cm^{-1}. The material (unlike the monophenol) dissolved readily in 10% sodium hydroxide to give a pale yellow solution which changed to green and then to black on standing in air. The substance was analyzed as its derivatives.

The dimethyl ether XIV was prepared as follows. A mixture of 0.100 g of diphenol XII, 1 g of barium hydroxide, 10 ml of methyl iodide, 10 ml of N,N-dimethylformamide, and 0.01 ml of water was stirred for 20 hr and shaken with 20 ml of water and 50 ml of ether, and the ether layers were combined. The ether solution was washed twice with 50 ml of 20% hydrochloric acid, three times with 50-ml portions of sodium thiosulfate solution, and once with 50 ml of water. The solution was dried and evaporated, and the residue was chromatographed on 10 g of silica gel with 0, 1, 2, 4, 10, and 30% ether–pentane as eluent. The eluates provided 0.050 g (45%) of diether XIV which, when recrystallized twice from ether–methylene chloride, gave mp 236.4–237.4° dec (yellow).

The diacetyl derivative (XV) of diphenol XII was prepared as follows. A mixture of 0.400 g (1.67 mmol) of XII, 20 ml of pyridine, and 20 ml of acetic anhydride was stirred at 60° for 5 hr and at 25° for 48 hr. After addition of 50 ml of 20% hydrochloric acid and 50 ml of ether, the layers were separated and the aqueous layer was extracted with an additional 50 ml of ether. The ether layers were combined, washed twice with 25-ml portions of 20% hydrochloric acid, three times with 25-ml portions of 10% sodium hydroxide, and twice with 25-ml portions of water, dried, and evaporated to give 0.42 g of crude ester. This material was chromatographed on 40 g of silica gel with 0, 1, 2, 5, 10, and 15% ether–pentane as the eluent. In this way 0.195 g (54%) of the desired ester was obtained. This material was recrystallized from ether–methylene chloride, mp 231.6–232.7°. *Anal.* Calcd for $C_{20}H_{20}O_4$: C, 74.05; H, 6.22. Found: C, 74.01; H, 6.39.

Pseudo-*o*-dihydroxy[2.2]paracyclophane (XVI) and Its Dimethyl Derivative (XVII).[9] Application of the above procedure to 0.200 g of pseudo-*o*-dibromo[2.2]paracyclophane (II) gave 0.012 g of [2.2]paracyclophane (10%), 0.026 g (22%) of 4-hydroxy[2.2]paracyclophane, and 0.021 g (16%) of the desired XVI. The retardation factors (R_f) of the last two compounds on silica gel were 0.50 and 0.18, respectively. The ir spectrum of diphenol XVI (KBr, Perkin-Elmer 421 spectrophotometer) showed intense hydroxyl absorption at 3358 cm^{-1}.

The dimethyl derivative (XVII) was prepared by the above procedure in 44% yield, mp 147.5–149° (pentane). *Anal.* Calcd for $C_{18}H_{20}O_2$: C, 80.56; H, 7.51. Found: C, 80.64; H, 7.52.

Cyanation of Pseudo-*o*-dibromo[2.2]paracyclophane (II). A mixture of 3.0 g (8.2 mmol) of II, 15 ml of quinoline (refined), and 0.81 g (9.1 mmol) of cuprous cyanide (J. T. Baker Chemical Co.) was heated at 225° under nitrogen. A small amount of pyridine was added to cause refluxing, and heating was continued for 21 hr. The reaction mixture was poured out of the flask before it solidified and stirred with 100 ml of 15% ammonium hydroxide and 200 ml of ether. The organic layer was separated and washed successively with 15% ammonium hydroxide, water, three portions of 5 *N* hydrochloric acid, saturated sodium bicarbonate solution, and saturated sodium chloride solution. After drying, the solvent was removed and the residue chromatographed on 700 g of silica gel. Elution with 5% ether–pentane gave a yellow solid, which was washed with ether to leave 270 mg (9% yield) of white solid, mp 246–249°; with pseudo-*p*-dibromo[2.2]paracyclophane (III), mmp 246–249°. The ether washings contained 230 mg (7.7%) of a tan solid, mp 201–207°, with pseudo-*o*-dibromo[2.2]paracyclophane (II), mmp 201–207°. The nmr spectrum showed no major impurities. Elution with 9% ether–pentane gave a white crystalline solid, which was sublimed to give 0.53 g of pseudo-*p*-bromocyano-[2.2]paracyclophane (XIX) (21%), mp 217–219°. Recrystallization from dichloromethane–ether gave an analytical sample, mp 221.5–223.5°. *Anal.* Calcd for $C_{17}H_{14}BrN$: C, 65.40; H, 4.52. Found: C, 65.49; H, 4.50.

At 15% ether–pentane, 0.54 g of pseudo-*o*-bromocyano[2.2]-paracyclophane (XVIII) was eluted. The crude product was sublimed to yield 503 mg (19%), mp 175–180°. Recrystallization from ether gave mp 178–182°. Several more recrystallizations failed to raise the melting point possibly due to decomposition or isomerization during melting, since the sample of XVIII became yellow. *Anal.* Calcd for $C_{17}H_{14}BrN$: C, 65.40; H, 4.52. Found: C, 65.56; H, 4.31.

Elution of the chromatograph column with 30% ether resulted in elution of 291 mg (5%) of pseudo-*p*-dicyano[2.2]paracyclophane (XXI). Sublimation and crystallization of XXI from dichloromethane–ether gave 217 mg (10%), mp 237.5–239°. *Anal.* Calcd for $C_{18}H_{14}N_2$: C, 83.69; H, 5.46. Found: C, 83.47; H, 5.57.

With 40% ether–pentane pseudo-*o*-dicyano[2.2]paracyclophane (XX) was eluted. The crude product was sublimed to give 217 mg (10%), mp 173.5–175.5°. Crystallization of XX from dichloromethane–ether raised the melting point to 177.6–179°. *Anal.* Calcd for $C_{18}H_{14}N_2$: C, 83.69; H, 5.46. Found: C, 83.83; H, 5.53.

Cyanation of Pseudo-*p*-dibromo[2.2]paracyclophane (III). The reaction was carried out as above using 8 g (21.9 mmol) of pseudo-*p*-dibromo[2.2]paracyclophane, 2.16 g (24.1 mmol) of cuprous cyanide, 20 ml of quinoline, and 2 ml of pyridine. The crude product was crystallized from chloroform–ether to give 2.1 g of white crystals, mp 233–235°, which were shown to be a mixture of pseudo-*p*-dibromo isomer (III) and pseudo-*p*-bromocyano material (XIX) (infrared and tlc analysis). Crystallization of this mixture gave sharp melting material with melting point intermediate between those of the pure compounds. Chromatography on 450 g of silica gel gave 0.5 g (6%) of pure III, 0.8 g of pseudo-*p*-bromocyano compound XIX, and 0.7 g of mixture. Chromatography of the mother liquors from the original crystallization separated 0.8 g (10%) of II, a further 0.3 g of XIX (total yield, 18%), and 1.2 g (18%) of XVIII. These are all crude yields.

Pseudo-*p*-dicarbomethoxy[2.2]paracyclophane. A mixture of 10 ml of glacial acetic acid, 10 ml of hydrochloric acid, and 150 mg (0.58 mmol) of pseudo-*p*-dicyano[2.2]paracyclophane (XXI) was refluxed for 2 weeks. The diacid proved to be completely insoluble in 200 ml of ethyl acetate so the reaction mixture was filtered after dilution with water. The crude acid was dried and refluxed with 20 ml of 1,2-dichloroethane, 3 ml of methanol, and 0.25 ml of sulfuric acid until the acid had dissolved (2 weeks). Isolation and crystallization of the product from dichloromethane–ether gave 97 mg of pseudo-*p*-dicarbomethoxy[2.2]paracyclophane, mp 196–197.5°. A second crop of 42 mg brought the yield to 74%. *Anal.* Calcd for $C_{20}H_{20}O_4$: C, 74.05; H, 6.22. Found: C, 74.22; H, 6.21.

Dichlorination of [2.2]Paracyclophane (I). A slow stream of chlorine gas was passed into a suspension of 5 g (20.4 mmol) of I and 0.1 g of iodine in 250 ml of dichloromethane. The reaction was followed by vpc. It did not proceed cleanly stepwise, and seemed to speed up as it went on. When the reaction was quenched by addition of 10% sodium bisulfite solution, approximately 30% of trichlorinated material had formed. The bulk of the remainder was dichloro[2.2]paracyclophane. The solution was washed twice with sodium bisulfite solution and once with saturated sodium chloride solution and was dried over sodium sulfate. After removal of solvent, the crude product was crystallized from dichloromethane–ether; first crop 0.4 g, second crop 0.43 g. These were combined and recrystallized again to give 0.57 g (10% yield) of pseudo-*p*-dichloro[2.2]paracyclophane (XXII), pure by nmr. A further crystallization gave 0.22 g of hexagonal plates, mp 212.5–214°. *Anal.* Calcd for $C_{16}H_{14}Cl_2$: C, 69.33; H, 5.09. Found: C, 69.54; H, 5.14.

Nitration of [2.2]Paracyclophane (I). A mixture of 15 g of I and 600 ml of glacial acetic acid was refluxed for 15 min and cooled rapidly to 75°, and 155 ml of fuming nitric acid (90%) was added. After stirring for 2.0 min the brown solution was poured into 3 l. of ice–water. The product was filtered, washed well with water, and dissolved in dichloromethane. This solution was washed twice with 10% sodium hydroxide solution and once with water and then dried. Solvent was removed, and the residue was chromatographed on 1 kg of alumina.

Elution with 3.5 l. of 8–10% ether–pentane gave, after crystallization from dichloromethane–ether, 4.8 g of 4-nitro[2.2]paracyclophane (26% yield). Elution with 2 l. of 15–25% ether–pentane gave 942 mg of material. Crystallization from dichloromethane yielded 293 mg (1.4%) of pseudo-*p*-dinitro[2.2]paracyclophane (XXVI), mp 245–248°. Recrystallization from chloroform afforded an analytical sample of XXVI, mp 249–250°. *Anal.* Calcd for $C_{16}H_{14}N_2O_4$: C, 64.42; H, 4.73. Found: C, 64.62; H, 4.84. Crystallization of the mother liquor from above gave 437 mg (2%) of pseudo-*m*-dinitro[2.2]paracyclophane (XXIV), mp 196–199°. Recrystallization gave XXIV with mp 199–200°. *Anal.* Calcd for $C_{16}H_{14}N_2O_4$: C, 64.42; H, 4.73. Found: C, 64.19; H, 4.80.

Elution with 4 l. of 30–80% ether–pentane (793 mg) afforded 429 mg (2%) of pseudo-*o*-dinitro[2.2]paracyclophane (XXV), mp 243–245° dec, after crystallization from dichloromethane–ether. A second recrystallization gave pure XXV, mp 245.5–246.5°. *Anal.* Calcd for $C_{16}H_{14}N_2O_4$: C, 64.42; H, 4.73. Found: C, 64.53; H, 4.73.

Elution with 2 l. of 80–100% ether–pentane and crystallization of the product (225 mg) from dichloromethane–ether yielded 153 mg (0.7%) of pseudo-*gem*-dinitro[2.2]paracyclophane (XXIII). A second recrystallization gave an analytical sample, mp 268° dec. *Anal.* Calcd for $C_{16}H_{14}N_2O_4$: C, 64.42; H, 4.73. Found: C, 64.52; H, 4.85.

The two dinitro[2.2]paracyclophanes isolated previously,[6] to which the pseudo-*ortho* and pseudo-*para* structures (low and high melting isomers, respectively) had been assigned, contained some impurities but consisted mainly of XXIV and XXIII, respectively, from tlc and mixture melting point comparisons.

Thermal Isomerization of Pseudo-*m*-dinitro[2.2]paracyclophane (XXIV). Exactly 102 mg of XXIV was placed in a tube which was evacuated to 0.01 mm, sealed, and heated at 200° for 24.5 hr. The extensively charred product was chromatographed on 20 g of silica gel. Elution with 300 ml of 10% ether–pentane gave 51 mg of XXIV. Elution with 200 ml of 20% ether–pentane followed by 400 ml of 40% ether–pentane yielded 12 mg of material identified as dinitro compound XXIII by tlc comparisons. Recrystallization from dichloromethane–ether gave 5 mg, mp 266.5–268° dec; with XXIII isolated from nitration of [2.2]paracyclophane mmp 267–268.5°.