Acknowledgment.—The help of Dr. M. A. Melchior and F. Cassidy in the interpretation of nmr and gc spectra, respectively, is gratefully acknowledged. The advice of Dr. G. E. Milliman during the initial phase of this work was of great value. Most of the experimental operations were carried out with greatest competence by Mr. R. R. Phillips.

Direction of Cyclization of 1,2-Bis-(cyanomethyl)benzenes[1a]

ADRIENNE S. DEY, ANDRE ROSOWSKY, AND EDWARD J. MODEST

The Children's Cancer Research Foundation
and the Departments of Biological Chemistry and Pathology,
Harvard Medical School, Boston, Massachusetts 02115

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2-Amino-3-cyano-1H-indenes bearing a single chlorine substituent on the benzene ring were required as synthetic intermediates.[1b] A convenient route to amino nitriles of this type is the base-catalyzed Thorpe cyclization of 1,2-bis(cyanomethyl)benzenes, which has been reported for the unsubstituted parent compound, **1a**.[2] Unsymmetrically substituted dinitriles, such as 4-chloro-1,2-bis(cyanomethyl)benzene (**1b**) and 3-chloro-1,2-bis(cyanomethyl)benzene (**1c**), can each give rise to two isomeric products, depending on which cyanomethyl group undergoes anion formation most easily in the presence of base. This note describes a useful chemical method to establish the direction of cyclization of these dinitriles with complete certainty. This method, outlined in Scheme I, may be of general interest and applicability for similar systems.

Cyclization of the unsymmetrical dinitriles **1b** and **1c** afforded the corresponding cyano ketones; alkylation gave the cyano enol ethers, which were oxidized to homophthalic acids with chromic acid under mild conditions. The direction of cyclization of the dinitriles, which proved to be in accordance with predictions based on classical electronic effects, was confirmed by identification of the homophthalic acids.

Dinitriles **1b** and **1c** were prepared by bromination of 4-chloro-*o*-xylene[3] and 3-chloro-*o*-xylene, and reaction of the resulting 1,2-bis(bromomethyl) compounds with sodium cyanide in aqueous ethanol.[4] Cyclization of the dinitriles was accomplished in absolute ethanol in the presence of a catalytic amount of sodium ethoxide according to the method previously described for the cyclization of **1a**.[2] The amino group in amino nitriles **2b** and **2c** was hydrolyzed by refluxing in 6 *N* sulfuric acid for 3 hr. Treatment of the strongly enolic cyano ketones **3b** and **3c** with ethereal diazomethane yielded the corresponding enol ethers, **4b** and **4c**. All the chloro-substituted indenes prepared in this work were sharp melting and appeared to be single compounds by thin layer chromatography. Gas-liquid chromatography of the enol ethers also failed to reveal the presence of more than one component. Thus, it seemed likely that dinitriles **1b** and **1c** were both undergoing cyclization unidirectionally. Since the structures of the cyclization products could not be determined by physical methods, it was necessary to resort to chemical degradation.

Attempted ozonolysis of **3a** gave only unchanged starting material. However, gentle oxidation of ethyl enol ether **4a**[5] with 1 equiv of chromic acid gave a mixture of unreacted starting material and a product which proved to be ethyl *o*-carboxyphenylacetate (**5a**).[6] When the oxidation was carried out with 2 equiv of chromium trioxide, the product appeared to be a mixture of **5a** and another compound, which is probably the intermediate acyl cyanide shown in Scheme I. This assignment was supported by the infrared spectrum of the mixture, which contained a nitrile band at 2230 cm^{-1} and a carbonyl peak at 1780 cm^{-1}. The latter peak lies in the high wave number region characteristically ascribed to C=O functions attached directly to strong electron-attracting groups.[7] The presence of a small amount of the presumed acyl cyanide was also indicated by the nmr spectrum, which contained, in addition to the signals arising from **5a**, a minor second set of peaks displaced by only about 2 cps.

Similar oxidation of **4b** with 1 equiv of chromium trioxide, gave, in addition to some unchanged **4b**, a product whose analysis and spectra were consistent with structure **5b**. On the other hand, oxidation with 2 equiv of chromium trioxide and direct saponification of the crude product afforded a 63% yield of 4-chlorohomophthalic acid (**6b**). Since no unchanged **4b** was recovered, it was clear that the employment of 2 equiv of oxidant had resulted in a more complete reaction. The identification of **6b** was made by comparison of its infrared spectrum with that of an authentic specimen,[8] and also by mixture melting point determination. The formation of **6b** during the oxidation of **4b** established unequivocally that the Cl substituent in indenes **2b**–**4b** was attached to the 5 rather than the 6 position. Hence, the base-catalyzed cyclization of dinitrile **1b** had to proceed *via* preferential ionization of the cyanomethyl group *meta* to the Cl atom.

Oxidation of **4c** with 2 equiv of chromium trioxide gave a 48% yield of a single product identified as 6-chlorohomophthalic acid (**6c**) by comparison with an authentic sample prepared as shown in Scheme II.

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[1] (a) This investigation was supported in part by Research Contract DA-49-193-MD-3008 from the U. S. Army Medical Research and Development Command, Walter Reed Army Institute of Research, and Research Career Development Award K3-CA-22,151 from the National Cancer Institute, National Institutes of Health, U. S. Public Health Service. This is publication No. 656 from the Army Research Program on Malaria. (b) A. Rosowsky, A. S. Dey, J. Battaglia, and E. J. Modest, *J. Heterocycl. Chem.*, **6**, 613 (1969).

[2] (a) C. W. Moore and J. F. Thorpe, *J. Chem. Soc.*, **93**, 165 (1908); (b) W. Schroth and W. Treibs, *Ann. Chem.*, **639**, 214 (1961).

[3] D. R. Lyon, F. G. Mann, and G. H. Cookson, *J. Chem. Soc.*, 662 (1947).

[4] A. C. Cope and S. W. Fenton, *J. Amer. Chem. Soc.*, **73**, 1668 (1951).

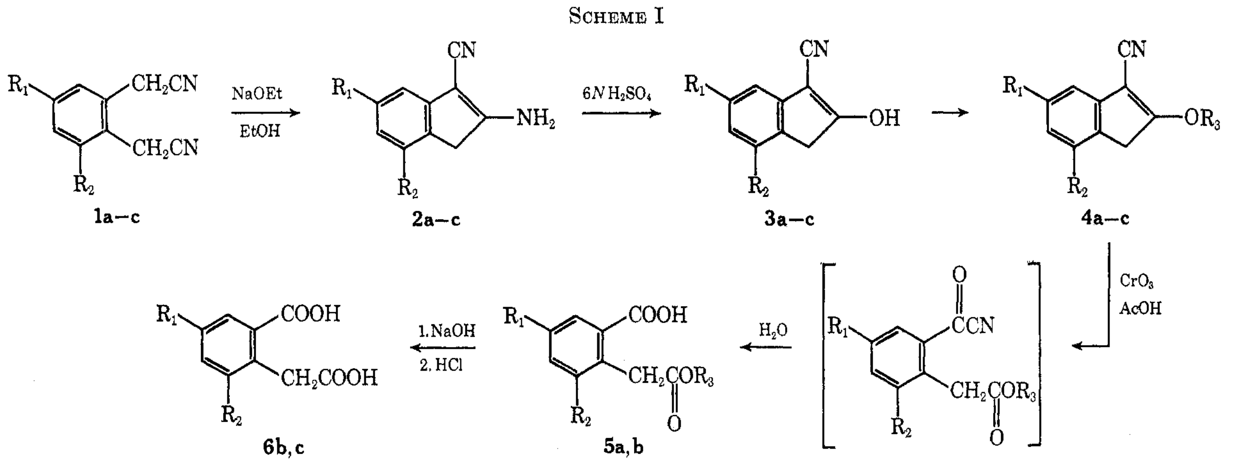
[5] Compound **4a** was prepared directly from **2a** by refluxing with ethanol in sulfuric acid as described by Moore and Thorpe.[2a]

[6] This compound has been claimed previously as the product of the reaction of *o*-carboxyphenylacetonitrile with ethanol and sulfuric acid: H. W. Johnston, C. E. Kaslow, A. Langsjoen, and R. L. Shriner, *J. Org. Chem.*, **13**, 477 (1948). The material isolated by these workers was a liquid, bp 164–169° (19 mm), whereas our product was a solid, mp 98–100° (see Experimental Section). It is probable that the material described by Johnston and coworkers was actually a mixture of at least two compounds.

[7] L. J. Bellamy, "The Infrared Spectra of Complex Molecules," John Wiley & Sons, Inc., New York, N. Y., 1958, p 125.

[8] We are very grateful to Dr. P. A. S. Smith, of the Department of Chemistry, University of Michigan, for furnishing us with a sample of 4-chlorohomophthalic acid.

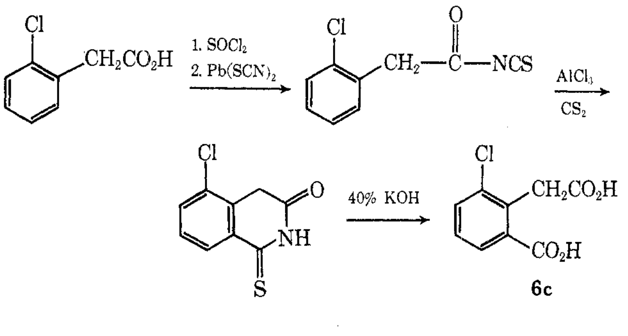
SCHEME I



a, $R_1 = R_2 = H, R_3 = C_2H_5$
b, $R_1 = Cl, R_2 = H, R_3 = CH_3$
c, $R_1 = H, R_2 = Cl, R_3 = CH_3$

Although several substituted homophthalic acids were prepared *via* this route by Smith and Kan,[9] **6c** was not described. The identification of **6c** as the oxidation product of **4c** proved that the cyclization of dinitrile **1c** proceeded, as in **1b**, *via* anion formation on the cyanomethyl group *meta* to the Cl atom.

SCHEME II



The present finding that dinitriles **1b** and **1c** undergo cyclization unidirectionally in the presence of base can be interpreted in terms of classical electronic effects. The Hammett constant, σ, which is considered a measure of net polar effect (inductive and resonance), is + 0.23 for *p*-Cl and +0.37 for *m*-Cl substituents.[10] Since positive σ values denote net electron withdrawal, one would predict that in **1b** the cyanomethyl group *meta* to the Cl substituent should be more acidic than the *para*-cyanomethyl group. On this basis, the expected product should be **2b**, in agreement with the experimental result. Although Hammett σ constants are not very useful in predicting the net polar effect of *ortho* substituents, the Taft σ^* constant, which is considered to reflect more accurately the combined effect of polar and steric factors, can be used for this purpose.[11] The σ^* constant for *o*-Cl (+0.20) is very similar to σ for the *p*-Cl substituent. Hence with respect to the cyclization of **1c**, one would predict that the cyanomethyl group *meta* to the Cl substituent should be more acidic than the *ortho*-cyanomethyl group and that the favored product should therefore be **2c**.

In summary, the chromic acid oxidation of enol ethers **4a–c** represents a useful method for the selective cleavage of the double bond in this type of indene derivative. The reaction is simple to perform and proceeds cleanly, gives reasonable yields of homophthalic acids, and can probably be extended successfully to other compounds of similar structure.

Experimental Section[12]

4-Chloro-1,2-bis(cyanomethyl)benzene (1b).—Bromination of 4-chloro-*o*-xylene[8] according to a standard procedure[13] gave, after repeated vacuum distillation, a 23% yield of >90% glpc-pure α,α'-dibromo-4-chloro-*o*-xylene: bp 102–106° (0.05 mm) [lit.[3] 111–127° (0.1 mm)]. The dibromide (16 g, 0.05 mol) was added fairly rapidly and with vigorous stirring to a solution of NaCN (5.9 g, 0.12 mol) in 50 ml of 50% EtOH under N_2. After being refluxed for 30 min, the mixture was cooled and poured into 300 ml of water, and the product was extracted into $CHCl_3$ (200 ml total). The combined $CHCl_3$ layers were washed with water, dried, and evaporated under reduced pressure. Crystallization of the brown residue from absolute EtOH gave 6.8 g (67%) of material melting at 77–81°. A second crystallization from aqueous ethanol gave yellow solid: mp 80–82°. Analytically pure colorless crystals were obtained upon repeated crystallization of a separate sample[14] from *i*-PrOH: mp 81°; ir (KCl) 2270 cm^{-1} (C≡N); nmr ($CDCl_3$) δ 3.73 (singlet, $-CH_2CN$).

Anal. Calcd for $C_{10}H_7ClN_2$: C, 63.00; H, 3.70; Cl, 18.60; N, 14.70. Found: C, 62.89; H, 3.65; Cl, 18.80; N, 14.60.

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(9) P. A. S. Smith and R. O. Kan, *J. Org. Chem.*, **29**, 2261 (1964).

(10) H. H. Jaffé, *Chem. Rev.*, **53**, 191 (1953).

(11) R. W. Taft, Jr., in "Steric Effects in Organic Chemistry," M. S. Newman, Ed., John Wiley & Sons, Inc., New York, N. Y., 1956, p 619.

(12) Ultraviolet spectra were measured with Cary Model 11 and Model 15 spectrophotometers. Infrared spectra were taken in potassium chloride disks with a Perkin-Elmer Model 137B double-beam recording spectrophotometer. Nmr spectra were determined in deuteriochloroform solution on a Varian A-60 instrument, with tetramethylsilane as the internal reference. Glpc analyses were performed on an F & M Model 720 instrument, using 6 ft × 1/4 in. 10% silicone rubber (SE-30) columns and helium as the carrier gas. Analytical samples were dried over Drierite at 70–100° (0.05 mm). Melting points were measured in Pyrex capillary tubes in a modified Wagner–Meyer apparatus [E. C. Wagner and J. F. Meyer, *Ind. Eng. Chem., Anal. Ed.*, **10**, 584 (1938)] at a heating rate of 2°/min, and are uncorrected. Microanalyses were performed by Galbraith Laboratories, Knoxville, Tenn.

(13) E. F. M. Stephenson in "Organic Syntheses," Coll. Vol. IV, John Wiley & Sons, New York, N. Y., 1963, p 984.

(14) This sample of **1b** was obtained *via* an alternate, but less satisfactory, route involving ditosylation of 4-chlorobenzene-1,2-dimethanol[15,16] *via* the tosyl chloride–sodium hydride procedure,[17] and subsequent reaction of the ditosylate with sodium cyanide in dimethyl sulfoxide.

(15) J. Tirouflet, *C. R. Acad. Sci., Paris*, **238**, 2246 (1954).

(16) R. F. Bird and E. E. Turner, *J. Chem. Soc.*, 5050 (1952).

(17) J. K. Kochi and G. S. Hammond, *J. Amer. Chem. Soc.*, **75**, 3443 (1953).

3-Chloro-1,2-bis(cyanomethyl)benzene (**1c**).[18]—2,3-Dimethylaniline was diazotized and treated with CuCl in the usual fashion.[3] After being heated briefly to 55°, the reaction mixture was steam distilled. The distillate, which appeared to contain a significant amount of 2,3-dimethylphenol in addition to the expected product,[19] was basified with 5% NaOH and extracted with Et_2O. The organic layer was washed several times with 5% NaOH, rinsed to neutrality, and evaporated. The combined products from two runs were purified further by repeated basic extraction and vacuum distillation until no more 2,3-dimethylphenol was detectable by glpc to yield pure 3-chloro-*o*-xylene, 51.9 g (22%), bp 93–95° (33 mm) [lit.[20] 187–190° (1 atm)]. Bromination of this material according to the procedure used with the 4-chloro isomer gave after two vacuum distillations 55.6 g (50%) of α,α'-dibromo-3-chloro-*o*-xylene, bp 105–106° (0.005 mm), mp 31.5–35° (solidifying in the receiver).

Anal. Calcd for $C_8H_7Br_2Cl$: C, 32.20; H, 2.36; Br, 53.56; Cl, 11.88. Found: C, 31.99; H, 2.36; Br, 53.83; Cl, 11.96.

The above dibromide was treated with NaCN in refluxing EtOH as described for the preparation of the 4-chloro isomer. Crystallization from EtOH afforded 18.3 g (52%) of yellow solid: mp 130–131.5°; ir (KCl) 2270 cm^{-1} ($C{\equiv}N$); nmr ($CDCl_3$) δ 3.88 and 3.97 (singlets, $-CH_2CN$). The analytical sample had mp 127–129°.

Anal. Calcd for $C_{10}H_7ClN_2$: C, 63.00; H, 3.70; Cl, 18.60; N, 14.70. Found: C, 62.91; H, 3.54; Cl, 18.62; N, 14.69.

2-Amino-5-chloro-3-cyano-1H-indene (**2b**).—To a solution of **1b** (9.6 g, 0.05 mol) in 30 ml of absolute EtOH at reflux was added under N_2 a solution of Na (0.1 g, 0.004 mol) in absolute EtOH (5 ml). A dense solid was formed within 2 min. After being heated an additional 5 min, the mixture was cooled and filtered, and the solid was washed with a little cold EtOH to give 5.1 g (53%) of gray-purple powder, which tended to darken upon standing. Recrystallization from 95% EtOH gave very small purplish needles: mp 250–253° dec. Further recrystallization did not improve the appearance of the product.

Anal. Calcd for $C_{10}H_7ClN_2$: C, 63.00; H, 3.70; Cl, 18.60; N, 14.70. Found: C, 63.12; H, 3.57; Cl, 18.82; N, 14.71.

2-Amino-7-chloro-3-cyano-1H-indene (**2c**).—A solution of **1c** (1.0 g, 0.0052 mol) in the minimum amount (9 ml) of refluxing EtOH was treated, under N_2, with a solution of Na (0.011 g, 0.00044 mol) in absolute EtOH (0.2 ml). The reaction mixture, which rapidly turned brown and then black, was refluxed for 40 min, then cooled, and filtered. Recrystallization of the crude product (0.5 g, 50%) from absolute EtOH gave small beige needles: mp 213–216° dec; ir (KCl) 2200 cm^{-1} (conjugated $C{\equiv}N$).

Anal. Calcd for $C_{10}H_7ClN_2$: C, 63.00; H, 3.70; Cl, 18.60; N, 14.70. Found: C, 63.30; H, 3.72; Cl, 18.75; N, 14.64.

6-Chloro-1-cyano-2-indanone (**3b**).—A mixture of **2b** (1.9 g, 0.01 mol), 19 ml of concentrated H_2SO_4, and 95 ml of water was refluxed with stirring for 3 hr, then cooled, diluted with 100 ml of water, and filtered. Recrystallization of the crude product (1.8 g, 94%) from aqueous EtOH gave a beige powder: mp 193–195° dec; ir (KBr) 2260 cm^{-1} ($C{\equiv}N$), 3500 cm^{-1} (enolic OH).

Anal. Calcd for $C_{10}H_6ClNO$: C, 62.68; H, 3.16; Cl, 18.50; N, 7.31. Found: C, 62.77; H, 3.32; Cl, 18.57; N, 7.16.

4-Chloro-1-cyano-2-indanone (**3c**).—A mixture of **2c** (1.6 g, 0.0082 mol), 15 ml of concentrated H_2SO_4, and 75 ml of water was stirred under reflux for 3 hr, then cooled, and filtered. Crystallization of the crude product (1.5 g, 94%) from aqueous EtOH gave a beige powder: mp 206–209° dec; ir (KCl) 2250 cm^{-1} ($C{\equiv}N$).

Anal. Calcd for $C_{10}H_6ClNO$: C, 62.68; H, 3.16; Cl, 18.50; N, 7.31. Found: C, 62.51; H, 3.18; Cl, 18.34; N, 7.54.

5-Chloro-3-cyano-2-methoxy-1H-indene (**4b**).—A suspension of **3b** (1.9 g, 0.01 mol) in Et_2O was treated with freshly prepared ethereal CH_2N_2 until gas evolution ceased. The resulting solution was evaporated under reduced pressure, and the brown residue was crystallized from aqueous EtOH: 1.3 g (63%), mp 114–116° dec. Further recrystallization from aqueous EtOH gave yellow crystals: mp 120–122°; ir (KCl) 2240 cm^{-1} ($C{\equiv}N$); nmr ($CDCl_3$) δ 4.25 (singlet, OCH_3), 3.55 (singlet, $ArCH_2$).

Anal. Calcd for $C_{11}H_8ClNO$: C, 64.24; H, 3.92; Cl, 17.24; N, 6.81. Found: C, 64.39; H, 4.05; Cl, 17.48; N, 6.54.

7-Chloro-3-cyano-2-methoxy-1H-indene (**4c**).—Reaction of **3c** with ethereal CH_2N_2 as described for the preparation of **4b** gave a 63% yield of beige powder. One crystallization from aqueous ethanol gave the analytical sample: mp 140–142° dec; ir (KCl) 2230 cm^{-1} ($C{\equiv}N$); nmr ($CDCl_3$) δ 4.27 (singlet, OCH_3), 3.55 (singlet, $ArCH_2$).

Anal. Calcd for $C_{11}H_8ClNO$: C, 64.24; H, 3.92; Cl, 17.24; N, 6.81. Found: C, 63.91; H, 3.83; Cl, 17.33; N, 6.90.

Oxidation of 3-Cyano-2-ethoxy-1H-indene (**4a**). **Procedure A.**—To a solution of **4a**[5] (0.50 g, 0.0027 mol) in 25 ml of glacial AcOH at 50° was added a warm solution of CrO_3 (0.25 g, 0.0025 mol) in 30 ml of glacial AcOH. After being kept at 50° (internal) in a bath for 10 min and then at room temperature for 80 min, the mixture was poured into ice water. The precipitate was filtered to give 0.30 g of material, mp 72–78°, consisting mainly of starting material mixed with some oxidation product. The solid was redissolved in 25 ml of glacial AcOH and treated with additional CrO_3 (0.15 g, 0.0015 mol) in a bath at 65–70° for 1 hr. The mixture was poured into 200 ml of ice water, and a minute quantity of unchanged **4a** was filtered off. The filtrate was extracted with Et_2O, and the organic layer was washed with water, dried, and evaporated to give a yellow oil. Addition of water to the oil gave some orange solid, mp 63–69°, consisting again mainly of unchanged **4a**. However, extraction of the cloudy filtrate with Et_2O, followed by the usual work-up, gave a residue which solidified upon standing overnight at room temperature. Repeated crystallization from benzene–petroleum ether (bp 40–60°) gave yellow needles of **5a** (0.05 g, 9%): mp 98–100°; ir (KCl) 1680 cm^{-1} (acid C=O), 1730 cm^{-1} (ester C=O), 3040 cm^{-1} (associated OH); nmr ($CDCl_3$) δ 4.23 (quartet, OCH_2CH_3), 4.12 (singlet, $ArCH_2CO$), 1.27 (triplet, CH_2CH_3).

Anal. Calcd for $C_{11}H_{12}O_4$: C, 63.45; H, 5.80. Found: C, 63.68; H, 5.78.

Oxidation of 5-Chloro-3-cyano-2-methoxy-1H-indene (**4b**). **Procedure B.**—A solution of **4b** (0.5 g, 0.0024 mol) in 20 ml of glacial AcOH at 95° was treated with CrO_3 (0.25 g, 0.0025 mol). After being stirred at 95–105° (internal) for 50 min, the mixture was poured into water and extracted with Et_2O. The organic layer was washed with water, dried, and evaporated under reduced pressure to give a yellow oil which solidified under petroleum ether (bp 40–60°). The yellow, somewhat gummy solid (0.25 g), consisted of equal parts of unreacted **4b** and methyl 2-carboxy-4-chlorophenylacetate (**5b**), as shown by the nmr spectrum; pure **4b** could be recovered by recrystallization from aqueous EtOH. Dilution of the filtrate remaining after recovery of **4b** with $CHCl_3$ afforded crude **5b** and recrystallization from benzene–petroleum ether gave analytically pure orange crystals: mp 110–113°; nmr ($CDCl_3$) δ 4.10 (singlet, $ArCH_2CO$), 3.76 (singlet, OCH_3).

Anal. Calcd for $C_{10}H_9ClO_4$: C, 52.53; H, 3.96; Cl, 15.50. Found: C, 52.77; H, 3.82; Cl, 15.49.

Treatment of the original reaction product with 10% NaOH in the cold, followed by filtration to remove dark insoluble material and acidification of the filtrate with 12 *N* HCl, gave a small fraction of unreacted **4b**. However, ether extraction of the cloudy acid filtrate gave a yellow oil which crystallized slowly upon standing. The solid was suspended in $CHCl_3$ and a trace of undissolved 4-chlorohomophthalic acid (**6b**) filtered off: mp 195–198° with gas evolution (rapid heating); ir (KCl) 1710 cm^{-1} (acid C=O). The mixture melting point with authentic **6b**[8] was 196–199°.

Procedure C.—A solution of **4b** (0.56 g, 0.0027 mol) in 20 ml of glacial AcOH on the steam bath was treated with CrO_3 (0.56 g, 0.0056 mol). The mixture was kept on the steam bath, with occasional shaking, for 1 hr, then poured into 400 ml of cold water, and extracted with 100 ml of $CHCl_3$, followed by 100 ml of Et_2O. The combined organic layers were evaporated under reduced pressure, and the residue was treated with 20 ml of 10% NaOH. Some dark insoluble material was removed by filtration, and the basic filtrate was heated on the steam bath for 30 min. Acidification of the cooled solution with 12 *N* HCl gave 0.14 g (24%) of **6b**: mp 195–198° dec. Extraction of the acid filtrate with Et_2O gave an oil which crystallized partially. Washing of this solid

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[18] This compound was first isolated unexpectedly when a commercial batch of "4-chloro-*o*-xylene" (K & K Laboratories, Inc., Plainview, N. Y.) was subjected to bromination and treatment with sodium cyanide in the usual manner. Fractional crystallization of the product yielded both the desired **1b** and, in addition, a substantial amount of **1c**. Analysis of the starting 4-chloro-*o*-xylene by nmr then showed clearly that this material actually contains 4-chloro- and 3-chloro-*o*-xylene in a ratio of approximately 1:1.

[19] The apparent ease of hydrolysis of this diazonium salt is noteworthy in view of the fact that the corresponding reaction of 3,4-dimethylaniline[8] proceeded without complication.

[20] A. F. Dokukina and M. M. Koton, *Zh. Obshch. Khim.*, **29**, 2201 (1959); *Chem. Abstr.*, **54**, 10905 (1960).

with $CHCl_3$ gave an additional 0.23 g (39%) of **6b**: mp 195–197° dec. The total yield obtained by this procedure was 0.37 g (63%).

Oxidation of 7-Chloro-3-cyano-2-methoxy-1H-indene (4c).—Upon being heated with CrO_3 (2 equiv) and worked up in a manner similar to the preceding experiment (procedure C), **4c** gave a 48% yield of 6-chlorohomophthalic acid (**6c**). Recrystallization from water gave colorless crystals: mp 174–176° with gas evolution; ir (KCl) 1680 cm^{-1} (aromatic COOH), 1705 cm^{-1} (aliphatic COOH). This product was identical with the authentic sample of **6c** prepared from *o*-chlorophenylacetic acid (see below) and the mixture melting point was not depressed.

Anal. Calcd for $C_9H_7ClO_4$: C, 50.36; H, 3.28. Found: C, 50.34; H, 3.01.

5-Chloro-1-thio-1,2,3,4-tetrahydro-1,3(2H,4H)-isoquinolinedione.—A mixture of *o*-chlorophenylacetyl chloride[21] (8.6 g, 0.046 mol), PbSCN (14.7 g, 0.046 mol), and 18 ml of benzene was refluxed with stirring for 5 hr, then filtered twice, and evaporated under reduced pressure. Short-path distillation of the residue gave 8.1 g (84%) of almost colorless liquid: bp 107–110° (0.25 mm); ir (KCl) 1730 cm^{-1} (C=O), 1980 cm^{-1} (broad, SC≡N). A solution of this *o*-chlorophenylacetyl isothiocyanate (8.0 g, 0.038 mol) in 10 ml of CS_2 was added dropwise to a stirred suspension of $AlCl_3$ (11.1 g, 2.2 molar equiv) in 30 ml of CS_2, while cooling in an ice bath. When addition was complete, the mixture was refluxed for 5 hr, then cooled in ice, and treated with 12 ml of 1 *N* HCl. The brown reaction product was broken up with a spatula to give a bright orange solid, which was filtered off and washed with water. Crystallization from glacial AcOH gave several crops of bright orange product (total 3.6 g, 45%): mp 247–250° dec. The analytical sample had mp 250–252° dec.

Anal. Calcd for C_9H_6ClNOS: C, 51.07; H, 2.86; N, 6.62. Found: C, 50.77; H, 2.90; N, 6.37.

6-Chlorohomophthalic Acid (6c).—5-Chloro-1-thio-1,2,3,4-tetrahydro-1,3(2H,4H)-isoquinolinedione (1.0 g, 0.0047 mol) was hydrolyzed with 40 ml of 40% KOH under reflux for 2.5 days in a flask of alkali-resistant glass. After being left at room temperature for 3 days, the mixture was refluxed an additional 6 hr, then cooled, acidified with HCl, diluted with water to dissolve the precipitated inorganic material, and extracted twice with ether. Evaporation of the dried ether extract gave 0.68 g (67%) of crude light yellow product: mp 157° with gas evolution. Crystallization from water afforded a small first crop of malodorous material probably containing sulfur. Extraction of the filtrate with ether gave light yellow material: mp 167–169° with gas evolution. Recrystallization from glacial AcOH gave pure **6c** as a white powder: mp 172–174° (gas evolution). The infrared spectra of this material and of the product obtained from the oxidation of **4c** were identical, and a mixture melting point was not depressed.

Registry No.—**1b**, 22479-38-5; **1c**, 22479-39-6; **2b**, 22479-41-0; **2c**, 22528-32-1; **3b**, 22479-42-1; **3c**, 22479-43-2; **4b**, 22479-44-3; **4c**, 22479-45-4; **5a**, 22479-46-5; **5b**, 22482-73-1; **6c**, 22482-74-2; 5-chloro-1-thio-1,2,3,4-tetrahydro-1,3(2H,4H)-isoquinolinedione, 22482-75-3; α,α'-dibromo-3-chloro-*o*-xylene, 22479-40-9.

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[21] L. R. Cerecedo and C. P. Sherwin, *J. Biol. Chem.*, **58**, 215 (1923).

The Bromination of Butadiene in Methanol

VICTOR L. HEASLEY AND PAUL H. CHAMBERLAIN

Department of Chemistry, Pasadena College,
Pasadena, California 91104

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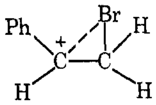
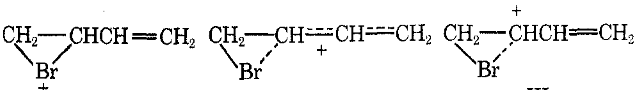
Recent studies[1,2] on the bromination of styrene and substituted styrenes suggest that the intermediates in these reactions are best described as unsymmetrically bridged bromonium ions with weak bonding between the bromine atom and the benzylic carbon atoms, as is illustrated below for styrene. Failure to achieve a symmetrically bridged bromonium ion in these reactions is undoubtedly due to increased stabilization of the carbonium ion system by the phenyl ring. On the other hand, the bromonium ion involved in bromination of *cis*- and *trans*-2-butene was shown to involve symmetrical bridging.[2]



In the course of our studies on the bromination of dienes, we became interested in the nature of the bonding in the intermediates in these reactions. In the addition of bromine to butadiene, at least three charge distributions could be involved. Their structures are shown below. Intermediate I is a bromonium ion with symmetrical bridging. Intermediate II represents the charge as highly delocalized across the bromine atom and the adjacent allylic system. Intermediate III shows the charge as essentially localized on the secondary carbonium ion. This intermediate should assume increasing importance as the polarity of the solvent becomes greater. In this regard, Rolston and Yates[2] and Buckles, Miller, and Thurmaier[3] have shown that, in the bromination of substituted styrenes and stilbenes, respectively, the charge becomes localized to form the most stable carbonium ion as the polarity of the solvent is increased.



I II III

It seemed to us that bromination in methanol might permit differentiation between these intermediates. Intermediate I should be attacked by the methanol molecule[4] at either carbon atom of the bromonium ion to give both 4-bromo-3-methoxy-1-butene (**1**) and 3-bromo-4-methoxy-1-butene (**2**). Intermediate II should lead to significant quantities of 1-bromo-4-methoxy-2-butene (**3**), presumably the *trans* isomer, by attack at the terminal carbon atom of the allylic system; **1** and perhaps some **2** would also be expected. Attack by methanol on III should give primarily **1**. All of the intermediates could give **3** by a S_N2' attack by methanol on the terminal carbon atom of the allylic system.

Formation of 3,4-dibromo-1-butene (**4**) and *trans*-1,4-dibromo-2-butene (**5**) would be expected.

Results and Discussion

The results in Table I show that, of the methoxybromides, 4-bromo-3-methoxy-1-butene (**1**) is the prin-

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[1] R. C. Fahey and H. J. Schneider, *J. Amer. Chem. Soc.*, **90**, 4429 (1968).

[2] J. H. Rolston and K. Yates, *ibid.*, **91**, 1469 (1969); J. H. Rolston and K. Yates, *ibid.*, **91**, 1477 (1969); J. H. Rolston and K. Yates, *ibid.*, **91**, 1483 (1969).

[3] R. E. Buckles, J. L. Miller, and R. J. Thurmaier, *J. Org. Chem.*, **32**, 888 (1967).

[4] It is possible that the weakly nucleophilic solvent might not open this bromonium ion (I). In that case, the product would be exclusively the dibromides.