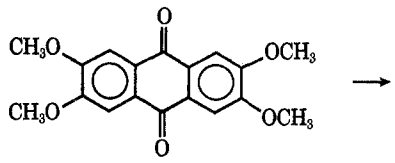
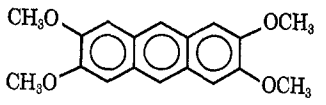
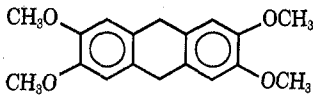
readily available 2,3,6,7-tetramethoxyanthraquinone[11] (2), which was converted by $Zn/OH^-$ to the anthracene 3, showing correct molecular weight (mass spectros-



1



2



3

copy) and consistent nmr and infrared spectra. Reduction of 3 with lithium–ammonia[12] led to **1b**[14] (correct molecular ion).

The nmr spectrum ($CCl_4$) of **1b** showed an aromatic singlet at $\delta$ 6.68 (4 H) and two partially overlapping singlets at 3.78 (total 16), representing the 12 methoxy protons and the 4 methylene protons. At 100 MHz, the two singlets were sufficiently well resolved to permit adequate integration (12:4) with the methylene protons appearing as a singlet 2.5 Hz upfield from the methoxy signal. Thus, the equivalence of the four methylene protons is consistent with a rapid inversion process and demonstrates that methoxy substituents have no unusual effect on this process.

### Experimental Section

**2,3,6,7-Tetramethoxyanthraquinone.**—The anthraquinone was prepared by the dichromate oxidation of 2,3,6,7-tetramethoxy-9,10-dimethylanthracene according to published procedure.[11]

**2,3,6,7-Tetramethoxyanthracene.**—The aforementioned anthraquinone (4 g) was refluxed for 48 hr with zinc dust (10 g) in 100 ml of 10% aqueous sodium hydroxide.[15] The solid residue was filtered, washed, dried, and boiled in 75 ml of nitrobenzene. Filtration and refrigeration gave crystals (0.5 g): mp 371–373° (lit.[8] 376°); nmr ($CDCl_3$) $\delta$ 7.95 (s, Ar-9,10, 2), 7.3 (s, Ar, 4), and 4.0 (s, $OCH_3$, 12).

**2,3,6,7-Tetramethoxy-9,10-dihydroanthracene.**—The anthracene above (0.15 g) was suspended in 65 ml of dry ether and added to 100 ml of refluxing ammonia. An excess of lithium metal was added and the dark blue-green solution was stirred for 30 min. Solid ammonium chloride was then added and the reaction was worked up by ether extraction. This gave 50 mg of a white solid which recrystallized from methanol: mp ~230° (lit.[8] 230–250°, dependent on rate of heating); mass spectra *m/e* 300 (calcd for $C_{18}H_{20}O_4$, 300.4); nmr described in text.

**Registry No.—3,** 26952-97-6.

(11) P. Boldt, *Ber.*, **100**, 1270 (1967).

(12) A modified Birch reduction for which complications and side reactions in anthracene systems are virtually unknown.[13]

(13) R. G. Harvey, *Syn.*, 161 (1970).

(14) Our material appears identical with that reported in ref 8 shown not to be the same as ref 7.

(15) E. L. Martin, *J. Amer. Chem. Soc.*, **58**, 1438 (1936). Yields are improved (55%), however, by added copper sulfate. See L. Fieser and M. Fieser, Ed., "Reagents for Organic Synthesis," Wiley, New York, N. Y., 1967, p 1282.

## The Methanolysis of Phenyl-Substituted Benzhydryl Chlorides

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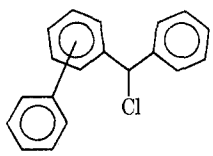
*Received January 19, 1971*

Neighboring group participation[2] in solvolytic displacement reactions of ortho-substituted benzhydryl and benzyl systems has been reported for a number of nucleophilic groups (*e.g.*, $COOC_6H_5$,[3] $COOCH_3$,[3] COOH,[3] $NO_2$[4]). In these cases[3,4] the rate of solvolysis is greater for the ortho compound than for the para compound. In cases where there is an absence of participation, the ortho/para rate ratio is less than unity (*e.g.*, $CH_3$,[3] $OCOCH_3$,[3] $OCOC_6H_5$,[3] halogen,[5] $OCH_3$)[6].

In view of the great interest in phenyl participation in solvolysis reactions,[2,7] we wish to disclose our studies with *o*-, *m*-, and *p*-phenyl-substituted benzhydryl chlorides.



1, *o*-$C_6H_5$
2, *m*-$C_6H_5$
3, *p*-$C_6H_5$

The benzhydryl chlorides 1, 2, and 3 were prepared by hydrogen chloride and/or thionyl chloride treatment of the corresponding carbinols, the syntheses of which are described in the Experimental Section and illustrated in Scheme I for 1.

The rates and activation parameters for the methanolysis of 1, 2, and 3 and benzhydryl chloride itself (4) at several temperatures are tabulated in Table I. The products in each case were isolated and identified as the unrearranged methyl ethers. As seen from Table I, the ortho/para rate ratio (1/3) is less than unity (0.16) and this, coupled with the lack of rearrangement, clearly indicates the absence of phenyl participation in 1. It was felt that, if phenyl participation during methanolysis of 1 were occurring, 9-phenylfluorene (5) would have formed. In fact, it was observed that treatment of *o*-phenylbenzhydrol (10) with thionyl chloride or hydrogen chloride above room temperature gave 5.[8] Apparently, under the milder meth-

(1) (a) We gratefully acknowledge partial financial support of this work by the donors of the Petroleum Research Fund, administered by the American Chemical Society, the National Science Foundation, and the Research Corporation. (b) Undergraduate Research Assistant in the Dartmouth Honors Degree Program, 1969–1970.

(2) B. Capon, *Quart. Rev., Chem. Soc.*, **18**, 45 (1964).

(3) A. Singh, L. J. Andrews, and R. M. Keefer, *J. Amer. Chem. Soc.*, **84**, 1179 (1962).

(4) A. D. Mease, M. J. Strauss, I. Horman, L. J. Andrews, and R. M. Keefer, *ibid.*, **90**, 1797 (1968).

(5) G. M. Bennett and B. Jones, *J. Chem. Soc.*, 1815 (1935).

(6) M. Simonetta and G. Favini, *ibid.*, 1840 (1954).

(7) For a leading reference, see A. F. Diaz and S. Winstein, *J. Amer. Chem. Soc.*, **91**, 4300 (1969).

(8) The acid-catalyzed rearrangement of **10** to **5** has been reported: H. H. Hatt, A. Pilgrim, and E. F. M. Stephenson, *J. Chem. Soc.*, 478 (1941).

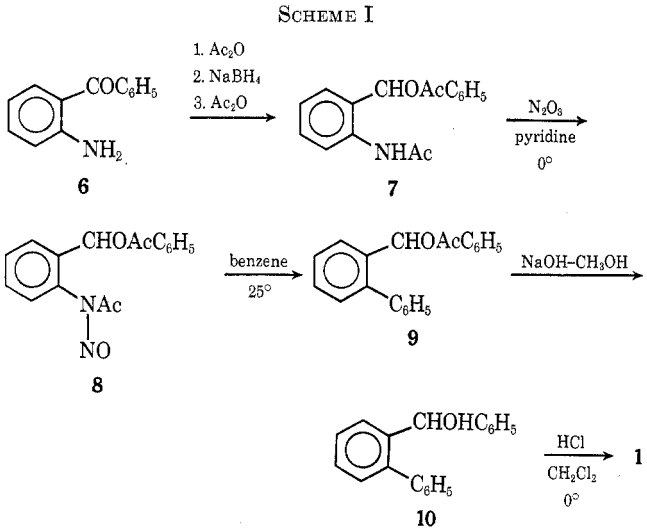
TABLE I

KINETIC DATA FOR METHANOLYSIS OF PHENYL-SUBSTITUTED BENZHYDRYL CHLORIDES

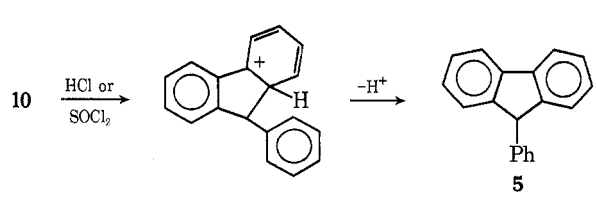
| RCl | Temp,[a] °C | Rate constant,[b] sec$^{-1}$ | Relative rate | $\Delta H^{\ddagger}$, kcal/mol | $\Delta S^{\ddagger}$, eu |
|---|---|---|---|---|---|
| 1 | 15.00 | $(4.03 \pm 0.15) \times 10^{-4}$ | | | |
| | 20.00 | $(8.23 \pm 0.17) \times 10^{-4}$ | | | |
| | 25.00 | $(1.40 \pm 0.03) \times 10^{-3}$ | 2.98 | $16.3 \pm 0.3$ | $-8.9 \pm 0.9$ |
| | 30.10 | $(2.22 \pm 0.08) \times 10^{-3}$ | | | |
| | 35.00 | $(3.38 \pm 0.17) \times 10^{-3}$ | | | |
| 2 | 20.10 | $(2.87 \pm 0.05) \times 10^{-4}$ | | | |
| | 25.00 | $(4.70 \pm 0.08) \times 10^{-4}$ | 1.00 | $18.3 \pm 1.4$ | $-7.8 \pm 4.6$ |
| | 30.00 | $(8.25 \pm 0.10) \times 10^{-4}$ | | | |
| 3 | 15.00 | $(3.28 \pm 0.10) \times 10^{-3}$ | | | |
| | 15.00 | $(3.0 \pm 0.2) \times 10^{-3}$ [c] | | | |
| | 20.00 | $(5.35 \pm 0.08) \times 10^{-3}$ | | | |
| | 25.00 | $(8.51 \pm 0.12) \times 10^{-3}$ | 18.1 | $13.7 \pm 0.6$ | $-14.2 \pm 1.9$ |
| | 25.00 | $(6.7 \pm 0.3) \times 10^{-3}$ [c] | | | |
| | 30.30 | $(1.07 \pm 0.09) \times 10^{-2}$ | | | |
| | 35.00 | $(1.75 \pm 0.02) \times 10^{-2}$ | | | |
| | 35.00 | $(1.5 \pm 0.1) \times 10^{-2}$ [c] | | | |
| 4 | 15.00 | $(3.40 \pm 0.23) \times 10^{-4}$ | | | |
| | 20.00 | $(5.82 \pm 0.25) \times 10^{-4}$ | | | |
| | 25.00 | $(1.02 \pm 0.03) \times 10^{-3}$ | 2.17 | $18.3 \pm 0.2$ | $-2.6 \pm 0.8$ |
| | 25.00 | $(8.0 \pm 1.0) \times 10^{-4}$ [c,d] | | | |
| | 30.00 | $(1.70 \pm 0.05) \times 10^{-3}$ | | | |
| | 35.00 | $(2.95 \pm 0.17) \times 10^{-3}$ | | | |

[a] Believed accurate to ±0.01°. [b] Determined by conductance unless otherwise indicated. [c] Determined by a titrimetric method. [d] Lit.[10] $8.28 \times 10^{-4}$ sec$^{-1}$.

SCHEME I




anolysis conditions, stabilization of the transition state by solvent is sufficient, and internal stabilization through phenyl participation is unnecessary. In the




more vigorous chlorination reactions, where solvent stabilization is lacking, there is a greater demand for internal stabilization of the developing positive charge by the *o*-phenyl group. It remains to be seen whether the demand for phenyl participation can be increased by observing the solvolysis of **1** in solvents of lower nucleophilicity and higher ionizing power (*e.g.*, HCOOH, $CF_3COOH$, $FSO_3H$, etc.)[9] than methanol.

The low **1**/**3** rate ratio probably results from steric hindrance to solvation in the transition state by the *o*-phenyl group in **1** and geometric difficulty in achieving maximum stabilization of the developing positive charge from three coplanar phenyl rings in **1** relative to **3**.

A $\sigma\rho$ calculation using $\rho = -4.22$[10] for benzhydryl chloride methanolysis at 25° and $\sigma^+$ values for phenyl[11] gave $3.54 \times 10^{-4}$ sec$^{-1}$ for **2**, and $5.79 \times 10^{-3}$ sec$^{-1}$ for **3**, in good agreement with the observed rates (Table I). Indeed, using $\sigma^+ = -0.218$ as determined[12] from the ethanolysis of diarylcarbinyl chlorides the predicted rate for **3** is $8.50 \times 10^{-3}$ sec$^{-1}$.

### Experimental Section

***o*-Acetamidobenzhydryl Acetate (7).**—To a stirred solution of 53.5 g (0.271 mol) of *o*-aminobenzophenone (Aldrich Chemical Co.) in 250 ml of pyridine at 0° was added 80 ml of acetic anhydride in one portion. The solution was allowed to warm to room temperature with stirring overnight. It was poured into benzene–water, and the organic layer was separated and washed with dilute HCl and water. Drying and concentration of the organic layer *in vacuo* afforded 50 g (77%) of *o*-acetamidobenzophenone, mp 99–101° (lit.[13] mp 88.5–89°), as off-white cubes from 95% ethanol.

A mixture of 30 g (0.125 mol) of *o*-acetamidobenzophenone 14.8 g of sodium borohydride, 400 ml of 95% ethanol, and 100 ml of water was stirred for 1 hr at 0°, and then stirred overnight at room temperature. To the solution was added 100 ml of water and enough dilute HCl to destroy the excess hydride. Extraction with chloroform and washing and drying of the organic layer

(9) For an example and leading reference, see P. C. Myhre and E. Evans, *J. Amer. Chem. Soc.*, **91**, 5641 (1969).

(10) S. Nishida, *J. Org. Chem.*, **32**, 2692 (1967).

(11) H. C. Brown and Y. Okamoto, *J. Amer. Chem. Soc.*, **80**, 4979 (1958).

(12) J. Packer, J. Vaughan, and A. F. Wilson, *J. Org. Chem.*, **23**, 1215 (1958).

(13) A. Bischler and D. Barad, *Ber.*, **25**, 3081 (1892).

gave, on concentration *in vacuo*, 28.5 g (94%) of *o*-acetamidobenzhydrol, mp 123–125° (lit.[14] mp 118°), as white plates.

A mixture of 28.5 g (0.118 mol) of *o*-acetamidobenzhydrol, 90 ml of pyridine, and 75 ml of acetic anhydride was stirred overnight at room temperature. The solution was poured into water, treated with 3 g of potassium carbonate, and extracted with methylene chloride. This gave, after the usual washing, drying, and concentration, a yellow oil which slowly crystallized to afford 30 g (90%) of **7**, mp 133–136°, as white plates.

***o*-Phenylbenzhydryl Acetate (9).**—A 500-ml, three-neck flask, equipped with drying tube, gas inlet tube, and magnetic stirring bar, was charged with 30 g (0.11 mol) of **7** and 250 ml of pyridine. The solution was cooled to 0° and a mixture of nitrogen trioxide ($N_2O_3$) and nitrogen was passed through a Drierite tower and into the stirred solution at 0° for 3.5 hr. The dark green solution was poured into ice water and extracted with benzene. The chilled benzene solution of **8** was dried quickly with sodium sulfate, filtered, and allowed to stir at room temperature for 24 hr. The dark solution was concentrated *in vacuo* and the resulting red oil was chromatographed over silica gel. The first fractions (benzene elution) crystallized on standing to afford 6 g (20%) of **9**, mp 62–65°, as light yellow prisms from ether–hexane. The same compound was obtained in yields of up to 37% from *o*-benzamidobenzophenone by an analogous sequence.

Pertinent spectra data for **9** are as follows: ir ($CHCl_3$) 2940, 1725, 1370, 1220, and 1020 $cm^{-1}$; nmr ($CDCl_3$) $\delta$ 1.90 (s, 3) and 6.9–7.6 (m, 15) ppm; mass spectrum (70 eV) *m/e* (rel intensity) 302 (16), 244 (21), 243 (25), 242 (100), 241 (34), and 165 (33).

*Anal.* Calcd for $C_{21}H_{18}O_2$: C, 83.42; H, 6.00. Found: C, 83.45; H, 6.08.

***o*-Phenylbenzhydrol (10).**—A mixture of 7 g (0.0234 mol) of **9**, 10 g of sodium hydroxide, 600 ml of methanol, and 150 ml of water was stirred at room temperature for 2 hr. The methanol was removed *in vacuo* and the solution was extracted with chloroform. This afforded, on washing, drying, and concentration *in vacuo*, a yellow–orange oil which slowly crystallized to give 6 g (100%) of **10**, mp 66–68° (lit.[8] mp 71°), as white needles, This material proved to be identical with the sodium borohydride reduction product of an authentic sample of *o*-phenylbenzophenone.[15]

***o*-Phenylbenzhydryl Chloride (1).**—A stirred, ice-cold mixture of 6 g of **10**, 200 ml of dry methylene chloride, and several grams of Drierite was treated with hydrogen chloride gas for 1 hr. The filtered solution was concentrated *in vacuo* at 0° to give 5 g (80%) of **1**, mp 80–82°, as white plates from hexane.

Pertinent spectral data for **1** are as follows: ir ($CHCl_3$) 3095, 1610, 1480, 1405, 1265, 1070, and 695 $cm^{-1}$; nmr ($CDCl_3$) $\delta$ 6.22 (s, 1) and 7.25 (m, 14) ppm.

*Anal.* Calcd for $C_{19}H_{15}Cl$: C, 81.86; H, 5.42; Cl, 12.72. Found: C, 82.12; H, 5.52; Cl, 12.73.

Treatment of **10** with boiling thionyl chloride gave 9-phenylfluorene (**5**) or mixtures of **5** and **1** depending on the conditions. Work-up of the thionyl chloride reaction mixture (see procedure for **3**) gave **5**, mp 146–148° (lit.[16] mp 147–148°), as white crystals.

Pertinent spectral data for **5** are as follows: nmr ($CDCl_3$) $\delta$ 5.02 (s, 1) ppm (lit.[17] 5.02 ppm); mass spectrum (70 eV) *m/e* 242, 226, 216, 214, 165, 122, 120, and 119.

***m*-Phenylbenzhydryl Chloride (2).**—A standard Grignard reaction involving benzaldehyde and *m*-bromobiphenyl (Pfaltz and Bauer Chemical Co.) gave a 60% yield of *m*-phenylbenzhydrol, mp 70–73° (lit.[8] mp 81°). This was converted in 86% yield to **2** in the manner described above for **1**, but could not be induced to crystallize. The oil was, however, found to be pure by complete methanolysis and titration with sodium hydroxide.

Pertinent spectral data for **2** are as follows: ir ($CHCl_3$) 3010, 1650, 1590, 1470, 1430, and 1070 $cm^{-1}$; nmr ($CDCl_3$) $\delta$ 6.12 (s, 1) and 7.33 (m, 14) ppm.

***p*-Phenylbenzhydryl Chloride (3).**—A typical sodium borohydride reduction of *p*-phenylbenzophenone (Aldrich Chemical Co.) gave *p*-phenylbenzhydrol (80%), mp 95–96° (lit.[18] mp 93–95°), as white needles from aqueous ethanol. Treatment of this alcohol with hydrogen chloride in the manner described for **1** or treatment with a fourfold excess of thionyl chloride at reflux for 30 min, followed by pouring into ice water and chloroform extraction, gave **3** (85–95%), mp 72–73° (lit.[8] mp 72°), as white needles from hexane.

Pertinent spectral data for **3** are as follows: ir ($CHCl_3$) 3090, 1620, 1490, 1460, 1410, 1220, 1075, 1010, and 693 $cm^{-1}$; nmr ($CDCl_3$) $\delta$ 6.12 (s, 1) and 7.34 (m, 14) ppm.

*Anal.* Calcd for $C_{19}H_{15}Cl$: C, 81.86; H, 5.42; Cl, 12.72. Found: C, 81.83; H, 5.43; Cl, 12.88.

**Benzhydryl Chloride (4).**—This material was used as received from Aldrich Chemical Co. An infrared spectrum showed the absence of hydroxyl absorption.

**Methanolysis Products.**—The three methyl ethers (from **1**, **2**, and **3**) were obtained in essentially quantitative yield. 9-Phenylfluorene (**5**) could not be detected (tlc, nmr) in the methanolysis product of **1**. Only the methyl ether from the methanolysis of **1** was fully characterized. The corresponding methyl ethers from **2** and **3** were identified by spectral data.

*o*-Phenylbenzhydryl methyl ether, mp 66–68°, exhibited the following nmr data ($CDCl_3$): $\delta$ 3.20 (s, 3), 5.35 (s, 1), and 7.2 (m, 14) ppm.

*Anal.* Calcd for $C_{20}H_{18}O$: C, 87.56; H, 6.61. Found: C, 87.86; H, 6.50.

*p*-Phenylbenzhydryl methyl ether, mp 80–82°, exhibited the following nmr data ($CDCl_3$): $\delta$ 3.37 (s, 3), 5.23 (s, 1), and 7.3 (m, 14) ppm.

*m*-Phenylbenzhydryl methyl ether, oil, exhibited the following nmr data ($CDCl_3$): $\delta$ 3.29 (s, 3), 5.19 (s, 1), and 7.3 (m, 14) ppm.

**Kinetics.**—Two conventional methods were used to determine solvolytic rate constants: conductance and titrimetry. Since most of the reactions were quite rapid, the conductance method gave better reproducibility and was far more convenient.

The conductance technique has been adequately described in the literature[18,19] and will only be briefly mentioned here. A small sample of the chloride (about 0.05 g) was dissolved in about 3 or 4 ml of benzene in a 150-ml beaker. About 150–200 ml of methanol, which was purified by distillation and dried over Type 3 molecular sieves, was poured into a larger beaker (400 ml). The conductivity cell was emptied, rinsed with methanol twice, and then left empty. Once the sample had been completely dissolved in benzene, the clock was started as soon as the methanol reached the chloride solution. About 40–60 ml of methanol was added. The solution was stirred briefly and then poured into the empty conductivity cell. The cell was rinsed once and then filled to about 0.5–1.0 cm above the plates. The electrode wires were connected from the bridge (Type RC16B2, made by Industrial Instruments, Inc., Cedar Grove, N. J.) to the conductivity cell in the bath. The resistance bridge had been previously calibrated to give readings accurate to $\pm 1\%$. After the connections had been made, the resistance was dialed. The frequency of the resistance bridge was set at 1000 cps, and the sensitivity was maximized in all cases. Cell resistance was determined when the dark triangle in the green window had maximum area. Readings were taken at 1.00 min, at 30-sec intervals until 7 min, at 1-min intervals until 10 min, and at 2-min intervals until 20 min. Faster reactions were monitored every 15 sec; slower reactions were monitored beyond 20 min. Infinity points were calculated after at least 10 half-lives (greater than 99.9% reaction). Solvolyses at temperatures greater than 25° or less than 20° were run in the same manner, except that the methanol used was allowed to equilibrate in the temperature bath for about 5 min before pouring it into the chloride solution. All rate constants were calculated at each time point and all errors determined were standard errors.[20]

The titrimetric method was that used by earlier workers[21] except that phenolphthalein was used as the indicator in the present study.

**Registry No.**—**1**, 30469-78-4; **2**, 30469-79-5; **3**, 7515-73-3; **4**, 90-99-3; **7**, 30651-46-8; **9**, 30545-62-1; **10**, 30469-82-0; *o*-phenylbenzhydryl methyl ether,

(14) S. Gabriel and R. Stelzner, *Ber.*, **29**, 1305 (1896).

(15) We wish to thank Professor DeLos F. DeTar (Florida State University) for kindly providing us with this sample.

(16) "Elsevier's Encyclopedia of Organic Chemistry," Vol. 13, Elsevier, New York, N. Y., 1946, p 29.

(17) G. W. H. Scherfe and R. K. Brown, *Can. J. Chem.*, **39**, 799 (1961).

(18) J. F. Norris and A. A. Morton, *J. Amer. Chem. Soc.*, **50**, 1795 (1928).

(19) H. A. Hammond and A. Streitwieser, Jr., *Anal. Chem.*, **41**, 2032 (1969).

(20) D. P. Shoemaker and C. W. Garland, "Experiments in Physical Chemistry," McGraw-Hill, New York, N. Y., 1962, Chapter 2.

(21) H. C. Brown, J. D. Brady, M. Grayson, and W. H. Bonner, *J. Amer. Chem. Soc.*, **79**, 1897 (1957).

30469-83-1; *p*-phenylbenzhydryl methyl ether, 30469-84-2; *m*-phenylbenzhydryl methyl ether, 30470-00-9.

**Acknowledgment.**—The authors wish to thank Professor Michael J. Strauss (University of Vermont) for a valuable discussion.

## Selective Cyanylation of Sulfhydryl Groups. II. On the Synthesis of 2-Nitro-5-thiocyanatobenzoic Acid

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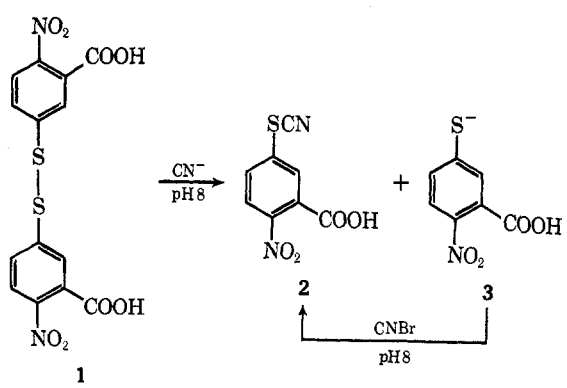
*Received November 30, 1970*

We have recently described a method for the selective cyanylation of sulfhydryl groups under mild conditions, employing 2-nitro-5-thiocyanatobenzoic acid (NTCB, **2**).[1] The reagent was shown to be particularly useful for the reversible blocking of cysteine residues with the cyano group in peptides and proteins and for radioactive labeling of proteins at cysteine residues when using $^{14}C$-NTCB. The reagent is also a promising tool for the selective nonenzymatic cleavage of peptide chains at cysteine residues, since *N*-acyl-β-thiocyanoalanines were shown to undergo cyclization to labile *N*-acyl-2-iminothioazolidine rings with subsequent cleavage of the *N*-acyl function.[2,3]

NTCB was originally prepared[1] by treatment of 5,5′-dithiobis(2-nitrobenzoic acid) (DTNB, Ellman's reagent,[4] **1**) with NaCN, forming besides **2** an equimolar amount of the thionitrobenzoate **3**. The latter was removed from the product mixture by treatment with bromoacetyl-cellulose, thus shifting the equilibrium toward quantitative completion of the reaction.

We now describe an improved synthesis of NTCB giving twice as high yield of the product as in the previous method. Instead of removing **3** from the reaction mixture, it is also converted into the desired product by treatment with an equimolar amount of cyanogen bromide. Thus 1 mol of **1** gives 2 mol of **2** in practically quantitative yields.




Both steps of the synthesis can be followed by the appearance and disappearance of the characteristic color of **3** [$\lambda_{max}$ 412 mμ (ε 13,600)].[5]

For obtaining a quantitative yield of **2**, the presence of excess cyanide is necessary also in the second step. Thus, when the pure thiol **3** (prepared by reducing the disulfide **1** with β-mercaptoethanol) was treated with cyanogen bromide without addition of cyanide salt, the yield of the thiocyanate was only 58%, the rest of the thiol (42%) being converted into the disulfide **1**. (The products were separated and determined by a quantitative paper electrophoretic method, described in the Experimental Section.) The disulfide was probably formed *via* the thiocyanate, by reaction with the still unreacted thiol. Indeed, when the thiol **3** was treated with excess thiocyanate **2** at pH 7–8, the disulfide **1** was formed. These findings point to the existence of equilibrium 1. It is therefore concluded that the presence of excess cyanide during the CNBr reaction shifts the equilibrium to the left, in the direction of the desired thiocyanate.

$$RSCN + RS^- \rightleftharpoons RSSR + CN^- \quad (1)$$

This interpretation is supported by two recent reports on the reaction of cyanogen bromide with thiols. Foye, *et al.*,[6] found that the reaction of a thiol with cyanogen bromide (in 2:1 molar ratio) provides a synthesis of disulfides, whereas Kottke, *et al.*,[7] reported that treatment of thiols with "nascent cyanogen bromide" (excess cyanide followed by dropwise addition of bromine) afforded the corresponding thiocyanates in good yields. Under the experimental conditions of the latter reaction, excess cyanide was present continuously during the synthesis, probably effecting equilibrium 1 as suggested above.

Under the appropriate conditions, the reaction of aromatic thiols with cyanogen bromide seems advantageous over common routes to aryl thiocyanates, such as reacting aryl halides or diazonium salts with metal thiocyanates, since the aryl thiocyanates obtained by these methods are often accompanied by the corresponding isothiocyanates.[8] This contamination was also observed in our earlier attempts to prepare **2** from either 5-chloro-2-nitrobenzoic acid or diazotized 5-amino-2-nitrobenzoic acid.

### Experimental Section

Melting points were determined with a Fisher–Johns apparatus and were uncorrected. Infrared spectra were recorded on a Perkin-Elmer 237 spectrophotometer, uv spectra on a Cary 15 spectrophotometer, and mass spectra on a MAT CH4 mass spectrophotometer. Paper electrophoresis was run in a Savant high-voltage electrophoresis apparatus Model LT-48A using pyridine acetate buffer of pH 3.5. Descending paper chromatography was run with 25:6:25 1-butanol–acetic acid–water. Whatman No. 1 paper was used for both electrophoresis and chromatography.

**2-Nitro-5-thiocyanatobenzoic Acid (2).**—To a 150-ml aqueous solution containing 7.5 g of $KHCO_3$ and 2.0 g (31 mmol) of KCN, 3.0 g (7.5 mmol) of 5,5′-dithiobis(2-nitrobenzoic acid) (**1**,

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(5) In ref 4, this ε value was attributed to solutions of **3** by analogy to *p*-nitrothiophenolate, without having isolated the thionitrobenzoate. This value is confirmed in the present work for the isolated pure compound.

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(8) R. G. R. Bacon in "Organic Sulfur Compounds," Vol. I, N. Kharasch, Ed., Pergamon Press, Oxford, London, New York, Paris, 1961, p 306.