1e. In the tropylium salts **2a–c**, the vinyl proton peaks were merged with the aryl protons. In the dihydro alcohols **3a–b**, the $-CH_2CH_2-$ protons were present as multiplets at δ 2.75 and 2.87, respectively; this peak appeared at 2.8–2.9 in **3c–e**, and as a singlet at 3.15–3.20 in **4a–b**. Signals for aryl protons and alkyl substituents appeared at the expected positions.

Registry No.—**1b**, 5371-47-1; **1c**, 15735-61-2; **1e**, 15856-55-0; **2a**, 15722-31-3; **2b**, 15722-32-4; **2c**, 15722-33-5; **3b**, 5371-46-0; **3c**, 15735-63-4; **3d**, 15735-64-5; **3e**, 4821-67-4; **4a**, 15722-34-6; **4b**, 15722-35-7.

Indolothiapyrylium Compounds. IV. Indolo[3,2-c]thiapyrylium Perchlorate[1,2]

THOMAS E. YOUNG AND CYRUS J. OHNMACHT[3]

William H. Chandler Chemistry Laboratory, Lehigh University, Bethlehem, Pennsylvania

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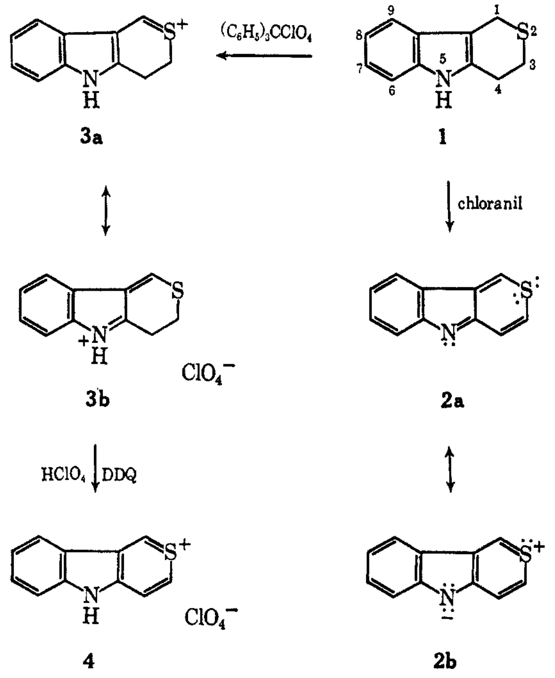
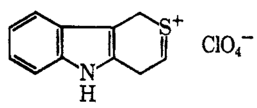
In a recent article,[2] we reported that 1,3,4,5-tetrahydrothiapyrano[4,3-*b*]indole (**1**) and several of its substituted analogs were readily dehydrogenated with chloranil or dicyanodichloroquinone (DDQ) to yield the corresponding thiapyrano[4,3-*b*]indoles (*e.g.*, **2** from **1**), which represent a new class of pseudoazulenes having pronounced thiapyrylium-like character of the sulfur-containing ring (*cf.* canonical form **2b**). Although the parent thiapyranoindole (**2**), at 10^{-4} *M* concentration in 95% ethanol, could be titrated spectrophotometrically with ethanolic hydrogen chloride to give the conjugate cation, repeated attempts to prepare indolothiapyrylium salts (**4**) by direct interaction of **2** with acids gave tars which were exceedingly difficult to purify. We now wish to report the isolation of indolo[3,2-*c*]thiapyrylium perchlorate (**4**),[4] prepared by the alternative route shown in formulas **1** → **3** → **4**.



3a **1** **3b** **2a** **4** **2b**

1,3,4,5-Tetrahydrothiapyrano[4,3-*b*]indole (**1**)[2,5] reacted with an equimolar portion of trityl perchlorate[6] in refluxing glacial acetic acid to give a 94% yield of 3,4-dihydroindolo[3,2-*c*]thiapyrylium perchlorate (**3**), and the same product was obtained in only slightly reduced yield (84%) when a 100% excess of trityl perchlorate was used. This orange crystalline compound (**3**) exhibited an intense visible absorption at 414 mμ (log ε 4.20) attributable to the chromophore $-\overset{+}{N}H{=}C{-}C{=}C{-}S- \longleftrightarrow -NH{-}C{=}C{-}C{=}\overset{+}{S}-$ (*cf.* **3a** ⟷ **3b**), and lying in the same range (400–420 mμ) as the long wavelength absorption of the thiapyrano[4,3-*b*]indoles (**2**)[2] and the benz[*b*]indolo[2,3-*d*]thiapyrylium perchlorates.[7]

The nmr spectrum of **3** (*cf.* Experimental Section) was also consistent with the assigned structure in which H-1 appeared as a singlet resonance band at very low field (δ 9.48) as expected[7,8] for a proton adjacent to a thionium sulfur. The observation that both the low-field proton of the $-CH{=}\overset{+}{S}-$ group and the four methylene protons (δ 3.65) appeared as singlets ruled out the possibility of the alternate structure (**5**) in which the $-\overset{+}{S}{=}CH{-}CH_2-$ group should exhibit an AX_2 splitting pattern.[9]



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Dehydrogenation of **3** with dicyanodichloroquinone in acetic acid containing perchloric acid afforded a 33% yield of indolo[3,2-*c*]thiapyrylium perchlorate (**4**), a stable green-yellow salt, which was also stable in glacial acetic acid solution and recrystallized well from this solvent. In acetonitrile, containing excess perchloric acid to suppress dissociation[10] of the cation, this salt (**4**) exhibited an ultraviolet-visible spectrum essentially identical with that previously illustrated[2] for the same cation produced from **2** with ethanolic hydrogen chloride at spectrophotometric concentration.

The nmr spectrum of **4** (*cf.* Experimental Section) showed well-defined absorptions of three unusually deshielded protons assignable to H-1, -3, and -4. As in the case of other polynuclear thiapyrylium compounds[8] the two most deshielded protons (H-1 and -3) are associated with positions of unusually low electron density and exhibit characteristic splitting[8] (J_{13} = 3.0 cps) through the thionium sulfur. The HMO electron density pat-

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[1] Abstracted in part from the Ph.D. Thesis of C. J. Ohnmacht, Lehigh University, 1966.

[2] Part III: T. E. Young, C. J. Ohnmacht, and C. R. Hamel, *J. Org. Chem.*, **32**, 3622 (1967).

[3] Warner-Lambert Research Fellow, 1965–1966.

[4] For consistency with the recommended name of the free base (**2**) *viz.*, thiapyrano[4,3-*b*]indole, the name of the cation (**4**) should be thiapyrano-[4,3-*b*]indolium. However, the alternate name indolo[3,2-*c*]thiapyrylium appears to be more accurately descriptive of the structure of cation **4**, and is therefore preferred.

[5] G. M. Bennet and W. B. Waddington, *J. Chem. Soc.*, 2829 (1929).

[6] K. A. Hoffman and H. Kirmreuther, *Ber.*, **42**, 4865 (1909).

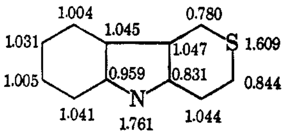
[7] T. E. Young and P. H. Scott, *J. Org. Chem.*, **30**, 3613 (1965).

[8] T. E. Young and C. J. Ohnmacht, *ibid.*, **32**, 1558 (1967).

[9] J. D. Roberts, "An Introduction to the Analysis of Spin-Spin Splitting in High Resolution Nuclear Magnetic Resonance Spectra," W. A. Benjamin, Inc., New York, N. Y., 1962, p 64.

[10] As previously discussed in detail[8] the cation of **4** dissociates to the free base (**2**) in nonacidic solvents, and in 95% ethanol solution exhibits an apparent pK_a = 5.2 at 25°.

tern (summarized on formula **6**)[11–13] further shows that the positive charge distribution is +0.391 on sulfur and +0.239 on nitrogen with the remaining charge distributed dominantly on the carbons of the sulfur-containing ring. The corroborative agreement of the charge density calculation with the observed nmr spectrum clearly characterizes this moiety as an indolo[3,2-*c*]thiapyrylium cation.



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Experimental Section[14]

3,4-Dihydroindolo[3,2-*c*]thiapyrylium Perchlorate (3).—In a three-necked flask equipped with a magnetic stirrer was placed 6.70 g (0.0354 mol) of 1,3,4,5-tetrahydrothiapyrano[4,3-*b*]indole,[2,5] and 100 ml of glacial acetic acid, and the mixture was heated to 90° under a flow of dry nitrogen. Trityl perchlorate,[6] (12.0 g, 0.0351 mol) was then added slowly from a small erlenmeyer flask attached to the reaction flask with a piece of Gooch tubing. When all of the trityl perchlorate had been added, the solution temperature was held at 90° for 10 min, then refluxed for 10 min, the solution being deep orange at this point. The solution was then allowed to cool to room temperature with stirring as orange crystals separated. After standing at room temperature for 2 hr, the crystals were collected by filtration, washed with glacial acetic acid, then washed with ether, and air dried to give 9.56 g (94% yield) of orange crystals, mp 164–169° dec. Three recrystallizations from glacial acetic acid gave analytically pure **3**, mp 175–177° dec.

Anal. Calcd for $C_{11}H_{10}ClNO_4S$: C, 45.92; H, 3.50; N, 4.87; S, 11.14. Found: C, 46.11; H, 3.30; N, 4.80; S, 11.06.

Ultraviolet-visible spectrum gave $\lambda_{\max}^{1\%\ \mathrm{HClO_4\ in\ MeCN}}$ 257 mμ (log ε 4.15), 263 (4.10) sh, 294 (3.63), 414 (4.20).

The nmr spectrum in deuteriotrifluoroacetic acid showed H-1 at δ 9.48 (singlet integrating for one proton) and the methylene protons, H-3 and H-4, as a singlet at 3.65 (integration for four protons). The N–H and remaining aromatic protons at H-6, -7, -8, and -9 appeared as a low lying multiplet at δ 7.83 (one proton, not specifically assignable) and an intense multiplet at 7.58 (integration for four protons).

Indolo[3,2-*c*]thiapyrylium Perchlorate (4).—A stirred solution of 2.02 g (7.0 mmol) of **3**, 1.59 g (7.0 mmol) of 2,3-dichloro-5,6-dicyanoquinone, 1 ml of 70% perchloric acid, and 50 ml of glacial acetic acid was refluxed for 2 hr during which the solution became dark red. The mixture was then allowed to cool to room temperature, and the green-brown crystals which had formed were collected by filtration, washed with dry ether, and dried *in vacuo* over potassium hydroxide. The yield was 1.10 g of crude product, mp 158–165°. Recrystallization from acetic acid yielded 0.65 g (33%) of olive-drab crystals, mp 200–203° dec, with shrinking at 192°. Three more recrystallizations from acetic acid yielded analytically pure **4** as green-yellow crystals, mp 217–220° dec.

Anal. Calcd for $C_{11}H_8ClNO_4S$: C, 46.24; H, 2.82; S, 11.22. Found: C, 46.24; H, 3.09; S, 11.24.

Ultraviolet-visible spectrum showed $\lambda_{\max}^{1\%\ \mathrm{HClO_4\ in\ MeCN}}$ 240 mμ (log ε 4.04), 267 (4.41) sh, 277 (4.47), 297 (4.17) sh, 330 (3.69), 359 (3.60).

The nmr spectrum in deuteriotrifluoroacetic acid showed H-1 at δ 10.13 (doublet, J_{13} = 3.0 cps), H-3 at 9.16 (quartet, J_{13} = 3.0 cps, J_{34} = 9.5 cps), and H-4 at 8.85 (doublet, J_{34} = 9.5 cps), each integrating for one proton. The N–H and remaining aromatic protons at H-6, -7, -8, and -9 appeared as a doublet (J = 7.5 cps, integration for one proton) at δ 8.43 (not explicitly assignable) and an unresolved multiplet centered at 7.77 (integration for four protons).

Registry No.—**3,** 15816-29-2; **4,** 15816-28-1.

Acknowledgments.—We are grateful to the Warner-Lambert Research Institute for support of this work and to the National Science Foundation for a grant to purchase the nmr spectrometer.

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(11) The electron densities of cation **4** were derived from Hückel molecular orbital calculations performed as previously described[2] using the parameters $\alpha_N = \alpha + 2\beta$ and $\beta_{CN} = \beta$ for pyridinium nitrogen[12] and $\alpha_S = \alpha + \beta$ and $\beta_{CS} = 0.6\beta$ for the sulfur atom.[13]

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(13) R. Zahradník, *ibid.*, **5**, 1 (1965).

(14) Melting points were determined on a Mel-Temp apparatus (Laboratory Devices, Inc., Cambridge, Mass.) and are corrected. Ultraviolet-visible spectra were recorded on a Beckman DK-2A spectrophotometer. Nmr spectra were determined on a Varian A-60 instrument using tetramethylsilane as an internal standard. Analyses were performed by Dr. V. B. Fish of Lehigh University and by Galbraith Microanalytical Laboratories, Knoxville, Tenn.

Reinvestigation of the Orientation of Halogen Substitution in Imidazoles by Nuclear Magnetic Resonance Spectroscopy[1a]

M. S. R. NAIDU[1b] AND H. B. BENSUSAN[1c]

Department of Biochemistry,
Case Western Reserve University School of Medicine,
Cleveland, Ohio

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The chemistry of imidazole and the position of halogen substitution under different conditions of reaction have been studied in detail but hitherto the interpretation of some of the observations has proved difficult.[2] Pauly and his coworkers[3] iodinated imidazole and 4(5)-methylimidazole in alkaline conditions and concluded that the monoiodinated products obtained either by direct iodination or by deiodination were the C-2-substituted products. The diiodoimidazoles obtained either in alkaline media[3a] or at pH 7[4] were considered to be 2,4(5) substituted. It has also been shown that in alkaline media diazo coupling to imidazole occurs at the C-2 position.[5] Bromination of N-methylimidazole with cyanogen bromide also led to the exclusive formation of 2-bromoimidazole.[6] Monobromo and dibromo products obtained by bromination of 4(5)-methylimidazole[7] and imidazole in chloroform and by debromination of the fully halogenated derivatives were shown to be 4- and 5-substituted compounds.[8,9] Nitration and sulfonation in

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(1) (a) Supported by the Research Grants AM-01825, HD-00669, and FR-5410 from the National Institutes of Health, U. S. Public Health Service. (b) Recipient of a Fulbright Travel Award through the U. S. Educational Foundation in India. Department of Chemistry, Sri Venkateswara University, Tirupati, A. P., India. (c) To whom correspondence should be addressed at the Benjamin Rose Hospital, 2073 Abington Road, Cleveland, Ohio 44106.

(2) (a) M. J. S. Dewar, "The Electronic Theory of Organic Chemistry," Oxford University Press, London, 1949, p 192; (b) K. Schofield, *Quart. Rev.* (London), **4**, 382 (1950); (c) K. Hofmann, "Imidazole and its Derivatives," Interscience Publishers, Inc., New York, N. Y., 1953, pp 111–124; (d) E. S. Schipper and A. R. Day, "Heterocyclic Compounds," Vol. 4, R. C. Elderfield, Ed., John Wiley and Sons, Inc., New York, N. Y., p 194; (e) R. D. Brown, "Current Trends in Heterocyclic Chemistry," A. Albert, G. M. Badger, and C. W. Shoppee, Ed., Academic Press Inc., New York, N. Y., 1958, p 13; (f) J. H. Ridd, "Physical Methods in Heterocyclic Chemistry," Vol. 1, A. R. Katritzky, Ed., Academic Press Inc., New York, N. Y., 1963, pp 109–160.

(3) (a) H. Pauly and K. Gundermann, *Ber.*, **41**, 3999 (1908); (b) H. Pauly, *ibid.*, **43**, 2243 (1910); (c) H. Pauly and E. Arauner, *J. Prakt. Chem.*, **118**, 33 (1928).

(4) J. H. Ridd, *J. Chem. Soc.*, **1955**, 1238.

(5) R. G. Fargher and F. L. Pyman, *ibid.*, **115**, 217 (1919).

(6) W. J. Langenbeck, *J. Prakt. Chem.*, (2) **119**, 77 (1928).

(7) F. L. Pyman, *J. Chem. Soc.*, **97**, 1815 (1910).

(8) F. L. Pyman and G. M. Timmis, *ibid.*, **123**, 494 (1923).

(9) I. E. Balaban and F. L. Pyman, *ibid.*, **121**, 947 (1922).