of a Grignard reagent with a suitable ketone. All the alcohols were distilled from sodium before use. *trans*-1,2-Dibromocyclohexane was prepared from cyclohexene.[9]

Complex Base Preparation. A solution of the activating alcohol (30 mmol) in THF (10 mL) was added dropwise to a suspension of $NaNH_2$ (90 mmol) in THF (20 mL) at room temperature under nitrogen. The mixture was then heated for 2 h at 45–50 °C. If during these operations a light pink color appeared the complex base gave poor results. The coloration apparently results from the presence of peroxides in the reactants or solvent.

Elimination Reactions. A solution of 1 (20 mmol) in THF (40 mL) was slowly added to the prepared complex base mixture at 25 °C under nitrogen. Small aliquots were periodically removed, hydrolyzed, extracted with Et_2O, and analyzed by gas chromatography (Girdel 75 CD/PT gas chromatograph with 5-m SE-30 columns). Upon completion of the reaction, the product mixture was quenched with ice–water and extracted with Et_2O, and the Et_2O extract was dried over $CaCl_2$. Yields of 1-bromocyclohexene and cyclohexene were measured by gas chromatography using cyclooctane and benzene, respectively, as internal standards.

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Registry No. 1, 822-86-6; 1-butanol Na, 2372-45-4; 1-hexanol Na, 19779-06-7; 1-dodecanol Na, 18888-95-4; 2-methyl-1-propanol Na, 13259-29-5; 2,2-dimethyl-1-propanol Na, 3561-85-1; 2-propanol Na, 683-60-3; 2-butanol Na, 7726-51-4; 2-pentanol Na, 75495-33-9; 2-octanol Na, 68488-95-9; 3-pentanol Na, 36402-10-5; 3-octanol Na, 75495-34-0; 2,4-dimethyl-3-pentanol Na, 67638-47-5; cyclohexanol Na, 22096-22-6; 2-methyl-2-propanol Na, 865-48-5; 2-methyl-2-hexanol Na, 75495-35-1; 2-methyl-2-decanol Na, 67638-50-0; 3-methyl-3-pentanol Na, 67638-48-6; 3-methyl-3-heptanol Na, 75495-36-2; 3-methyl-3-undecanol Na, 75495-37-3; 5-butyl-5-nonanol Na, 75495-38-4; 1-methylcyclohexanol Na, 75495-39-5; tetrahydro-2-furanmethanol Na, 59137-52-9; 2-phenoxyethanol Na, 26109-86-4; 2-(2-ethoxyethoxy)ethanol Na, 52382-21-5; 4-methoxybenzenemethanol Na, 53942-86-2; sodium amide, 7782-92-5; 1-bromocyclohexene, 2044-08-8; cyclohexene, 110-83-8.

(9) Lisher, M. W. *J. Am. Chem. Soc.* **1941**, *63*, 143.

Pyrrolo[1,2-*c*]thiazole, a Ring-Fused Nonclassical Thiazole System

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The initial report of the transient existence of 1,3-dimethylthieno[3,4-*c*]thiophene[1] has attracted the attention of several research groups to the unusual physical and chemical properties of the nonclassical condensed thiophenes. Subsequently, the number of these so-called "tetravalent sulfur" compounds has increased to include examples of a variety of condensed heterocyclic systems and stable derivatives are now known.[2] In contrast, examples of nonclassical sulfur systems containing a bridgehead nitrogen atom as part of the sulfur-containing ring are quite rare.[3] We now report evidence supporting the transient existence of the pyrrolo[1,2-*c*]thiazole system.

Reaction of commercially available thiazolidine-4-carboxylic acid (1) and acetic anhydride[4] in the presence of dimethyl acetylenedicarboxylate (DMAD) afforded 1*H*,3*H*-pyrrolo[1,2-*c*]thiazole 2 (Scheme I) which was easily converted to its corresponding sulfoxide 3 with *m*-chloroperoxybenzoic acid (MCPBA). Dehydration of 3 in refluxing acetic anhydride resulted in a complex mixture from which none of the desired pyrrolothiazole 4 could be isolated. When, however, the same dehydration was carried out in the presence of *N*-phenylmaleimide (NPM) a mixture of 1:1 cycloadducts was isolated. Chromatographic separation and subsequent characterization demonstrated these adducts to be exo and endo adducts **5a** and **5b**. The exo/endo structural assignments were based on the NMR spectra of the adducts according to the established practice of ascribing a greater deshielding effect of the sulfur bridge on the imide α-protons of the endo adduct.[5] The formation of these adducts presumably arises from the in situ generation of nonclassical thiazole 4 and subsequent 1,3-dipolar cycloaddition of the added dipolarophile across the thiocarbonyl ylide form **4a**. Treatment of the exo/endo mixture, **5a**/**5b**, with sodium methoxide[3a,5b,6] afforded indolizine 6, further supporting the thiocarbonyl ylide as the site of the previous cycloaddtion. By TLC small amounts of 6 could also be observed in the reaction mixture of the previous trapping experiment.

Dehydration of 3 in the presence of dimethyl acetylenedicarboxylate (Scheme II) was also anticipated to occur across the thiocarbonyl ylide to yield 7 which was further expected to spontaneously eliminate sulfur[5,7] to give indolizine 8. In reality, reaction of 3 and DMAD produced a complex mixture from which a colorless solid was isolated in low yield. Both the mass spectrum and the elemental analysis of this material demonstrated it to be a primary 1:1 cycloadduct of 4 and DMAD, thereby eliminating 8 as a possible structure. The NMR spectrum of the product ultimately led to its being assigned cyclazine structure 9, resulting from cycloaddition across the azomethine ylide form **4b**.[8] The chemical shift of the Δ^3-pyrroline methyl was diagnostic, occurring at δ 1.67 instead of the δ 2.2–2.6 range observed for the pyrrole methyls in this study. Similar regiochemistry has been observed in the cycloadditions of the thiazolo[3,4-*b*]indazole system[3a] with olefinic and acetylenic dipolarophiles.

Experimental Section

Dimethyl 5-Methyl-1*H*,3*H*-pyrrolo[1,2-*c*]thiazole-6,7-dicarboxylate (2). L-Thiazolidine-4-carboxylic acid (5.3 g, 40 mmol), dimethyl acetylenedicarboxylate (7.4 mL, 60 mmol), and Ac_2O (40 mL) were refluxed for 3 h. The reaction was cooled to room temperature and the excess Ac_2O was removed at reduced pressure. The resulting brown residue was triturated with CH_3OH, affording a beige solid which crystallized from CH_3OH as beige prisms: 5.0 g (49%); mp 133–135 °C; NMR ($CDCl_3$) δ 2.33 (s, 3, CH_3), 3.78 (s, 3, ester), 3.84 (s, 3, ester), 4.22 (s, 2, 1-CH_2), 4.89 (s, 2, 3-CH_2). Anal. Calcd for $C_{11}H_{13}NO_4S$: C, 51.75; H, 5.13;

(1) M. P. Cava and N. M. Pollack, *J. Am. Chem. Soc.*, **89**, 3639 (1967).
(2) (a) M. P. Cava and M. V. Lakshmikantham, *Acc. Chem. Res.*, **8**, 139 (1975); (b) C. A. Ramsden, *Tetrahedron*, **33**, 3203 (1977); (c) K. T. Potts, *Chem. Heterocycl. Compd.*, **30**, 317, (1977).
(3) (a) K. T. Potts and J. L. Marshall, *J. Org. Chem.*, **41**, 129 (1976); (b) H. Schimoharada, S. Ikeda, S. Kajigaeshi, S. Kanemasa, *Chem. Lett.*, 1237 (1977).
(4) R. Huisgen, H. Gotthardt, H. O. Bayer and F. C. Schaefer, *Chem. Ber.*, **103**, 2611 (1970).
(5) (a) M. P. Cava, M. Behforouz, G. E. M. Husbands, and M. Srinivasan, *J. Am. Chem. Soc.*, **95**, 2561 (1973); (b) K. T. Potts and D. McKeough, *ibid.*, **96**, 4298 (1974).
(6) (a) K. T. Potts and D. McKeough, *J. Am. Chem. Soc.*, **96**, 4276 (1974); (b) K. T. Potts, J. Baum, and E. Houghton, *J. Org. Chem.*, **39**, 3631 (1974).
(7) (a) R. Helder and H. Wynberg, *Tetrahedron Lett.*, 605 (1972); (b) H. Gotthardt and F. Reiter, *Chem. Ber.*, **112**, 266 (1979).
(8) The only other materials which could be isolated from this reaction were a higher R_f reddish gum, which appeared to be a multiple condensation product of DMAD, and a lower R_f, uncharacterizable material reminiscent of that formed from the reaction of 3 and Ac_2O in the absence of an added dipolarophile.

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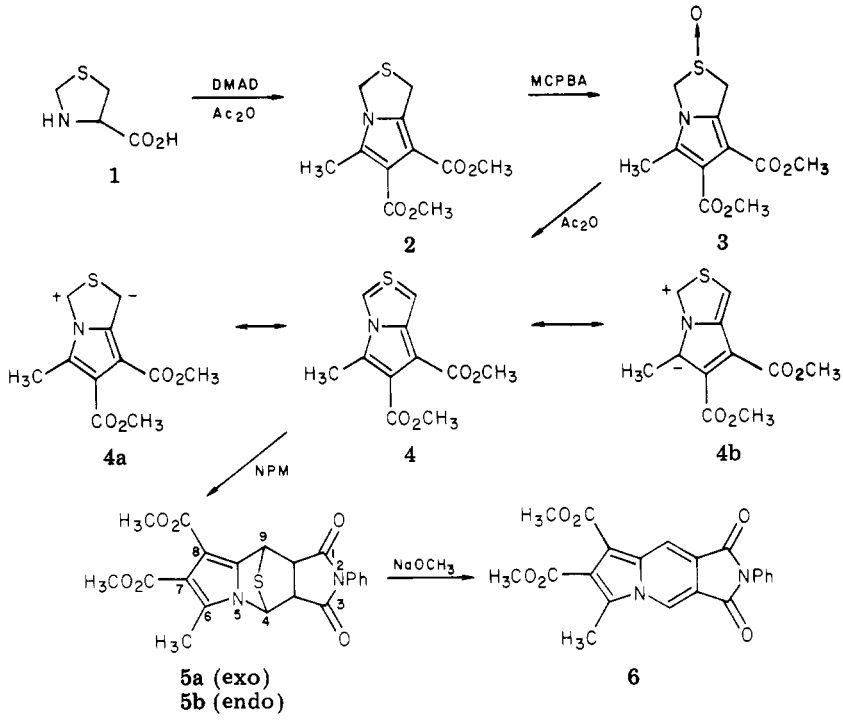
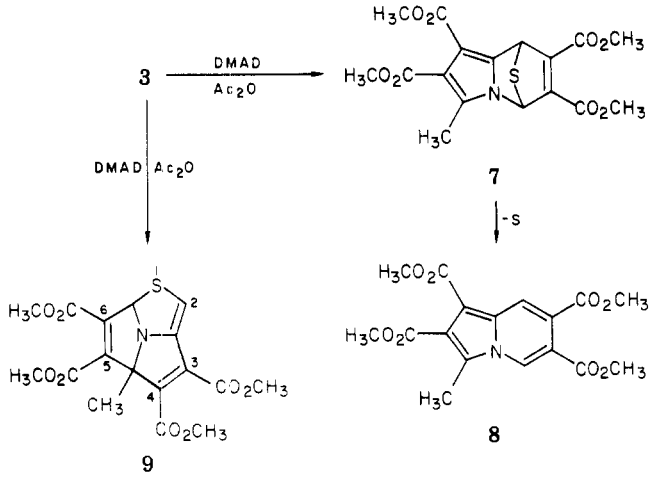
Scheme I



Scheme II



N, 5.49. Found: C, 51.64; H, 5.16; N, 5.28.

Dimethyl 5-Methyl-1*H*,3*H*-pyrrolo[1,2-*c*]thiazole-6,7-dicarboxylate 2-Oxide (3). To a solution of 2 (5.5 g, 22 mmol) in CH_2Cl_2 (100 mL) at 0 °C was added portionwise MCPBA (4.8 g, 24 mmol). After ca. 0.5 h the cooling bath was removed and after being stirred overnight the reaction mixture was washed in turn with 10% aqueous Na_2SO_3, saturated aqueous $NaHCO_3$, and saturated aqueous NaCl and then dried over Na_2SO_4. Filtration of the drying agent and evaporation of the filtrate afforded a colorless solid which crystallized from CH_3OH as colorless needles: 4.2 g (72%); mp 135–137 °C; NMR ($CDCl_3$) δ 2.32 (s, 3, CH_3), 3.78 (s, 3, ester), 3.80 (s, 3, ester), 4.28 (AB q, 2, 1-CH_2), 4.86 (AB q, 2, 3-CH_2). Anal. Calcd for $C_{11}H_{13}NO_5S$: C, 48.70; H, 4.83; N, 5.16. Found: C, 48.63; H, 5.02; N, 5.11.

General Procedure for Generation and Cycloaddition of 4. Sulfoxide 3 (0.27 g, 1.0 mmol) and the dipolarophile (1.2 mmol) were refluxed in Ac_2O (5 mL) for 3 h. The reaction was cooled to room temperature, concentrated at reduced pressure, and triturated with CH_3OH. The resulting crude product was collected by filtration and purified as indicated.

Dimethyl 2,3,3a,4,9,9a-Hexahydro-6-methyl-1,3-dioxo-2-phenyl-4,9-epithio-1*H*-pyrrolo[3,4-*f*]indolizine-7,8-dicarboxylate (5). The crude, off-white, exo/endo mixture was purified by preparative layer chromatography (40% EtOAc/$CHCl_3$),[9] affording higher R_f exo adduct **5a** (R_f 0.35) and lower R_f endo adduct **5b** (R_f 0.27). Crystallization of **5a** from $CHCl_3$/EtOH afforded a colorless powder: 0.25 g (59%); mp 210–211 °C; NMR (Me_2SO-d_6) δ 2.43 (s, 3, CH_3), 3.56 (br d, 1, 3a- or 9a-H), 3.68 (s, 3, ester), 3.75 (s, 3, ester), 3.93 (br d, 1, 9a- or 3a-H), 5.37 (s, 1, 9-H), 6.63 (s, 1, 4-H), 7.1-7.6 (m, 5, aromatic); mass spectrum, *m/e* (relative intensity) 426 (M^+, 42). Anal. Calcd for $C_{21}H_{18}N_2O_6S$: C, 59.15; H, 4.25; N, 6.57; S, 7.52. Found: C, 58.91; H, 4.36; N, 6.33; S, 7.54.

Crystallization of **5b** from $CHCl_3$/EtOH afforded a colorless powder: 0.03 g (7%);[10] mp 245–247 °C; NMR (Me_2SO-d_6) δ 2.18 (s, 3, CH_3), 3.63 (br s, 6, esters), 4.22 (br s, 2, 3a-H, 9a-H). 5.45 (s, 1, 9-H), 6.65 (m, 3, 4-H, aromatic), 7.25 (m, 3, aromatic); mass spectrum, *m/e* (relative intensity) 426 (M^+, 97). Anal. Calcd for $C_{21}H_{18}N_2O_6S$: C, 59.15; H, 4.25; N, 6.57. Found: C, 58.98; H, 4.20; N, 6.45.

Tetramethyl 4a,6a-Dihydro-4a-methylthiazolo[2,3,4-*cd*]pyrrolizine-3,4,5,6-tetracarboxylate (9). The crude yellowish powder was crystallized twice from 1:1 EtOAc/hexane, affording a colorless powder: 0.06 g (15%); mp 239–241 °C dec; NMR ($CDCl_3$) δ 1.67 (s, 3, 4a-CH_3), 3.78 (br s, 12, esters), 4.95 (s, 1, 6a-H), 5.69 (s, 1, 2-H); mass spectrum, *m/e* (relative intensity) 395 (M^+, 47). Anal. Calcd for $C_{17}H_{17}NO_8S$: C, 51.64; H, 4.33; N, 3.54; S, 8.11. Found: C, 51.47; H, 4.46; N, 3.36; S, 8.02.

Dimethyl 2,3-Dihydro-6-methyl-1,3-dioxo-2-phenyl-1*H*-pyrrolo[3,4-*f*]indolizine-7,8-dicarboxylate (6). To a solution of $NaOCH_3$, preformed from metallic Na (0.38 g, 16 mmol) and dry CH_3OH (10 mL), was added a solution of the **5a**/**5b** mixture (3.5 g, 8.2 mmol) in dry CH_2Cl_2 (50 mL). After 2 h the reaction was quenched with saturated aqueous NH_4Cl. The CH_2Cl_2 layer was separated and dried over Na_2SO_4. Filtration of the drying agent and evaporation of the filtrate gave an orange oil which was column chromatographed (silica gel, 10% EtOAc/$CHCl_3$) affording a yellow solid which crystallized from EtOAc as yellow matted needles: 1.7 g (53%); mp 209–211 °C; NMR ($CDCl_3$) δ 2.62 (s, 3, CH_3), 3.98 (s, 3, ester), 4.00 (s, 3, ester), 7.51 (s, 5, aromatic), 8.50 (s, 1, 9-H), 8.62 (s, 1, 4-H). Anal. Calcd for $C_{21}H_{16}N_2O_6$: C, 64.28; H, 4.11; N, 7.14. Found: C, 64.03; H, 4.19; N, 6.99.

Registry No. 1, 34592-47-7; 2, 75475-91-1; 3, 75475-92-2; 4, 75475-93-3; 5a, 75495-02-2; 5b, 75521-61-8; 6, 75475-94-4; 9, 75475-95-5; DMAD, 762-42-5; *N*-phenylmaleimide, 941-69-5.

(9) Preparative layer chromatography was carried out on E. Merck silica gel plates (2 mm, 20 × 20 cm).

(10) The predominance of the exo adduct, while generally not observed in the cycloadditions of NPM and phenylated nonclassical sulfur systems, has been observed with 1,3-dimethylthieno[3,4-*c*]thiophene.[1]