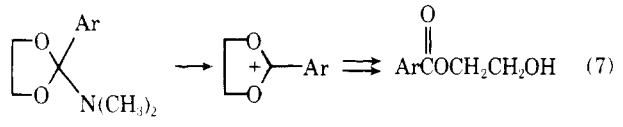
the amount of carboxylic acid ester in the reaction product at the expense of *N*-hydroxybenzimidate ester. The fact that hydroxylamine adds reversibly to carbonyl compounds at neutral pH, and that oximes are formed only by slow further reaction of the adduct,[17] offers some support for this hypothesis. Further evidence comes from a recent study of the hydrolysis of tertiary amide acetals, **5**, closely related to the hydroxylamine adduct **4**, which shows that in neutral and acidic solution these substances react by strongly preferential loss of the amino group to give carboxylic acid ester products (eq 7).[18]



(7)

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Acknowledgment. We are grateful to the Natural Sciences and Engineering Research Council of Canada (formerly National Research Council of Canada), the National Science Foundation of the United States, and the donors of the Petroleum Research Fund, administered by the American Chemical Society, for their financial support of this work.

Registry No.—2-Methoxy-2-(*p*-methoxyphenyl)-1,3-dioxolane, 66137-63-1; hydroxylamine, 7803-49-8; methyl benzoate, 93-58-3; (*E*)-methyl *N*-hydroxybenzimidate, 68525-45-1; (Z)-methyl *N*-hydroxybenzimidate, 68525-46-2; 2-hydroxyethyl benzoate, 94-33-7.

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(13) Dioxolenium ion formation requires proton transfer from catalyst to substrate plus C–O bond breaking. These two bonding changes could occur in either a concerted or a stepwise fashion, and if the latter is the case, dioxolenium ion formation could be a two-step process. We have recently shown that it is not.[14]
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The Pyrrolo[3,4-*c*]pyrazole System, a New 10π-Electron Heteropentalene[1]

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Nitration of ethyl 1-methyl-5-phenyl-4-(2-pyridyl)pyrrole-2-carboxylate, prepared from 2-phenyl-*N*-(ethyloxalyl)sarcosine, 2-ethynylpyridine, and Ac_2O at 95–100 °C, and treatment of the nitro compound with $(EtO)_3P$ at reflux gave ethyl 8-methyl-9-phenylpyrrolo[3′,4′:2,3]pyrazolo[1,5-*a*]pyridine-7-carboxylate, a new 10π-electron triazapentalene. Reaction with dimethyl acetylenedicarboxylate occurred at the azomethine ylide giving a stable 1:1 cycloadduct; a similar reaction occurred with *N*-phenylmaleimide, except that under the more drastic reaction conditions employed the elements of CH_3NH_2 were extruded from the initial 1:1 adduct. The synthesis of a variety of substituted thiophenes by similar cycloaddition and nitration procedures is also described.

The title ring system **1**, a 10π-electron azapentalene which cannot be represented by a classical, noncharge-separated structure, belongs to a group of heteropentalenes which up to now has included only polyaza derivatives with or without nitrogen atoms at the points of fusion of the bicyclic system.[2] The sulfur analogue of **1**, the thieno[3,4-*c*]pyrazole system **2**, is a "nonclassical" thiophene[2,3] showing many of the interesting properties of the parent thieno[3,4-*c*]thiophene system including cycloadditions at the thiocarbonyl ylide dipole.[2,3,4a] These properties were present to some degree in the thiazolo[3,4-*b*]indazole system **3**, a structural analogue of **2** with a bridgehead nitrogen atom.[4b] Thus **1** represents an extremely interesting heteropentalene, intermediate between the very reactive "nonclassical" thiophenes on one hand and the considerably less reactive polyazapentalenes at the other extreme. A study of its synthesis and properties is thus of considerable interest to this area of chemistry and this publication describes the first successful synthesis of **1** and its behavior in cycloaddition reactions.

There are two principal routes to **1**: either formation of a pyrrole nucleus onto a preformed pyrazole ring, or ring closure of a substituted pyrrole to form the pyrazole ring. The difficulty in forming a pyrrole nucleus of this type led us to favor the latter approach, involving N–N bond formation as in **4**, a scheme which was successful[4b] in the synthesis of **3**. Synthetic procedures described in the literature for azapentalenes are best suited to the synthesis of polyaza derivatives. Thus tetraazapentalenes are formed by the dimerization of either oxalonitrilebis(phenylimine)[5] or arylazoethynylarenes,[5,6] by the reductive cyclization of 4-azoxypyrazoles with $P(OEt)_3$,[7,8] or by oxidative ring closure of 5-benzyl-4-arylazapyrazoles.[8] The corresponding hexaazapentalenes are readily formed on thermolysis of 4-azido-5-phenylazo-1,2,3-triazoles.[9] These ring systems are very stable and their lack of reactivity is in marked contrast to that observed with several of the "nonclassical" thiophene systems,[2,3] the multiplicity of nitrogen atoms while assisting in their synthesis apparently depresses their reactivity.

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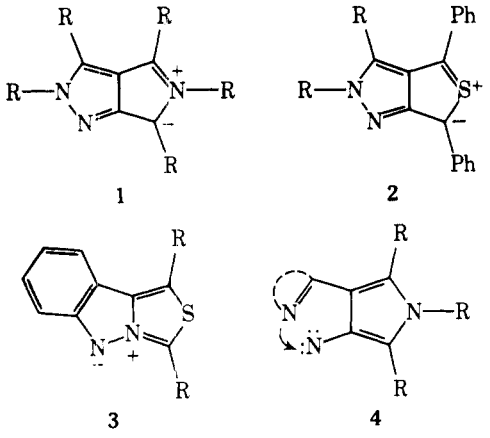
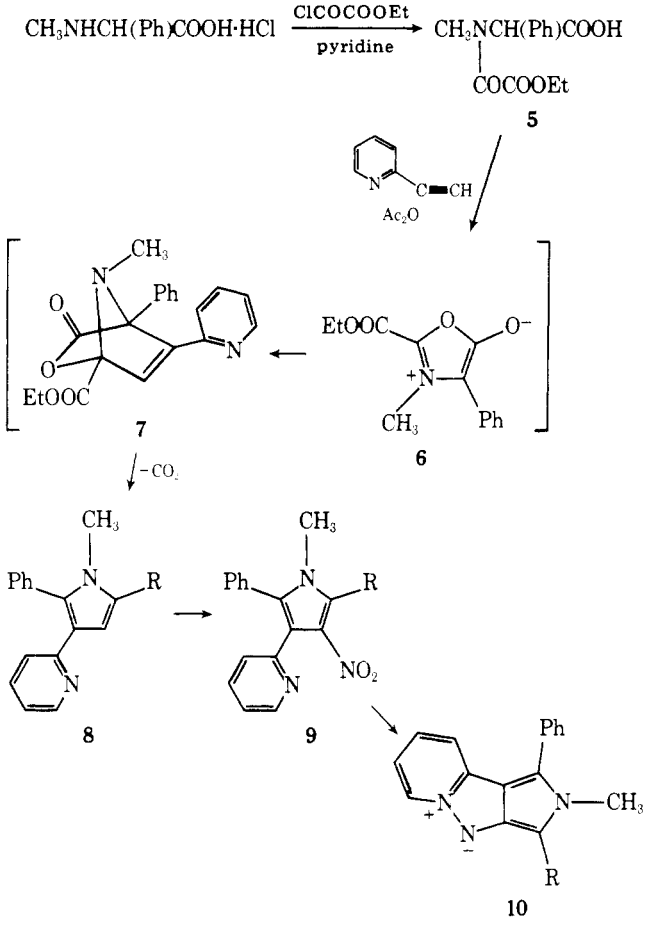


1 2 3 4

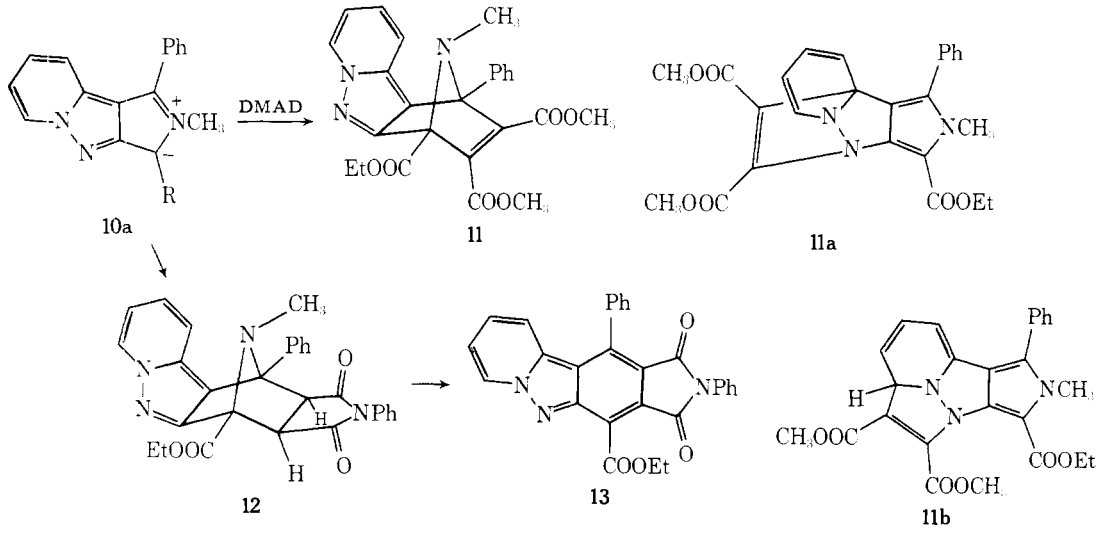
The most direct route to **1** would be by ring closure of readily available 3,4-diacylpyrazoles,[4] analogous to the method used for the synthesis of isoindoles.[10] However, our preliminary experiments in this area were not promising and an approach utilizing a preformed pyrrole nucleus was finally adopted. A successful method of N–N bond formation in this general area has involved generation of a nitrene or nitrene-like intermediate with subsequent reaction at a trigonal nitrogen atom. To form **1** by this method would require an intermediate such as **4**. If the azomethine group were incorporated into a heterocyclic ring, the synthetic obstacles are reduced considerably and the required pyrrole should be readily available by a cycloaddition followed by nitration at the 4 position. Using the in situ procedure[11] for the formation of pyrroles from *anhydro*-5-hydroxyoxazolium hydroxides and acetylenic dipolarophiles, 2-phenyl-*N*-(ethyloxalyl)sarcosine (**5**), prepared from *N*-methyl-2-phenylglycine hydrochloride and ethyloxalyl chloride in pyridine, was treated with 2-ethynylpyridine in Ac_2O at 95–100 °C for 15 h, giving ethyl 1-methyl-5-phenyl-4-(2-pyridyl)pyrrole-2-carboxylate (**8**, R = COOEt) (49%). The intermediacy of the nonisolated **6** and **7** is based on analogous reactions in the literature. Treatment of **8** with fuming HNO_3 at 0 °C was found to be the best method of nitration giving the 4-nitro derivative **9** (26%) which on heating in xylene with $P(OEt)_3$ over 7 days afforded ethyl 8-methyl-9-phenylpyrrolo[3′,4′:2,3]pyrazolo[1,5-*a*]-pyridine-7-carboxylate (**10**, R = COOEt) (40%) as lustrous yellow prisms (Scheme I). Spectral and analytical data (Experimental Section) confirmed the assigned structures and the regiospecificity of the addition of 2-ethynylpyridine to the intermediate *anhydro*-5-hydroxyoxazolium hydroxide **6** was evident from the chemical shift of the pyrrole C_3–H at δ 7.7, indicating its proximity to the ethoxycarbonyl substituent.[12] The disappearance of this proton in the nitration product also

Scheme I



confirmed that nitration had occurred in the pyrrole nucleus and not in the phenyl substituent.

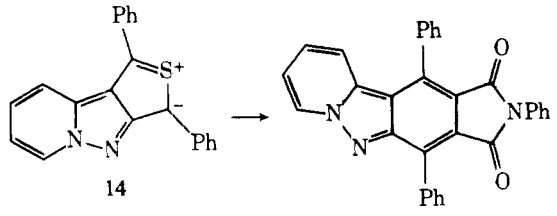
The azapentalene **10** may be represented by several canonical forms, the most important being the pyridinium ylide **10** and the azomethine ylide **10a**. Reaction with dimethyl acetylenedicarboxylate occurred at the azomethine ylide giving the 1:1 adduct **11** whose structure was evident from the analytical and spectral data (Experimental Section). Had addition occurred across the pyridinium ylide **10**, the adduct formed, **11a** or **11b**, should have a N–CH_3 absorption at ca. δ 3.8–4.2 compared to that observed in the adduct at δ 2.1. It should also be noted that cycloadditions at ring fusion positions to give adducts similar to **11a** are extremely rare. Formation of **11** occurred in boiling benzene over 12 h, in contrast to the corresponding reaction of **10** with *N*-phenylmaleimide



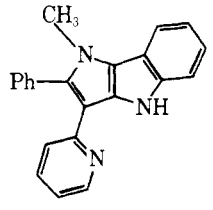
10a 11 11a 12 13 11b

with required refluxing xylene over a 7-day period. In the latter case, however, the initial 1:1 adduct **12** was not obtained, the product isolated being **13** formed by elimination of the elements of CH_3NH_2 from **12**. It was not possible to determine in what form this fragment was eliminated from **12**.

The structure of **13** was determined from its analytical and spectral data and also from the close similarities in its properties with those of the corresponding 1,4-diphenyl derivative **15** obtained from the corresponding sulfur analogue **14** of **10**



14 **15**



16

and *N*-phenylmaleimide under similar reaction conditions.[13] In both cases no reaction at the azomethine imine ylide was observed.

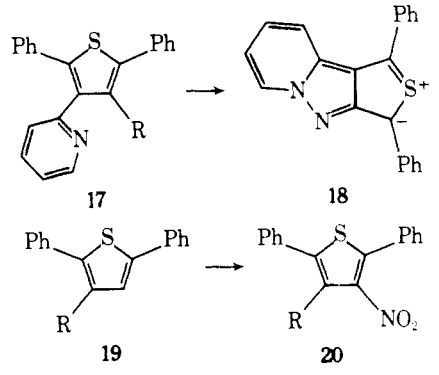
The need to direct the nitro group in **9** into the 4 position requires a substituent in the 5 position of the pyrrole nucleus. In early experiments a 5-phenyl substituent was used (see Experimental Section) and in this instance the nitrene cyclization took a different course. Hydrogen abstraction from the 5-phenyl group occurred and spectral data indicated that the product obtained in extremely low yield was the indole **16**. Although unexpected at the time, a similar hydrogen abstraction also occurred on deoxygenation of 4-(2-nitrophenyl)-2-phenylthiazole with $P(OEt)_3$, this being avoided by the introduction of a 5-ethoxycarbonyl substituent, ring closure then occurring to ethyl 3-phenylthiazolo[3,4-*b*]indazole-1-carboxylate.[4b]

The above nitrene cyclization route should also be applicable to the synthesis of other heteropentalenes containing a fused pyrazole system. Thus ring closure of the thiophene **17** (R = NO_2) would give the thieno[3,4-*c*]pyrazole **18**, this ring system previously being prepared by the P_4S_{10} ring closure of a 3,4-dibenzoylpyrazole.[4] As in the above cases, the 2-pyridyl-substituted thiophene **17** (R = H) was prepared by a cycloaddition procedure from 2-ethynylpyridine and *anhydro*-2,5-diphenyl-4-hydroxy-1,3-dithiolium hydroxide,[14] the cycloaddition of this dipolarophile with *anhydro*-4-hydroxy-2,3,5-triphenylthiazolium hydroxide[15] which would yield the same product being unsuccessful. Unfortunately, 2-ethynylpyridine was not sufficiently reactive to undergo cycloaddition with *anhydro*-5-hydroxy-3-methyl-1,2,3-oxadiazolium hydroxide, thus precluding a synthesis of the pyrazolo[3,4-*c*]pyrazole system by this nitrene cyclization route. The structure of **17** (R = H) was readily established from analytical and spectral data, the mass spectrum of **17** (R = H) being particularly characteristic.

The conversion of **17** (R = H) into its nitro derivative could not be achieved using a wide variety of nitration conditions. In most instances water soluble, yellow oxidation products resulted. This failure to achieve nitration compared to the easy nitration of a substituted thiophene can be attributed to deactivation of the thiophene nucleus by protonation of the pyridyl substituent. This was verified by successful nitrations of similar model compounds not containing a pyridyl substituent but containing an electron-withdrawing substituent in the 3 position.

Ethyl 2,5-diphenylthiophene-3-carboxylate (**19**, R = COOEt) and 3-benzoyl-2,5-diphenylthiophene (**19**, R = COPh) were readily prepared in 82 and 93% yields, respectively, by the cycloaddition of ethyl propiolate and benzoylacetylene, respectively, to *anhydro*-2,5-diphenyl-4-hydroxydithiolium hydroxide. Both were readily characterized by analytical and distinctive spectral data (Experimental Section).

The thiophene ester **19** (R = COOEt) underwent nitration quite readily in refluxing acetic acid, affording the corresponding 4-nitro derivative **20** (R = COOEt) in 70% yield. The



17 **18**

19 **20**

absence of a resonance attributable to a 4-thiophene proton indicated nitration had occurred in the thiophene ring and not in one of the phenyl substituents. The phenyl resonances occurred as a 10-proton multiplet consisting for the most part of an intense singlet at δ 7.52, most likely the result of a fortuitous coincidence of the resonances of the two phenyl groups, both of which are forced out of the plane of the thiophene ring by steric interaction with the 3 and 4 substituents. The thienyl ketone **19** (R = COPh) also underwent ready nitration in acetic acid at room temperature affording **20** (R = COPh) in 62% yield.

Experimental Section[16]

2-Phenyl-*N*-(ethyloxalyl)sarcosine (5). *N*-Methyl-2-phenylglycine hydrochloride[11b] (10.1 g, 0.05 mol) in pyridine (100 mL) was treated with ethyloxalyl chloride (6.8 g, 0.05 mol) in the cold and the resulting mixture was stirred at room temperature for 24 h. Solvent was removed under reduced pressure and the residue was poured into cold water (200 mL). The organic material was taken up in chloroform and dried ($MgSO_4$). Removal of solvent gave a colorless gum: 13.0 g (100%); IR ($CHCl_3$) 2980 (CH), 1730, 1650 cm^{-1} (CO); NMR ($CDCl_3$) δ 8.8 (bs, 1, COO**H**), 7.2–8.2 (m, 5, aromatic), 5.6 (s, 1, >C**H**), 4.4 (q, 2, COO**CH$_2$**CH$_3$, J = 7.0 Hz), 2.9 (s, 3, NCH$_3$), 1.4 (t, 3, COOCH$_2$**CH$_3$**).

Ethyl 1-Methyl-5-phenyl-4-(2-pyridyl)pyrrole-2-carboxylate (8, R = COOEt). A mixture of 2-phenyl-*N*-(ethyloxalyl)sarcosine (13.25 g, 0.05 mol), 2-ethynylpyridine[17] (5.15 g, 0.05 mol), and acetic anhydride (150 mL) was heated on an oil bath (95–100 °C) for 15 h. The reaction mixture was cooled, the solvent removed under reduced pressure, and the residue triturated with ethanol to give colorless prisms: 7.5 g (49%); mp 142–144 °C. Recrystallization from methanol gave colorless prisms: mp 146 °C; IR (KBr) 2975 (CH), 1687 cm^{-1} (CO); NMR ($CDCl_3$) δ 8.56 (d, 1, aromatic), 7.7 (s, 1, H$_3$), 7.6–6.6 (m, 8, aromatic), 4.3 (q, 2, COO**CH$_2$**CH$_3$, J = 7.0 Hz), 3.8 (s, 3, NCH$_3$), 1.4 (t, 3, COOCH$_2$**CH$_3$**, J = 7.0 Hz); mass spectrum *m/e* (rel intensity), M$^+$· 306 (100).

Anal. Calcd for $C_{19}H_{18}N_2O_2$: C, 74.49; H, 5.92; N, 9.15. Found: C, 74.09; H, 5.92; N, 9.04.

Ethyl 1-Methyl-3-nitro-5-phenyl-4-(2-pyridyl)pyrrole-2-carboxylate (9, R = COOEt). Ethyl 1-methyl-5-phenyl-4-(2-pyridyl)pyrrole-2-carboxylate (1.0 g) at 0 °C was treated with fuming nitric acid over several minutes. The reaction mixture was stirred at 0 °C for 30 min and then at room temperature for another 15 min when it was poured onto ice and stirred for 1 h affording a pale-yellow solid: 400 mg, mp 130–134 °C. Recrystallization from methanol gave very pale yellow needles: 300 mg (26%); mp 138 °C; IR (KBr) 2975

(CH), 1700 (CO), 1530, 1360 (NO_2) cm^{-1}; NMR ($CDCl_3$) δ 8.53 (d, 1, aromatic), 7.6–6.8 (m, 8, aromatic), 4.4 (q, 2, $COOCH_2CH_3$, J = 7.0 Hz), 3.8 (s, 3, NCH_3), 1.4 (t, 3, $COOCH_2CH_3$, J = 7.0 Hz); mass spectrum, *m/e* (rel intensity), M^+· 351 (100).

Anal. Calcd for $C_{19}H_{17}N_3O_4$: C, 64.95; H, 4.88; N, 11.96. Found: C, 64.96; H, 4.88; N, 11.99.

Ethyl 8-Methyl-9-phenylpyrrolo[3′,4′:2,3]pyrazolo[1,5-*a*]-pyridine-7-carboxylate (10, R = COOEt). Ethyl 1-methyl-3-nitro-5-phenyl-4-(2-pyridyl)pyrrole-2-carboxylate (2.0 g) in xylene (50 mL) and triethyl phosphite (8 mL) were heated under reflux for 7 days under nitrogen. The solvent was removed under reduced pressure at room temperature and the residue was triturated with dry ether to provide a golden yellow solid: 720 mg (40%); mp 208–210 °C; IR (KBr) 2975 (CH), 1675 cm^{-1} (CO); NMR ($CDCl_3$) δ 8.9 (d, 1, aromatic), 7.8–7 (m, 8, aromatic), 4.6 (q, 2, $COOCH_2CH_3$, J = 7.0 Hz), 4.3 (s, 3, NCH_3), 1.5 (t, 3, $COOCH_2CH_3$, J = 7.0 Hz); mass spectrum, *m/e* (relative intensity), M^+· 319 (100).

Anal. Calcd for $C_{19}H_{17}N_3O_2$: C, 71.45; H, 5.37; N, 13.16. Found: C, 71.47; H, 5.61; N, 13.30.

***N*-Phenylmaleimide Adduct (13).** Ethyl 8-methyl-9-phenylpyrrolo[3′,4′:2,3]pyrazolo[1,5-*a*]pyridine-7-carboxylate (64 mg), *N*-phenylmaleimide (52 mg), and xylene (15 mL) were refluxed for 7 days in a nitrogen atmosphere. The reaction mixture was cooled and the solvent was removed under reduced pressure. The residue was dissolved in benzene and the undissolved material was filtered off. Dilution of the solution with ethyl ether gave yellow prisms: 60 mg (65%); mp 250–255 °C; IR (KBr) 2975 (CH), 1770, 1710 cm^{-1} (CO); NMR ($CDCl_3$) δ 8.6 (m, 1, aromatic), 7.2–7.8 (m, 13, aromatic), 4.7 (q, 2, $COOCH_2CH_3$, J = 7.0 Hz), 1.4 (t, 3, $COOCH_2CH_3$, J = 7.0 Hz); mass spectrum, *m/e* (relative intensity), M^+· 461 (100).

Anal. Calcd for $C_{28}H_{29}N_3O_4$: C, 72.87; H, 4.15; N, 9.11. Found: C, 73.06; H, 4.19; N, 9.16.

Reaction of Dimethyl Acetylenedicarboxylate with Ethyl 8-Methyl-9-phenylpyrrolo[3′,4′:2,3]pyrazolo[1,5-*a*]pyridine-7-carboxylate. Ethyl 8-methyl-9-phenylpyrrolo[3′,4′:2,3]-pyrazolo[1,5-*a*]pyridine-7-carboxylate (0.11 g, 0.002 mol) and freshly distilled DMAD (0.25 g, 0.002 mol) were refluxed in benzene (10 mL) under nitrogen for 12 h. Volatile components were removed at 50 °C (1 mm) leaving a brown oil which was purified by preparative-layer chromatography (silica gel PF-254, 4 × 0.75 mm, eluted with ethyl acetate) to a pale yellow oil. On cooling, a pale yellow solid **11** separated which crystallized from methanol as cream prisms: 0.11 g (70%); mp 223–224 °C; IR (KBr) 1730 cm^{-1} (CO); NMR ($CDCl_3$) δ 8.5 (m, 1, aromatic), 6.8–7.8 (m, 8, aromatic), 4.4 (q, 2, $COOCH_2CH_3$, J = 7.0 Hz), 3.7 (s, 3, $COOCH_3$), 3.5 (s, 3, $COOCH_3$), 2.1 (s, 3, NCH_3), 1.3 (t, 3, $COOCH_2CH_3$, J = 7.0 Hz); mass spectrum, *m/e* (rel intensity) M^+· 461 (78%).

Anal. Calcd for $C_{25}H_{23}N_3O_6$: C, 65.07; H, 5.02; N, 9.11. Found: C, 64.66; H, 4.97; N, 9.13.

2-(2,5-Diphenyl-1-methylpyrrol-3-yl)pyridine (8, R = Ph). *N*-Benzoyl-*N*-methyl-2-phenylglycine[11b] (25.8 g, 0.096 mol) and 2-ethynylpyridine[17] were heated in Ac_2O (130 mL) for 10 h at 105 °C. Evaporation of the volatile components afforded an oil which was taken up in hot MeOH and cooled to deposit 27.3 g (95%) of tan prisms which crystallized from MeOH as colorless prisms: mp 128.5–130 °C; IR (KBr) 1590, 1480 cm^{-1}; NMR ($CDCl_3$) δ 8.51–8.67 (d, 1,6-pyridyl), 6.79–7.70 (m, 14, aromatic), 3.39 (s, 3, CH_3); M^+· 310 (90), 309 (100).

Anal. Calcd for $C_{22}H_{18}N_2$: C, 85.13; H, 5.85; N, 9.03. Found: C, 85.18; H, 5.81; N, 8.98.

Nitration of 2-(2,5-Diphenyl-1-methylpyrrol-3-yl)pyridine (8, R = Ph). The title pyrrole (1.0 g, 0.0032 mol) and concentrated HNO_3 (specific gravity 1.42, 0.3 mL) in HOAc (10 mL) were stirred at room temperature. The initially bright yellow solution turned greenish-brown after a 30-min induction period. This color slowly faded to orange, and after 11 h the reaction mixture was diluted with H_2O (50 mL) and extracted with PhH. The organic layer was dried (Na_2SO_4) and evaporated to 0.9 g of orange oil which was taken up in hot MeOH (3.5 mL) and cooled to deposit a yellow solid which crystallized from MeOH as fine, bright yellow needles of 2-(2,5-diphenyl-1-methyl-4-nitropyrrol-3-yl)pyridine (**9**, R = Ph): 0.1 g (9%); mp 211–212 °C; IR (KBr) 1490, 1350 (NO_2) cm^{-1}; NMR ($CDCl_3$) δ 8.54 (d, 1, 6-pyridyl), 6.98–7.62 (m, 13, aromatic), 3.23 (s, 3, CH_3); M^+· 355 (95), 354 (100).

Anal. Calcd for $C_{22}H_{17}N_3O_2$: C, 74.35; H, 4.82; N, 11.84. Found: C, 74.48; H, 4.82, N, 11.74.

2-(2,5-Diphenylthien-3-yl)pyridine (17, R = H). A solution of 2-ethynylpyridine (13.7 g, 0.13 mol) and *anhydro*-2,5-diphenyl-4-hydroxy-1,3-dithiolium hydroxide[14] (2.43 g, 0.09 mol) in toluene (120 mL) was refluxed under N_2 for 26 h. Removal of the solvent left a brown oil which was taken up in hot MeOH and, on cooling, deposited 9.7 g (34%) of a light-brown solid. An additional crop was obtained by chromatography of the mother liquors (florisil, 180 g, eluted with PhH), recovery 4.3 g (total yield 50%). Recrystallization from MeOH afforded colorless needles: mp 86–88 °C; IR (KBr) 1580, 1470 cm^{-1}; NMR ($CDCl_3$) δ 8.54–8.63 (m, 1, 6-pyridyl), 6.79–7.81 (m, 14, aromatic); M^+· 313 (55), 312 (100).

Anal. Calcd for $C_{21}H_{15}NS$: C, 80.49; H, 4.82; N, 4.47. Found: C, 80.40; H, 4.84; N, 4.45.

Ethyl 2,5-Diphenylthiophene-3-carboxylate (19, R = COOEt). *anhydro*-2,5-Diphenyl-4-hydroxy-1,3-dithiolium hydroxide (6.1 g, 0.022 mol) and ethyl propiolate (3.20 g, 0.033 mol) in toluene (30 mL) were heated at 100 °C for 16 h. The volatile components were removed by distillation at 100 °C (0.1 mm) and the residual brown oil was chromatographed (silica gel, 20 g, eluted with PhH) to give a pale-pink oil which was taken up in hot MeOH and cooled to deposit colorless prisms: 5.9 g (82%); mp 53–55 °C; IR (KBr) 1700 (CO) cm^{-1}; NMR ($CDCl_3$) δ 7.69 (s, 1, thiophene H), 7.12–7.69 (m, 10, phenyl), 4.20 (q, 2, CH_2), 1.18 (t, 3, CH_3).

Anal. Calcd for $C_{19}H_{16}O_2S$: C, 74.00; H, 5.23. Found: C, 74.09; H, 5.23.

Nitration of Ethyl 2,5-Diphenylthiophene-3-carboxylate. A solution of the thiophene ester **19** (R = COOEt) (0.5 g, 0.0016 mol) and fuming HNO_3 (0.6 g) in HOAc (6 mL) was refluxed 1 h, poured into H_2O (50 mL), and the reaction mixture extracted twice with $CHCl_3$. The organic layer was washed twice with H_2O, dried (Na_2SO_4), and evaporated to afford, after crystallization from MeOH, ethyl 2,5-diphenyl-4-nitrothiophene-3-carboxylate (**20**, R = COOEt) as very fine, yellow matted needles: 0.4 g (70%); mp 90–92 °C; IR (KBr) 1720 (CO), 1530, 1350 (NO_2) cm^{-1}; NMR ($CDCl_3$) δ 7.27–7.67 (bs, 10, phenyl), 4.22 (q, 2, CH_2), 1.19 (t, 3, CH_3).

Anal. Calcd for $C_{19}H_{15}NO_4S$: C, 64.57; H, 4.28; N, 3.96. Found: C, 64.42; H, 4.22; N, 3.94.

3-Benzoyl-2,5-diphenylthiophene (19, R = COPh). *anhydro*-2,5-Diphenyl-4-hydroxy-1,3-dithiolium hydroxide (4.05 g, 0.015 mol) and benzoylacetylene[18] (2.00 g, 0.017 mol) in toluene (25 mL) were refluxed for 8 h. Evaporation of the solvent afforded a brown oil which was chromatographed (silica gel, 25 g, eluted with PhH); crystallization from MeOH gave pale-yellow prisms: 4.7 g (93%); mp 76.5–78.5 °C; IR (KBr) 1645 (CO) cm^{-1}; NMR ($CDCl_3$) δ 7.02–7.99 (m, 16, aromatic).

Anal. Calcd for $C_{23}H_{16}OS$: C, 81.14; H, 4.74. Found: C, 81.14; H, 4.73.

3-Benzoyl-2,5-diphenyl-4-nitrothiophene 20 (R = COPh). 2,5-Diphenyl-3-benzoylthiophene (0.5 g, 0.002 mol) and fuming HNO_3 (0.25 g) in HOAc (10 mL) were allowed to stand at room temperature for 36 h. The resulting yellow needles were collected by filtration, the filtrate poured into H_2O (50 mL), and the aqueous solution extracted with $CHCl_3$. The organic layer was washed twice with H_2O and the solvent evaporated to afford a bright yellow solid which crystallized from a large volume of EtOH. The resulting solid was combined with the product obtained by the above filtration and recrystallization from CH_3CN afforded bright-yellow needles: 0.35 g (62%); mp 169.5–170.5 °C; IR (KBr) 1655 (CO), 1520, 1350 (NO_2) cm^{-1}; NMR ($CDCl_3$) δ 7.66–8.01 (m, 2, aromatic), 7.02–7.53 (m, 13, aromatic).

Anal. Calcd for $C_{23}H_{15}NO_3S$: C, 71.68; H, 3.92; N, 3.64. Found: C, 71.66; H, 3.90; N, 3.58.

Registry No.—**5**, 68510-71-4; **8** (R = COOEt), 68510-72-5; **8** (R = Ph), 68510-73-6; **9** (R = COOEt), 68510-74-7; **9** (R = Ph), 68510-75-8; **10** (R = COOEt), 68539-78-6; **11**, 68510-76-9; **13**, 68510-77-0; **17** (R = H), 68510-78-1; **19** (R = COOEt), 68510-79-2; **19** (R = COPh), 68510-80-5; **20** (R = COOEt), 68510-81-6; **20** (R = COPh), 68510-82-7; *N*-methyl-2-phenylglycine hydrochloride, 28544-42-5; ethyloxalyl chloride, 4755-77-5; 2-ethynylpyridine, 1945-84-2; *N*-phenylmaleimide, 941-69-5; *N*-benzoyl-*N*-methyl-2-phenylglycine, 28544-45-8; DMAD, 762-42-5; *anhydro*-2,5-diphenyl-4-hydroxy-1,3-dithiolium hydroxide, 68510-83-8; ethyl propiolate, 623-47-2; benzoylacetylene, 3623-15-2.

References and Notes

(1) (a) Partial support of this work by U.S. Public Health Service Research Grant CA 08495, National Cancer Institute, is gratefully acknowledged; (b) NDEA Trainee.

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Notes

Mesoionic Compounds. 47. Cycloadditions with the 4(5*H*)-Oxazolone System[1]

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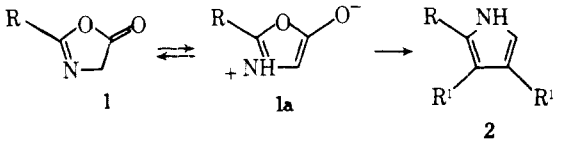
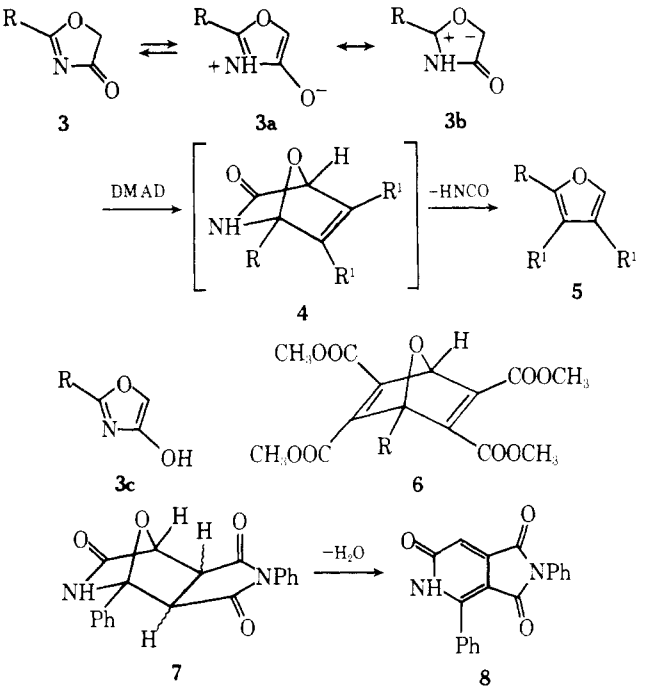
Cycloadditions with a variety of mesoionic ring systems have been utilized as convenient routes to other heterocyclic systems. With those ring systems containing nitrogen, the final product always contained a substituted nitrogen atom, restricting somewhat the appeal of this route. Ring systems capable of undergoing tautomerism such as the 5(4*H*)-oxazolones (**1**) undergo[2] cycloaddition with acetylenic dipolarophiles via the tautomer **1a** giving pyrroles **2**. 4(5*H*)-Thiazolones also react with olefinic dipolarophiles[3a] forming thiophenes and pyridones depending on the substitution pattern, and the corresponding 5(4*H*)-thiazolones form a variety of cycloadducts and Michael adducts with electron-deficient olefins.[3b] 3-Hydroxypyridine, via its tautomer, has been shown to undergo cycloaddition with benzyne[4a] and also with acrylonitrile and ethyl acrylate.[4b] We now report our utilization of the 4(5*H*)-oxazolones in cycloaddition reactions leading to 2,3,4-trisubstituted furans, this being a useful complement to the formation of furans from *anhydro*-2,5-disubstituted-4-hydroxyoxazolium hydroxides.[5]



The reaction of 2-phenyl-4(5*H*)-oxazolone (**3**, R = Ph) with excess dimethyl acetylenedicarboxylate (DMAD) in refluxing acetic anhydride gave dimethyl 2-phenylfuran-3,4-dicarboxylate (**5**, R = Ph, R^1 = $COOCH_3$) (26%). Under similar conditions, 2-(4-chlorophenyl)-4(5*H*)-oxazolone (**3**, R = *p*-ClC_6H_4) yielded dimethyl 2-(4-chlorophenyl)furan-3,4-dicarboxylate (**5**, R = *p*-ClC_6H_4; R^1 = $COOCH_3$) (29%), as well as a second product, identified as tetramethyl 1-(4-chlorophenyl)-7-oxabicyclo[2.2.1]hepta-2,5-diene-2,3,5,6-tetracarboxylate (**6**; R= *p*-ClC_6H_4) (19%), the latter product resulting from a Diels–Alder reaction of **5** (R = *p*-ClC_6H_4; R^1 = $COOCH_3$) with dimethyl acetylenedicarboxylate. The structures of these products were evident from analytical and spectral data (Experimental Section). The mode of formation of the furans **5** is less clear, the tautomer **3a** and the carbonyl ylide dipole **3b** being likely contributors to the reaction.



Thermal extrusion of isocyanic acid from the intermediate 1:1 cycloadduct **4** would lead to **5**, a sequence consistent with that shown to be in effect with the 5(4*H*)-oxazolones and with the *anhydro*-4-hydroxyoxazolium hydroxide system. An alternative route involves Diels–Alder addition of DMAD to the 4-hydroxyoxazole tautomer **3c**, oxazoles having been shown to act in this fashion giving furans after extrusion of a nitrile from the initial 1:1 adduct.[7] The latter route appears unlikely as the 5(4*H*)-oxazolones were shown not to react in this fashion[2] and in the 4(5*H*)-thiazolones, the 4-alkoxy- and 4-acetoxythiazoles did not undergo cycloaddition under reaction conditions successful with the unblocked thiazolones.

Evidence in favor of the dipolar mechanism comes from the increased yield of **5** obtained with increase in solvent polarity in the cycloaddition. Thus in changing from Ac_2O to sulfolane the reaction was completed in a significantly shorter time and the yield of **5** (R = Ph; R^1 = $COOCH_3$) increased from 26 to 45%. Further increases in the yield of **5** (to 61%) resulted from the use of the hydrochloride salt of **3** (R = Ph) in sulfolane as solvent. Although Lewis acids are known[7,8] to exert a catalytic effect on certain Diels–Alder reactions, the above indications make us favor the dipolar mechanism in the present case.

Dibenzoylacetylene also reacted readily with **3** (R = Ph) giving 3,4-dibenzoyl-2-phenylfuran (**5**, R = Ph; R^1 = COPh)

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