The Synthesis of Novel Polycyclic Heterocyclic Ring Systems *via* Photocyclization. **1.** Thieno[3',2':4,5]thieno[2,3-*c*]quinoline and Thieno[2',3':4,5]thieno[2,3-*c*]quinoline

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The synthesis of two previously unknown heterocyclic ring systems, namely, thieno[3',2':4,5]thieno[2,3-*c*]quinoline and thieno[2',3':4,5]thieno[2,3-*c*]quinoline is reported. These two novel ring systems were assembled by photocyclization of the appropriate anilides.

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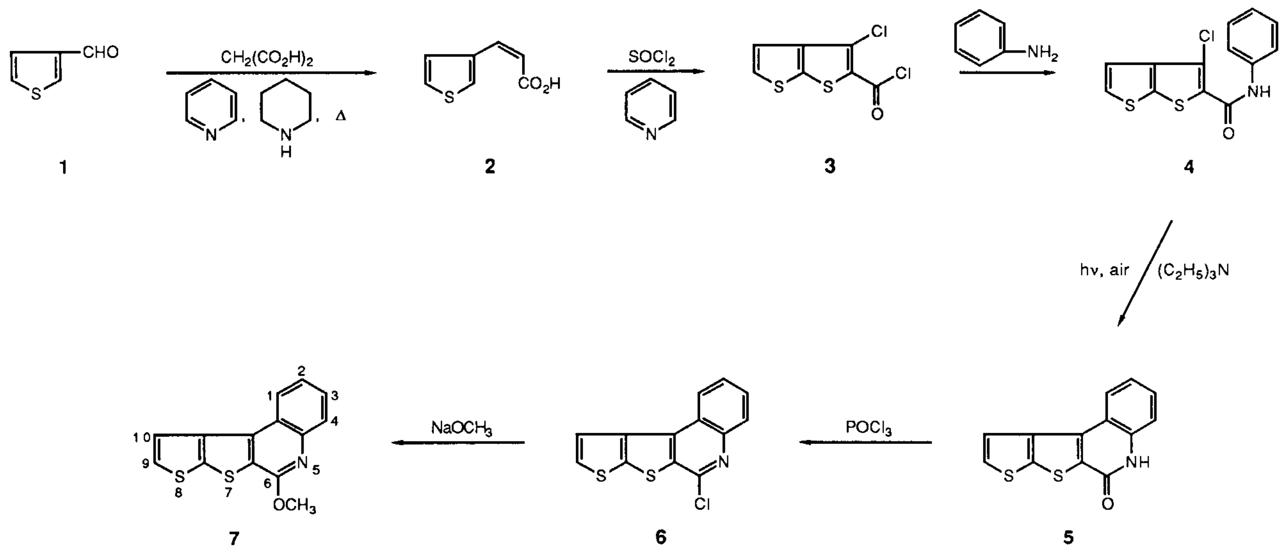
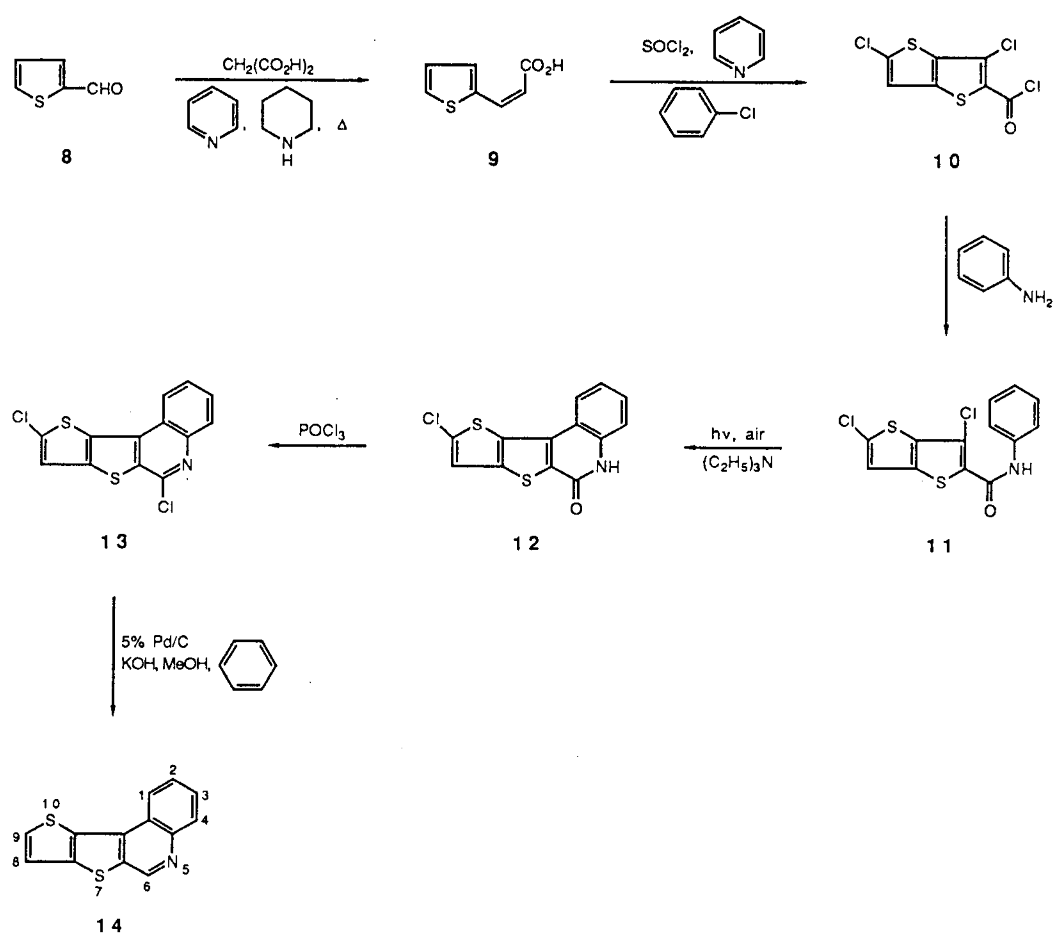
In an effort to expand our program to synthesize polycyclic heterocycles suspected of occurring in coal-derived products we have undertaken the synthesis of two previously unknown heterocyclic ring systems, namely thieno[3',2':4,5]thieno[2,3-*c*]quinoline and thieno[2',3':4,5]thieno[2,3-*c*]quinoline. We have previously reported *via* photocyclization [2] the synthesis of various members of the following ring systems: naphtho[1',2':4,5]thieno[2,3-*c*]quinoline [3-4], naphtho[2',1':4,5]thieno[2,3-*c*]quinoline [5], [1]benzothieno[2,3-*c*]quinoline [6-8], [1]benzothieno[2,3-*c*]-1,5-naphthyridine [9], [1]benzothieno[2,3-*c*]-1,6-naphthyridine [9], [1]benzothieno[2,3-*c*]-1,7-naphthyridine [9], and [1]benzothieno[2,3-*c*]-1,8-naphthyridine [9]. Hence the present report represents an expansion of our previous efforts.

Condensation of 3-thiophenecarboxaldehyde (**1**) with malonic acid afforded 3-(3-thienyl)acrylic acid (**2**) [10]. Treatment of **2** with thionyl chloride and pyridine provided 3-chlorothieno[2,3-*b*]thiophene-2-carboxoyl chloride (**3**) [10] in 51% yield. The reaction of aniline with **3** in benzene solution gave 3-chloro-*N*-phenylthieno[2,3-*b*]thiophene-2-carboxamide (**4**) in 87% yield. Photocyclization of **4** in benzene solution containing triethylamine afforded thieno[3',2':4,5]thieno[2,3-*c*]quinolin-6(5*H*)-one (**5**) in 75% yield. Chlorination of **5** was accomplished by refluxing in phosphorus oxychloride to provide 6-chlorothieno[3',2':4,5]thieno[2,3-*c*]quinoline (**6**) in 99% yield. Compound **6** was converted into 6-methoxythieno[3',2':4,5]thieno[2,3-*c*]quinoline (**7**) in 76% yield when allowed to react with sodium methoxide in benzene solution (Scheme I). Initial efforts to prepare the unsubstituted ring system, thieno[3',2':4,5]thieno[2,3-c]quinoline were unsuccessful.

Scheme I



Scheme II



2-Thiophenecarboxaldehyde (**8**) upon condensation with malonic acid afforded 3-(2-thienyl)acrylic acid (**9**) [10-11] in 73% yield. Thionyl chloride cyclization of **9** in chlorobenzene solution afforded 3,5-dichlorothieno[3,2-*b*]thiophene-2-carboxoyl chloride (**10**) [10-11] in 11% yield. Reaction of **10** with aniline gave 3,5-dichloro-*N*-phenylthieno[3,2-*b*]thiophene-2-carboxamide (**11**) in 84% yield. Photocyclization of **11** in benzene in the presence of triethylamine afforded 9-chloro[2′,3′:4,5]thieno[2,3-*c*]quinolin-6(5*H*)-one (**12**) in 69% yield. Chlorination of **12** with phosphorus oxychloride gave 6,9-dichlorothieno[2′,3′:4,5]thieno[2,3-*c*]quinoline (**13**) in 88% yield. Catalytic dechlorination of **13** with palladium on charcoal in 1:1 benzene-methanol solution in the presence of potassium hydroxide afforded the unsubstituted thieno[2′,3′:4,5]thieno[2,3-*c*]quinoline (**14**) in 59% yield (Scheme II).

EXPERIMENTAL

Melting points were determined on a Thomas-Hoover melting point apparatus and are uncorrected. The ir spectra were recorded on a Perkin Elmer 337 spectrometer. The ^{1}H-nmr were obtained on a JEOL FX-90Q spectrometer in the solvent indicated with TMS as the internal reference standard and chemical shifts are reported in ppm (δ) and J values in Hz. The mass spectra were determined on a Hewlett-Packard model 5980A mass spectrometer. Elemental analyses were performed by MHW Laboratories, Phoenix, Arizona.

3-Chloro-*N*-phenylthieno[2,3-*b*]thiophene-2-carboxamide (4).

A solution of 7.5 g (0.08 mole) of aniline was added dropwise to a stirred solution of 9.5 g (0.04 mole) of 3-chlorothieno[2,3-*b*]thiophene-2-carboxoyl chloride (**3**) in 150 ml of benzene at room temperature. After the addition was complete, the mixture was allowed to reflux for one hour. After cooling the crystals were collected by filtration and the filtrate was evaporated to dryness. The combined solid was washed with water and then recrystallized from ethanol to yield 10.2 g (0.035 mole, 87% yield) of **4** as light yellow prisms, mp 151-152°; ^{1}H-nmr (deuteriochloroform): 7.05-7.70 (m, 7H), 8.70 (bs, 1H, NH); ms: m/e 293 (M$^+$, 21), 203 (40), 201 (100), 173 (13).

Anal. Calcd. for $C_{13}H_8ClNOS_2$: C, 53.15: H, 2.74; N, 4.77; S, 21.83. Found: C, 52.93; H, 3.00; N, 4.79; S, 21.70.

Thieno[3′,2′:4,5]thieno[2,3-c]quinolin-6(5*H*)-one (5).

A solution of 0.5 g (1.7 mmoles) of **4** and 0.15 g (1.7 mmoles) of triethylamine in 500 ml of dry benzene was irradiated for 2 hours with a 450 Watt Hanovia medium pressure mercury vapor lamp. During the course of the reaction, a slow stream of air was passed through the solution. The solvent was evaporated *in vacuo* and the residue was washed with water and air dried to give 0.33 g (1.28 mmoles, 75% yield) of **5** as a white solid, mp >270°; ir (Nujol): 1680 cm^{-1} (C=O stretching); ^{1}H-nmr (deuteriochloroform and deuteriotrifluoroacetic acid): 7.50-7.95 (m, 5H, ArH), 8.20-8.50 (m, 1H, ArH); ms: m/e 259.6 (M$^+$ +2, 0.9), 258.6 (M$^+$ +1, 9.5), 257.6 (M$^+$ 15.8), 256.6 (100). This compound was used in the next step without further purification.

6-Chlorothieno[3',2':4,5]thieno[2,3-c]quinoline (**6**).

A mixture of compound **5** (1.6 g, 6.2 mmoles) and phosphorus oxychloride (40 ml) was gently refluxed for 3.5 hours. After removal of excess phosphorus oxychloride, the residue was poured carefully into ice-water. The precipitate was collected by filtration and recrystallized from benzene to afford 1.7 g (6.16 mmoles, 99% yield) of *6* as yellow prisms, mp 186-187°; ^{1}H-nmr (deuteriochloroform): 7.40-8.45 (m, 6H, ArH); ms: m/e 277.6 (M$^+$ +2, 8), 276.6 (M$^+$ +1, 42), 274.6 (100), 196.7 (9.5), 68.7 (9.1).

Anal. Calcd. for $C_{13}H_6ClNS_2$: C, 56.62; H, 2.19; N, 5.08; S, 23.25. Found: C, 56.44; H, 2.43; N, 5.00; S, 23.13.

6-Methoxythieno[3',2':4,5]thieno[2,3-*c*]quinoline (**7**).

A solution of **6** (0.4 g, 1.45 mmoles) in benzene (60 ml) was added dropwise to a stirred solution of sodium methoxide in methanol [prepared by the portionwise addition of sodium (0.2 g, 8.7 mg-atoms) to 20 ml of methanol] at ice bath temperature. The mixture was heated to reflux overnight, then the excess solvent was removed under reduced pressure to give a solid product. The solid was stirred in 100 ml of water and extracted with benzene (2 x 100 ml). The combined extracts were washed with water, brine, and dried over anhydrous magnesium sulfate. After filtration the filtrate was evaporated to dryness and the solid was recrystallized from hexane to yield 3 g (1.11 mmoles, 76% yield) of **7** as colorless needles, mp 150-151°; ^{1}H-nmr (deuteriochloroform): 4.26 (s, 3H, OCH_3), 7.44-7.74 (m, 3H including a doublet at 7.59, J = 5.37 Hz), 7.93-8.07 (m, 2H including a doublet at 7.96, J = 5.37 Hz), 8.39-8.50 (m, 1H).

Anal. Calcd. for $C_{14}H_9NOS_2$: C, 61.97; H, 3.34; N, 5.16; S, 23.63. Found: C, 61.75; H, 3.51; N, 5.15; S, 23.47.

3,5-Dichloro-*N*-phenylthieno[3,2-*b*]thiophene-2-carboxamide (**11**).

This compound was synthesized from **10** (7.1 g, 0.026 mole) [10-11], aniline (5.6 g, 0.06 mole) and benzene (100 ml) in a manner similar to that described for 3-chloro-*N*-phenylthieno[2,3-*b*]thiophene-2-carboxamide (**4**) to give 7.2 g (0.022 mole, 84% yield) of **11** as colorless prisms, mp 214-215° (from ethanol); ^{1}H-nmr (DMSO-d$_6$): 7.03-7.45 (m, 3H, ArH), 7.58-7.73 (m, 2H, ArH), 7.63 (s, 1H, thiophene-H), 9.92 (bs, 1H, NH); ms: m/e 331.9 (M$^+$ +4, 0.5), 330.9 (M$^+$ +3, 3.4), 329.9 (M$^+$ +2, 2.5), 326.9 (20.8), 238.8 (16.1), 236.8 (71.9), 234.8 (100).

Anal. Calcd. for $C_{13}H_7Cl_2NOS_2$: C, 47.57; H, 2.15; N, 4.27; S, 19.54. Found: C, 47.53; H, 2.40; N, 4.30; S, 19.43.

9-Chlorothieno[2',3':4,5]thieno[2,3-*c*]quinolin-6(5*H*)-one (**12**).

This compound was prepared from **11** (0.5 g, 1.5 mmoles) in a manner similar to that described for thieno[3',2':4,5]thieno[2,3-*c*]quinolin-6(5*H*)-one (**5**) to give 0.3 g (1.03 mmoles, 69% yield) of **12** as colorless prisms, mp >270°; ir (potassium bromide): 1650 cm^{-1} (C=O stretching); ^{1}H-nmr (deuteriochloroform and deuteriotrichloroacetic acid): 7.30-8.00 (m, 5H, ArH which includes a singlet at 7.70 assigned to the thiophene-H); ms: m/e 228.7 (13.7), 227.7 (74.0), 200.7 (31.5), 183.7 (39.7), 92.7 (75.3), 80.7 (52.1), 68.8 (100). This compound was used in the next step without further purification.

6,9-Dichlorothieno[2',3':4,5]thieno[2,3-*c*]quinoline (**13**).

This compound was synthesized from **12** (1.5 g, 5.1 mmoles) in a manner similar to that described for the preparation of 6-chlorothieno[3',2':4,5]thieno[2,3-*c*]quinoline (**6**) to give 1.4 g (4.5 mmoles, 88% yield) of **13** as pale yellow prisms, mp 208° (brom benzene); ^{1}H-nmr (deuteriochloroform): 7.78-7.93 (m, 2H, ArH), 7.86 (s, 1H, thiophene-H), 8.03-8.17 (m, 2H, ArH); ms: m/e 314.6 (M$^+$ +4, 1.1), 313.6 (M$^+$ +3, 2.5), 312.6 (M$^+$ +2, 16.4), 310.6 (M$^+$, 73.9), 308.6 (100), 273.6 (20.3), 238.6 (68.4).

Anal. Calcd. for $C_{13}H_5Cl_2NS_2$: C, 50.33; H, 1.62; N, 4.52; S, 20.67. Found: C, 50.27; H, 2.23 [12]; N, 4.57; S, 20.59.

Thieno[2',3':4,5]thieno[2,3-*c*]quinoline (**14**).

A mixture of **13** (0.55 g, 1.77 mmoles) and potassium hydroxide (0.11 g, 1.96 mmoles) in methanol (80 ml) and benzene (80 ml) was catalytically dechlorinated using 5% palladium on carbon (0.5 g) at atmospheric pressure and at room temperature. After the uptake of the equivalent amount of hydrogen, the catalyst was removed by filtration and the solvent was removed under reduced pressure. The residue was treated with water and extracted with benzene. The benzene extract was dried over anhydrous sodium sulfate. After filtration the filtrate was evaporated to dryness and the residue was recrystallized from benzene to yield 0.25 g (1.04 mmoles, 59% yield) of **14** as yellow prisms, mp 182-183°; ^{1}H-nmr (deuteriochloroform): 7.36 (d, 1H, J = 5.2 Hz), 7.40-7.80 (m, 3H, including a doublet at 7.70, J = 5.2 Hz), 8.00-8.30 (m, 2H), 9.23 (s, 1H, H-6); ms: m/e 242.8 (M$^+$ +2, 10), 241.9 (M$^+$ +1, 16.8), 240.9 (M$^+$, 100), 195.9 (10.8).

Anal. Calcd. for $C_{13}H_7NS_2$: C, 64.70; H, 2.92; N, 5.80; S, 26.57. Found: C, 64.61; H, 3.07; N, 5.80; S, 26.47.

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REFERENCES AND NOTES

[1] To whom inquiries regarding this work should be directed at the Department of Chemistry, University of South Florida.

[2] Recently, the photocyclization of substituted alkenes and related compounds has been reviewed comprehensively: F. B. Mallory and C. W. Mallory, "Photocyclization of Stilbenes and Related Molecules", "Organic Reactions", Vol **30**, John Wiley and Sons, Inc, New York, 1984, pp 1-456. The generalities of the photocyclization of amides are discussed, pp 98-112, with the discussion of specific examples of dehydrohalogenative photocyclization, pp 100-101 and tabular results indicated on pp 340-343, 346, 354-355.

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[12] A more satisfactory analysis for hydrogen in compound **13** could not be obtained, however, conversion of **13** into **14** leaves no doubt concerning the identify of **13**.