

Novel Polycyclic Heterocyclic Ring Systems *via* Photocyclization. **2** [1].Benzo[*h*][1]benzothieno[2,3-*c*]quinoline andBenzo[*f*][1]benzothieno[2,3-*c*]quinoline

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The synthesis of two previously unknown unsubstituted heterocyclic ring systems namely, benzo[*h*][1]benzothieno[2,3-*c*]quinoline (**6**) and benzo[*f*][1]benzothieno[2,3-*c*]quinoline (**12**) is reported. These two novel ring systems have been assembled by photocyclization of the appropriate amides.

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Oxidative photocyclization reactions of stilbenes and anilides and their analogs have been shown to be of value in the synthesis of polycyclic aromatic hydrocarbons and heterocycles [3]. In a previous paper [1] we reported the synthesis of several novel heterocyclic ring systems *via* photocyclization of the appropriate anilides. In a continuation of our studies on the synthesis of novel heterocyclic ring systems we now report the extension of a photo-induced cyclization leading to two previously unknown ring systems, namely benzo[*h*][1]benzothieno[2,3-*c*]quinoline (**6**) and benzo[*f*][1]benzothieno[2,3-*c*]quinoline (**12**).

A search of the literature revealed that the synthesis of benzo[*h*][1]benzothieno[2,3-*c*]quinolin-6(5*H*)-one (**4**) was described by Kanaoka *et al.* [4], however no further effort to obtain the parent ring system was reported and experimental details and spectroscopic data were not reported. The requisite starting material, 3-chlorobenzo[*b*]thiophene-2-carboxoyl chloride (**1**), for the synthesis of the aforementioned two ring systems was prepared according to known procedures [5-7]. Thus treatment of **1** with 1-naphthalenamine (**2**) in benzene solution provided 3-chloro-*N*-(1-naphthyl)benzo[*b*]thiophene-2-carboxamide (**3**) in 86% yield. Photocyclization of **3** in benzene solution containing triethylamine gave benzo[*h*][1]benzothieno[2,3-*c*]quinolin-6(5*H*)-one (**4**) in 90% yield. Chlorination of **4** was performed by refluxing in phosphorus oxychloride to yield 6-chlorobenzo[*h*][1]benzothieno[2,3-*c*]quinoline (**5**) in 53% yield. Catalytic dechlorination of **5** with 10% Pd-C in 1:1 benzene-methanol solution in the presence of potassium hydroxide afforded the parent ring system, namely benzo[*h*][1]benzothieno[2,3-*c*]quinoline (**6**) in 56% yield (Scheme I). The ¹H nmr of **6** shows two doublets at δ 7.95 and 8.73 ppm with J = 9.28 Hz attributed to H13 and H12, respectively. A singlet located at 9.38 was assigned to H6.

Likewise, when **1** was allowed to react with 2-naphthalenamine (**7**) in benzene solution, 3-chloro-*N*-(2-naphthyl)benzo[*b*]thiophene-2-carboxamide (**8**) was obtained. Photo-

cyclization of **8** in benzene in the presence of triethylamine provided benzo[*f*][1]benzothieno[2,3-*c*]quinolin-8(7*H*)-one (**9**) in 83% yield. It should be noted that the other cyclization product, namely benzo[*g*][1]benzothieno[2,3-*c*]quinolin-7(6*H*)-one (**10**) was not obtained. Chlorination of **9** was accomplished by refluxing in phosphorus oxychloride to yield 8-chlorobenzo[*f*][1]benzothieno[2,3-*c*]quinoline (**11**) in 86% yield. The unsubstituted benzo[*f*][1]benzothieno[2,3-*c*]quinoline (**12**) was obtained in 72% yield by catalytic dechlorination of **11** with 10% Pd-C in 1:1 benzene-methanol solution containing potassium hydroxide. Compound **12** shows no singlets as expected for **13** other than the singlet at δ 9.23 ppm assigned to H8 in its ¹H nmr spectrum. It shows two doublet of doublets at δ 8.69 and 8.88 with J = 7.81, 1.49 Hz and J = 7.57, 1.71 Hz, attributed to H13 and H1, respectively. The structure of **12** was further confirmed by a 1D-HOHAHA nmr experiment [8].

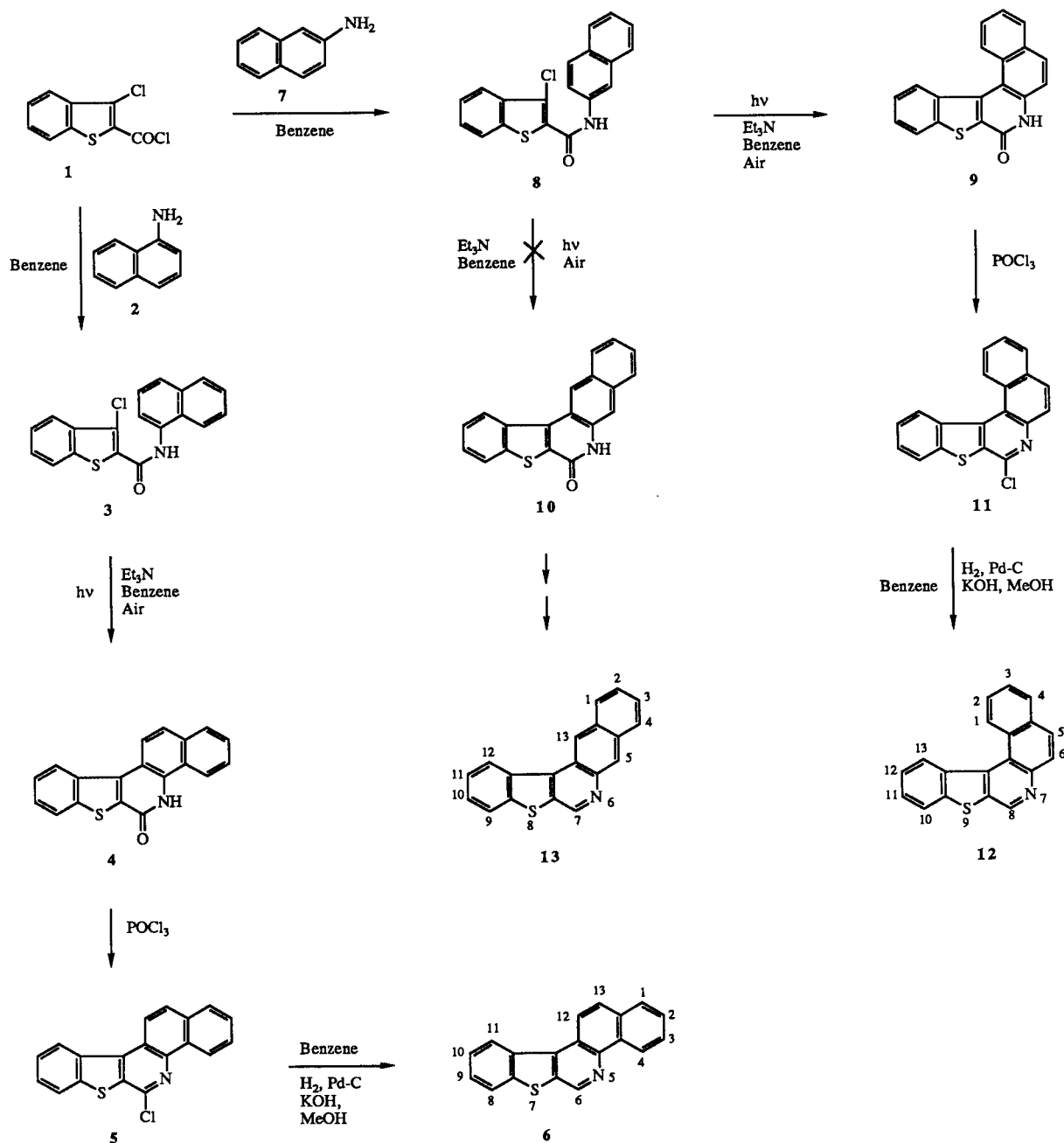
EXPERIMENTAL

Melting points were obtained on a Thomas-Hoover melting point apparatus and are uncorrected. The ir spectra were recorded on a Beckman FT 1100 spectrometer as potassium bromide pellets and frequencies are expressed in cm⁻¹. The ¹H nmr spectra were obtained on a JEOL FX-90Q spectrometer in the solvent indicated with TMS as the internal standard and chemical shifts are reported in ppm (δ) and J values in Hz. Elemental analyses were performed by M-H-W Laboratories, Phoenix, Arizona.

3-Chloro-*N*-(1-naphthyl)benzo[*b*]thiophene-2-carboxamide (**3**).

A mixture of 3.0 g (12.98 mmoles) of **1** and 1.86 g (12.99 mmoles) of 1-aminonaphthalene (**2**) in 100 ml of benzene was heated under reflux for 4 hours. After cooling the solid was collected by filtration and recrystallized from benzene to afford 3.79 g (11.22 mmoles, 86%) of **3** as colorless needles, mp 187-189°; ir (potassium bromide): 3224 (NH stretching), 3052 (aromatic CH stretching), 1628 (>C=O stretching); ¹H nmr (deuteriochloroform): δ 7.41-8.29 (m, 11H, arom), 9.33 (br s, 1H, NH).

Scheme I



Anal. Calcd. for $C_{19}H_{12}ClNOS$: C, 67.55; H, 3.58; N, 4.15; S, 9.49. Found: C, 67.58; H, 3.61; N, 4.32; S, 9.27.

Benzo[*h*]1benzothieno[2,3-*c*]quinolin-6(5*H*)-one (4).

A mixture of 0.5 g (1.48 mmoles) of **3** in 500 ml of benzene containing 0.15 g of triethylamine was irradiated with a 450 watt Hanovia medium pressure mercury lamp for 5 hours. A slow stream of air was passed through the solution during the course of the reaction. The solid was collected by filtration and then washed with water to give 0.31 g (1.03 mmoles, 70%) of **4**, mp > 300°; ir (potassium bromide): 3147 (NH stretching), 3052

(aromatic CH stretching), 1653 (>C=O stretching); 1H nmr (DMSO- d_6): 140°, δ 7.55-8.24 (m, 7H including doublet at δ 7.84 with $J_{12,13} = 9.00$ Hz attributed to H13), 8.76 (d, $J_{12,13} = 9.00$ Hz, 1H, H12), 8.85-8.99 (m, 2H, arom). This compound was used in the next reaction without further purification.

6-Chlorobenzo[*h*]1benzothieno[2,3-*c*]quinoline (5).

A mixture of 1.52 g (5.04 mmoles) of **4** and 50 ml of phosphorus oxychloride was heated at 110-120° for 8 hours. After cooling the mixture was poured into 400 ml of ice-water very slowly and carefully. The solid was collected by filtration and recrystallized from

benzene to give 0.86 g (2.69 mmoles, 53%) of **5** as colorless needles, mp 222-224°; ir (potassium bromide): 3044, 3032 (aromatic CH stretching); ¹H nmr (deuteriochloroform): δ 7.54-8.10 (m, 7H, arom), 8.72-8.89 (m, 2H, arom), 9.27-9.38 (m, 1H, H4); a doublet appears at 8.77 with J_{12,13} = 9.28 Hz attributed to H12.

Anal. Calcd. for C₁₉H₁₀ClNS: C, 71.36; H, 3.15; N, 4.38; S, 10.03. Found: C, 71.47; H, 3.36; N, 4.37; S, 10.27.

Benzo[h][1]benzothieno[2,3-c]quinoline (**6**).

A mixture of 0.4 g (1.25 mmoles) of **5**, 70.2 mg (1.25 mmoles) of potassium hydroxide, 0.1 g of 10% Pd-C, 50 ml of benzene, and 50 ml of methanol was hydrogenated at room temperature under atmospheric pressure until the uptake of hydrogen ceased. The mixture was filtered and the filtrate was evaporated to dryness *in vacuo*. The residual solid was recrystallized from cyclohexane to afford 0.2 g (0.7 mmole, 56%) of **6** as colorless needles, mp 182-184°; ir (potassium bromide): 3055, 3029 (aromatic CH stretching); ¹H nmr (deuteriochloroform): δ 7.52-8.05 (m, 7H, arom), 8.68-8.86 (m, 2H, arom), 9.33-9.44 (m, 2H, arom); two doublets appear at 7.95 and 8.73 with J_{12,13} = 9.28 Hz attributed to H13 and H12, respectively; the singlet at 9.38 is assigned to H6.

Anal. Calcd. for C₁₉H₁₁NS: C, 79.97; H, 3.89; N, 4.91. Found: C, 80.15; H, 3.83; N, 4.86.

3-Chloro-N-(2-naphthyl)benzo[b]thiophene-2-carboxamide (**8**).

A mixture of 2.0 g (8.65 mmoles) of **1** and 1.30 g (8.65 mmoles, 95% pure from Aldrich Chemical Co.) of 2-aminonaphthalene in 40 ml of benzene was heated under reflux for 4 hours. The mixture was evaporated to dryness *in vacuo* and the solid residue was recrystallized from benzene to give 1.66 g (4.91 mmoles, 57%) of **8** as colorless needles, mp 187-189°; ir (potassium bromide): 3317 (NH stretching), 3055 (aromatic CH stretching), 1643 (>C=O stretching); ¹H nmr (deuteriochloroform): δ 7.35-7.98 (m, 10H, arom), 8.39 (d, J_{1,3'} = 2.19 Hz, 1H, H1'), 9.06 (br s, 1H, NH).

Anal. Calcd. for C₁₉H₁₂ClNOS: C, 67.55; H, 3.58; N, 4.15; S, 9.49. Found: C, 67.75; H, 3.61; N, 4.17; S, 9.66.

Benzo[f][1]benzothieno[2,3-c]quinolin-8(7H)-one (**9**).

A mixture of 0.5 g (1.48 mmoles) of **8** and 0.15 g of triethylamine in 500 ml of benzene was irradiated with a 450 watt Hanovia medium pressure mercury lamp for 5 hours. A slow stream of air was passed through the solution during the course of the reaction. The solid was collected by filtration and then washed with water to yield 0.37 g (1.23 mmoles, 83%) of **9**, mp >300°; ir (potassium bromide): 3134 (NH stretching), 1671 (>C=O stretching); ¹H nmr (DMSO-d₆): 150°, δ 7.33-7.71 (m, 5H, arom), 7.94-8.23 (m, 3H, arom), 8.40-8.61 (m, 2H, arom). This compound was used without further purification in the next reaction.

8-Chlorobenzo[f][1]benzothieno[2,3-c]quinoline (**11**).

A mixture of 0.79 g (2.62 mmoles) of **9** and 30 ml of phosphorus oxychloride was heated at 110-120° for 4 hours. After cooling in an ice-bath, the mixture was poured into 300 ml of ice-water very slowly and carefully. The solid was collected by filtration and recrystallized from cyclohexane to give 0.72 g (2.25 mmoles, 86%) of **11** as colorless crystals, mp 196-198°; ir (potassium bromide): 3065 (aromatic stretching); ¹H nmr (deuteriochloroform): δ 7.30-7.75 (m, 4H, arom), 7.92-8.05 (m, 4H, arom), 8.75 (dd, J_{12,13} = 7.82 Hz, J_{11,13} = 1.71 Hz, 1H, H13), 8.92 (dd, J_{1,2} = 7.57 Hz, J_{1,3} = 1.95 Hz, 1H, H1).

Anal. Calcd. for C₁₉H₁₀ClNS: C, 71.36; H, 3.15; N, 4.38; S, 10.03. Found: C, 71.45; H, 3.14; N, 4.38; S, 9.93.

Benzo[f][1]benzothieno[2,3-c]quinoline (**12**).

A mixture of 0.65 g (2.03 mmoles) of **11**, 0.114 g (2.03 mmoles) of potassium hydroxide, 0.1 g of 10% Pd-C, 80 ml of benzene, and 80 ml of methanol was hydrogenated at room temperature under atmospheric pressure until the up-take of hydrogen ceased. The mixture was filtered and the filtrate was evaporated to dryness *in vacuo*. The solid was recrystallized from cyclohexane to give 0.43 g (1.47 mmoles, 72%) of **12** as fine yellow needles, mp 173-175°; ir (potassium bromide): 3057 (aromatic CH stretching); ¹H nmr (deuteriochloroform): δ 7.18-7.66 (m, 4H, arom), 7.84-8.08 (m, 4H, arom), 8.69 (dd, J_{12,13} = 7.81 Hz, J_{11,13} = 1.49 Hz, 1H, H13), 8.88 (dd, J_{1,2} = 7.57 Hz, J_{1,3} = 1.71 Hz, 1H, H1), 9.23 (s, 1H, H8).

Anal. Calcd. for C₁₉H₁₁NS: C, 79.97; H, 3.89; N, 4.91. Found: C, 80.06; H, 4.08; N, 4.94.

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