The Synthesis of Novel Polycyclic Heterocyclic Ring Systems *via* Photocyclization. **8** [1]. [1]Benzothieno[2,3-*c*]naphtho[1,2-*h*]quinoline and [1]Benzothieno[2,3-*c*]naphtho[1,2-*h*][1,2,4]triazolo[4,3-*a*]quinoline

Kenji Sasaki and Raymond N. Castle* [2]

Department of Chemistry, University of South Florida,
Tampa, FL 33620-5250

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The previously unknown polycyclic heterocyclic ring systems, namely, [1]benzothieno[2,3-*c*]naphtho[1,2-*h*]quinoline and [1]benzothieno[2,3-*c*]naphtho[1,2-*h*][1,2,4]triazolo[4,3-*a*]quinoline were synthesized *via* photocyclization of 3-chloro-*N*-(1'-phenanthryl)benzo[*b*]thiophene-2-carboxamide.

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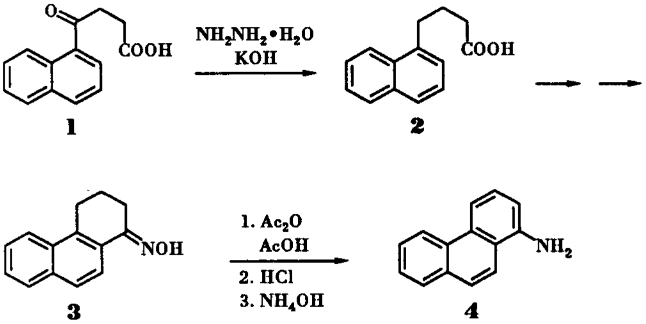
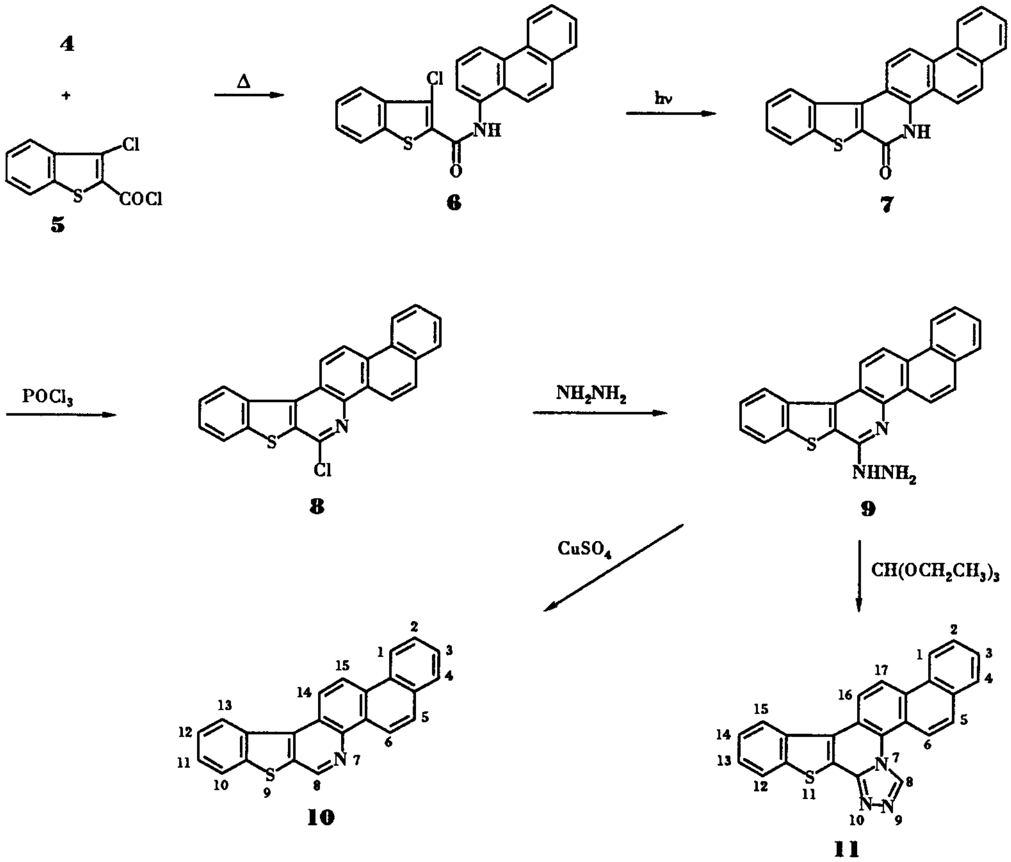
We have been interested in the synthesis of novel polycyclic heterocyclic ring systems *via* photocyclization of the appropriate amides [1a-g] and their spectroscopic properties [3a-b]. As a continuation of our studies of novel heterocyclic ring systems we now report the extension of a photoinduced cyclization leading to two previously unknown heterocyclic ring systems, namely, [1]benzothieno[2,3-*c*]naphtho[1,2-*h*]quinoline (**10**) and [1]benzothieno[2,3-*c*]naphtho[1,2-*h*][1,2,4]triazolo[4,3-*a*]quinoline (**11**).

As shown in Scheme 1, 3-(1'-naphthoyl)propionic acid (**1**) was reduced to 4-(1'-naphthyl)butyric acid (**2**) by the

Scheme 1



Scheme 2



Huang-Minlon reaction [6] in good yield. Compound **2** was converted to 1-oxo-1,2,3,4-tetrahydrophenanthrene oxime (**3**) by the methods of Haworth [4] and Beringer *et al.* [5]. This compound was aromatized using acetic anhydride and acetic acid to afford the intermediate 1-acetylaminophenanthrene which was hydrolyzed in ethanolic hydrochloric acid and was used without purification to give 1-aminophenanthrene (**4**) in 75% overall yield from **3**.

Compound **4** (Scheme 2) was allowed to react with 3-chlorobenzo[*b*]thiophene-2-carbonyl chloride (**5**) [1b] in benzene solution, and 3-chloro-*N*-(1'-phenanthryl)benzo[*b*]thiophene-2-carboxamide (**6**) was obtained in 58% yield. Photocyclization of amide **6** gave the lactam, [1]benzothieno[2,3-*c*]naphtho[1,2-*h*]quinolin-8(7*H*)-one (**7**), in 77% yield. Chlorination of **7** with phosphorus oxychloride afforded 8-chloro[1]benzothieno[2,3-*c*]naphtho[1,2-*h*]quinoline (**8**) in 75% yield. Compound **8** reacted with anhydrous hydrazine in ethanol to provide 8-hydrazino[1]benzothieno[2,3-*c*]naphtho[1,2-*h*]quinoline (**9**) in 75% yield. Refluxing **9** with aqueous acetic acid and a 10% solution of copper sulfate produced **10** in 84% yield whereas refluxing of a suspension of **9** in ethanol with triethyl orthoformate gave **11** in 76% yield.

A detailed 2D nmr study of **10** and **11** is in progress and preliminary results confirm the structures of **10** and **11** and will be reported in a forthcoming publication.

EXPERIMENTAL

Melting points were determined 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 ^{1}H 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-(1'-Naphthoyl)propionic Acid (1).

This compound was prepared by the method of Haworth [4] in 28% yield as pale yellow plates, mp 128-131° (from ethyl acetate, lit [4] mp 129-131°; lit [7] mp 131-132°).

4-(1'-Naphthyl)butyric Acid (2).

A mixture of 45.6 g (0.20 mole) of compound **1**, 38.0 g (0.68 mole) of potassium hydroxide, 28 ml of 85% hydrazine hydrate, and 280 ml of diethylene glycol was refluxed for 1 hour 40 minutes. The water from the reaction mixture was evaporated and the temperature allowed to rise to 200°. Refluxing of the reaction mixture was continued for an additional 5 hours. After cooling, the reaction mixture was diluted with 600 ml of water and the mixture was poured slowly into 400 ml of 6*N* hydrochloric acid. The precipitated pale brown solid was collected by filtration and dissolved in 700 ml of ether. The ether solution was washed with water, dried over anhydrous sodium sulfate, and evaporated to dryness. Recrystallization of the residue from cyclohexane gave 41.0 g (96%) of compound **2** as pale brown plates, mp 104-107° (lit [4] mp 106-107°, lit [7] mp 106-107°).

1-Oxo-1,2,3,4-tetrahydrophenanthrene Oxime (3).

After cyclization of **2** by the method of Haworth [4] in 83% yield as pale yellow prisms, mp 92-94° (from cyclohexane, lit [4] mp 95-96°, lit [7] mp 96°), compound **3** was prepared by the method of Beringer *et al.* [5] in 95% yield as colorless prisms, mp 167-169° (from benzene, lit [7] mp 165-166°, lit [8] mp 167°).

1-Aminophenanthrene (4).

A solution of 4.22 g (20.0 mmoles) of **3** in a mixture of 20 ml of acetic anhydride and 20 ml of acetic acid was refluxed for 90 hours. After cooling, the reaction mixture was poured into 400 ml of ice-water. This mixture was extracted with ethyl acetate and the organic layer was washed with water, dried over anhydrous sodium sulfate, and evaporated to afford a brown viscous oil. This oil was subjected to the following hydrolysis without further purification. A solution of the above viscous oil in a mixture of 50 ml of concentrated hydrochloric acid and 250 ml of ethanol was refluxed for 28 hours. After cooling, the reaction mixture was concentrated to about 100 ml and poured into 350 ml of ice-water. The mixture was washed with a small amount of benzene, and the aqueous layer was basified with concentrated ammonium hydroxide. The alkaline mixture was extracted with ethyl acetate and the organic layer was washed with water, dried over anhydrous sodium sulfate, and evaporated to afford a brown powder, which was recrystallized from a mixture of benzene and *n*-hexane to give 2.90 g (75%) of **4** as pale brown needles, mp 144-146° (lit [9] mp 145-146°, lit [10] mp 145-146°).

3-Chloro-*N*-(1'-phenanthryl)benzo[*b*]thiophene-2-carboxamide (6).

A solution of 3.47 g (15.0 mmoles) of **4** and 2.90 g (15.0 mmoles) of **5** in 120 ml of benzene was refluxed for 6 hours. After cooling, the reaction mixture was concentrated to about 6 ml and the precipitated solid was collected by filtration. The solid was recrystallized from benzene to give 3.37 g (58%) of **6** as pale brown prisms, mp 200-202°; ir (potassium bromide): 3410 (N-H stretching), 3050 (aromatic C-H stretching), 1653 (C=O stretching); ^{1}H nmr (DMSO-d$_6$): 7.59-7.89 (m, 6H, Ar-H), 7.91-8.24 (m, 5H, Ar-H), 8.78-8.94 (m, 2H, phenanthrene ring-4',5'-H), 10.66 (s, 1H, NH).

Anal. Calcd. for $C_{23}H_{14}ClNOS$: C, 71.21; H, 3.63; N, 3.61; S, 8.26. Found: C, 71.27; H, 3.51; N, 3.58; S, 8.40.

[1]Benzothieno[2,3-*c*]naphtho[1,2-*h*]quinolin-8(7*H*)-one (7).

To a solution of 500 mg (1.29 mmoles) of **6** in 500 ml of a mixture of cyclohexane and benzene (2:1, v/v) was added 0.2 ml of triethylamine, and the solution was irradiated with a 450 watt Hanovia medium pressure mercury lamp for 8 hours. After cooling, the pale yellow solid which precipitated during the reaction was collected by filtration and washed thoroughly with water, dried at 100° for 3 hours *in vacuo* to give 349 mg (77%) of compound **7** as a pale yellow solid, mp >300°; ir (potassium bromide): 3160 (N-H stretching) 3060 (aromatic C-H stretching), 1653 (C=O stretching); ^{1}H nmr (DMSO-d$_6$): 7.70-8.37 (m, 8H, Ar-H), 8.88-9.21 (m, 4H, 1,13,14,15-H), 10.82 (s, 1H, NH). This compound was used in the next step without further purification because of its low solubility.

8-Chloro[1]benzothieno[2,3-*c*]naphtho[1,2-*h*]quinoline (8).

A suspension of 2.00 g (5.70 mmoles) of **7** and 60 ml of phosphorus oxychloride was refluxed for 23 hours. After cooling, the reaction mixture was evaporated to dryness, and 200 ml of ice-water was poured carefully onto the residue. The mixture was basified with sodium hydrogen carbonate and extracted with ethyl acetate. During the extraction, the undissolved solid in both layers was filtered and thoroughly washed with water. The organic layer was washed with water, dried over anhydrous sodium sulfate, and evaporated to give 224 mg of yellow crystalline residue. The residue was combined with the hot-benzene soluble fraction of the above filtered solid and recrystallized from benzene to afford 1.58 g (75%) of compound **8** as colorless needles, mp 258-259°; ir (potassium bromide): 3065, 3050 (aromatic C-H stretching); ^{1}H nmr (deuteriochloroform): 7.60-7.77 (m, 4H, Ar-H), 7.98-8.11 (m, 3H, Ar-H), 8.74-9.00 (m, 4H, 1,13,14,15-H), 9.38 (d, 1H, J = 9.1 Hz, 6-H).

Anal. Calcd. for $C_{23}H_{12}ClNS$: C, 74.68; H, 3.27; N, 3.78; S, 8.66. Found: C, 74.77; H, 3.20; N, 3.76; S, 8.51.

8-Hydrazino[1]benzothieno[2,3-*c*]naphtho[1,2-*h*]quinoline (**9**).

To a stirred suspension of 1.50 g (4.06 mmoles) of **8** in 70 ml of ethanol was added 11 ml (351 mmoles) of anhydrous hydrazine over a period of 50 minutes. The mixture was refluxed for 3 days. After cooling, the crystalline precipitate in the reaction mixture was collected by filtration and recrystallized from benzene to afford 1.11 g (75%) of **9** as pale yellow needles, mp 250-252° dec; ir (potassium bromide): 3291, 3271 (N-H stretching), 3047 (aromatic C-H stretching); ^{1}H nmr (DMSO-d_6): 4.91 (s, 2H, NH_2), 7.60-7.81 (m, 4H, Ar-H), 7.98-8.31 (m, 3H, Ar-H), 8.61 (s, 1H, NH), 8.70-9.12 (m, 4H, 1,13,14,15-H), 9.37 (d, 1H, J = 9.2 Hz, 6-H).

Anal. Calcd. for $C_{23}H_{15}N_3S$: C, 75.59; H, 4.13; N, 11.49. Found: C, 75.54; H, 4.10; N, 11.39.

[1]Benzothieno[2,3-*c*]naphtho[1,2-*h*]quinoline (**10**).

A suspension of 200 mg (0.55 mmole) of **9** in 4 ml of water and 4 ml of acetic acid was heated to boiling and treated dropwise with 3 ml of a 10% solution of copper sulfate. The mixture was refluxed for 4 hours. After cooling, the reaction mixture was poured into 40 ml of ice-water, and the mixture was basified with 2*N* sodium hydroxide. The mixture was extracted with dichloromethane and the organic layer was washed with water, dried over anhydrous sodium sulfate, and evaporated to dryness. The crystalline residue was recrystallized from benzene to give 154 mg (84%) of **10** as pale yellow needles, mp 254-256°; ir (potassium bromide): 3050, 3019 (aromatic C-H stretching); ^{1}H nmr (deuteriochloroform): 7.60-7.77 (m, 4H, Ar-H), 7.98-8.14 (m, 3H, Ar-H), 8.77-9.00 (m, 4H, 1,13,14,15-H), 9.51 (d, 1H, J = 9.2 Hz, 6-H), 9.52 (s, 1H, 8-H).

Anal. Calcd. for $C_{23}H_{13}NS$: C, 82.35; H, 3.90; N, 4.17. Found: C, 82.13; H, 4.12; N, 3.96.

[1]Benzothieno[2,3-*c*]naphtho[1,2-*h*][1,2,4]triazolo[4,3-*a*]quinoline (**11**).

A suspension of 200 mg (0.55 mmole) of **9** in 8 ml of triethyl orthoformate and 16 ml of ethanol was refluxed for 22 hours. After cooling, the crystalline precipitate was collected by filtration and recrystallized from benzene to give 158 mg (76%) of **11** as pale brown needles, mp 302-305° dec; ir (potassium bromide): 3160, 3057 (aromatic C-H stretching); ^{1}H nmr (deuteriochloroform): 7.55-7.82 (m, 4H, Ar-H), 7.97-8.11 (m, 3H, Ar-H), 8.54-9.07 (m, 5H, 1,6,15,16,17-H), 9.93 (s, 1H, 8-H).

Anal. Calcd. for $C_{24}H_{13}N_3S$: C, 76.77; H, 3.48; N, 11.19. Found: C, 76.88; H, 3.50; N, 11.12.

REFERENCES AND NOTES

[1a] Part **1**: S. L. Castle, J.-K. Luo, H. Kudo and R. N. Castle, *J. Heterocyclic Chem.*, **25**, 1363 (1988); [b] Part **2**: J.-K. Luo and R. N. Castle, *J. Heterocyclic Chem.*, **27**, 1031 (1990); [c] Part **3**: M. J. Musmar and R. N. Castle, *J. Heterocyclic Chem.*, **28**, 203 (1991); [d] Part **4**: J.-K. Luo, A. S. Zektzer and R. N. Castle, *J. Heterocyclic Chem.*, **28**, 737 (1991); [e] Part **5**: J.-K. Luo and R. N. Castle, *J. Heterocyclic Chem.*, **28**, 1825 (1991); [f] Part **6**: R. N. Castle, S. Pakray and G. E. Martin, *J. Heterocyclic Chem.*, **28**, 1997 (1991); [g] Part **7**: K. Sasaki and R. N. Castle, *J. Heterocyclic Chem.*, **29**, 963 (1992).

[2] To whom correspondence should be directed at the Department of Chemistry, University of South Florida, Tampa, FL 33620-5250, USA.

[3a] J. P. Shockcor, R. C. Crouch, G. E. Martin, A. Cherif, J.-K. Luo and R. N. Castle, *J. Heterocyclic Chem.*, **27**, 455 (1990); [b] R. C. Crouch, C. W. Andrews, G. E. Martin, J.-K. Luo and R. N. Castle, *Magn. Reson., Chem.*, **28**, 774 (1990).

[4] R. D. Haworth, *J. Chem. Soc.*, 1125 (1932).

[5] F. M. Beringer, L. L. Chang, A. W. Fenster and R. R. Rossi, *Tetrahedron*, **25**, 4339 (1969).

[6] Huang-Minlon, *J. Am. Chem. Soc.*, **68**, 2487 (1946).

[7] G. Schroeter, H. Müller and Y. S. Huang, *Ber.*, **62**, 645 (1929).

[8] W. Langenbeck and K. Weissenborn, *Ber.*, **72**, 754 (1939).

[9] W. E. Bachmann and C. H. Boatner, *J. Am. Chem. Soc.*, **58**, 2097 (1936).

[10] H. Dannenberg and E. Meyer, *Chem. Ber.*, **102**, 2384 (1969).