THE JOURNAL OF Organic Chemistry®

VOLUME 35, NUMBER 4 APRIL 1970

The Chemistry of Indenothiophenes. II. 4H-Indeno[1,2-*b*]thiophene and 8H-Indeno[1,2-*c*]thiophene

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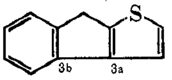
Received August 6, 1969

The syntheses of 4H-indeno[1,2-*b*]thiophene (**2**) and 8H-indeno[1,2-*c*]thiophene (**3**) are described. Upon metalation with *n*-butyllithium and treatment with Dry Ice, the former yields exclusively 4H-indeno[1,2-*b*]thiophene-4-carboxylic acid (**13**), while the latter gives 8H-indeno[1,2-*c*]thiophene-8-carboxylic acid (**14**, 38%), 8H-indeno[1,2-*c*]thiophene-1-carboxylic acid (**15**, 14%), and 8H-indeno[1,2-*c*]thiophene-3-carboxylic acid (**16**, 48%). These results are discussed in terms of the mode of fusion of the thiophene nuclius and direct bridging between the benzene and thiophene rings.

An earlier paper[2] concerning the chemistry of indenothiophenes described the synthesis and metalation of 8H-indeno[2,1-*b*]thiophene (**1**). In this paper we wish to report the syntheses and metalative properties of 4H-indeno[1,2-*b*]thiophene (**2**) and 8H-indeno[1,2-*c*]thiophene (**3**).



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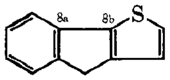

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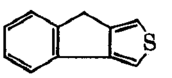

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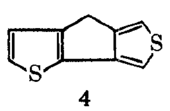
Interest in these and similar systems has been stimulated by recent reports of studies dealing with competitive metalation between hydrogen atoms attached to thiophene rings and those in methylene groups attached to thiophene rings.[3]

Janssen and DeJong[3b] have reported the metalation of three cyclopentadithiophenes,[4] **4**, **5**, and **6**, in both ether



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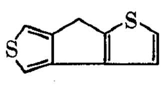

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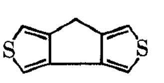

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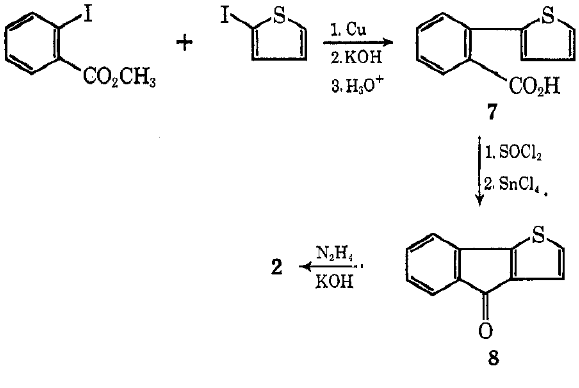
and cyclohexylamine solution, using *n*-butyllithium and lithium cyclohexylamide as base. A study of the ultraviolet spectra of these anions led to the conclusion that the negative charge resides in the central ring of each system. However, compounds derived from these anions have not yet been reported to verify these assignments.

Synthesis of 4H-Indeno[1,2-*b*]thiophene (2).—Initial attempts to synthesize **2** *via* the phosphorus pentasulfide ring closure of 2-formylmethyl-1-indanone dimethyl acetal were unfruitful. Since reaction of the pyrrolidine enamine of 1-indanone with bromoacetaldehyde dimethyl acetal gave, depending on the vigor of the reaction conditions, either unchanged enamine or 1-indanone, this approach was abandoned. The actual synthetic sequence used to prepare **2** is shown in Scheme I.

Scheme I



Modification of the procedure of Chow and coworkers[5] using Ullmann coupling of methyl *o*-iodobenzoate and 2-iodothiophene gave a mixture from which methyl 2-thienylbenzoate was obtained. Saponification of this methyl ester afforded *o*-2-thienylbenzoic acid (**7**) in an overall yield of 32%. Cyclization of **7** was accomplished *via* the acid chloride using stannic chloride to give 4H-indeno[1,2-*b*]thiophen-4-one (**8**) in 78% yield. Wolff–Kishner reduction of **8** afforded **2** in 68% yield.

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[1] NDEA Fellow, 1967–1969.

[2] D. W. H. MacDowell and T. B. Patrick, *J. Org. Chem.*, **32**, 2441 (1967).

[3] (a) O. Meth-Cohn and S. Gronowitz, *Acta Chem. Scand.*, **20**, 1733 (1966); (b) M. J. Janssen and J. DeJong, *Rec. Trav. Chim. Pays-Bas*, **86**, 1246 (1967); (c) J. Skramstad, *Acta Chem. Scand.*, **23**, 703 (1969).

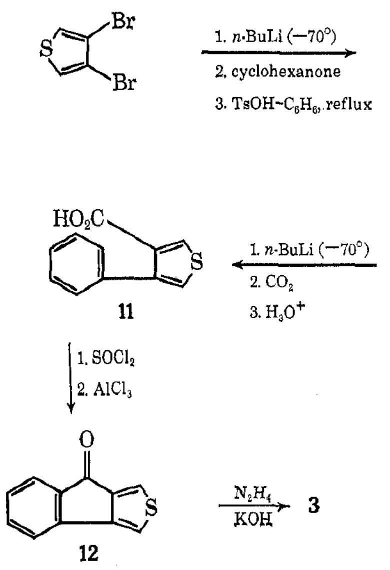
[4] A. Kraak, A. W. Wiersema, P. Jordens, and H. Wynberg, *Tetrahedron*, **24**, 3381 (1968).

[5] A. W. Chow, N. M. Hall, J. R. E. Hoover, M. M. Dolan, and R. J. Ferlauto, *J. Med. Chem.*, **9**, 551 (1966).

The reduced compound **2** is a white, crystalline solid with a strong odor resembling that of fluorene.

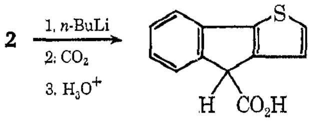
Synthesis of 8H-Indeno[1,2-*c*]thiophene (3).—Preliminary attempts to form this system by utilizing the Hinsberg condensation of diethyl thiodiglycolate with indan-1,2,3-trione following the procedure of Wynberg[6] were unsuccessful, and afforded only recovered indan-1,2,3-trione and thiodiglycolic acid. The successful synthesis of **3** is outlined in Scheme II.

Scheme II



Halogen–metal interchange in 3,4-dibromothiophene provided the best method of obtaining the precursor acid, 3-phenylthiophene-4-carboxylic acid (**11**). Treatment of 4-bromo-3-thienyllithium with cyclohexanone at −70° afforded the corresponding cyclohexanol, which was dehydrated by means of *p*-toluenesulfonic acid in refluxing benzene to yield 3-bromo-4-(1-cyclohexenyl)thiophene (**9**) in 86% yield. Dehydrogenation of **9** with chloranil in refluxing xylene for 10 hr provided optimum conditions for the preparation of 3-bromo-4-phenylthiophene (**10**). In contrast to work reported by Szmuszkovicz[7] and Gronowitz,[8] it was found that the use of benzene or chlorobenzene as a solvent in this dehydrogenation was unsatisfactory. The bromide obtained in this manner had a dark red color, and careful purification by sublimation or column chromatography over alumina was necessary to ensure good results in the conversion into **11**. Halogen–metal exchange in **10** at −70°, followed by carbonation, gave yields of 3-phenylthiophene-4-carboxylic acid (**11**) of 76–84%. Ring closure of **11** *via* the acid chloride proceeded under the influence of aluminum chloride in carbon disulfide solution for 24 hr to produce 8H-indeno[1,2-*c*]thiophen-8-one (**12**) in 82–91% yield. Wolff–Kishner reduction of **12** produced **3** in 60% yield. 8H-Indeno[1,2-*c*]thiophene (**3**) is a white, crystalline solid possessing an odor resembling that of fluorene. Gronowitz[9] has reported the use of a mixture of lithium aluminum hydride and aluminum chloride to reduce 1,2,4,6-tetramethyl-7H-cyclopenta[1,2-*c*:3,4-*c*′]dithiophen-7-one to 1,3,4,6-tetramethyl-7H-cyclopenta[1,2-*c*:3,4-*c*′]-dithiophene in 92% yield. However, reduction of **12** under the same conditions produced only 30–40% **3** after purification by column chromatography. Further elution with more polar solvents produced a quantity of resinous material, the identity of which was not further investigated. Lowering the relative amounts of lithium aluminum hydride to aluminum chloride[10] produced a 55:45 mixture of **3** and the corresponding alcohol (by nmr). It is noteworthy that both 2- and 3-benzoylthiophene are reduced to the corresponding benzyl compounds in greater than 90% yields under the same conditions that produced the mixture of alcohol and **3** from **12**.

Metalation Experiments.—It was previously reported[2] that metalation of **1** with *n*-butyllithium in ether solution occurred exclusively at the methylene bridge; no metalation on the thiophene ring was detected. Treatment of **2** with slightly more than 1 equiv of ethereal *n*-butyllithium followed by carbonation, work-up as in the case of **1**,[2] and examination of the nmr spectrum of the crude product revealed an aromatic absorption at τ 2.0–3.0 and a singlet for the methine proton at τ 5.20. The absence of any absorption at τ 5.20–10.0 indicated that metalation had occurred exclusively at the methylene bridge of **2**.



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The nmr spectrum of the crude product obtained by similar treatment of **3** with 1 equiv of ethereal *n*-butyllithium followed by work-up as described for **2** revealed bands at τ 1.25 (m), 2.2–3.0 (m, aromatic), 5.17 (s), 6.08 (s), and 6.28 (s). On the basis of previous work,[2] the singlet at τ 5.17 is assigned to the methine hydrogen of 8H-indeno[1,2-*c*]thiophene-8-carboxylic acid (**14**). The singlet at τ 6.08 is assigned to the methylene hydrogens of 8H-indeno[1,2-*c*]thiophene-1-carboxylic acid (**15**), which are shifted downfield owing to the inductive effect of the neighboring carboxyl group. The multiplet at τ 1.25 and the singlet at τ 6.28 are assigned to the C_4 hydrogen and methylene hydrogens, respectively, of the 8H-indeno[1,2-*c*]thiophene-3-carboxylic acid (**16**). The relative amounts of these products formed in the metalation–carbonation reaction are 38% **14**, 14% **15**, and 48% **16**. These values were determined by weighing the paper under the curves traced out in the recording of the nmr spectrum, and are the average of three experiments.

The acid **16** was isolated in pure form through fractional crystallization of a mixture of acids from benzene–hexane. The assignment of the C_4 hydrogen at τ 1.25 is based on an examination of molecular models. The proximity of the neighboring carboxyl group to the C_4 hydrogen allows it to exert a negative anisotropic effect on the C_4 hydrogen, causing it to absorb at lower field than the other aromatic hydrogens. This assign-

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[6] H. Wynberg and H. J. Kooreman, *J. Amer. Chem. Soc.*, **87**, 1739 (1965).

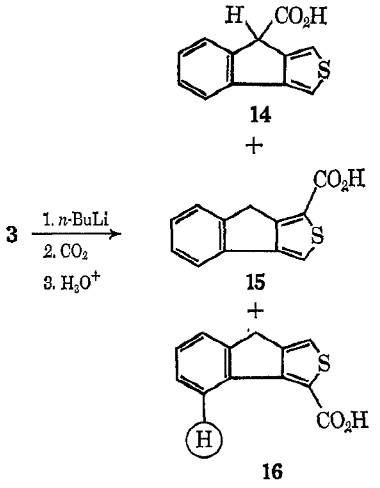
[7] L. F. Fieser and J. Szmuszkovicz, *ibid.*, **70**, 3352 (1948); J. Szmuszkovicz and E. J. Modest, *ibid.*, **72**, 571 (1950).

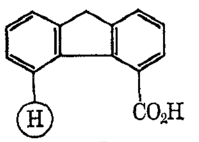
[8] S. Gronowitz and N. Gjos, *Acta Chem. Scand.*, **21**, 2823 (1967).

[9] S. Gronowitz, J. E. Skramstad and B. Eriksson, *Ark. Kemi*, **28**, 99 (1967).

[10] R. F. Nystrom and C. R. A. Berger, *J. Amer. Chem. Soc.*, **80**, 2896 (1958).

ment was confirmed by examination of the nmr spectrum of fluorene-4-carboxylic acid (**17**), whose spectrum reveals a multiplet at τ 1.50 of the same character as the C_4 hydrogen in **16**.





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Discussion

The differences in metalative properties of **1**, **2**, and **3** may be rationalized in the following manner: The 3a–3b bridge in **1** and the 8a–8b bridge in **2**, respectively, along with the b fusion of the thiophene ring, convey to these molecules a formal similarity to fluorene and indene. Thus an anion generated at the methylene bridge in **1** and **2** is delocalized extensively, which causes the methylene hydrogens to become more acidic than those on the α position of the thiophene ring. However, c fusion of the thiophene ring in **3** causes considerable loss of delocalization for the anion formed at the methylene bridge when compared with that in **1** and **2**. This is indicated by the formation of substantial amounts of additional products, **15** and **16**, upon carbonation of the metalation product of **3**. Furthermore, it allows the thiophene C_3 hydrogen to become slightly more acidic than the methylene hydrogen and provides an excellent example of the less extensive electron delocalization across the 3,4 bond in thiophene[11] compared with that in the 2,3 bond.

These results are in qualitative agreement with the pK_a values calculated for the methylene bridge hydrogens of **1**, **2**, and fluorene by simple Hückel molecular orbital theory.[12] See Table I.

The formal resemblance of **1** and **2** to fluorene is reflected in the comparable calculated pK_a values. Consequently, it is not unexpected to find that metalation of **1** and **2** occurs exclusively at their respective methylene bridges. However, the pK_a value calculated for **3** suggests that the hydrogens on its methylene bridge are somewhat less acidic than those in **1** and **2** and is in qualitative agreement with the observed lower degree of metalation of the methylene bridge of **3**.

TABLE I

	τ (CH_2)	Calcd pK_a[a]
Fluorene	6.19	25
1	6.20	24
2	6.39	25
3	6.30	27

[a] Reference 12.

Experimental Section[13]

4H-Indeno[1,2-b]thiophen-4-one (8).—To a three-necked, 500-ml flask, fitted with a calcium chloride drying tube and containing o-(2-thienyl)benzoic acid[5] (7, 13.97 g, 0.0685 mol) dissolved in dry benzene (140 ml) and dry N,N-dimethylformamide (3.5 ml) was added thionyl chloride (7.0 ml). The solution was heated at reflux for 2 hr and cooled, and the benzene evaporated. The brown residue was kept under nitrogen and was freed from the last traces of thionyl chloride by treatment with four successive portions of dry benzene, followed by evaporation of each portion of benzene. Final evaporation of the benzene left the acid chloride as a brown oil, ir (neat) 1770 cm^{-1} (acid chloride C=O).

A solution of the acid chloride obtained above in dry benzene (100 ml) was added to a three-necked, 500-ml flask protected by a calcium chloride drying tube and cooled to −2°. A solution of stannic chloride (9.8 ml) in dry benzene (40 ml) was added at such a rate as to keep the temperature at 4°. After addition was completed, the dark mixture was stirred for 10 min at 4° and for a further 10 min without external cooling.

The dark mixture was poured onto a slurry of ice (400 ml) and 1 *M* hydrochloric acid (200 ml) and was stirred well. The layers were separated and the aqueous layer was extracted with benzene (500 ml) in three portions. The benzene solution was washed twice with water, three times with 1 *M* sodium hydroxide (75 ml), three times with water, and twice with brine, dried ($MgSO_4$), and concentrated to leave 9.84 g (78%) of orange solid, mp 99–101°. Sublimation at 95–97° (0.6–1.1 mm) afforded an analytical sample: mp 101° (lit.[14] mp 99°); uv max (95% C_2H_5OH) 255 mμ (ϵ 36,500), 264 (39,600), and 294 (5850); ir (KBr) 1710 cm^{-1} (ketone C=O); nmr ($CDCl_3$) τ 2.2–3.1 (m, 6, $C_{11}H_6OS$).

Anal. Calcd for $C_{11}H_6OS$: C, 70.94; H, 3.25; S, 17.22. Found: C, 70.78; H, 3.31; S, 17.22.

4H-Indeno[1,2-b]thiophene (2).—4H-Indeno[1,2-b]thiophen-4-one (8, 0.50 g, 2.69 mmol) was mixed with 95% hydrazine (1.1 ml), potassium hydroxide (0.50 g), and diethylene glycol (5 ml) at 45° (oil-bath temperture) in a three-necked, 100-ml flask fitted with a condenser arranged for downward distillation. The mixture was heated to 195° over a 1-hr period and maintained at this temperature for 0.5 hr. The reaction mixture was cooled, water (20 ml) was added, and the mixture was distilled. This procedure was repeated until 80 ml of distillate had collected. The distillate was extracted with three portions of ether. The combined ether solutions were washed twice with water and twice with brine, dried ($MgSO_4$), and concentrated to leave 320 mg (68%) of white solid, mp 66–68°. An analytical sample was obtained by sublimation at 60–65° (1.0 mm): mp 68–69°; uv max (95% C_2H_5OH) 225 mμ (ϵ 6640), 232 (5800), 265 (sh, 8760), 288 (16,300), 299 (16,200), and 304 (11,900); ir (KBr) 750 cm^{-1}; nmr ($CDCl_3$) τ 2.4–3.0 (m, 6, $C_{10}H_6S$) and 6.39 (s, 2, $C_6H_4CH_2C_4H_2S$).

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(11) S. Gronowitz in "Organosulfur Chemistry," John Wiley & Sons, Inc., New York, N. Y., 1967, p 124.

(12) T. B. Patrick, Ph.D. Dissertation, West Virginia University, Morgantown, 1967. The pK_a values are based on the π energy differences between the anion and its conjugate acid as outlined in A. Streitwieser, Jr., "Molecular Orbital Theory for Organic Chemists," John Wiley & Sons, Inc., New York, N. Y., 1961, Chapter 14. These values were calculated using simple Hückel zero-order approximations on an IBM 7040 computer. The only sulfur parameters used were $h(s) = 1.0\ \beta_{cc}$, $hc(s) = 0.1\ \beta_{cc}$, and $Kc\text{-}s = 0.7\ \beta_{cc}$ following R. Zahradnik, Advan, Heterocycl. Chem., **5**, 58 (1965).

(13) All temperature readings are uncorrected. Elemental analyses were performed by Galbraith Laboratories, Knoxville, Tenn. Nuclear magnetic resonance spectra were recorded on a Varian HA-60 spectrometer using tetramethylsilane as an internal standard (τ 10) and solvents as specified. The ultraviolet spectra were determined in 95% ethanol on a Bausch and Lomb 505 spectrophotometer. Infrared spectra were recorded on a Perkin-Elmer Model 137 spectrometer.

(14) Y. Poirier and N. Lozac'h, *Bull. Soc. Chim. Fr.*, 1062 (1966).

Anal. Calcd for $C_{11}H_8S$: C, 76.69; H, 4.68; S, 18.62. Found: C, 76.89; 4.58; S, 18.70.

4H-Indeno[1,2-*b*]thiophene-4-carboxylic Acid (13).—A 250-ml, three-necked flask fitted with a reflux condenser, calcium chloride drying tube, and pressure-equalizing addition funnel was flame dried under nitrogen. To a solution of **2** (0.500 g, 2.90 mmol) (homogeneous by tlc) dissolved in anhydrous ether (30 ml) and contained in this flask was added ethereal 0.92 *M* *n*-butyllithium[15] (3.3 ml, 3.04 mmol). The resulting solution was then refluxed for 30 min, during which time it changed from yellow to orange-red in color. Refluxing was stopped and the reaction was quenched by adding *ca.* 10 g of freshly chipped Dry Ice. Several minutes after the vigorous reaction had subsided, water (25 ml) was added and the layers were separated. The aqueous layer was washed with three portions of ether and the combined ether washings were back washed with one portion of water. The combined aqueous portions were cooled, acidified with 1 *M* hydrochloric acid (7 ml), and extracted with three portions of ether. The ether solutions were washed with two portions of water and two portions of brine, dried ($MgSO_4$), and evaporated to leave 0.329 g (53%) of acid.

Evaporation of the neutral ether layer left 0.209 g of unchanged starting material.

An analytical sample of the acid was obtained by recrystallization from benzene: mp 212–213°; ir (KBr) 1690 cm^{-1} (acid C=O); nmr (acetone-d_6) τ 2.2–3.0 (m, 6, $C_{10}H_6S$), 3.6 (broad mound, 1, CO_2H), and 5.24 (s, 1, methine).

Anal. Calcd for $C_{12}H_8O_2S$: C, 66.65; H, 3.73; S, 14.83. Found: C, 66.32; H, 3.65; S, 15.03.

Methyl 4H-Indeno[1,2-*b*]thiophene-4-carboxylate.—An ethereal solution of diazomethane (9 ml, 0.107 g, 2.54 mmol) prepared from *p*-toluenesulfonylmethylnitrosamide was added to 4H-indeno[1,2-*b*]thiophene-4-carboxylic acid (**13**, 0.254 g, 1.23 mmol) dissolved in ether (25 ml). After nitrogen evolution had ceased, the solution was allowed to stand for 30 min and was diluted with an additional volume of ether (25 ml). The ether solution was washed with three 10-ml portions of dilute sodium hydroxide, three times with water, and twice with brine, dried ($MgSO_4$), and concentrated to leave 0.237 g (84%) of green oil which solidified on standing. Sublimation at 70–73° (0.10–0.15 mm) followed by careful recrystallization from hexane afforded an analytical sample: mp 72.5–73°; ir (KBr) 1725 cm^{-1} (ester C=O); nmr ($CDCl_3$) τ 2.25–2.40 (m, 6, $C_{10}H_6S$), 5.30 (s, 1, methine), and 6.27 (s, 3, OCH_3).

Anal. Calcd for $C_{13}H_{10}O_2S$: C, 67.80; H, 4.38; S, 13.96. Found: C, 67.97; H, 4.52; S, 13.83.

3-Bromo-4-(1-cyclohexenyl)thiophene (9).—An ethereal solution of 1.5 *M* *n*-butyllithium (226 ml, 0.338 mol) was added to a three-necked, 1-l. flask, fitted with a calcium chloride drying tube, which had been flame dried under nitrogen. The solution was cooled to −70° and a solution of 3,4-dibromothiophene (75.0 g, 0.310 mol) in anhydrous ether (90 ml) was added over an 8-min period. After the solution had been stirred for 7 min, a solution of freshly distilled cyclohexanone (30.4 g, 0.310 mol) in anhydrous ether (55 ml) was added rapidly. The resulting mixture was allowed to stir at −70° for 10 min and then for another 10 hr after removal of the cooling bath.

The yellow ethereal solution was cooled below room temperature and was acidified with 2 *M* hydrochloric acid (225 ml). The ether layer was washed with water (100 ml), saturated sodium bicarbonate solution (100 ml), twice with water, and twice with brine and dried ($MgSO_4$).

Concentration left the crude alcohol, which was dissolved in benzene (100 ml) and dehydrated by refluxing it for 3 hr with a catalytic amount of *p*-toluenesulfonic acid. The benzene solution was cooled, diluted with an equal volume of ether (emulsion prevention), washed twice with water and twice with brine, dried ($MgSO_4$), and distilled to give 64.7 g (86%) of product: bp 87–97° (0.2 mm); $n^{25}{}_D$ 1.6011; nmr ($CDCl_3$) τ 2.80 (d, 1, J = 4 Hz, H-2), 3.0 (d, 1, J = 4 Hz, H-5), 4.05–4.20 (m, 1, vinyl), 7.60–7.90 (m, 4 allylic CH_2), and 8.17–8.40 (m, 4, aliphatic CH_2).

Anal. Calcd for $C_{10}H_{11}BrS$: C, 49.40; H, 4.56; Br, 32.87; S, 13.18. Found: C, 49.52; H, 4.59; Br, 32.86; S, 13.35.

3-Bromo-4-phenylthiophene (10).—2,3,5,6-Tetrachlorobenzoquinone (66.6 g, 0.271 mol, purified by one recrystallization from benzene) was dissolved in refluxing anhydrous xylene (380 ml) contained in a three-necked, 1-l. flask under anhydrous conditions. After addition of a solution of 3-bromo-4-(1-cyclohexenyl)thiophene (**9**, 32.0 g, 0.132 mol) over a 5-min period, the reaction mixture was heated under reflux for 10 hr (*caution*, acidic fumes). The dark red solution was cooled below room temperature in an ice bath, which resulted in the formation of a voluminous amount of solid. The solid was separated by filtration and the filter cake was washed with small portions of cold xylene. The filtrate was washed with 20-ml portions of 2 *M* sodium hydroxide until the washings were clear (eight washings are required), twice with water, and twice with brine, dried ($MgSO_4$), and concentrated to give 31.2 g of red solid which was dissolved in a minimum amount of benzene and chromatographed on a 4.45 cm × 48 cm column containing 640 g of unactivated Alcoa F-20 alumina. The column was eluted with 6 l. of hexane. Concentration of eluent left 23.0 g (72%) of white solid, mp 62–68°. Recrystallization from methanol afforded an analytical sample: mp 69–70°; nmr ($CDCl_3$) τ 2.65 (s, 5, C_6H_5), 2.73 (d, 1, J = 3.5 Hz), and 2.85 (d, 1, J = 3.5 Hz).

Anal. Calcd for $C_{10}H_7BrS$: C, 50.22; H, 2.95; Br, 33.42; S, 13.14. Found: C, 50.09; H, 2.95; Br, 33.57; S, 13.27.

4-Phenylthiophene-3-carboxylic Acid (11).—To a three-necked, 100-ml flask under an atmosphere of dry nitrogen was added ethereal 2.11 *M* *n*-butyllithium (10.9 ml, 0.023 mol). This solution was cooled to −70° and 3-bromo-4-phenylthiophene (**10**, 5.0 g, 0.021 mol) in anhydrous ether (35 ml) was added over a 5-min period. The mixture was allowed to stir for 10 min at −70° before a large excess of Dry Ice was added cautiously through Gooch tubing. The mixture was allowed to warm to room temperature and water (35 ml) was added. The aqueous layer was separated and was washed twice with ether. The combined ether layers were washed once with water. The combined aqueous layers were cooled and acidified with 1 *M* hydrochloric acid (28 ml, pH 2). The precipitated acid was filtered, washed with small portions of cold water, and dried to give 3.6 g (84%) of white solid, mp 203–206°.

Recrystallization from methanol offered an analytical sample, mp 206–208°. In subsequent runs more satisfactory recrystallization from benzene occurred: ir (KBr) 1675 cm^{-1} (acid C=O); nmr (DMSO-d_6) τ 1.78 (d, 1, J = 3.5 Hz, H-2), 2.57 (d, 1, J = 3.50 Hz, H-5), and 2.63 (s, 5, C_6H_5).

Anal. Calcd for $C_{11}H_8O_2S$: C, 64.69; H, 3.95; S, 15.70. Found: C, 64.46; H, 4.07; S, 15.98.

8H-Indeno[1,2-*c*]thiophen-8-one (12).—To a hot suspension of 4-phenylthiophene-3-carboxylic acid (**11**, 12.6 g, 0.0616 mol) in dry benzene (164 ml) was added thionyl chloride (5.05 ml). The mixture was allowed to reflux for 2 hr, during which time the white suspension dissolved to give a pale yellow solution. Removal of benzene left the crude acid chloride, which was treated in a manner identical with that used to prepare the acid chloride of **7**, ir (neat) 1770 cm^{-1} (acid chloride C=O).

A solution of the crude acid chloride obtained above in reagent carbon disulfide (100 ml) was added over a 5-min period to a suspension of aluminum chloride (18.75 g, 0.141 mol) and reagent carbon disulfide (240 ml) contained in a three-necked, 1-l. flask under anhydrous conditions. The resulting brown mixture was heated under reflux for 24 hr and was then cooled and poured onto a mixture of 1 *M* hydrochloric acid (75 ml) and ice with stirring. The carbon disulfide layer was separated and evaporated, and the residue was dissolved in ether. The aqueous phase was extracted twice with ether. The combined ether layers were washed once with water and twice with brine, dried, ($MgSO_4$), and concentrated to leave 8.9 g (91%) of yellow solid, mp 88–90°.

An analytical sample was prepared by recrystallization from ethanol followed by sublimation at 80° (0.1 mm): mp 90–90.5°; uv max (95% C_2H_5OH) 256 mμ (sh, ϵ 48,000) and 263.5 (60,900); ir (KBr) 1720 cm^{-1} (ketone C=O); nmr ($CDCl_3$) τ 2.35 (d, 1, J = 2 Hz, H-1), 2.99 (d, 1, J = 2 Hz, H-3), and 2.5–2.9 (m, 4, C_6H_4).

Anal. Calcd for $C_{11}H_6OS$: C, 70.94; H, 3.25; S, 17.22. Found: C, 70.71; H, 3.14; S, 17.46.

8H-Indeno[1,2-*c*]thiophene (3).—The apparatus was assembled as described for **2** with a three-necked, 500-ml flask. 8H-Indeno[1,2-*c*]thiophen-8-one (**12**, 5.13 g, 0.0276 mol), potassium hydroxide (5.13 g), 95% hydrazine (10.25 ml), and diethylene glycol (51 ml) were mixed at 45° (oil-bath temperature). Over a 30-min period the mixture was heated to 200° which was maintained for 45 min. The mixture was cooled, water (100-

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(15) The *n*-butyllithium used in these carbonation reactions was analyzed by the double-titration method: H. Gilman and R. Jones, *Org. Reactions*, **6**, 339 (1951).

ml portions) was added, and the mixture was distilled until 800 ml of distillate had been collected. The distillate was extracted with three portions of ether. The ether extracts were washed three times with water and twice with brine, dried ($MgSO_4$), and concentrated to leave 2.85 g (60%) of tan solid, mp 88-92°. This solid was dissolved in a minimum amount of benzene and chromatographed on a 1.58 × 28.5 cm column packed with unactivated Alcoa F-20 alumina. Elution with 1 l. of hexane followed by concentration left 2.06 g of white solid, mp 90-92°. Recrystallization of a small sample from methanol afforded an analytical sample: mp 92-93°; uv max (95% C_2H_5OH) 230 mμ (ϵ 5630), 238 (8300), 264.5 (16,000), 273 (16,700) 280 (sh, 7100), 287 (8,600), and 299 (13,410); nmr ($CDCl_3$) τ 2.30-3.05 (m, 6, $C_{10}H_6S$) and 6.30 (s, 2, $C_6H_4CH_2C_4H_2S$).

Anal. Calcd for $C_{11}H_8S$: C, 76.69; H, 4.68; S, 18.62. Found: C, 76.53; H, 4.62; S, 18.78.

8H-Indeno[1,2-*c*]thiophene-3-carboxylic Acid (16).—A 100-ml, three-necked flask fitted with a calcium chloride drying tube, reflux condenser, and pressure-equalizing addition funnel was flame dried under a stream of nitrogen. To a solution of **3** (0.50 g, 2.90 mmol, homogeneous by tlc) dissolved in anhydrous ether (30 ml) was added ethereal 1.26 *M* *n*-butyllithium[15] (2.30 ml, 2.90 mmol). The solution turned dark red immediately upon addition of the *n*-butyllithium and was refluxed for 30 min. Refluxing was stopped and the reaction was quenched with *ca.* 10 g of freshly chipped Dry Ice. Several minutes after the vigorous reaction had subsided, water (20 ml) was added and the layers were separated. The aqueous layer was washed with four portions of ether and the ether solutions were back washed with one portion of water. The aqueous layers were combined, cooled, acidified with 1 *M* hydrochloric acid, and extracted with three portions of ether. The ether solution was washed with two portions of water and two portions of brine, dried ($MgSO_4$), and evaporated to leave 0.28 g (45%) of acidic material.

The neutral ether solution was evaporated to yield 0.10 g of unchanged starting material.

An analytical sample of **16** was obtained by recrystallization from benzene-hexane of a sample obtained in a similar experiment: mp 209-210° dec; ir (KBr) 1640 cm^{-1} (acid C=O); nmr (acetone-*d*) τ 1.25 (m, 1, H-4), 2.20-2.65 (m, 4, $C_{10}H_4S$), and 6.30 (s, 2, $C_6H_3CH_2C_4HS$).

Anal. Calcd for $C_{12}H_8O_2S$: C, 66.65; H, 3.73; S, 14.83. Found: C, 66.79; H, 3.78; S, 14.68.

Fluorene-4-carboxylic Acid (17).—Fluorenone-4-carboxylic acid (5 g) was reduced in the manner described by Weisburger and Weisburger:[16] yield 57%; mp 192-193° (lit.[16] mp 191-192°); ir (KBr) 1680 cm^{-1} (acid C=O); nmr ($CDCl_3$) τ −3.2 (s, 1, CO_2H), 1.5 (m, 1, H-4), 2.0-2.7 (m, 6, $C_{12}H_6$), and 6.10 (s, $C_{12}H_6CH_2$).

Anal. Calcd for $C_{14}H_{10}O_2$: C, 79.61; H, 4.77. Found: C, 79.82; H, 4.83.

Registry No.—**2**, 7260-71-1; **3**, 7260-70-0; **8**, 5706-08-1; **9**, 23062-40-0; **10**, 23062-41-1; **11**, 23062-42-2; **12**, 23062-43-3; **13**, 23062-44-4; **13** methyl ester, 23062-45-5; **16**, 23062-46-6; **17**, 6954-55-8.

Acknowledgment.—The authors wish to thank Mr. Robert Smith, Mr. Donald Wieland, and Kiyoshi Yamauchi for recording the nmr spectra.

(16) E. K. Weisburger and J. H. Weisburger, *J. Org. Chem.*, **20**, 1396 (1955).

Azepinoindoles. IV.[1] 1,2,3,4,5,10-Hexahydroazepino[3,4-*b*]indole and 1,2,3,4,5,10-Hexahydroazepino[2,3-*b*]indole

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Received August 11, 1969

The selective preparation of both 3,4,5,10-tetrahydroazepino[3,4-*b*]indol-1(2H)-one (**5**) and 3,4,5,10-tetrahydroazepino[2,3-*b*]indol-2(1H)-one (**14**) from 1,2,3,4-tetrahydrocarbazol-1-one *via* the Beckmann rearrangement is described. Rapid air oxidation of the initial product derived from the lithium aluminum hydride reduction of **14** gave 2,3,4,5-tetrahydroazepino[2,3-*b*]indol-5a(1H)-ol (**17**). The proof of structure **17** and some of its interesting chemistry is discussed.

Recently,[2] we reported the selective preparation of 3,4,5,6-tetrahydroazepino[4,3-*b*]indol-1(2H)-one and 3,4,5,6-tetrahydroazepino[3,2-*b*]indol-2(1H)-one *via* the Beckmann rearrangements of the oxime and tosyloxy oxime of 1,2,3,4-tetrahydrocarbazol-4-one with polyphosphoric acid and deactivated alumina, respectively. Concurrent with this study we investigated the preparation and chemistry of 3,4,5,10-tetrahydroazepino[3,4-*b*]indol-1(2H)-one (**5**) and 3,4,5,10-tetrahydroazepino-[2,3-*b*]indol-2(1H)-one (**14**). The latter investigation is the subject of the present discussion.

The reaction of 1,2,3,4-tetrahydrocarbazol-1-one (**1**)[3] with hydroxylamine (Chart I) gave a mixture of oximes **3** and **7** which could be separated by silica gel chromatography. Both oximes underwent a facile rearrangement in polyphosphoric acid to give the same lactam **5** in 73-85% yield.[4] This compound **5** was also obtained by the reaction of **1** with sodium azide in polyphosphoric acid.[5] Positive identification of **5** was supplied by its characteristic uv spectrum and by its lithium aluminum hydride reduction to **6**, which had previously been reported in the literature[6] and had an nmr singlet at δ 4.00 for the C-1 protons. Alkylation of **5** with triethyloxonium fluoroborate[7] gave the expected imino ether **11**, which reacted with amines to give amidines such as **12** and **13**.[8]

Since it was apparent that in polyphosphoric acid, analogous to our previous results,[2] oxime **7** was undergoing a facile isomerization to **3** prior to Beckmann rearrangement, we employed the method of Craig and Naik[9] for the preparation of **14**. Oximes **3** and **7** were converted into the corresponding tosyloxy derivatives **4** and **8** with *p*-toluenesulfonyl chloride in pyridine. Rearrangement of **4** with neutral alumina, which had been deactivated with 1% water, gave **5** in 81% yield. The analogous rearrangement of **8** on alumina which had been deactivated with 0.5% water gave the iso-

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(1) Part III: J. B. Hester, Jr., *J. Org. Chem.*, **32**, 4095 (1967).

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(3) S. Coffee, *Rec. Trav. Chim. Pays-Bas*, **42**, 528 (1923).

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