Synthesis and Isolation of Some Benzo[*c*]tellurophenes

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Received January 25, 2000

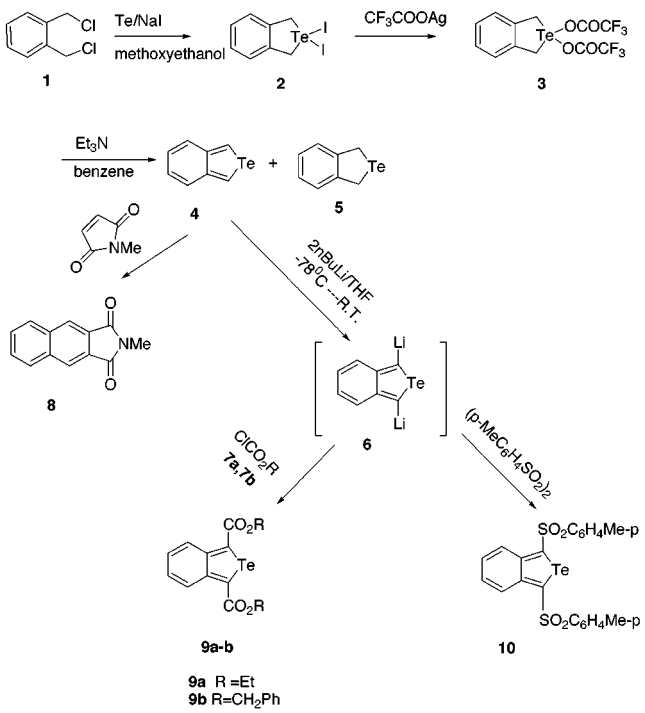
Introduction

The highly reactive *o*-quinonoid heterocycles benzo[*c*]-furan and benzo[*c*]thiophene have received much attention, both from the synthetic and the theoretical points of view.[1,2] In contrast, the unstable benzo[*c*]selenophene was generated by us via a base-catalyzed selenoxide dehydration[3] but was not further examined. The generation of the unstable benzo[*c*]tellurophene **4** appeared only fairly recently.[4] In contrast to reports on benzo[*b*]tellurophenes,[5] which are quite stable, the *o*-quinonoid benzo[*c*]tellurophene was found to be highly reactive. Herein we would like to report fully on the systematic synthesis of benzo[*c*]tellurophenes **4**, **13**, and **18**, as well as the functionalization of **4** to yield substituted **9a**, **9b**, and **10**.

Results and Discussion

1,3-Dihydro-2,2-diiodobenzo[*c*]tellurophene **2** can be prepared readily by the reaction of 1,2-bis(chloromethyl)-benzene **1** with tellurium and sodium iodide in methoxyethanol.[6] All attempts to eliminate the elements of hydrogen iodide from a base catalysis met with failure. It was found that triethylamine in refluxing benzene led to a very low yield of **4** via dehydroiodination, the major product being the deiodinated **5**. However, replacement of iodine in **2** by trifluoroacetate and subsequent treatment of the trifluoroacetate **3** with triethylamine under defined conditions cleanly produced benzo[*c*]tellurophene **4** and 1,3-dihydrobenzo[*c*]tellurophene **5**, in a ratio of 8:1 as estimated by the NMR spectrum. Benzo[*c*]tellurophene **4** is relatively more stable in benzene than in more polar solvents. Its solution in benzene can be frozen and stored below 0 °C for several months. However, on removal of the benzene it decomposed rapidly. The use of limited quantities of *n*-butyllithium removed 1,3-dihydrobenzo-[*c*]tellurophene **5**, and a sample of relatively pure benzo-

Scheme 1



[*c*]tellurophene **4** was obtained in low yield as a grayish white solid. Reaction of **4** with *N*-methylmaleimide furnished *N*-methylnaphthalimide (**8**).

The functionalization of the electron-rich benzo[*c*]-tellurophene **4** was studied. Direct introduction of various electrophiles via Friedel−Crafts reactions was unsuccessful as a result of the instability of the ring to acid. However, dilithiation was achieved by reaction with excess *n*-butyllithium, as evidenced by the formation of diesters **9a** and **9b** and the disulfonyl derivative **10**, in 60−70% yields, by quenching with the appropriate electrophiles **7a**, **7b**, and *p*-toluenesulfonic anhydride**,** respectively (Scheme 1). These diesters and the disulfonyl derivative **10** were relatively more stable than the parent heterocycle **4**. Interestingly enough, no monosubstituted derivatives were identified or isolated in these reactions.

Other electrophiles, such as acetyl chloride, benzoyl chloride, cyanogen bromide, *tert*-butyldimethylsilyl chloride, and trifluoroacetic anhydride failed to give isolable products with the dianion.

Attention was then focused on the synthesis of **13**, a benzo[*c*]tellurophene bearing an electron-withdrawing group (NO_2) on the six-membered ring. The known 4-nitro-*o*-xylene was converted to the dibromide **11** by reaction with *N*-bromosuccinimide and light. Crude dibromide **11** was directly converted to the 1,3-dihydrotellurophene diiodide **12** in 90% yield by reaction with tellurium and sodium iodide in methoxyethanol (Scheme 2). Not surprisingly, dehydroiodination proved facile upon treatment of **12** with triethylamine in refluxing benzene, leading to the isolation of the benzo[*c*]tellurophene **13** by direct crystallization of the product. Although **13** was stable at ambient temperature and atmosphere for several weeks, it did decompose upon prolonged exposure to air, and it was also sensitive to acid.

(1) (a) Dean, F. M. Furans and Their Benzo Derivatives. In *Comprehensive Heterocyclic Chemistry*; Katritzky, A. R., Rees, C. W., Eds.; Pergamon Press: Elmsford, 1984; Vol. 4, pp 531−712. (b) Friedrichsen, W. *Adv. Het. Chem.* **1980**, *26*, 135.

(2) (a) Kellogg, R. M. Thiophenes and Their Benzo Derivatives. In *Comprehensive Heterocyclic Chemistry*; Katritzky, A. R., Rees, C. W., Eds.; Pergamon Press: Elmsford, 1984; Vol. 4, pp 713−863. (b) Iddon, B. *Adv. Het. Chem.* **1972**, *14*, 331.

(3) Saris, L. E.; Cava, M. P. *J. Am. Chem. Soc.* **1976**, *98*, 867.

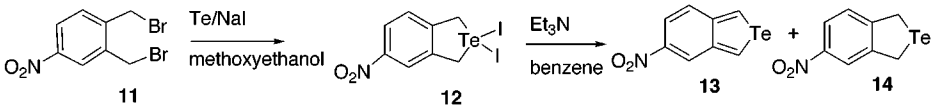
(4) Morkved, E. H.; Lakshmikantham, M. V.; Cava, M. P. *Tetrahedron Lett.* **1996**, *37*, 9149.

(5) Detty, M. R.; O'regan, M. B. Tellurium-Containing Heterocycles. In *The Chemistry of Heterocyclic Compounds*; Taylor, E. C., Ed.; John Wiley & Sons, Inc.: New York, 1994; Vol. 35, pp 71−80.

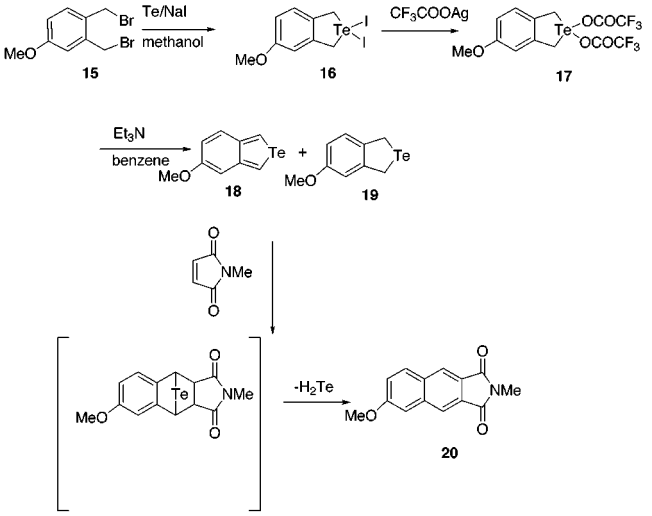
(6) Ziolo, R. F.; Gunther, W. H. H. *J. Organomet. Chem.* **1978**, *146*, 245.

10.1021/jo0001030 CCC: $19.00
Published on Web 07/27/2000

Scheme 2



Scheme 3



Finally, 5-methoxybenzo[*c*]tellurophene (**18**) was generated from the bistrifluoroacetate **17**, which in turn was made as depicted in Scheme 3. As expected, it was even less stable than **4**, precluding isolation. However, it was characterized by NMR and was trapped by *N*-methylmaleimide to give the naphthalimide **20** by spontaneous loss of the elements of hydrogen telluride.

Conclusion

The elusive benzo[c]tellurophene has been synthesized and funtionalized on the tellurophene ring via lithiation and treatment with electrophiles. The nitro and methoxy analogues have been made, the former being more stable than the latter.

Experimental Section

General Comments. Melting points are uncorrected. THF was freshly distilled from sodium−benzophenone. All mass peaks containing Te are reported for Te.[130]

Synthesis of 1,3-Dihydro-2,2-bis(trifluoroacetoxy)-benzo[*c*]tellurophene 3. A mixture of 2,2-diiodo-1,3-dihydrobenzo-[*c*]tellurophene **2**[6] (4.86 g, 10 mmol) and silver trifluoroacetate (4.42 g, 20 mmol) in benzene (200 mL) was stirred at room temperature for 2 h. After filtration, the filtrate was concentrated to give 1,3-dihydro-2,2-bis(trifluoroacetoxy)-benzo[*c*]tellurophene **3** (4.17 g, 91%). Mp: 160 °C (dec). ^{1}H NMR (C_6D_6) δ: 6.72 (dd, J = 5.7, 3.3 Hz, 2 H), 6.49 (dd, J = 5.1, 3.2 Hz, 2 H), 3.83 (s, 4 H). ^{13}C NMR (C_6D_6) δ: 162.4, 161.9, 137.8, 130.2, 128.6, 116.9, 113.7, 47.8.

Benzo[*c*]tellurophene 4. A mixture of 1,3-dihydro-2,2-bis-(trifluoroacetoxy)- benzo[*c*]tellurophene **3** (0.916 g, 2 mmol) and triethylamine (2.02 g, 20 mmol) in degassed benzene (200 mL) was refluxed under argon for 15 min. The resulting solution was washed with deionized water (200 mL × 2) and dried over sodium sulfate. Removal of solvent in vacuo at room temperature resulted in a mixture (0.36 g) of benzo[*c*]tellurophene **4** and 1,3-dihydro-benzo[*c*]tellurophene **5**. ^{1}H NMR ($CDCl_3$) (**4**) δ: 9.34 (s, 2 H), 7.32 (dd, J = 7.00, 3.20 Hz, 2 H), 6.72 (dd, J = 6.72, 2.92 Hz, 2 H) and that of **5** at δ 7.2, m (2H), 7.05m (2H), 4.5 s (4 H); a comparison of the intensities of the α H in **4** (9.34 s) to the benzylic H in **5** (4 H) at δ 4.5 showed a 8:1 ratio of **4**:**5**, the concentration of **4** being ∼89% in the mixture isolated in 78% yield.

Isolation of 4. The crude product mixture of **4** and **5** from the bistrifluoroacetate **3** (0.92 g) in dry benzene was cooled in an ice bath and was treated with TMEDA (0.210 g) followed by *n*-BuLi; after 1.5 h the mixture was quenched with water and worked up. The resulting oily product was dissolved in hexane and freed of an insoluble precipitate, and the solution in hexane was chilled (−78 °C) to give **4**, mp darkens ∼55 °C and melts at 70 °C. ^{1}H NMR (C_6D_6) δ: 8.84 s (2 H), 7.2 dd (2 H), 6.64 dd (2 H). MS *m/e* (relative intensity): 232 (M^+ ,100) 230 (95%), 103 (34%).

Diels−Alder Reaction of 4 with *N*-Methylmaleimide to Furnish Naphthalimide 8. A solution of benzo[c]tellurophene **(4)** was prepared from **3** as above, treated with a solution of *N*-methylmaleimide (0.111 g) in benzene (1 mL), refluxed for 2 h, and then stirred at 50−55 °C for 2 days. After removal of solvent, the residue was purified by column chromatography to give naphthalimide **8** (0.085 g. 45%). Mp 203−204 °C (lit.[7] 204−205 °C). ^{1}H NMR ($CDCl_3$) δ: 8.31 (5.24), 8.04 (dd. J = 6.1, 3.3 Hz, 2 H), 7.69 (dd, J = 6.2, 3.2 Hz, 2H), 3.25 (6 H). ^{13}C NMR ($CDCl_3$) δ: 168.3, 135.6, 130.5, 128.3, 128.1, 124.7, 24.4. MS *m/e* (relative intensity): 211 (M^+, 100).

1,3-Difunctionalized Benzo[*c*]tellurophenes 9a, 9b, and 10. A solution of benzo[*c*]tellurophene **4** in benzene prepared as above was concentrated to about 2 mL at room temperature. This solution was diluted with THF (20 mL), and a hexane solution of *n*-butyllithium (5.6 mmol, 2.5 M) was added dropwise at −70 °C. The reaction mixture was kept at room temperature for 1 h and recooled to −70 °C, and a solution of alkyl chloroformate **7a** or **7b** (5.6 mmol) in THF (5 mL) or *p*-toluenesulfonic anhydride (4.2 mmol) in THF (30 mL) was added. The reaction mixture was warmed to room temperature gradually and stirred for 1 h. The resulting mixture was washed with a saturated solution of sodium carbonate (5 mL), dried, and concentrated. The oily residue was subjected to column chromatography (SiO_2) to obtain 1,3-dialkoxycarbonyl-substituted benzo[*c*]tellurophenes **9a**, **9b**, or 1,3-ditosyl substituted benzo[*c*]tellurophene **10**.

1,3-Diethoxycarbonylbenzo[*c*]tellurophene 9a. Yield: 76%, mp 153−155 °C. ^{1}H NMR ($CDCl_3$) δ: 8.48 (dd J = 7.1 3.1 Hz, 2 H); 7.19 (dd, J = 7.1, 3.1 Hz, 2 H), 4.40 (q, J = 7.2 Hz, 4 H), 1.43 (t, J = 7.1 Hz). ^{13}C NMR ($CDCl_3$) δ: 166.8, 151.1, 138.0, 126.7, 124.5, 61.8, 14.6. MS *m/e* (relative intensity): 376 (M^+, 100), 374 (96) 331(61.7), 303 (89.4), 274 (20.6), 230 (22.7). HRMS calcd for $C_{14}H_4O_4Te^{130}$ 375.995438, found 375.994363.

1,3-Dibenzyloxycarbonylbenzo[*c*]tellurophene 9b. Yield: 74%, mp 103−105 °C. ^{1}H NMR ($CDCl_3$) δ: 8.51 (dd, J = 7.1, 3.7 Hz, 2 H), 7.28−7.48 (m, 10 H). 7.21 (dd, J = 7.0, 3.0 Hz, 2 H), 5.37 (s, 4 H). ^{13}C NMR ($CDCl)_3$ δ: 166.4, 151.4, 137.5, 136.0, 130.1, 128.9, 127.4, 126.9, 124.5, 67.4. MS *m/e* (relative intensity): 500 (M^+, 66.5), 393 (18.9). 366 (82.3), 232 (100), 191 (50.7). HRMS calcd for $C_{24}H_{18}O_4Te^{130}$ 500.026738, found 500.026093

1,3-Ditosylbenzo[*c*]tellurophene 10. Yield: 61%, mp 170 °C (dec). ^{1}H NMR ($CDCl_3$) δ: 7.93 (d, J = 7.2 Hz, 4 H), 7.78 (dd, J = 7.0, 3.0 Hz, 2 H), 7.30 (d, J = 7.2 Hz, 4 H), 7.11 (dd, J = 7.0, 3.1 Hz, 2 H), 2.39 (s, 6 H). ^{13}C NMR ($CDCl_3$) δ: 153.0, 147.1, 144.8, 138.0, 130.3, 128.2, 127.2, 122.5, 21.8. MS *m/e* (relative intensity): 540 (M^+, 29), 262 (17.7), 218 (27.8), 139 (120). HRMS calcd for $C_{22}H_{18}O_4S_2Te^{130}$ 539.970882, found 539.969774.

1,3-Dihydro-2,2-diiodo-5-nitrobenzo[*c*]tellurophene 12. A mixture of 4-nitro-*o*-xylene (1.51 g, 10 mmol) and *N*-bromosuccinimide (3.56 g, 20 mmol) in 1,2-dichloroethane (20 mL) was refluxed under illumination (250 W incandescent bulb) for 20 min. The reaction mixture was washed with water (20 mL × 2) and dried over sodium sulfate. Removal of solvent gave crude 1,2-bis(bromomethyl)-5-nitrobenzene **11** (yield 70%). The mixture of the crude compound **11** (7 mmol), finely powdered

(7) Gompper, R. *Chem. Ber.* **1960**, *93*, 198.

tellurium (0.768 g, 6 mmol) and sodium iodide (3.60 g, 24 mmol) in 2-methoxyethanol (10 mL) was refluxed for 20 min. Water (20 mL) was added, and the resulting precipitate was filtered and washed with water (20 mL) and ethyl ether (40 mL × 3) to give 1,3-dihydro-2,2-diiodo-5-nitrobenzo[*c*]tellurophene **12** (2.90 g, 91%). Mp 230−232 °C. ^{1}H NMR (DMSO-d_6) δ: 8.25 (s, 1 H), 8.11 (d, J = 8.5 Hz, 1 H), 7.62 (d, J = 8.3 Hz, 1 H), 4.82 (s, 2 H), 4.80 (s, 2 H). ^{13}C NMR ($CDCl_3$) δ: 147.9, 146.8, 142.3, 130.6, 124.5, 122.0, 45.9.

Synthesis of 5-Nitrobenzo[*c*]tellurophene 13. A mixture of 1,3-dihydro-5-nitro-2,2-diiodobenzo[*c*]tellurophene **12** (0.531 g, 1.0 mmol) and triethylamine (1.01 g, 10 mmol) in benzene (50 mL) was refluxed for 40 min under argon. The resulting mixture was washed with water (50 mL × 2), dried, and concentrated. The residue was purified by crystallization from Et_2O/*n*-C_5H_{12} to furnish 5-nitrobenzo[*c*]tellurophene **13** (0.17 g, 62%). Mp 90 °C (dec). ^{1}H NMR ($CDCl_3$) δ: 9.99 (s, 1 H), 9.53 (s, 1 H), 8.42 (s, 1 H), 7.62 (d, J = 9.6 Hz, 1 H), 7.44 (d, J = 9.6 Hz, 1 H). ^{13}C NMR ($CDCl_3$) δ: 147.9, 145.9, 134.3, 128.5, 126.9, 126.0, 123.1, 115.8. MS *m*/*e* (relative intensity): 277 (M^+, 100), 275 (73), 231 (69.5), 219 (33.3), 218 (27.8), 139 (100). HRMS calcd for $C_8H_5NO_2Te^{130}$ 276.938257, found 276.936188

1,3-Dihydro-2,2-diiodo-5-methoxybenzo[*c*]tellurophene16. A mixture of 3,4-dimethylanisole (1.36 g, 10 mmol) and *N*-bromosuccinimide (3.74 g, 21 mmol) in dichloromethane (90 mL) was refluxed under illumination (250 W incandescent bulb) for 40 min. The reaction mixture was washed with water (90 mL × 2) quickly and dried over sodium sulfate. Removal of solvent resulted in the crude 1,2-bis(bromomethyl)-5-methoxybenzene **15** (yield 60%). The mixture of the crude compound **15** (6 mmol), finely powdered tellurium (0.384 g, 3 mmol), and sodium iodide (3.60 g, 24 mmol) in dry methanol (15 mL) was refluxed for 30 min, resulting in the formation of diiodide **16**. Water (30 mL) was added. After filtration, the precipitate was washed with ethyl ether (40 mL × 3) to give 1,3-dihydro-2,2-diiodo-5-methoxylbenzo[*c*]tellurophene **16** (0.960 g, 36% overall). Mp 205 °C (dec). ^{1}H NMR (DMSO-d_6) δ: 7.22 (d, J = 8.4 Hz, 1 H), 6.87 (s, 1 H), 6.84 (d, J = 8.6 Hz, 1 H), 4.75 (s, 2 H), 4.72 (s, 2 H), 3.76 (s, 3 H). ^{13}C NMR (DMSO-d_6) δ: 158.4, 141.1, 131.3, 130.0, 113.8, 113.6, 55.4, 50.8, 50.0.

1,3-Dihydro-5-methoxy-2,2-bis(trifluoroacetoxy)benzo[*c*]tellurophene 17. A mixture of 1,3-dihydro-2,2-diiodo-5-methoxybenzo[*c*]tellurophene **16** (5.16 g, 10 mmol) and silver trifluoroacetate (94.42 g, 20 mmol) in benzene (200 mL) was stirred at room temperature for 3 h. After filtration, the filtrate was concentrated to yield 1,3-dihydro-5-methoxy-2,2-bis(trifluoroacetoxy)benzo[*c*]tellurophene **17** (4.49 g, 92%). Mp 150 °C (dec). ^{1}H NMR (C_6D_6) δ: 6.53−6.38 (m, 2 H), 6.10 (s, 1 H), 3.844 (s, 2 H), 3.839 (s, 2 H), 3.18 (S, 3 H). ^{13}C NMR (C_6D_6) δ: 162.5, 162.0, 160.4, 139.5, 130.3, 129.6, 116.9, 115.0, 114.4, 113.7, 55.3, 47.6, 46.9.

Synthesis of 5-Methoxybenzo[*c*]tellurophene 18. A mixture of 1,3-dihydro-5-methoxy-2,2-bis(trifluoroacetoxy)benzo[*c*]-tellurophene **17** (0.488 g, 1 mmol) and triethylamine (1.01 g, 10 mmol) in degassed benzene (50 mL) was stirred under argon at 50−55 °C for 2.5 h. The resulting solution was washed with deionized water (200 mL × 2) and dried over sodium sulfate. Removal of the solvent at room temperature gave crude 5-methoxybenzo[*c*]tellurophene **18**. ^{1}H NMR (C_6D_6) δ: 8.84 (s, 1 H), 8.57 (s, 1 H), 7.00 (d, J = 9.5 Hz, 1 H), 6.73 (d, J = 9.7 Hz, 1 H), 6.34 (s, 1 H), 3.31 (s, 3 H), mixed with **19**.

Diels−Alder Reaction of 5-Methoxybenzo[*c*]tellurophene 18 with *N*-Methylmaleimide To Furnish Naphthalimide 20. A solution of benzo[*c*]tellurophene **18** was prepared from **17** (1 mmol) as above, treated with a solution of *N*-methylmaleimide (0.111 g, 1 mmol) in benzene (1 mL), and stirred at 50−55 °C for 2 days. After removal of solvent, the residue was purified by column chromatography to give naphthalimide **20** (0.101 g, 42%). Mp 230 °C (dec). ^{1}H NMR ($CDCl_3$) δ: 8.23 (s, 1 H), 8.19 (s, 1 H), 7.92 (d, J = 9.8 Hz, 1 H), 7.41−7.27 (m, 2 H), 3.98 (s, 3 H), 3.23 (s, 3 H). ^{13}C NMR ($CDCl_3$) δ: 168.6, 160.3, 137.5, 131.8, 130.8, 128.9, 126.0, 124.5, 123.3, 121.8, 108.7, 55.8, 24.3. MS *m*/*e* (relative intensity): 241 (M^+, 83.5), 197 (100), 156 (37.1). HRMS calcd for $C_{14}H_{11}NO_3$ 241.073893, found 241.073131.

Acknowledgment. We thank the National Science Foundation for a grant (CHE-961235 0) in support of this work.

Supporting Information Available: ^{1}H and ^{13}C NMR spectra for compounds **3**, **9a**, **9b**, **10**, **12**, **13**, **16**, **17**, and **20** and ^{1}H NMR spectra for the highly labile compounds **4** and **18.** This material is available free of charge via the Internet at http://pubs.acs.org.

JO0001030