

SYNTHESIS OF FURAN- AND PYRROLE-CONTAINING α -OLIGOTHIOPHENES VIA 1,4-DIKETONES

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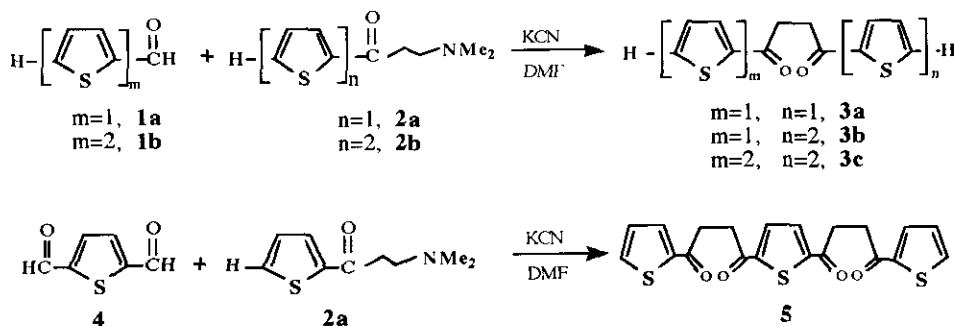
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Abstract - Cyclization of the 1,4-dithienyl-1,4-diketones (**3**) by acid catalyst furnished the α -thienylfurans, whereas condensation with ammonium acetate provided the α -thienylpyrroles. The 2,5-bis[4-(2-thienyl)-1,4-butanedionyl]thiophene (**5**) similarly gave the first syntheses of 2,5-bis[2-(5,2'-thienyl)pyrryl]thiophene (**12**) and 2,5-bis[2-(5,2'-thienyl)furyl]thiophene (**13**).

Thiophene oligomers have continually attracted much attention due to their biological activities^{1,2} and as starting materials for the preparation of organic conductors.^{3,4} Nevertheless, oligomers of similar structure such as mixed furan and thiophene or mixed pyrrole and thiophene are seldom reported.^{5,6} Here we describe a general synthetic route to a series of such heteropolyaromatic compounds *via* 1,4-diketones, yielding six linear α -polyaryls (**7**, **8**, **10**, **11**, **12**, and **13**).

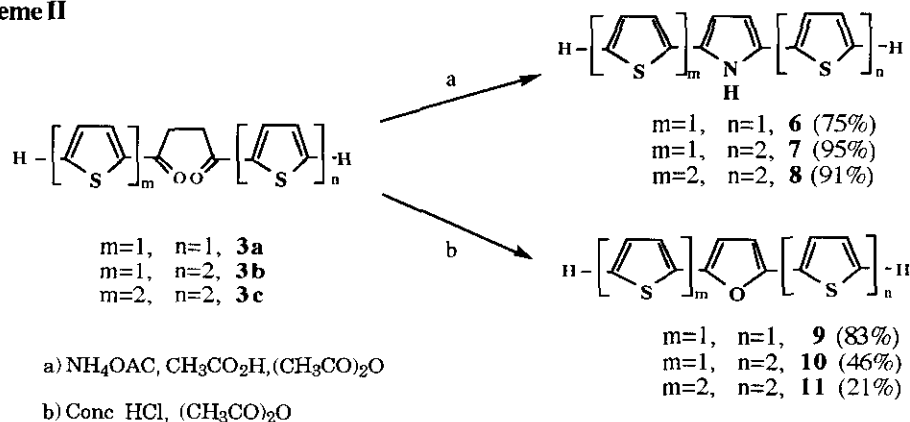
The preparation of 1,4-diketones (**3**) and bis-1,4-diketone (**5**) through the Michael addition of 2-

Scheme I

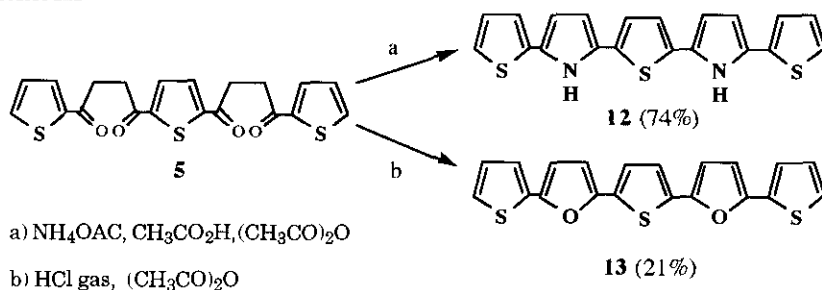


thienyl aldehydes (**1**) or (**4**) to Mannich base (**2a**), or (**2b**) has been reported by us (Scheme I).⁷ Treatment of readily accessible 1,4-diketones (**3**) with ammonium acetate in refluxing acetic acid⁸ furnished α -thienylpyrroles (**6**, **7**, and **8**) in good yields (Scheme II). The bis-1,4-diketone (**5**) similarly gave the 2,5-bis[2-(5,2'-thienyl)pyrrolyl]thiophene (**12**) in 74% yield (Scheme III).

Scheme II



Scheme III



An additional advantage of our strategy is that these 1,4-diketones (**3**) also allow to synthesize the other mixed heteroaromatic systems containing furan moiety such as (**9**, **10**, and **11**) (Scheme II). Closure of the 1,4-diketone (**3**) to the furan ring was accomplished with a catalytic amount of concentrated hydrochloric acid in acetic anhydride at 85-90 °C.⁹ Whereas, cyclization of the bis-1,4-diketone (**5**) with HCl gas in acetic anhydride at 75-80 °C gave 2,5-bis[2-(5,2'-thienyl)furyl]-thiophene (**13**) in 21% yield (Scheme III).

In conclusion, we have described a general route to heteropolyaromatic compounds (**6-13**).

The utilization of a 1,4-diketone moiety in the synthetic strategy allows for both systems to be obtained from a single precursor.

EXPERIMENTAL

Acetic anhydride was dried by distillation under argon from calcium hydride. Acetic acid was dried by distillation under argon from triacetyl borate.¹⁰ Ammonium acetate was dried in a vacuum oven at 50 °C. All reactions were performed under a nitrogen atmosphere unless otherwise mentioned. Nmr spectra (¹H and ¹³C) were recorded on a Varian Gemini 200 MHz. Mass spectra were obtained on a Jeol SX-102A instrument. Melting points are uncorrected. Infrared spectra were recorded on a Perkin Elmer System 2000 FT-IR apparatus. Ultraviolet spectra were obtained on a Hitachi U-3200 spectrophotometer. Elemental analyses were carried out on a Heraeus Elemental Analyzer.

2,5-Di(2-thienyl)pyrrole (6)

A mixture of 1,4-di(2-thienyl)-1,4-butanedione (**3a**) (200 mg, 0.8 mmol) in acetic acid (3.2 ml) was charged with anhydrous NH₄OAc (1.23 g, 16 mmol) and acetic anhydride (0.8 ml, 8.4 mmol). The reaction mixture was refluxed for 4 h. The cooled solution was poured into 50 ml of aqueous saturated sodium carbonate solution. The solution was extracted with diethyl ether (3 x 40 ml). The combined organic layers were washed with saturated NaCl solution, dried over anhydrous MgSO₄, and concentrated in vacuo. The residue was column chromatographed (silica gel, ethyl acetate) to give the title compound (140 mg, 75%) as a pale yellow solid, mp 80-82 °C (lit.,⁶ 83-84 °C).

2-[2-(5,2'-Bithienyl)]-5-(2-thienyl)pyrrole (7)

A mixture of 1-[2-(5,2'-bithienyl)]-4-(2-thienyl)-1,4-butanedione (**3b**) (98 mg, 0.295 mmol) in acetic acid (1.2 ml) was charged with anhydrous NH₄OAc (454 mg, 5.9 mmol) and acetic anhydride (0.3 ml, 3.2 mmol). The reaction mixture was refluxed for 48 h. The cooled solution was poured into 50 ml of aqueous saturated sodium carbonate solution. The solution was extracted with ether (3 x 40 ml). The combined organic layers were washed with saturated NaCl solution, dried over anhydrous MgSO₄, and concentrated in vacuo to give the title compound (**7**) (88 mg, 95%) as a greenish yellow solid, mp 138-140 °C; ir (KBr) 3437 cm⁻¹ (N-H); ¹H nmr(DMSO-d₆) δ 6.38 (2H, m), 7.11 (2H, m), 7.38 (6H, m), 11.62 (1H, s); ¹³C nmr(DMSO-d₆) δ

108.02, 108.29, 121.74, 122.26, 123.30, 123.48, 124.65, 124.99, 126.74, 127.87, 128.40, 132.97, 134.54, 135.48, 136.58; ms m/z (%) 313(100), 268(4), 203(4), 157(6), 121(6); uv (CHCl_3) 387.4 ($\log \epsilon$ 4.19), 245 (3.81); Anal. calcd for $\text{C}_{16}\text{H}_{11}\text{NS}_3$: C, 61.31; H, 3.54; N, 4.47. Found: C, 61.29; H, 3.57; N, 4.46; hrms calcd for $\text{C}_{16}\text{H}_{11}\text{NS}_3$ 313.0055, found 313.0051.

2,5-Bis[2-(5,2'-bithienyl)]pyrrole (8)

A suspension of 1,4-bis[2-(5,2'-bithienyl)]-1,4-butanedione (**3c**) (200 mg, 0.483 mmol) in acetic acid (2 ml) was charged with anhydrous NH_4OAc (355 mg, 4.61 mmol) and acetic anhydride (0.5 ml, 5.3 mmol). The reaction mixture was refluxed for 72 h. The greenish yellow precipitate was filtered from the cooled reaction mixture to give **8** (173 mg, 90.6%) as a brownish yellow solid, mp 215-217 °C; ir(KBr) 3409 cm^{-1} (N-H); ^1H nmr(DMSO- d_6) δ 6.43(2H, s), 7.08-7.51(10H, m), 11.69 (1H, s); ^{13}C nmr(DMSO- d_6) δ 108.55, 122.51, 123.54, 124.70, 125.05, 127.30, 128.42, 133.19, 134.33, 136.56; ms m/z (%) 395(100), 268(10), 198(26), 171(12); uv (CHCl_3) 412.2 ($\log \epsilon$ 4.54), 228.2 (4.22); Anal. calcd for $\text{C}_{20}\text{H}_{13}\text{NS}_4$: C, 60.73; H, 3.31; N, 3.54. Found: C, 60.66, H, 3.40; N, 3.54; hrms calcd for $\text{C}_{20}\text{H}_{13}\text{NS}_4$ 394.9933, found 394.9932.

2,5-Bis[2-(5,2'-thienyl)pyrryl]thiophene (12)

A mixture of 2,5-bis[4-(2-thienyl)-1,4-butanedionyl]thiophene (**5**) (100 mg, 0.24 mmol) in acetic acid (1.92 ml) was charged with anhydrous NH_4OAc (560 mg, 7.2 mmol) and acetic anhydride (0.5 ml, 5.3 mmol). The reaction mixture was refluxed for 24 h. The cooled solution was poured into 50 ml of aqueous saturated sodium carbonate solution. The solution was extracted with ether (3 x 40 ml). The combined organic layers were washed with saturated NaCl solution, dried over anhydrous MgSO_4 , and concentrated in vacuo to give the title compound (**12**) (67 mg, 73.7%) as a dark green solid, mp 206-208 °C; ir(KBr) 3437 cm^{-1} (N-H); ^1H nmr (DMSO- d_6) δ 6.34 (4H, br t, $J=2.3$ Hz), 7.09 (2H, dd, $J=3.7, 5.0$ Hz), 7.32 (2H, s), 7.38 (4H, m), 11.56 (2H, s); ^{13}C nmr(DMSO- d_6) δ 107.67, 107.92, 121.51, 122.03, 123.08, 127.24, 127.48, 127.87, 132.36, 135.64; ms m/z (%) 378(100), 189(11); uv (CHCl_3) 401.2 ($\log \epsilon$ 4.48), 240.4 (4.17); Anal. calcd for $\text{C}_{20}\text{H}_{14}\text{N}_2\text{S}_3$: C, 63.46; H, 3.73; N, 7.40. Found: C, 63.41; H, 3.72; N, 7.41; hrms calcd for $\text{C}_{20}\text{H}_{14}\text{N}_2\text{S}_3$ 378.0321, found 378.0324.

2,5-Di(2'-thienyl)furan (9)

A mixture of 1,4-di(2-thienyl)-1,4-butanedione (**3a**) (100 mg, 0.4 mmol), acetic anhydride (2 ml, 2.2 mmol), and concentrated hydrochloric acid (0.1 ml) was heated to 85-90 °C for 20 h. The

cooled solution was poured into 50 ml saturated sodium carbonate solution. The solution was extracted with ether (3 x 40 ml). The combined organic layers were washed with saturated NaCl solution, dried over anhydrous MgSO_4 , and concentrated in vacuo. The residue was column chromatographed (silica gel, ethyl acetate-hexane (1:4)) to give the title compound (**9**) (77 mg, 83%) as a white solid, mp 80-82 °C (lit.,⁵ 81-82 °C).

2-[2-(5,2'-Bithienyl)]-5-(2-thienyl)furan (**10**)

A mixture of 1-[2-(5,2'-bithienyl)]-4-(2-thienyl)-1,4-butanedione (**3b**) (100 mg, 0.3 mmol), acetic anhydride (1.83 ml, 19.4 mmol), and concentrated hydrochloric acid (0.1 ml) was heated to 85-90 °C for 25 h. The cooled solution was poured into 50 ml saturated sodium carbonate solution. The solution was extracted with ethyl acetate (3 x 40 ml). The combined organic layers were washed with saturated NaCl solution, dried over anhydrous MgSO_4 , and concentrated in vacuo. The residue was column chromatographed (silica gel, CH_2Cl_2 -hexane (1:1)) to give the title compound (**10**) (43 mg, 45.6%) as a brownish yellow solid, mp 95-97 °C; ^1H nmr(CDCl_3) δ 6.56 (2H, s), 7.18 (8H, m); ^{13}C nmr(CDCl_3) δ 107.36, 107.46, 122.83, 123.27, 123.73, 124.36, 124.52, 127.78, 127.94, 132.01, 133.36, 136.18, 137.20, 148.13, 148.78; ms m/z (%) 314(M^+ , 100), 285(10), 203(9), 157(8); uv (CHCl_3) 383.2 (log ϵ 4.34), 309.6 (3.83), 250.4 (3.90); Anal. calcd for $\text{C}_{16}\text{H}_{10}\text{OS}_3$: C, 61.12; H, 3.21. Found: C, 61.03; H, 3.32; hrms calcd for $\text{C}_{16}\text{H}_{10}\text{OS}_3$ 313.9895, found 313.9890.

2,5-Bis[2-(5,2'-bithienyl)]furan (**11**)

A mixture of 1,4-bis[2-(5,2'-bithienyl)]-1,4-butanedione (**3c**) (100 mg, 0.24 mmol), acetic anhydride (1.83 ml, 19.4 mmol), and concentrated hydrochloric acid (0.1 ml) was heated to 90-95 °C for 46 h. The cooled solution was poured into 50 ml saturated sodium carbonate solution. The solution was extracted with ethyl acetate (3 x 40 ml). The combined organic layers were washed with saturated NaCl solution, dried over anhydrous MgSO_4 , and concentrated in vacuo. The residue was column chromatographed (silica gel, CH_2Cl_2 -hexane (7:3)) to give the title compound (**11**) (20 mg, 21 %) as a greenish yellow solid, mp 189-191 °C; ^1H nmr(CDCl_3) δ 6.56 (2H, s), 7.01-7.26 (10H, m); ^{13}C nmr(CDCl_3) δ 107.64, 123.37, 123.76, 124.38, 124.58, 127.97, 131.90, 136.32, 137.20, 148.33; ms m/z (%) 396(M^+ , 100), 367(45), 335(30), 285(16); uv (CHCl_3) 400.8 (log ϵ 4.54), 350.2 (4.25), 256.0 (4.08); Anal. calcd for $\text{C}_{20}\text{H}_{12}\text{OS}_4$: C, 60.58; H, 3.05. Found: C, 60.45; H, 3.13; hrms calcd for $\text{C}_{20}\text{H}_{12}\text{OS}_4$ 395.9773, found 395.9771.

2,5-Bis[2-(5,2'-thienyl)furyl]thiophene (13)

A stirred solution of 2,5-bis[4-(2-thienyl)-1,4-butanedionyl]thiophene (**5**) (100 mg, 0.24 mmol) in acetic anhydride (10 ml, 106.0 mmol) was treated with HCl gas at 75-80 °C for 2 h. The cooled solution was poured into 30 ml ice water. The precipitate was filtered from the mixture, thoroughly washed with water. The crude product was column chromatographed (silica gel, CH₂Cl₂-hexane (1:1)) to give the title compound (**13**) (20 mg, 22%) as a yellow solid, mp 131-132 °C; ¹H nmr(CDCl₃) δ 6.57(4H, s), 7.04-7.33 (8H, m); ¹³C nmr(CDCl₃) δ 107.41, 107.53, 122.84, 123.26, 124.39, 127.79, 131.92, 133.35, 148.23, 148.81; ms m/z (%) 380(M⁺, 100), 269(8), 190(10), 121(9), 111(10); uv (CHCl₃) 415.8 (log ε 4.42), 333.8 (4.91), 247.8 (3.90), 205.6 (4.41); Anal. calcd for C₂₀H₁₂O₂S₃: C, 63.13; H, 3.18. Found: C, 63.01; H, 3.25; hrms calcd for C₂₀H₁₂O₂S₃ 380.0001, found 379.9979.

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