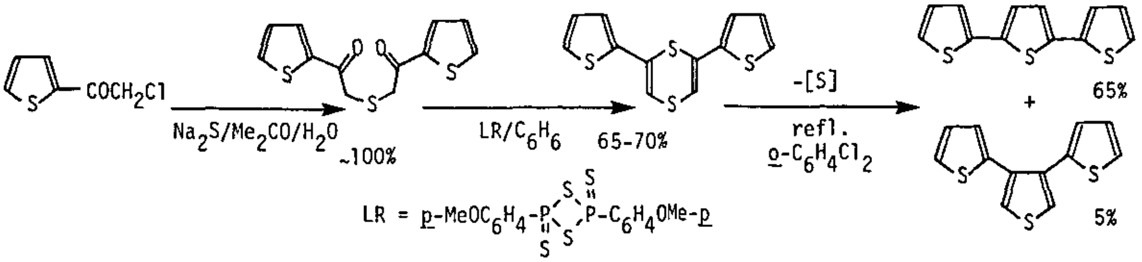
HETEROCYCLES, Vol. 26, No 7, 1987

PREPARATION OF α-QUATER-, α-SEXI-, AND α-OCTITHIOPHENES

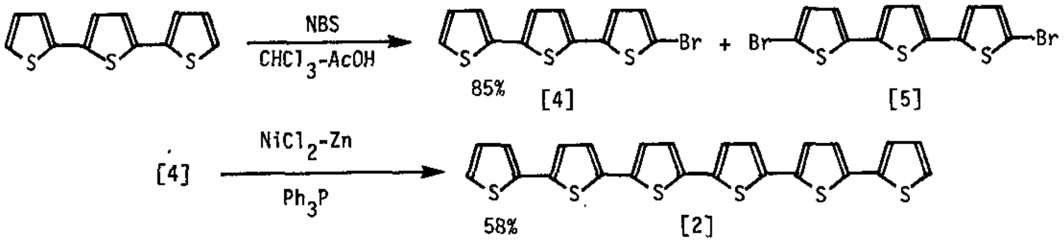
Juzo Nakayama,* Toru Konishi, Shigeru Murabayashi, and Masamatsu Hoshino
Department of Chemistry, Faculty of Science, Saitama University
Urawa, Saitama 338, Japan

Abstract — α-Quaterthiophene (1), α-sexithiophene (2), and α-octithiophene (3) (the highest member of α-oligothiophenes ever synthesized) were prepared from α-bithiophene, α-terthiophene, and α-quaterthiophene, respectively, via monobromination with N-bromosuccinimide followed by reductive coupling reaction with an activated nickel(0) reagent.

α-Oligothiophenes continue to attract much attention. Among them, studied in great detail is α-terthiophene, which shows photoenhanced activity against a wide variety of organisms[1] and also affords electroconductive, crystalline doped-polythiophene by electrochemical polymerization.[2] We have recently developed an efficient synthesis of α-ter-, α-quinque-, and α-septithiophenes.[3,4] The synthetic stratagem adopted by us involved thermal extrusion of sulfur from 2,6-diaryl-1,4-dithiins which predominantly produces 2,5-diarylthiophenes.[5,6] A typical example is found in our α-terthiophene synthesis depicted below.[3] In our systematic study on bioactivities and physicochemical properties of α-oligothiophenes, we were now faced to develop an efficient synthesis of α-quater-, α-sexi-, and α-octithiophenes (1, 2, and 3, respectively),[7] because the synthetic methodology described above is difficult to apply to the preparation of α-oligothiophenes containing even numbers of thiophene rings. Herein we report the preparation of 1, 2, and 3 by reductive coupling reaction of α-bromo derivatives of α-bi-, α-ter-, and α-quaterthiophenes, respectively.

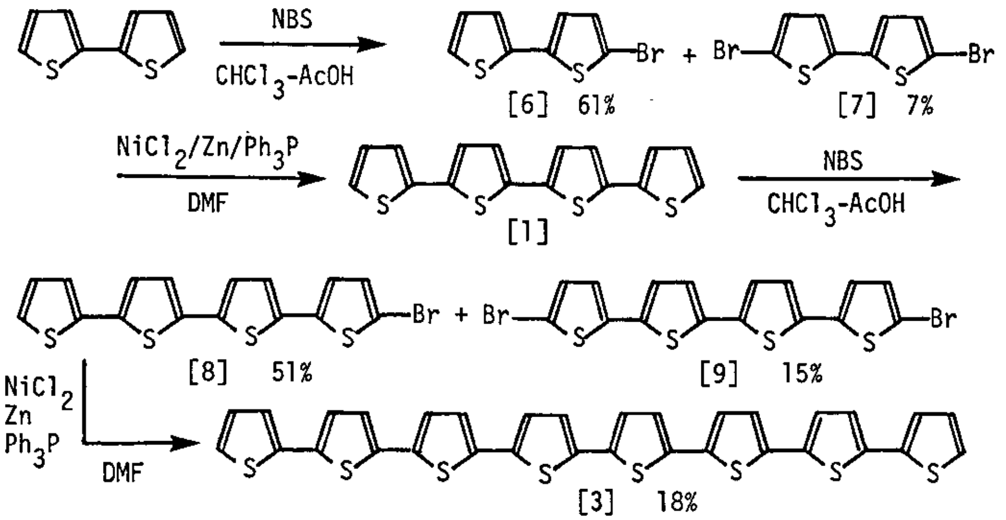


Bromination of α-terthiophene (10 mmol), which became readily obtainable in large quantities,[3] with N-bromosuccinimide (NBS, 10 mmol) in a 1:1 mixture of chloroform and acetic acid (60 ml) at room temperature produced the monobromo derivative 4, mp 135-136 °C, in 85% yield along with a small amount of the dibromo derivative 5, mp 155-157 °C. Preparation of biaryls by reductive coupling reaction of aryl halides can be attained by using a variety of metallic reagents. The coupling reagent of our choice is an activated nickel(0) reagent. Thus the reagent $Ni(PPh_3)_3$ was prepared *in situ* from 76 mg (0.6 mmol) of anhydrous nickel dichloride, 1.0 g (15.3 mg-atoms) of zinc powder, and 1.0 g (3.8 mmol) of triphenylphosphine in 10 ml of dimethylformamide (DMF) according to the literature method.[8] To this reagent was added a suspension of 1.63 g (5 mmol) of 4 in 10 ml of DMF. The mixture was heated at 70 °C for 3 h. Workup of the resulting mixture[9] gave the expected thiophene 2, mp 301-302 °C (lit.,[10] mp 304 °C), in 58% yield.[11,12]



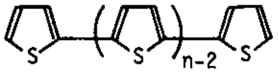
In a similar way oligothiophenes 1 and 3 were synthesized. Bromination of commercially available α-bithiophene (0.1 mol) with NBS (0.1 mol) in a 1:1 mixture of chloroform and acetic acid (400 ml) produced the monobromo derivative 6, mp 28.5-30 °C, in 61% yield and the dibromo derivative 7, mp 145-146 °C, in 7% yield. Treatment of 6 (10 mmol) with the foregoing nickel(0) reagent in DMF (30 ml) at 60-70 °C for 5 h afforded α-quaterthiophene (1), mp 215-216 °C (lit.,[10] mp 210 °C), in 66% yield.[13]

The thiophene 1 is hardly soluble in a 1:1 mixture of chloroform and acetic acid at room temperature. Bromination of 1 was therefore carried out by heating 1 (3 mmol) with NBS (3 mmol) in a 96:4 refluxing mixture of chloroform and acetic acid (155 ml). The reaction produced the monobromo derivative 8, mp 226-227 °C, in 51% yield and the dibromo derivative 9, mp 255-256 °C, in 15% yield. Separation of 8 and 9 was done by fractional recrystallization from 1,2-dichloroethane since 8 is more soluble than 9 in this solvent. The finely powdered 8 (1.5 mmol) was suspended in DMF (30 ml) containing the foregoing nickel(0) reagent and heated at 75-80 °C for 5 h. Workup of the reaction mixture[14] gave the desired thiophene 3 in 18% yield. The thiophene 3 is practically insoluble in any organic solvents and was purified by sublimation.[14] Although preparation of α-septithiophene was previously reported,[1,4,10] 3 is hitherto unknown and thus constitutes the highest member of α-oligothiophenes ever synthesized.



We have thus completed the preparation of α-ter, α-quater-, α-quinque-, α-sexi-, α-septi-, and α-octithiophenes. Their visual color and uv spectrum data are summarized in Table 1. Although their detailed chemistry is under way, the following is worthy of mention. The visual color apparently turns deep on going from α-bithiophene to α-sexithiophene, but α-sexi-, α-septi-, and α-octithiophenes are all red and closely resemble each other in appearance. In fact the bathochromic shift observed on going from α-sexithiophene to α-septithiophene is only 2 nm (though the position of λ_{max} of α-septithiophene is somewhat inaccurate because of its poor solubility in the solvent). This indicates that there exists the limit of conjugation between thiophene rings in the vicinity of six or seven thiophene rings. This is in accordance with the fact that de-doped polythiophene prepared by electrochemical polymerization of α-terthiophene is red like α-sexi-, α-septi-, and α-octithiophenes, though it consists of about 150 units of thiophene rings.[2]

Table 1. Visual Color and UV Spectrum Data (the Highest λ_{max} Value) of α-Oligothiophenes



n	2	3	4	5	6	7	8
visual color	colorless	pale yellow	chrome yellow	orange	red	red	red
$\lambda_{max}^{CHCl_3}$ (nm)	305[a]	360	391	416	438	440[b]	-[c]

a) Benzene as solvent. b) The value is somewhat inaccurate because of the poor solubility of the thiophene. c) The insolubility of the thiophene made it impossible to determine its uv spectrum.

REFERENCES AND NOTES

1. J. Kagan and S. K. Arora, *J. Org. Chem.*, 1983, **48**, 4317 and references cited therein.
2. Y. Yumoto and S. Yoshimura, *Synthetic Metals*, 1986, **13**, 185.
3. J. Nakayama, Y. Nakamura, T. Tajiri, and M. Hoshino, *Heterocycles*, 1986, **24**, 637.
4. J. Nakayama, Y. Nakamura, S. Murabayashi, and M. Hoshino, *Heterocycles*, 1987, **26**, 939.
5. J. Nakayama, H. Motoyama, H. Machida, M. Shimomura, and M. Hoshino, *Heterocycles*, 1984, **22**, 1527.
6. J. Nakayama, M. Shimomura, M. Iwamoto, and M. Hoshino, *Heterocycles*, 1985, **23**, 1907.
7. IUPAC names of 1, 2, and 3 are 2,2':5',2":5",2"'-quaterthiophene, 2,2':5',2":5",2"':5"',2"":5"",2""'-sexithiophene, and 2,2':5',2":5",2"':5"',2"":5"",2""':5""',2""":5""",2"""'-octithiophene, respectively.
8. I. Colon and D. R. Kelsey, *J. Org. Chem.*, 1986, **51**, 2627.
9. The mixture was cooled to room temperature and the precipitate was collected, washed with DMF (30 ml) and then with water, and air-dried completely. The brick-red solid was boiled with 700 ml of chlorobenzene for 1 h and filtered still hot. The filtrate was cooled to room temperature and the resulting crystalline precipitate was collected to give 0.72 g (58%) of 2.
10. W. Steinkopf, R. Leitsmann, and K. H. Hofmann, *Liebigs Ann. Chem.*, 1941, **546**, 180.
11. α-Sexithiophene was first obtained in a minuscule yield along with other thiophene oligomers by reaction of 2-iodothiophene with copper;[10] see also, W. Steinkopf, H. -J. v. Petersdorff, and R. Gording, *Liebigs Ann. Chem.*, 1937, **527**, 272. Recently this oligothiophene was synthesized from α-terthiophene via an organoborane reagent.[12]
12. J. Kagan and S. K. Arora, *Tetrahedron Lett.*, 1983, **24**, 4043.
13. For recent synthesis of α-quaterthiophene, see T. Kauffmann, *Angew. Chem.*, 1974, **86**, 321 and refs 1 and 12.
14. The reaction mixture was cooled to room temperature and the precipitate was collected, washed with DMF and then with water, dried, and washed with hot chloroform. The brown solid was suspended in 2N-HCl and stirred for 20 h to remove zinc. The insoluble red material was collected, washed with aqueous sodium bicarbonate solution and then water, dried, and subjected to sublimation. The sublimate at ∿320 °C/0.02-0.04 mmHg was discarded and the sublimate at 360-370 °C/0.02-0.04 mmHg was collected and resublimed to give 89 mg (18%) of pure α-octithiophene (3). The compound melted at 364 °C when its melting point was determined in a sealed capillary using an apparatus preheated at 360 °C, but it does not show a distinct melting point on slow heating from room temperature.
    IR (KBr) 3064, 1494, 1444, 1428, 1072, 832, 794, 688, 458 cm^{-1}. MS *m/z*, M$^+$ (relative intensity), 658 (100), 659 (42), 660 (44), 661 (16), 662 (9.5), 663 (3.0), 664 (1.3): *m/z* (relative intensity) 658 (100), 328 (100), 291 (32), 209 (36). Exact mass calcd for $C_{32}H_{18}S_8$ 657.9174, found 657.9207. Anal. Calcd for $C_{32}H_{18}S_8$: C, 58.33; H, 2.75; S, 38.92%. Found: C, 58.38; H, 2.87; S, 38.67%.

Received, 17th April, 1987