Pergamon

Tetrahedron Letters, Vol. 35, No. 49, pp. 9243-9246, 1994
Elsevier Science Ltd
Printed in Great Britain
0040-4039/94 $7.00+0.00

0040-4039(94)02008-6

The Synthesis of 4,4'(5')-Diformyltetrathiafulvalene

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Abstract: The synthesis of the title compound **9**, by three different routes, is described for the first time.

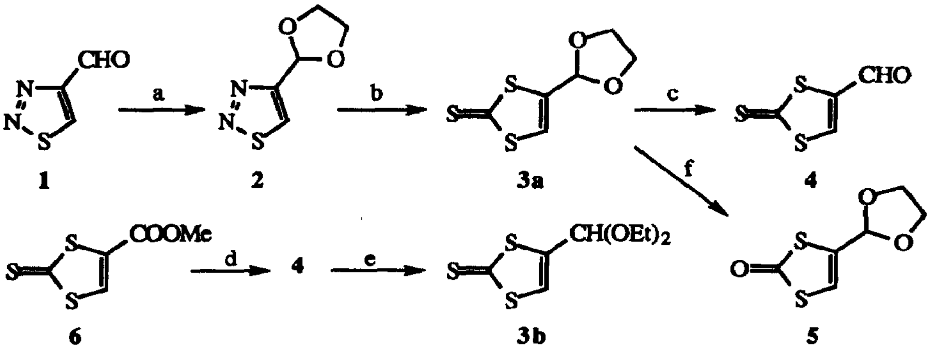
Tetrathiafulvalenes play a key role in the search for new organic conductors,[1] and therefore, a great deal of work has been devoted to the synthesis of these substances.[2] Among them, several formyltetrathiafulvalenes have been described. Monoformyl-,[3] 4,5-diformyl-,[4] and tetraformyltetrathiafulvalene[5], as well as some of their ethylenedithiotetrathiafulvalene[6a,b] and tetraselenafulvalene[6c,d] analogues have been prepared, their chemistry explored and they have emerged as versatile starting materials for the synthesis of new derivatives. Indeed, their Wittig reactions [4,7] afford new donors with extended conjugation and multi-stage redox assemblies among others, whereas aminomethyl,[8] hydroxymethyl [3b,5,6b] and nitronylnitroxide [9] derivatives (all of them prepared from the corresponding aldehydes) show interesting structural, electrical and magnetic properties in the solid state.

Given these precedents and in the search for new building blocks in tetrathiafulvalene chemistry, we became interested in the previously undescribed 4,4'(5')-diformyltetrathiafulvalene **9**, and in this communication we report the different syntheses of this compound that have been disclosed by our groups.

The first route uses 4-formyl-1,3-dithiole-2-thione (**4**) and its acetals **3** as key products (Scheme 1).

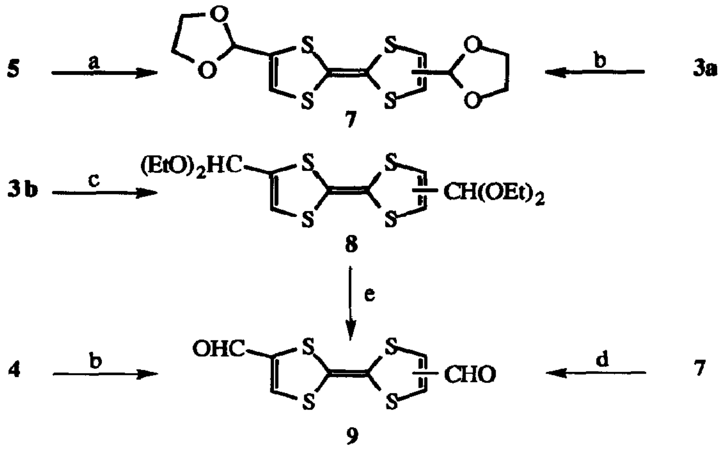
Thus, compound **1** [10] is transformed into **2**, which is converted into **3a** *via* generation of the corresponding alkynylthiolate in the presence of CS_2. In turn, **3a** can be hydrolyzed to **4** or transformed into **5** by reaction with mercury(II) acetate. Using a slightly different approach, **4** (which can also be prepared through reduction of **6** as previously described [7a] or from 4,5-diformyl-1,3-dithiole-2-thione [11]) has been converted into its diethylacetal **3b**.

Coupling of either **3a** or **5** affords the diprotected tetrathiafulvalene **7** in 30% yield, whereas coupling of **3b** gives **8**. Acidic hydrolysis of these bis(acetal) derivatives yields the desired diformyl compound **9** in good yield. On the other hand, the direct coupling of **4** to afford **9** can be carried out by using $Co_2(CO)_8$ but is quite unsatisfactory (Scheme 2).



Reagents and conditions: a: ethylene glycol, toluene, TosOH, reflux, 87%; b: CS_2, NaH, MeCN, 98%; c: H_3O^+, acetone, 98%; d: DIBALH, CH_2Cl_2, -85°C, 67%; e: $HC(OEt)_3$, EtOH, TosOH, 96%; f: $Hg(OAc)_2$, MeCN, 83%.

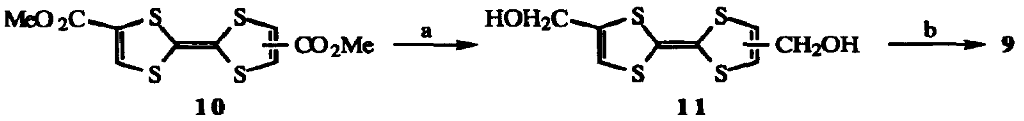
Scheme 1



Reagents and conditions: a: $P(OEt)_3$, 120°C, 30%; b: $Co_2(CO)_8$, toluene, reflux, 30% (for **3a**), 15% (for **4**); c: $P(OMe)_3$, 90°C, 18%; d: H_3O^+, 89% ; e: HCO_2H, 74%.

Scheme 2

The second route makes use of the easily available diester **10** [12] as a starting material (Scheme 3).

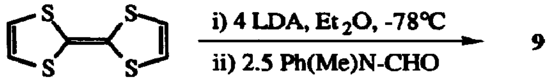


Reagents and conditions: a: DIBALH (6 eq.), THF, -10°C, 95%; b: SeO_2, dioxane, reflux, 45%.

Scheme 3

Its reduction with an excess of DIBALH in THF leads [13] to dialcohol **11** in nearly quantitative yield, in sharp contrast to the negative results already found with other reducing agents.[12b] Oxidation of this alcohol with selenium dioxide in refluxing dioxane affords the desired diformyl compound **9** in 45% yield and constitutes the key step of this approach[14], since very few oxidation reactions have been reported in TTF chemistry [15], no doubt because of its strong electron-donating properties. On the other hand, direct reduction of **10** to **9**, using DIBALH in CH_2Cl_2 at -78°C, takes place in only 13% yield.

A third route to compound **9** proceeds in one pot directly from TTF. Metalation of TTF[3] using LDA (4 equivalents) at -78°C, followed by addition of *N*-methyl-*N*-phenylformamide (2.5 equivalents) yields compound **9** (40% yield) (Scheme 4).



Scheme 4

Compound **9** is a dark red solid, isolated from each route as a mixture of (*E*) and (*Z*) isomers, as judged from its ^1H- and ^{13}C-NMR spectra.[16] Chromatographic separation of both isomers has not been achieved yet.

As could be expected, the electron-donating properties of **9** are weakened with regard to those of TTF itself, because of the strong electron-withdrawing effect of the formyl groups. Thus, cyclic voltammetry of **9** shows two reversible waves at $E_{pa}1 = 0.74$ V and $E_{pa}2 = 1.08$ V (TBA PF_6 / MeCN *vs.* Ag/AgCl, scan rate 100 mVs^{-1}); the values for TTF itself, $E_{pa}1 = 0.43$ V, $E_{pa}2 = 0.83$V.

To sum up, three different syntheses of the hitherto unreported 4,4'(5')-diformyltetrathiafulvalene are presented. The most prominent features of these approaches are: a) the easy synthesis of thione **3a** from thiadiazole **2**; b) the smooth reductions of **6** to **4** and **10** to **11** respectively; and c) the first selenium dioxide oxidation in the TTF series.

The chemistry of **9** and its derivatives is currently under investigation. Preliminary experiments establish that Wittig reactions proceed smoothly.

Acknowledgement. We are indebted to DGICYT (Project PB91-0932), French and Spanish Governments (Acciones Integradas HF-277 and HF-144 and PICASSO 1993 et 1994), Alliance (PN94.028) and EEC Human Capital and Mobility Programme for financial support. Doctoral fellowships to M. S. (DGICYT) and R. A. (DGA) are gratefully acknowledged. The work at Durham was funded by EPSRC and Zeneca FCMO.

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14. A mixture of **11** (200 mg, 0.75 mmol) and SeO_2 (166.5 mg, 1.5 mmol) in 25 mL of dry dioxane was refluxed until complete disappearance (TLC) of the starting dialcohol (2-2.5 h). The reaction mixture was cooled to 40°C, filtered, and the remaining solid was washed with a little dioxane. The filtrate was distilled under vacuum and the residue was treated with acetone. Filtration of the resulting solid and evaporation of the filtrate afforded crude **9**, which was purified by column chromatography (SiO_2 / CH_2Cl_2).
15. a) Treatment of tetrathiafulvalenes with MCPBA results in the corresponding mono *S*-oxides: Lakshmikantham, M. V.; Garito, A. F.; Cava, M. P. *J. Org. Chem.* **1978**, *43*, 4394-4395; Carlsen, L.; Bechgaard, K.; Jacobsen, C. S.; Johannsen, I. *J. Chem. Soc., Perkin Trans. 2* **1979**, 862-865; b) some tetrathiafulvalene alcohols can be oxidized to the corresponding aldehydes with activated MnO_2; Swern oxidation of these alcohols gives, however, disappointing results (Blanchard, P. *Ph.D. Thesis*, Universities of Nantes and Angers, 1994).
16. Compound **9** found: C, 37.2; H, 1.8%. $C_8H_4O_2S_4$ requires C, 36.9; H, 1.6%.Selected spectroscopic data for compound **9**: HRMS (EI^+, 70eV): found: 259.9100; calc. for $C_8H_4O_2S_4$: 259.9094. IR (Nujol) ν (C=O): 1640 cm^{-1} (vs). ^1H-NMR (dmso-d_6) δ: 9.54 (s, CHO), 8.28 and 8.27 (s, CH, (*E*) and (*Z*) isomers). ^{13}C-NMR (dmso-d_6) δ: 182.03 and 181.98 (CHO), 143.03 and 142.92 (=CH), 139.47 and 139.37 (<u>C</u>-CHO), 110.28 (C(S)S).

(*Received in UK* 29 *August* 1994; *revised* 4 *October* 1994; *accepted* 7 *October* 1994)