

BASE-CATALYZED HALOGEN DANCE OF 2-BROMOTETRATHIAFULVALENE

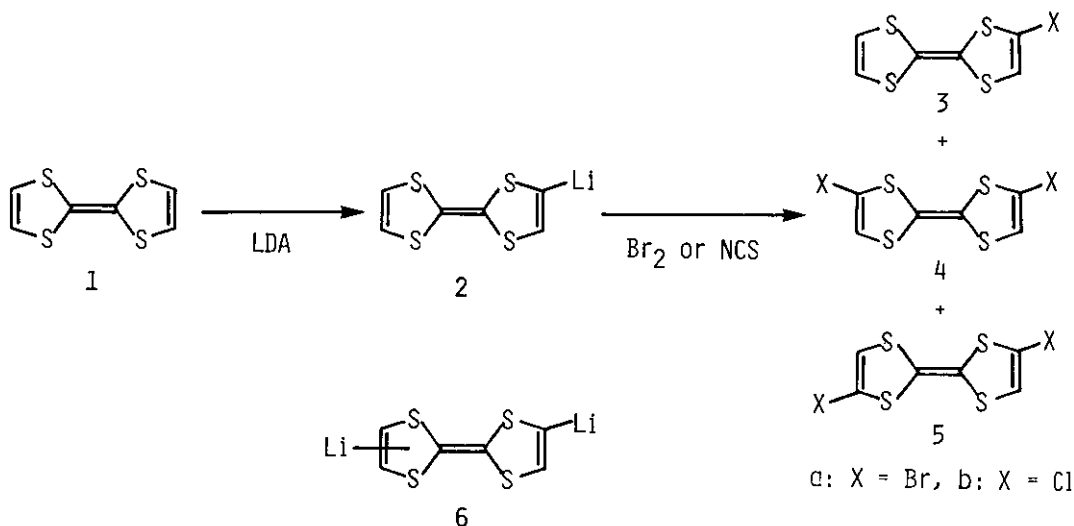
Juzo Nakayama,* Nagatoshi Toyoda, and Masamatsu Hoshino

Department of Chemistry, Faculty of Science, Saitama University,
Urawa, Saitama 338, Japan

Abstract — Halogenotetrathiafulvalenes were prepared by treating tetrathiafulvalene with lithium diisopropylamide (LDA) and then with halogenating agents. Treatment of 2-bromotetrathiafulvalene with LDA results in the bromine dance which affords tetrathiafulvalene, 2-bromotetrathiafulvalene, three positional isomers of dibromotetrathiafulvalene, and 2,3,6-tribromotetrathiafulvalene.

Tetrathiafulvalene (TTF, **1**) and related derivatives are compounds of current interest. We report here the preparation and base-catalyzed halogen dance of 2-halogenotetrathiafulvalenes.

Halogenation of TTF **1** cannot be attained by conventional methods.¹ Therefore, TTF was lithiated by lithium diisopropylamide (LDA)² and then treated with halogenating agents. To a stirred slurry of tetrathiafulvalenyllithium (**2**), prepared from **1** and

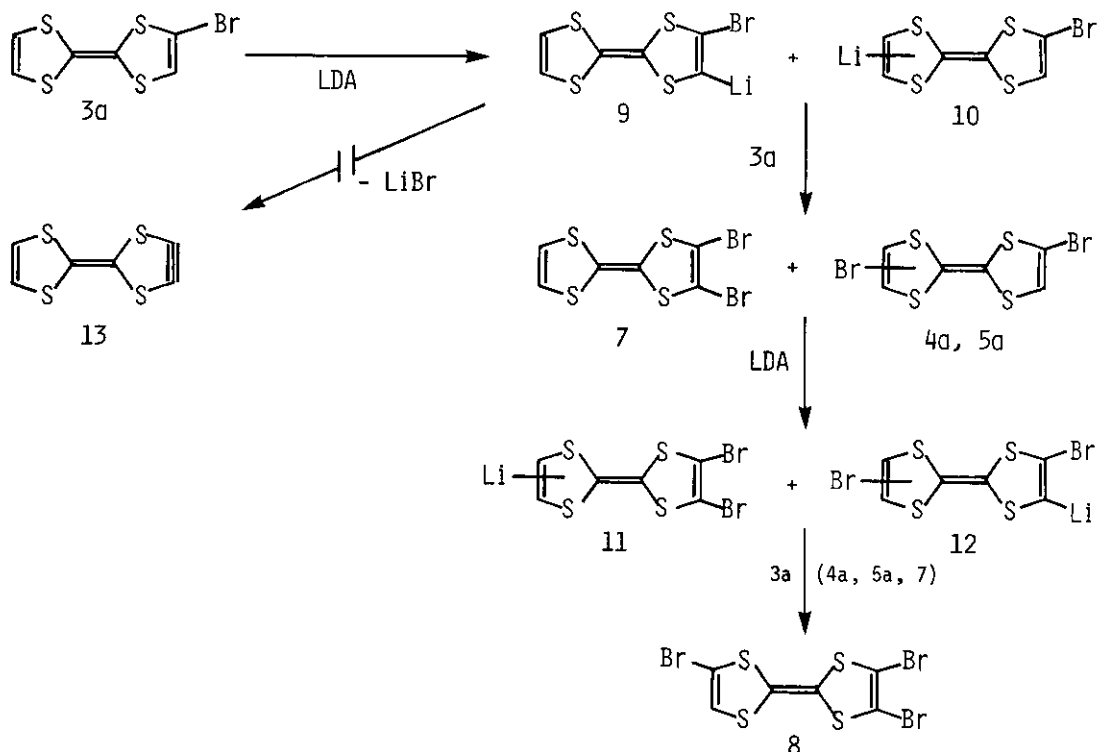


LDA, was added bromine at -78 °C. Workup of the mixture by column chromatography gave 2-bromoTTF (3a) in 34% yield and an isomeric mixture of dibromoTTF's in 5% yield. Although ¹H-NMR spectrum of the dibromoTTF mixture which only shows one singlet does not provide good information on the structure and composition of the mixture, ¹³C-NMR spectrum reveals that it consists of two isomers, each of which possesses three non-equivalent carbon atoms. Accordingly the dibromoTTF's formed are 2,6- and 2,7-dibromo isomers (5a and 4a), 2,3-dibromoTTF (7) being not produced. Reportedly 2 redistributes to 1 and dilithiated TTF 6 on warming.² Therefore 6 may be responsible for the formation of the dibromoTTF's. Inverse addition of 2 to bromine could neither improve the yield of 3a nor suppress the formation of the dibromoTTF's.

Chlorination of TTF 1 was done by adding N-chlorosuccinimide (NCS) to a slurry of 2 in ether at -78 °C. The reaction afforded 2-chloroTTF (3b, 11%) and dichloroTTF's (mixture of 4b and 5b, 10%).

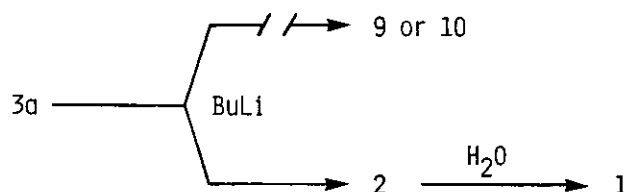
Treatment of bromoTTF 3a with LDA results in the interesting base-catalyzed halogen dance reaction. A solution of 3a in ether was added to a solution of a slight excess of LDA in pentane/hexane at -78 °C, and the resulting mixture was gradually warmed to room temperature and then heated at reflux. Workup of the mixture by column chromatography on silica gel surprisingly afforded TTF 1 (yield was not determined; see Experimental), bromoTTF 3a (12-27%), a mixture of dibromoTTF's 4a and 5a (2-5%), 2,3-dibromoTTF 7 (6-9%), and 2,3,6-tribromoTTF 8 (1-3%). All of these compounds exhibit spectral characteristics consistent with their assigned structures and give satisfactory elemental analysis results.

The observed base-catalyzed halogen dance may best be explained by an intermolecular deprotonation-transbromination sequence. The initial step is deprotonation of 3a by the amide ion; the both rings of 3a are competitively lithiated yielding 9 and 10. The transbromination of 9 and 10 mainly from 3a produces dibromoTTF's 4a, 5a, and 7. The deprotonation of dibromoTTF's yielding 11 and 12 followed by transbromination affords tribromoTTF 8. Although we initially expected the generation of 2,3-dehydrotetrathiafulvalene (13) from 9 by loss of lithium bromide, any sign for the formation of 13 was not detected. Although the base-catalyzed halogen dance has been well documented with heteroaromatic halides, especially with bromothiophenes, examples of the halogen dance observed with non-aromatic heterocycles like TTF seem uncommon.^{3,4}



Treatment of 3a with potassium *t*-butoxide also results in the base-catalyzed halogen dance. This reaction affords TTF 1 (17%) and a mixture of 4a and 5a (2%) with 9% recovery of 3a.

In contrast with the above results, treatment of 3a with butyllithium exclusively leads to the lithium-bromine exchange reaction. No lithium-hydrogen exchange resulting in the halogen dance occurs. Thus, when 3a was treated with an equivalent of butyllithium in ether at -78 °C and the mixture was gradually warmed and refluxed, the reaction afforded TTF 1 nearly quantitatively. The same reaction was also observed with a mixture of dichloroTTF's 4b and 5b. Treatment of this mixture with an equivalent of butyllithium gave 2-chloroTTF 3b as the main product.



EXPERIMENTAL

Bromination of Tetrathiafulvalene (1). A 1.18 M solution of butyllithium (17 ml, 20 mmol) in hexane was diluted with 20 ml of pentane, and then, to this was added diisopropylamine (2.8 ml, 20 mmol). After stirring for 0.5 h, the solution was injected through a septum cap to a stirred solution of 1⁴ (3.27 g, 16 mmol) in anhydrous ether (200 ml) at -78 °C under nitrogen, and the stirring was continued for 1 h. To the resulting yellow slurry of 2 was added a solution of bromine (2.56 g, 16 mmol) in benzene (12 ml) over a 0.25 h-period at -78 °C. After stirring for 1 h, the dark brown mixture was gradually warmed to room temperature, and the resulting insoluble material was filtered off. The filtrate was washed with water, dried, and evaporated. The brown oily residue was chromatographed on a silica gel column (Merck, Art 7734, 100 g). Elution with hexane gave 0.29 g (5%) of a mixture of dibromoTTF's 4a and 5a. Further elution gave a trace amount of yellow crystal whose structure was not examined in detail (TLC indicated that this is 2,3-dibromoTTF 7; R_f value of this compound agrees with that of 7). Finally elution with the same solvent gave 1.54 g (34%) of 3a.

2-Bromotetrathiafulvalene (3a): mp 52 °C (from hexane); orange needles; ¹H-NMR (CDCl₃) δ 6.27 (1H, s) and 6.33 (2H, s); MS m/e M^+ 282:284=1:1.2. Anal. Calcd for C₆H₃BrS₄: C, 25.44; H, 1.07; Br, 28.21; S, 45.28. Found: C, 25.27; H, 1.05; Br, 28.16; S, 45.41.

A mixture of 2,6- and 2,7-dibromotetrathiafulvalenes (5a and 4a): mp 128.5-129.5 °C (from hexane); orange crystals; ¹H-NMR (CDCl₃) δ 6.28 (s); ¹³C-NMR (CDCl₃) δ 100.46 and 100.59 (carbons carrying bromine), 112.07 (overlapped absorption due to carbons connecting two rings of 4a and 5a), and 117.83 and 117.86 (carbons carrying hydrogen); MS m/e M^+ 360:362:364=1:2.0:1.3. Anal. Calcd for C₆H₂Br₂S₄: C, 19.90; H, 0.56; Br, 44.13. Found: C, 19.90; H, 0.56; Br, 44.01.

Bromination of 1 (Inverse Addition). A slurry of 2 (8 mmol), prepared as described above at -78 °C, was pressed (N₂ pressure) through a Teflon tube inserted through a septum cap into a flask containing a stirred solution of bromine (8 mmol) in hexane (12 ml) cooled at -78 °C. The mixture was worked up as described above to give 3a (15%) and a mixture of 4a and 5a (8%).

Chlorination of 1. To a stirred slurry of 2 (5 mmol), prepared as described above, was added a solution of N-chlorosuccinimide (5 mmol) in tetrahydrofuran (10 ml) over a period of 0.25 h at -78 °C under nitrogen. The mixture was stirred for 0.5

h and gradually warmed to room temperature. Workup of the mixture by column chromatography (elution with hexane) gave 3b (11%) and a mixture of 4b and 5b (10%).

2-Chlorotetrathiafulvalene (3b): mp 65 °C (from hexane); orange needles; $^1\text{H-NMR}$ (CDCl_3) δ 6.13 (1H, s) and 6.31 (2H, s); MS m/e M^+ 238:240=1:0.43. Anal. Calcd for $\text{C}_6\text{H}_3\text{ClS}_4$: C, 30.17; H, 1.27; Cl, 14.85; S, 53.71. Found: C, 30.29; H, 0.72; Cl, 14.71; S, 53.62.

A mixture of 2,6- and 2,7-dichlorotetrathiafulvalenes (5b and 4b): mp 118-119 °C (from hexane); red needles; $^1\text{H-NMR}$ (CDCl_3) δ 6.33 (s); MS m/e M^+ 272:274:276=1:0.8:0.2. Anal. Calcd for $\text{C}_6\text{H}_2\text{Cl}_2\text{S}_4$: C, 26.37; H, 0.74; Cl, 25.95; S, 46.94. Found: C, 26.40; H, 0.72; Cl, 26.01; S, 46.96.

Treatment of 2-BromoTTF (3a) with LDA. A solution of LDA was prepared by adding a 1.38 M solution of butyllithium (3.6 ml, 5 mmol) to a solution of diisopropylamine (0.69 ml, 5 mmol) in pentane (5 ml). To a solution of 3a (1.13 g, 4 mmol) in ether (50 ml) was added the solution of LDA over a period of 0.5 h at -78 °C under nitrogen. The mixture was stirred for 2 h, gradually warmed to room temperature, and heated at reflux for 2 h. The mixture was washed with water, dried, and evaporated. The resulting residue was chromatographed on a silica gel column (70 g). Exhaustive elution with hexane gave 2,3,6-tribromoTTF 8 (1-3%), 2,3-dibromoTTF 7 (6-9%), a mixture of 2,6- and 2,7-dibromoTTF's 5a and 4a (2-5%), and bromoTTF 3a (12-27%) in this order.

Although the presence of TTF 1 in the reaction mixture was ascertained by TLC, it could not be isolated by column chromatography (it forms a charge transfer salt with silica gel or additives therein). When crude mixture was subjected to sublimation, 1 was isolated in a low yield. The reaction was repeated several times and is reproducible.

2,3-Dibromotetrathiafulvalene (7): mp 126-128 °C (from cyclohexane); orange crystals; $^1\text{H-NMR}$ (CDCl_3) δ 6.36 (s); $^{13}\text{C-NMR}$ (CDCl_3) δ 101.61 (carbons carrying bromine), 117.89 (carbons connecting two rings), and 118.93 (carbons carrying hydrogen); MS m/e M^+ 360:362:364=1:2.1:1.3. Anal. Calcd for $\text{C}_6\text{H}_2\text{Br}_2\text{S}_4$: C, 19.90; H, 0.56; Br, 44.13; S, 35.42. Found: C, 19.96; H, 0.57; Br, 44.12; S, 35.30.

2,3,6-Tribromotetrathiafulvalene (8): mp 146.5-148 °C dec (from hexane); orange needles; $^1\text{H-NMR}$ (CDCl_3) δ 6.31 (s); MS m/e M^+ 438:440:442:444=1:3.2:3.4:1.4. Anal. Calcd for $\text{C}_6\text{HBr}_3\text{S}_4$: C, 16.34; H, 0.23. Found: C, 16.45; H, 0.23.

Treatment of 2-BromoTTF 3a with Potassium t-Butoxide. A solution of potassium t-butoxide (135 mg, 1.2 mmol) in tetrahydrofuran (7 ml) was added to a stirred solution of 3a in tetrahydrofuran (5 ml) at 2 °C under nitrogen. The mixture was gradually warmed to room temperature and then refluxed for 1 h. The mixture was evaporated and methylene chloride (30 ml) was added to the residue. Insoluble material was filtered off and the filtrate was evaporated. The residue was subjected to sublimation to give TTF 1 (90 °C/1 mmHg) in 17% yield. The remaining material was chromatographed on a silica gel column (hexane as eluent) to give 3a (9%) and a mixture of 4a and 5a (2%).

Treatment of 2-BromoTTF 3a with Butyllithium. To a stirred solution of 3a (397 mg, 1.4 mmol) in ether (10 ml) was added a 1.18 M solution of butyllithium (1.2 ml, 1.4 mmol) over a period of 10 min. After stirring for 0.5 h, the mixture was warmed to room temperature and refluxed for 3 h. The mixture was washed with water, dried, and evaporated to afford TTF 1 nearly quantitatively.

Treatment of DichloroTTF's 4b and 5b with Butyllithium. A 1.18 M solution of butyllithium (0.52 ml, 0.61 mmol) was added to a solution of a mixture of 4b and 5b (166 mg, 0.52 mmol) in ether (10 ml) at -78 °C under nitrogen. The mixture was stirred for 0.5 h, warmed to room temperature, and refluxed for 2 h. Workup of the mixture by column chromatography gave 2-chloroTTF 3b (30%) and the starting material (25%).

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4. A referee suggested that dibromo- and tribromoTTF's (4a, 5a, 7, and 8) would be formed via multilithiated TTF as was assumed for the formation of 4 and 5 from 2. We thank the referee for this suggestion.
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