

## ON THE REACTION OF METALLATED ACETYLENES AND ALLENES WITH CARBON DISULFIDE. INFLUENCE OF THE ALKALI METAL COUNTER-ION AND THE SUBSTITUENTS IN THE ACETYLENE AND ALLENE ON THE COURSE OF THE REACTION

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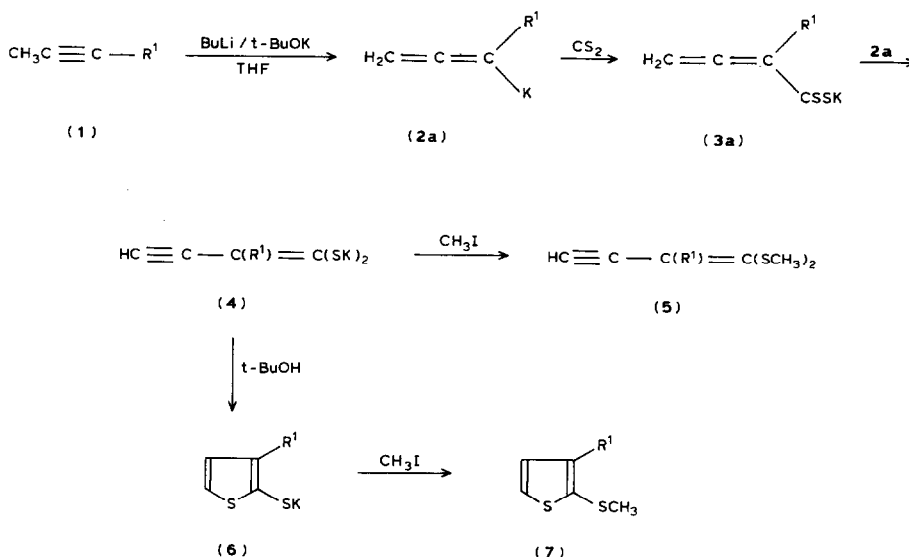
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### Summary

Addition at low temperatures of carbon disulfide to a solution of the lithium compound  $[H_2\bar{C}-\bar{C}\equiv CR^1]\cdot Li^+$  ( $R^1 = CH_3, C_3H_7, Ph, OCH_3, SCH_3$ ) results in the initial formation of an allenic carbodithioate  $H_2C=C=C(R^1)CSSLi$ , while for  $R^1 = t-C_4H_9$  or  $SiMe_3$  acetylenic carbodithioates  $R^1C\equiv CCH_2CSSLi$  are formed. The initial products undergo very rapid subsequent reactions. For  $R^1 = CH_3$  or  $C_3H_7$  the lithium compound adds (in the allenic form) in a conjugated fashion to the  $C=C-C=S$  system of the allenic carbodithioate. The acetylenic dithioates are deprotonated to give the geminal dithiolates  $R^1C\equiv C-CH=C(SLi)_2$ . For  $R^1 = Ph, OCH_3$  or  $SCH_3$ , subsequent deprotonation at the terminal carbon atom of the initial allenic dithioate gives enyne dithiolates  $HC\equiv C-C(R^1)=C(SCH_3)_2$ ; this reaction proceeds more satisfactorily with the potassium compounds.

### Introduction

Functionalisation of mesomeric acetylenic-allenic carbanions in general gives a mixture of the acetylenic and allenic derivative. The ratio of the two isomeric products depends upon the counter ion ( $MgX, Li, Na, K, Cu, ZnX$ , etc.), the solvent, and the substituents, and upon the nature of the functionalisation reagent and its substituents. The various metallation and derivatization reactions have recently been reviewed by Klein [1] (for Li-compounds) and Epsztein [2] (for alkali and other metal compounds). Interaction between allenylmagnesium bromide  $H_2C=C=CHMgBr$  and thioketones and dithioesters has been shown to result in carbophilic attack with formation of acetylenic products. Vermeer et al. [3] obtained acetylenic dithioesters  $HC\equiv C-C(R^1)(R^2)CSSCH_3$  from the reaction of  $R^1R^2C=C=CHLi$  with  $CS_2$  and subsequent methylation. A few years ago, we reported on syntheses of condensed bicyclic thiophenes [4] and 2,3-disubstituted thiophenes [5]



SCHEME 1.  $\text{R}^1$  = alkyl, phenyl,  $\text{SCH}_3$ ,  $\text{OCH}_3$ ,  $\text{NR}_2$ ,  $\text{CH}_2\text{NR}_2$  ( $\text{R} = \text{CH}_3$  or  $\text{C}_2\text{H}_5$ ).

(Scheme 1). Metallation of acetylenic compounds (1) with the 1/1 mixture of *n*-BuLi and *t*-BuOK [6], followed by reaction with carbon disulfide then addition of *t*-butyl alcohol followed by methyl iodide gave the 2,3-disubstituted thiophenes 7 in reasonable yields.

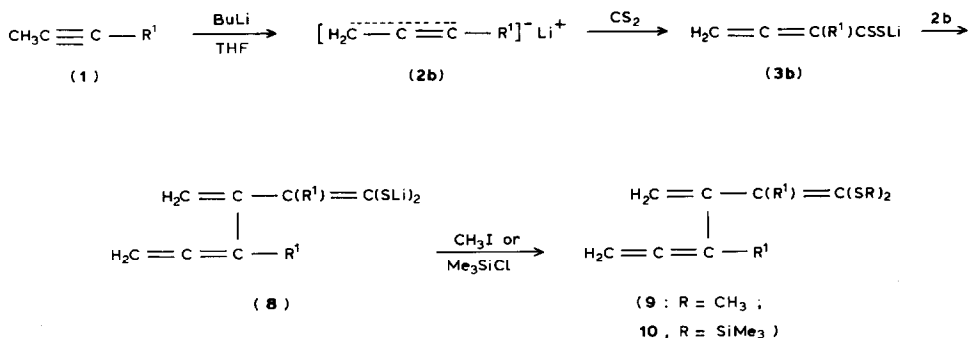
The precursor of the thiophene derivatives 6 and 7 is the enyne dithiolate 4, formed in a very rapid subsequent deprotonation of the initial products 3a from the reaction with  $\text{CS}_2$ . Intermediate 4 could also be intercepted by reaction with methyl iodide, to give the ketene-*S,S*-acetal (5).

In continuation of this study we have examined the reactions of the lithium compounds (2b) with  $\text{CS}_2$ .

## Results and discussion

The lithio derivatives of 2-butyne and 2-hexyne were prepared from the 2-alkynes and butyllithium in a THF/hexane mixture. Addition at about  $-100^\circ\text{C}$  of half of the equivalent amount of carbon disulfide to the resulting solution, followed by methylation with methyl iodide or silylation with trimethylchlorosilane, afforded (after the usual aqueous work-up) the ketene-*S,S*-acetals 9 and 10 in good yields. The structures were assigned on the basis of spectral data (*vide infra*).

The formation of these compounds can be visualized as shown in Scheme 2. The crucial step is a very rapid conjugate addition of the lithium compound to the  $\text{C}=\text{C}-\text{C}=\text{S}$  system in the initial allenic carbodithioate 3b, resulting in intermediate 8. Inspection of the structure 8 ( $\text{R}^1 = \text{CH}_3$ ) led to the expectation that protonation under suitable conditions could result in conversion into the carbodithioate 11, which is the valence-tautomer of thiopyran derivative 12. Addition of a mixture of *t*-butyl alcohol and hexamethylphosphoric triamide (HMPT) to the reaction mixture obtained from lithiated 2-butyne and  $\text{CS}_2$ , followed by methylation with methyl

SCHEME 2.  $\text{R}^1 = \text{CH}_3, \text{C}_3\text{H}_7$ .

iodide did, indeed, give in excellent yield, a product (whose spectroscopic ( $^1\text{H}$ ,  $^{13}\text{C}$  NMR and mass spectrum) characteristics were in agreement with structure **13**.

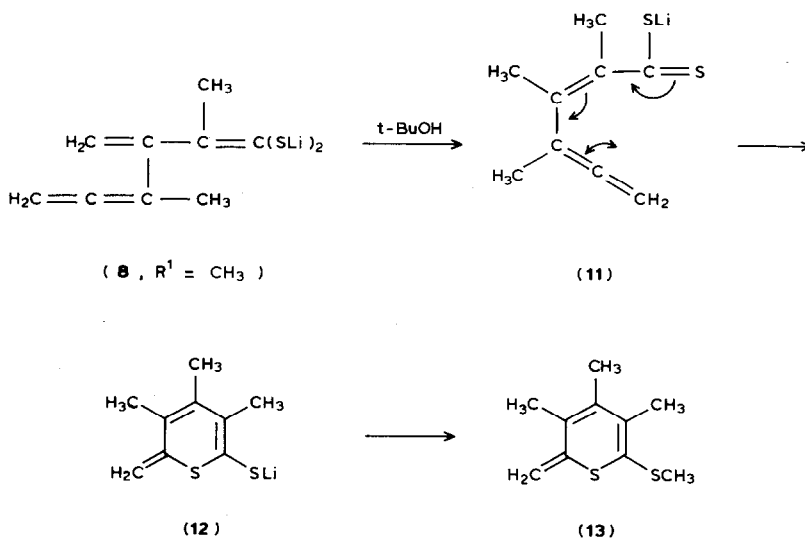
In an attempt to obtain addition evidence for the intermediate occurrence of the allenic dithioate **3b**, a solution of **2b** ( $\text{R}^1 = \text{CH}_3$ ) was added at low temperatures to a large (200 mol %) excess of  $\text{CS}_2$  (i.e. inverse addition), after which the mixture was treated with methyl iodide.

The infrared spectrum of the very unstable product obtained after the usual work-up showed an allenic absorption at  $1950\text{ cm}^{-1}$ , while the signals at 2.6 ppm (singlet) and around 4.8 ppm (complicated multiplet) in the NMR spectrum might be ascribed to the  $\text{H}_3\text{C-S}$  and allene protons (ratio about 3/2). Attempted distillation resulted in extensive polymerisation (sometimes explosive decomposition occurred). From the results described above it can be concluded that the lithium derivatives of 2-butyne and 2-hexyne react exclusively in the "allenic form" with  $\text{CS}_2$ .

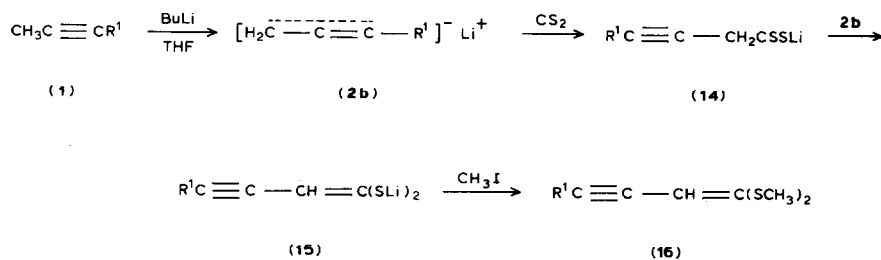
The reactions of the lithium compounds of trimethylsilylpropyne  $\text{CH}_3\text{C}\equiv\text{C-SiMe}_3$  and *t*-butylpropyne  $\text{CH}_3\text{C}\equiv\text{C-t-C}_4\text{H}_9$  with  $\text{CS}_2$  showed a different regiochemistry. Addition of half of the equivalent amount of  $\text{CS}_2$  to a solution of the lithiated acetylenes, followed by reaction with methyl iodide, afforded the ketene-*S,S*-acetals **16** in good yields. This result can be explained by assuming that an acetylenic dithioate (**14**) is initially formed. In a very fast subsequent reaction this intermediate is deprotonated to the geminal dithiolate **15**, which is isolated as the ketene-*S,S*-acetal **16** (Scheme 4).

The regiochemistry in the reaction of these lithiated alkynes seems to be a consequence of steric effects of the bulky groups.

In our previous paper [5] we showed that potassium compounds **2a** with a hetero substituent or phenyl group ( $\text{R}^1 = \text{OCH}_3, \text{SCH}_3, \text{Ph}$ ) reacted with  $\text{CS}_2$  to give enynedithiolates **4** which after addition of methyl iodide afforded compound **5**. In the course of the present study we have investigated the reaction of  $\text{CS}_2$  with the lithio derivatives **2b** obtained from  $\text{H}_2\text{C}=\text{C}=\text{CHOCH}_3$ ,  $\text{H}_2\text{C}=\text{C}=\text{CHSCH}_3$  or  $\text{CH}_3\text{C}\equiv\text{CPh}$  and BuLi in THF. The isolated products were the same as in the case of the potassium compounds. Thus, initially allenic carbodithioates are formed; these are deprotonated by **2b** at the terminal carbon atom of the allenic system to give dilithium dithiolates analogous to **4** (compare Scheme 1). Since the yields of the



SCHEME 3

SCHEME 4.  $\text{R}^1 = t\text{-C}_4\text{H}_9$ ,  $\text{SiMe}_3$ .

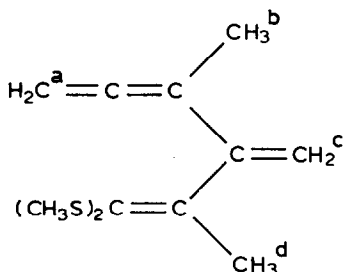
ketene- $S,S$ -acetals **5** were lower than those obtained from the reactions with the potassium compounds, we have not studied further the reactions of lithiated heterosubstituted and phenyl-substituted allenes with  $\text{CS}_2$ .

## Experimental

### 1. Reaction of 2-butyne and 2-hexyne with butyllithium, followed by reaction with carbon disulfide and methyl iodide or trimethylchlorosilane (see Scheme 2)

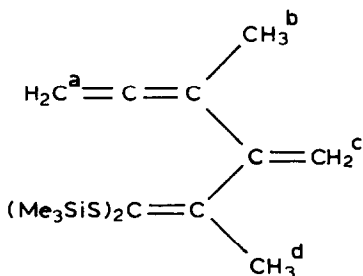
$\text{THF}$  (80 ml) was added to a solution of 0.10 mol of  $n$ -butyllithium in 70 ml of hexane. 2-Butyne (0.10 mol, for the preparation see ref. 7) or 2-hexyne (0.10 mol, see below) was added in one portion at  $-10^\circ\text{C}$ . The temperature was allowed to rise to  $20\text{--}25^\circ\text{C}$  and kept at that level for an additional half hour. The solution was then cooled to  $-100^\circ\text{C}$  and a mixture of 0.05 mol of carbon disulfide and 20 ml of  $\text{THF}$  was added during 5 min, with the temperature kept between  $-80$  and  $-100^\circ\text{C}$ . After an additional 20 min (at  $-80^\circ\text{C}$ ) 0.15 mol (excess) of methyl iodide or 0.12 mol of trimethylchlorosilane was added dropwise during 10 min with the mixture

kept between  $-60$  and  $-80^{\circ}\text{C}$ . The resulting orange or yellow suspension was then warmed to  $0^{\circ}\text{C}$ , then ice water (100 ml) was added with vigorous stirring. The organic layer and two ethereal extracts were dried over  $\text{MgSO}_4$  and subsequently concentrated in vacuo. The remaining liquid was distilled through a short column to give pure products (purity  $> 95\%$ ) according to  $^1\text{H}$  NMR spectroscopy. Mass spectroscopy showed the expected parent peaks.



B.p.  $\sim 60^{\circ}\text{C}/0.1$  mmHg,  $n_{\text{D}}^{20}$  1.5792, yield 61%.  $^1\text{H}$  NMR spectral data (internal standard  $\text{Me}_4\text{Si}$  with  $\delta$  0 ppm, solvent  $\text{CCl}_4$ ):  $\delta(\text{H}^a)$  4.71 (m),  $J_{ab}$  2.9 Hz;  $\delta(\text{H}^c)$  4.96 and 4.71 (two broadened s,  $J_{bc}$  1.5 Hz);  $\delta(\text{CH}_3\text{S})$  2.11 and 2.20 (two s);  $\delta(\text{H}^d)$  2.04 (broadened s,  $J_{cd}$  1.5 Hz);  $\delta(\text{H}^b)$  1.83 (t,  $J_{ba}$  2.9 Hz).

The ketene-*S,S*-acetal obtained from 2-hexyne (**9**,  $\text{R} = \text{CH}_3$ ,  $\text{R}^1 = \text{C}_3\text{H}_7$ ) has b.p.  $\sim 80^{\circ}\text{C}/0.1$  mmHg,  $n_{\text{D}}^{20}$  1.5572, yield 67%.



B.p.  $110^{\circ}\text{C}/0.3$  mmHg,  $n_{\text{D}}^{20}$  1.5226, yield 60%.  $^1\text{H}$  NMR data (solvent  $\text{CDCl}_3$ ;  $\text{HCCl}_3$ ,  $\delta$  7.23 ppm, as internal standard):  $\delta(\text{H}^a)$  4.72 (m);  $\delta(\text{H}^b)$  1.86 (t);  $\delta(\text{H}^c)$  4.73 (broadened s) and 5.00 (two broadened s),  $\delta(\text{SiMe}_3)$  0.36 (s) and 0.50 ppm (s).

The IR spectra of compounds **9** and **10** showed characteristic absorptions: *inter alia* at  $3100\text{ cm}^{-1}$  ( $\text{H}_2\text{C}=\text{C}<$ , weak),  $1940\text{ cm}^{-1}$  ( $\text{H}_2\text{C}=\text{C}=\text{C}<$ , medium) and  $1610\text{ cm}^{-1}$  ( $\text{C}=\text{C}$ ).

## 2. Lithiation of the acetylenes **1** ( $\text{R} = t\text{-C}_4\text{H}_9$ and $\text{SiMe}_3$ ) followed by reaction with carbon disulfide and methyl iodide (see Scheme 4)

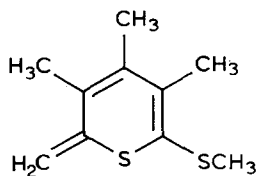
To a solution of 0.10 mol of the lithiated acetylene (prepared as described in exp. 1; for the preparation of the acetylenes see ref. 7) in 70 ml of THF and 70 ml of hexane was added at  $-100$  to  $-80^{\circ}\text{C}$  0.05 mol of  $\text{CS}_2$  as described in Exp. 1. After an additional 20 min (at  $-60^{\circ}\text{C}$ ) 0.15 mol of methyl iodide was introduced during 10 min. The temperature was then allowed to rise to  $0^{\circ}\text{C}$  and the product was isolated as described in Exp. 1.  $t\text{-C}_4\text{H}_9\text{C}\equiv\text{CCH}=\text{C}(\text{SCH}_3)_2$ , b.p.  $\sim 60^{\circ}\text{C}/0.5$  mmHg,  $n_{\text{D}}^{20}$  1.5386, was obtained in 45% yield (calculated on the acetylene). The  $^1\text{H}$  NMR

spectrum (solvent  $\text{CCl}_4$ , internal standard  $\text{Me}_4\text{Si}$ ,  $\delta$  0 ppm) showed signals at 1.26 (s, t-Bu), 2.30 and 2.40 ppm (two s,  $\text{CH}_3\text{S}$ ) and 5.53 ppm (s,  $\text{H}_2\text{C}=\text{}$ ).

$\text{Me}_3\text{SiC}\equiv\text{C}-\text{CH}=\text{C}(\text{SCH}_3)_2$ , b.p.  $105^\circ\text{C}/1.3\text{ mmHg}$ ,  $n_{\text{D}}^{20}$  1.5662, was obtained in 47% yield (based on the acetylene).

### 3. Formation of the thiopyran derivative 13 (see Scheme 3)

A mixture of t-butylalcohol (0.10 mol) and dry hexamethylphosphoric triamide (40 ml) was added at  $-20^\circ\text{C}$  to the mixture obtained from the reaction of 0.10 mol of lithiated 2-butyne with 0.05 mol of  $\text{CS}_2$ . The resulting solution was kept for 30 min at  $30^\circ\text{C}$  and then cooled to  $0^\circ\text{C}$ . Methyl iodide (0.10 mol) was added during 5 min with the mixture kept between 0 and  $20^\circ\text{C}$ . After an additional 15 min water (200 ml) was added, and the product was extracted with diethyl ether. The combined organic solutions were washed six times with water and subsequently dried over  $\text{MgSO}_4$ . The solvent was then removed in vacuo (the last traces in a high-vacuum) with a bath temperature between 30 and  $40^\circ\text{C}$ .



(13)

**13** (undistilled).  $n_{\text{D}}^{20}$  1.6482, yield 90%.  $^1\text{H}$  NMR data (solvent  $\text{CCl}_4$ , internal standard  $\text{Me}_4\text{Si}$ ,  $\delta$  = 0 ppm):  $\delta(\text{H}_2\text{C}=\text{})$  4.63 (geminal coupling 0.18 Hz),  $\delta(\text{SCH}_3)$  2.30, and  $\delta(\text{CH}_3)$  2.10 (s), 1.97 (s) and 1.80 (s).

### 4. Preparation of 2-hexyne

To a solution of 3 g of t-BuOK in 50 ml of DMSO was added at  $20^\circ\text{C}$  0.15 mol of 1-hexyne (see ref. 7). The mixture was kept for 30 min at  $25^\circ\text{C}$  then the volatile product was removed under reduce pressure with the vapours condensed in a receiver cooled at  $-70^\circ\text{C}$ . During the evacuation the flask was gradually heated to  $80^\circ\text{C}$ . Redistillation of the contents of the receiver at normal pressure gave 2-hexyne, b.p.  $84^\circ\text{C}/760\text{ mmHg}$ ,  $n_{\text{D}}^{20}$  1.4180, in 90% yield.

## References

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