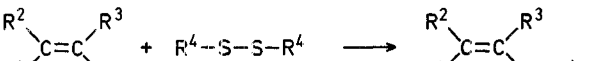
Alkenylcopper Derivatives; 27[1]. Synthesis of 1-Alkenyl Thioethers by Cleavage of Disulfides with 1-Alkenylcopper Reagents

A. Alexakis*, J. F. Normant

Laboratoire de Chimie des Organo-Elèments tour 44–45, 4 place Jussieu, F-75230 Paris Cédex 05, France

1-Alkenyl thioethers are useful intermediates in organic synthesis[2]. They may be prepared by a variety of methods; however, only few of these methods afford products of high stereoisomeric purity. One such method consists of the addition of an organocopper or cuprate species to an alkynyl thioether[3,4,5] and affords highly pure 1-alkenyl sulfides. Another method is the cleavage of a disulfide by a 1-alkenylmetal reagent, usually an organolithium reagent[6]. 1-Alkenylcopper and -cuprate derivatives, easily obtained by carbocupration of alkynes[7], are known to afford olefins of high stereoisomeric purity. It has also been shown that these reagents react with *S*-methyl methanethiosulfonate ($H_3C—SO_2—SCH_3$) to give 1-alkenyl methyl sulfides[8]. However, this electrophile is quite expensive (and two equivalents of it are needed) and other thiosulfonate esters have to be prepared. We describe here the reaction of 1-alkenylcopper and -cuprate reagents with simple and commercially available disulfides according to the following general scheme.



Lithium bis[(*Z*)-1-alkenyl]-cuprates[9] (**1**) react rapidly with 2 equivalents of diphenyl disulfide in tetrahydrofuran to afford the 1-alkenyl thioether **3** (e.g., **3a**) in ~ 50 % yield. This result indicates that, in the absence of any added reagent or cosolvent, only one alkenyl group of the cuprate **1** undergoes the reaction. Addition of dimethyl sulfoxide or dimethylformamide in varying amounts does not improve the yield of **3** significantly. However, upon addition of 1 equiv of hexamethylphosphoric triamide (HMPT), the reaction rate increases strikingly and all of the diphenyl disulfide is consumed (100 % yield of **3a** according to G. L. C.). Thus, both of the organic groups of cuprate **1** are used in this reaction (Scheme **A**).

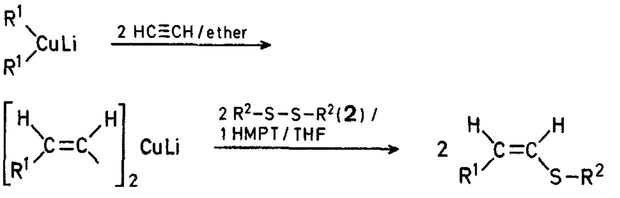
We also examined the behaviour of other commercialy available disulfides (**2**) towards 1-alkenylcuprates under the same experimental conditions (Scheme **A**). Dibenzyl disulfide reacted smoothly as did dimethyl disulfide, affording the cor-

Table. 1-Alkenyl Thioethers (**3**, **5**, **7**, **9**) prepared

Product	Yield[a] [%]	b.p. [°C]/torr	n_D^{20}	Molecular Formula[b]	I.R. (neat) ν [cm^{-1}H	^{1}H-N.M.R. (CDCl$_3$/TMS$_{int}$) δ [ppm]	^{13}C-N.M.R. (CDCl$_3$/TMS$_{int}$) δ [ppm]
3a	84	63°/0.1	1.5592	$C_{10}H_{12}S$ (164.3)	30,70, 3010, 1610, 1585, 735, 680	7.2–7.3 (m, 5H$_{arom}$); 6.17 (d, 1H, CH=); 5.78 (dt, 1H, CH=, J_{cis} = 9 Hz); 2.26 (dt, 2H, CH$_2$); 1.06 (t, 3H, CH$_3$)	134.9, 122.1 (CH=); 136.5, 128.9, 128.7, 126.0 (C$_{arom}$); 22.6 (CH$_2$); 13.6 (CH$_3$)
3b	69	67°/0.1	1.5576	$C_{11}H_{14}S$ (178.3)	3080, 3060, 3020, 1600, 745, 665	7.25–7.35 (m, 5H$_{arom}$); 5.97 (d, 1H, CH=); 5.61 (dt, 1H, CH=, J_{cis} = 10 Hz); 3.88 (s, 2H, C$\underline{H}_2$—C$_6$H$_5$); 2.15 (dt, 2H, CH$_2$); 0.96 (t, 3H, CH$_3$)	132.0, 123.1 (CH=); 138.2, 128.8, 128.5, 127.0 (C$_{arom}$); 37.9 (C$\underline{H}_2$—C$_6$H$_5$); 22.6 (CH$_2$); 13.4 (CH$_3$)
3c	49	110–113°/15	1.4912	$C_{10}H_{20}S$ (172.3)	3010, 1615, 880	5.97 (d, 1H, CH=); 5.62 (dt, 1H, CH=, J_{cis} = 10 Hz); 2.28 (s, 3H, SCH$_3$); 2.14 (dt, 2H, CH$_2$—C=)	129.1, 126.6 (CH=); 17.0 (SCH$_3$)
5	58	103–105°/0.01	1.5327	$C_{14}H_{20}O_2S$ (252.4)	3060, 3010, 1640, 1585, 1050, 850, 740, 690	7.25–7.50 (m, 5H$_{arom}$); 6.68 (s, 1H, CH=); 4.82 [s, 1H, C$\underline{H}$(OC$_2$H$_5$)$_2$]; 3.62 (m, 4H, OCH$_2$); 1.92 (d, 3H, H$_3$C—C=)	—
7	66	83–85°/0.01	1.5231	$C_{11}H_{14}OS$ (194.3)	3060, 3010, 1645, 1585, 1230, 860 740, 680	7.2–7.3 (m, 5H$_{arom}$); 6.41 (s, 1H, CH=); 3.63 (s, 3H, OCH$_3$); 2.09 (q, 2H, CH$_2$—C=); 1.02 (t, 3H, CH$_3$)	149.8 (O—CH=); 110.0 (S—C=); 135.7, 128.6, 128.4, 125.3 (C$_{arom}$); 60.0 (OCH$_3$); 26.1 (CH$_2$); 13.8 (CH$_3$)
9a	82	76–77°/0.1	1.5681	$C_{11}H_{14}S$ (178.3)	3060, 3010, 1620, 1585, 840, 810 735, 690	7.20–7.35 (m, 5H$_{arom}$); 5.88 (s, 1H, CH=); 2.30 (q, 2H, CH$_2$); 1.84 (s, 3H, H$_3$C—C=); 1.02 (t, 3H, CH$_3$)	145.1 (C=); 114.9 (S—CH=); 137.6, 128.8, 127.8, 125.5 C$_{arom}$); 26.8 (CH$_2$); 18.0 (H$_3$C—C=); 12.3 (CH$_3$)
9b	72	124–126°/0.01	1.5567	$C_{17}H_{26}OS$ (278.45)	3060, 3010, 1620, 1585, 1085, 810, 740, 685	7.25–7.40 (m, 5H$_{arom}$); 5.98 (s, 1H, CH=); 3.38 (t, 2H, CH$_2$—O); 2.12 (dt, 2H, CH$_2$—C=); 1.90 (s, 3H, H$_3$C—C=); 1.18 (s, 9H, *t*-C$_4$H$_9$)	143.5 (C=); 115.8 (S—CH=); 137.6, 128.7, 127.8, 125.5 (C$_{arom}$); 72.3 (O—C—); 61.1 (CH$_2$—O)

[a] Yield of distilled product, based on **1** and **2**.

[b] All microanalyses gave satisfactory results: C ±0.15; H ±0.36.



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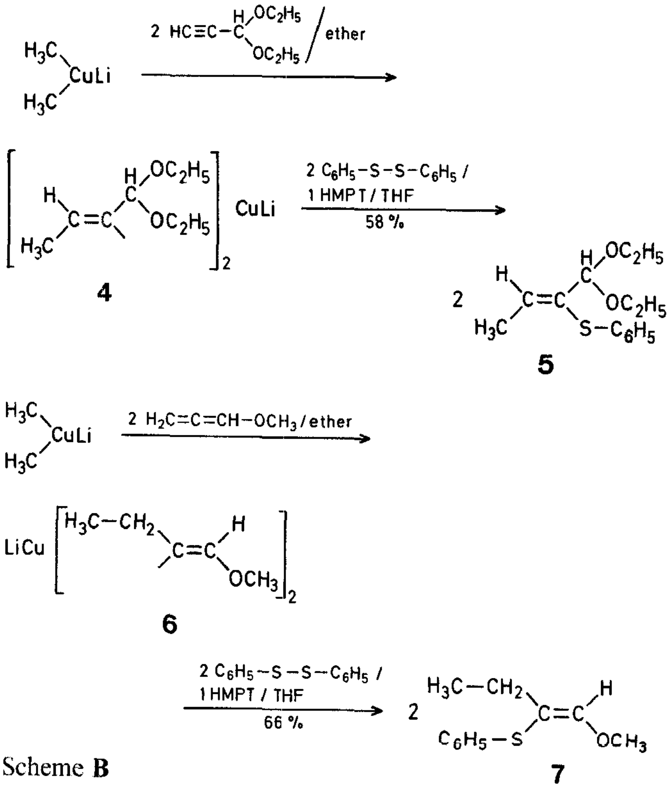
3	R^1	R^2	Yield [%]
a	C_2H_5	C_6H_5	84
b	C_2H_5	$-CH_2-C_6H_5$	69
c	n-C_7H_{15}	CH_3	49
d	n-C_4H_9	t-C_4H_9	0

Scheme **A**

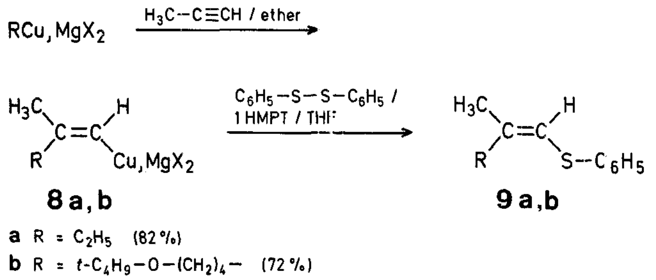
responding 1-alkenyl thioethers **3b** and **3c**, respectively. Di-*t*-butyl disulfide, on the other hand, was completely inert, probably due to the bulkiness of the *t*-butyl group. Anyhow, from a synthetic point of view, phenyl 1-alkenyl thioethers are more versatile[2] and these are, precisely, the sulfides which are best prepared by this method.

1-Alkenyl cuprates bearing certain functionalities may also be used in the reaction. For example, cuprate **4**, obtained by carbocupration of propynal diethyl acetal[10] and cuprate **6**, obtained by carbocupration of methoxyallene[1], react with diphenyl disulfide to give thioethers **5** and **7**, respectively (Scheme **B**). In both cases, the two alkenyl groups of the cuprate are used.



Scheme **B**

Magnesium-1-alkenylcopper reagents **8** are usually less reactive than lithium 1-alkenylcuprates **1**. They are easily obtained by carbocupration non-functionalized 1-alkynes such as propyne[7,11]. In the absence of HMPT, they do not react with diphenyl disulfide. However, in the presence of only 1 equiv of HMPT they react smoothly, affording in high yield the 1-alkenyl thioethers **9** (Scheme **C**).



Scheme **C**

It should be mentioned that in no case is any stereochemical scrambling observed, although 1-alkenyl thioethers are known to be isomerized by light or radical initiators[2]. Thus, the present method represents a simple and straightforward route to 1-alkenyl thioethers.

1-Alkenyl Thioethers (3, 5, 7, 9); General Procedure (given here for 1-Alkenyl Phenyl Thioethers):

An ethereal solution (100 ml) of the lithium bis[1-alkenyl]-cuprate (**1**, **4**, **6**; 15 mmol) or the magnesium-1-alkenylcopper reagent (**8**; 30 mmol) is cooled to −40°C. A solution of HMPT (5.4 ml, 30 mmol) in tetrahydrofuran (20 ml) is added dropwise, with stirring, followed by a solution of diphenyl disulfide (6.54 g, 30 mmol) in tetrahydrofuran (40 ml). The mixture is warmed to room temperature (20°C) and stirred for 3–4 h, then hydrolyzed with saturated ammonium chloride solution (50 ml) at −10°C. Pentane (100 ml) is added and the salts are filtered off. The organic phase is separated, washed with saturated ammonium chloride solution (3 × 30 ml), dried with magnesium sulfate (or potasium carbonate for **5** and **7**), and concentrated in vacuo. The residue is distilled through a 10 cm Vigreux column.

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* Address for correspondence.

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