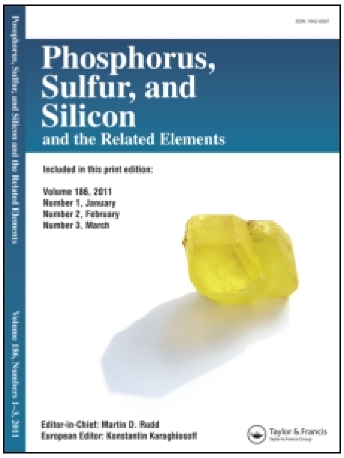

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PREPARATION OF 1,3-DITHIOL-2-ONES FROM 1,2-BIS-TRIISOPROPYLSILANYLSULFANYL ALKENES UNDER MILD ACIDIC CONDITIONS

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1,2-Bis-triisopropylsilanylsulfanyl alkenes are readily converted to 1,3-dithiol-2-ones with phosgene under very mild acidic conditions at room temperature.

Keywords: 1,3-Dithiol-2-one; Lewis acid; phosgene; silyl; sulfide; zinc chloride

Recently we have described the preparation of a series of 1,2-bis-triisopropylsilanylsulfanyl alkenes **2** via a palladium cross-coupling reaction between disulfide **1** and several alkynes.[1,2] These compounds subsequently were treated with tetrabutylammonium fluoride (TBAF) to remove the silyl protecting groups and to allow both of the resulting mercaptides to react with various electrophiles. These electrophiles included alkyl halides, epoxides, acyl chlorides, thiophosgene, and chloroformates (Scheme 1). The last two electrophiles provided cyclic adducts namely 1,3-dithiol-2-thiones and 1,3-dithiol-2-ones. We previously experienced problems in the preparation of 1,3-dithiol-2-ones using phosgene. We found that phosgene was much too reactive under the basic conditions (TBAF) used to furnish the cycloadduct **3** in reasonable yield, so instead we looked at much less reactive species such as chloroformates to produce the 1,3-dithio-2-ones. The chloroformates had just the right balance between stability toward TBAF and reactivity with mercaptides. In our search to find a practicable way to circumvent the problem of high reactivity of phosgene toward TBAF, we sought different conditions to resolve this.

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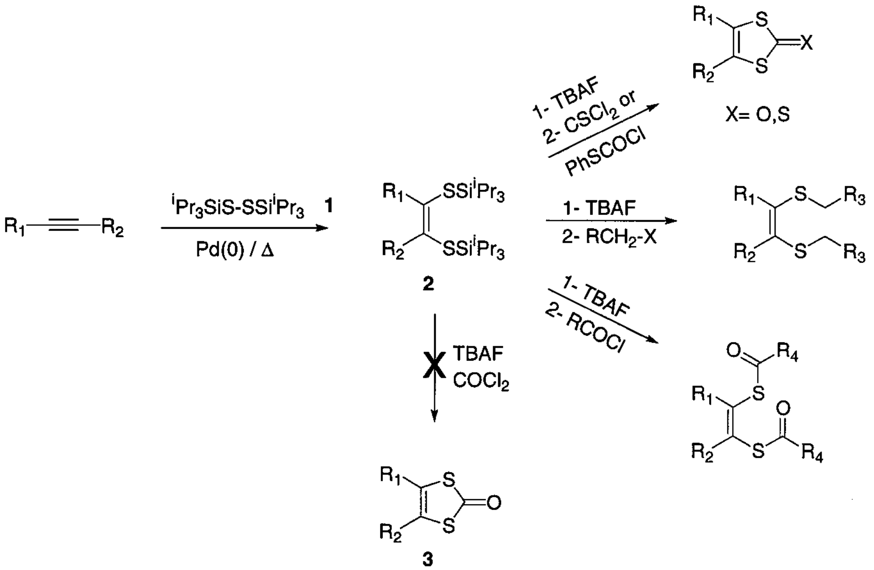


SCHEME 1

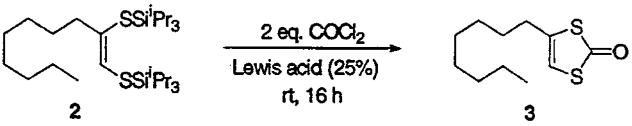
RESULTS

The action of phosgene onto trimethylsilyl ethylsulfide already has been reported.[3] This gives the corresponding dithiocarbonic acid S,S′-diethyl ester in 88% yield. In our hands, treatment of **2** and phosgene under the same conditions (pyridine/0°C) provided only starting material. It seems that the triisopropylsilanyl groups completely inhibit the spontaneous reaction with phosgene due to their bulkiness. We also have reacted **2** and phosgene at room temperature and up to 110°C with no success, yielding only the unreacted alkene.

Since mildly basic and neutral conditions were not successful, we then turned our attention to mildly acidic conditions. To achieve this, a number of Lewis acids were tested to convert **2** into **3** using 2 equivalents of phosgene (1.9 M in toluene) in dichloromethane at room temperature for 18 h. Table I shows the results of our study with 1,2-bis-triisopropylsilanylsulfanyl-dec-1-ene as a model substrate. We encountered no success with phosgene alone nor with our first two Lewis acids, $BF_3 \cdot OEt_2$ and $FeCl_3$. We only recovered the starting material along with some decomposition product. Our first positive result came using $SnCl_4$ where we isolated a 38% yield of the desired adduct.

The yield of the reaction was improved considerably when zinc derivatives were used. For example, a 25% solution of zinc chloride

TABLE I Lewis Acid Catalyzed Formation of 1,3-Dithiol-2-ones **3**



Entry	Lewis acid	Yield (%)
1	None	nr[a]
2	$BF_3{\cdot}OEt_2$	0[b]
3	$FeCl_3$	0[b]
4	$SnCl_4$	38[c]
5	$SnCl_2$	nr
6	$ZnCl_2$	75[d]
7	ZnI_2	74
8	$ZnOTf_2$	57
9	$InCl_3$	71

[a] No reaction even at 110°C.
[b] Slight decomposition.
[c] Complete conversion after 24 h.
[d] 11% conversion at 0°C with 50% of $ZnCl_2$.

(1.0 M in ether) gave an isolated yield of 75% of **3**. In a similar way, a suspension of zinc iodide in dichloromethane gave essentially the same result yielding 74% of **3**. Not all zinc catalysts were equally good. For example, zinc triflate was not as effective as the previous two catalysts and only a 57% yield of the 1,3-dithiol-2-one was isolated. Two other distinct catalysts were investigated to conclude this study. The first one was $FeCl_3$, which only gave decomposition products. The second one surprisingly gave better results then expected. A suspension of $InCl_3$ in dichloromethane gave an isolated yield of 71% of the desired product comparable to the results obtained with the zinc halides. This certainly is not a systematic list of catalysts but gives rather a general idea of the kind of catalyst one can use. Based on these results the conditions of entry 6 were selected as standard for the subsequent reactions.

The next step was to prepare a series of 1,2-bis-triisopropylsilanylsulfanyl alkenes, according to the reported procedure[1] in order to study the scope and limitations of this reaction. All of the examples in Table II previously were described except for entry 8.* We also have compared this approach to the one using phenyl chlorothionoformate[1] in the first four cases (Table II). We already have seen that when R_1 = octyl one

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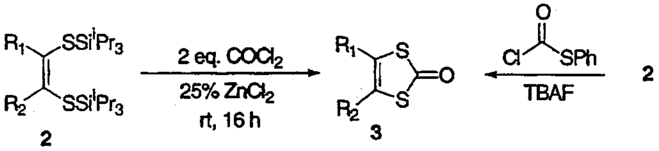
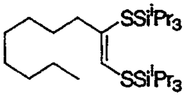
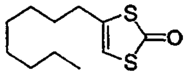
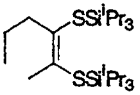
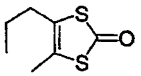
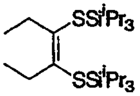
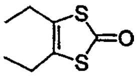
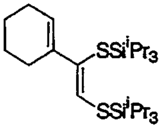
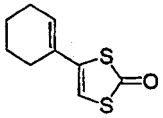
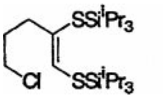
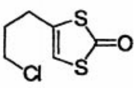
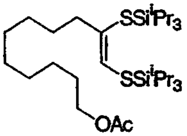
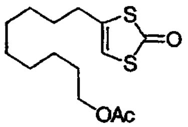
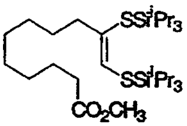
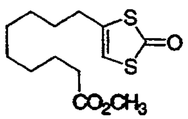
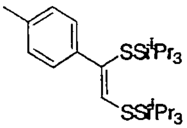
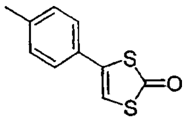
*The compounds not described in the Experimental section already have been reported.

TABLE II Preparation of 1,3-Dithiol-2-ones from Phosgene and 1,2-Bis-triisopropylsilanylsulfanyl-alkenes. Comparison with Phenyl Chlorothionoformate



Entry	Substrate	Product	Yield (%) ($COCl_2$)	Yield (%) (ClCOSPh)
1			75	63
2			82	67
3			72	40
4			64	63
5			53	—
6			71	—
7			73	—
8			64 (3 days)	—

can isolate **3** in 75% yield. When compared to the chloroformate/TBAF methodology, we did in fact increase the yield of **3** by 12%. A similar improvement was seen with $R_1 = $ propyl, $R_2 = $ methyl (entry 2) and $R_1 = R_2 = $ ethyl (entry 3) giving 15% and 32%, respectively, more of the cyclic adducts. The superiority of $ZnCl_2$ over chloroformate/TBAF was not general but at least was comparable. This was observed with $R_1 = $ cyclohexenyl of entry 4. Both methods basically gave the same result.

A number of functionalities were well tolerated under these conditions. For instance, both the acetate group (entry 6) and the methyl ester (entry 7) gave good yields of the corresponding 1,3-dithiol-2-one, whereas the terminal chloride (entry 5) was less successful yielding 55% of the desired product. We have observed something slightly different in the course of the reaction when an aromatic group was placed in conjugation with the 1,2-bis-triisopropylsilanylsulfanyl alkene (entry 8). In fact the tolyl group greatly slowed down the rate of reaction and what would have normally taken 18 h required 3 days to go to completion. The conjugation also diminished the yield of final product to 64%, a situation we have seen with the cyclohexenyl group (entry 4).

CONCLUSIONS

We have shown that 1,3-dithiol-2-ones can be prepared readily under mild acidic conditions from 1,2-bis-triisopropylsilanylsulfanyl alkenes and phosgene with a catalytic amount of $ZnCl_2$ or several other Lewis acids. Also, this method is at least equal to or superior to the one using phenyl chlorothionoformate.

Experimental

1-(1,2-Bis-triisopropylsilanylsulfanyl-vinyl)-4-methyl Benzene

A solution of 4-ethynyltoluene (3.6 mmol), disulfide **1** (3.9 mmol), and tetrakistriphenylphosphine palladium (0.18 mmol) in 1.8 mL of toluene was heated to 140°C in a sealed tube for 16 h. The solution was cooled and the solvent was removed. Purification on a short pad of silica gel using hexane/toluene (9-1) gave 0.75 g (42%) of the desired compound. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 1.05 (s, 18H), 1.15 (d, 18H, $J = 7.3$ Hz), 1.35 (1H, m), 2.34 (s, 3H), 6.67 (s, 1H), 7.08 (d, 2H, $J = 7.7$ Hz), and 7.37 (2H, d, $J = 7.7$ Hz); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 12.7, 13.5, 18.3, 18.4, 21.0, 126.8, 127.0, 128.4, 131.6, 136.5, and 141.2; HRMS calcd for $C_{27}H_{50}S_2Si_2 + K^+$: 533.2530. Found: 533.2529.

General procedure for the preparation of 1,3-dithiol-2-ones. To a 0.3 M solution of 1,2-bis-triisopropylsilanylsulfanyl alkenes in dichloromethane was added phosgene (2 equivalents, 1.9 M in toluene) and 25% of a 1.0 M solution of $ZnCl_2$ in ether. The solution was stirred 16–18 h, quenched with an ammonium chloride solution, and diluted with ethyl acetate. The organic phase was separated, dired, and the solvent removed. Purification by flash chromatography using hexane-ethyl acetate gave the desired product.

4-(3-chloropropyl)-1,3-dithiol-2-one. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.0 (m, 2H), 2.76 (t, 2H, J = 7.4 Hz), 3.55 (t, 2H, J = 6.2 Hz), and 6.4 (s, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 29.7, 31.5, 43.2, 112.5, 134.3, and 193.3; HRMS calcd for $C_6H_7OS_2Cl + H^+$: 194.97051. Found: 194.97050.

9-(2-Oxo-1,3-dithiol-4-yl) nonyl acetate. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 1.31 (m, 10H), 1.60 (m, 4H), 2.04 (s, 3H), 2.57 (t, 2H, J = 8.0 Hz), 4.05 (t, 2H, J = 6.8 Hz), and 6.33 (s, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 20.8, 25.7, 28.6, 28.9, 29.0, 29.1, 32.7, 64.4, 110.8, 136.5, 171.0, and 193.7; HRMS calcd for $C_{14}H_{22}O_3S_2 + H^+$: 303.10886. Found: 303.10882.

Methyl 9-(2-oxo-1,3-dithiol-4-yl) nonanoate. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 1.31 (m, 8H), 1.61 (m, 4H), 2.30 (t, 2H, J = 7.5 Hz), 2.57 (t, 2H, J = 7.2 Hz), 3.66 (s, 3H), and 6.32 (s, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 24.7, 28.5, 28.8, 28.9, 29.1, 32.7, 33.9, 51.2, 110.9, 136.5, 174.0, and 193.6; Elemental analysis calcd for $C_{13}H_{20}O_3S_2$: C, 54.14; H, 6.99; S, 22.23. Found: C, 54.06; H, 7.14, S, 22.35.

4-(4-Methylphenyl)-1,3-dithiol-2-one. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.36 (s, 3H), 6.75 (s, 1H), 7.19 (d, 2H, J = 7.4 Hz), and 7.29 (d, 2H, J = 7.4 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 21.2, 110.7, 126.1, 129.7, 129.8, 135.0, 139.3, and 192.7; m.p: 80–81°C (hexane/dichloromethane); HRMS calcd for $C_{10}H_8OS_2 + H^+$: 209.0095. Found: 209.0095.

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