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Oxidative Fragmentations of Selected 1-Alkenyl Sulfoxides. Chemical and Spectroscopic Evidence for 1-Alkenesulfinyl Chlorides.

Adrian L. Schwan*, Mark L. Kalin, Kristin E. Vajda, Ting-Jian Xiang and Denis Brillon

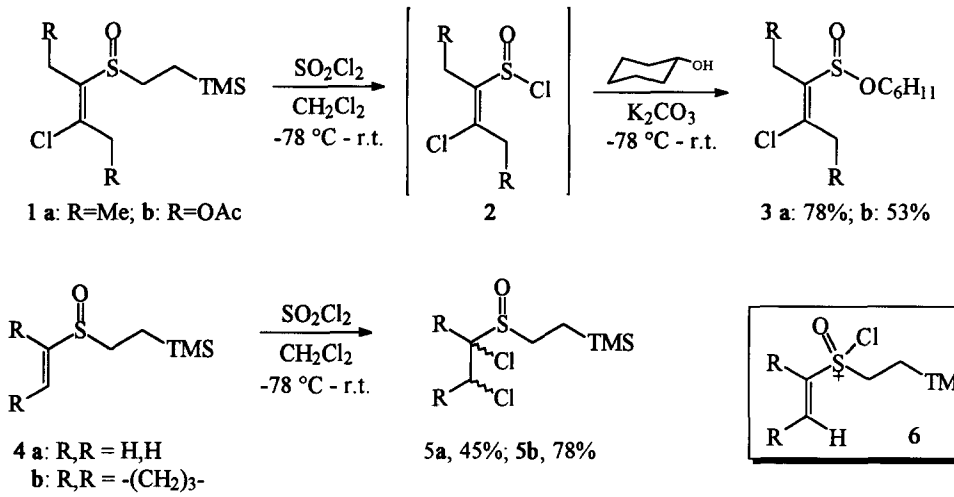
Guelph-Waterloo Centre for Graduate Work in Chemistry, Guelph Campus, Department of Chemistry and Biochemistry, University of Guelph, Guelph, Ontario, CANADA, N1G 2W1

Abstract A collection of 1-alkenyl sulfoxides possessing diphenylmethyl, *p*-methoxybenzyl or 2-(trimethylsilyl)ethyl groups can be converted to 1-alkenesulfinyl chlorides using SO_2Cl_2. The 1-alkenesulfinyl chlorides were spectroscopically characterized by IR and were chemically captured as their cyclohexyl or 3-phenylpropyl 1-alkenesulfinate esters. Copyright © 1996 Elsevier Science Ltd

The sulfinyl chloride functional group is a vital component of synthetic organosulfur chemistry.[1] In general, it is *the* starting point for the delivery of a sulfinyl group into a variety of substrates. For instance, a sulfinyl chloride is the essential starting component for the general approach to chiral sulfoxides[2] originated by Andersen.[3,4] Of the many routes available for the synthesis of arene- and alkanesulfinyl chlorides,[1,5-7] most are based on the chlorination of a sulfur acid or thiol derivative.[1,5] The absence of a general preparation of 1-*alkene*sulfinyl chlorides may be due to either the limited accessibility of alkenyl substituted thiols and sulfur acids, or the unwanted reactivity of the double bond during the chlorination reaction.

We have developed a preparation of arene- and alkanesulfinyl chlorides that has as its foundation the chlorination of a *sulfoxide*.[6,7] Thus, we have shown that the reaction of SO_2Cl_2 with aryl and alkyl 2-(trimethylsilyl)ethyl sulfoxides affords sulfinyl chloride via oxidative cleavage of the C-S bond on the side of the 2-(trimethylsilyl)ethyl group. Having developed a method that circumvents the thiol or sulfur acid derivative, we felt 1-alkenyl 2-(trimethylsilyl)ethyl sulfoxides may be suitable for the generation of 1-alkenesulfinyl chlorides. A general approach to 1-alkenesulfinyl chlorides would be quite valuable, since the double bond would be available for further elaboration before or after utilization of the sulfinyl chloride.

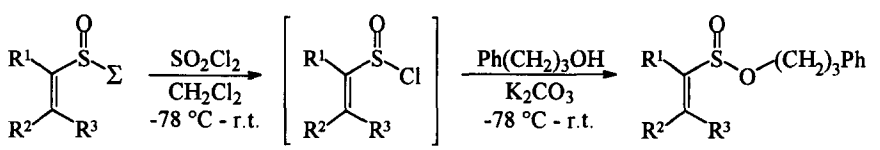
Four alkenyl 2-(trimethylsilyl)ethyl sulfoxides were prepared through the use of 2-(trimethylsilyl)ethanesulfenyl chloride.[8,9] These compounds were reacted with SO_2Cl_2 using our established conditions (1.2 eq., CH_2Cl_2, -78 °C - r.t.).[6] After warming, TLC indicated that the reactions of **1a** and **1b** could contain sulfinyl chloride, based on elution behavior similar to a carboxylic acid chloride.[10] Cyclohexanol and K_2CO_3 were added to these mixtures and the isolated products were cyclohexyl sulfinates (**3a,b**) as shown in Scheme 1. These reactions were repeated in order to obtain IR spectra. Solution IR cells (0.1 mm, CH_2Cl_2) allowed the observation of clear strong peaks for proposed sulfinyl chlorides **2a** and **2b** at 1153 and 1156 cm^{-1}, respectively. The sulfinyl stretching frequencies and the subsequent isolation of sulfinates **3** comprise evidence consistent with the presence of 1-alkenesulfinyl chlorides in solution.[1]



Scheme 1

Compounds **4a** and **b** were offered similar treatment but did not partake in the fragmentation reaction. Rather, the only products isolated were α,β-dichlorination products **5** which may be formed through an additive Pummerer reaction.[11] The α,β-dichlorination reaction presumably occurs since the activating effect of the 2-(trimethylsilyl)ethyl group is not persuasive enough to induce C-S bond cleavage in the postulated intermediate, chlorosulfoxonium ion **6**.[12] The chlorination reaction limits the generality of this particular approach and the limitation is particularly underscored by the fact that the parent ethenyl 2-(trimethylsilyl)ethyl sulfoxide (**4a**) does not afford ethenesulfinyl chloride.

At this point we sought to change the 2-(trimethylsilyl)ethyl unit to something that may prompt C-S bond cleavage more readily. Our investigation brought us to the diphenylmethyl (DPM)[12,13] and *p*-methoxybenzyl (PMB)[14] groups. A collection of alkenyl sulfoxides (**7**,**8**) bearing these groups were prepared[15,16] and subjected to the fragmentation conditions. Once again, evidence characteristic of 1-alkenesulfinyl chlorides in solution was acquired through IR and TLC analysis.[17] These sulfinyl chlorides (**9**) were captured as sulfinate esters (**10**) by the addition of 3-phenylpropanol (Scheme 2). After consumption of **9**, the mixtures were filtered, concentrated and subjected to flash chromatography on silica gel. The separations were complicated by hydrolysis of the by-products of the fragmentations, diphenylmethyl chloride (from **7**) or *p*-methoxybenzyl chloride (from **8**).[18] Analytically pure sulfinates could be obtained after a second flash



7: Σ = diphenylmethyl (DPM)
8: Σ = *para*-methoxybenzyl (PMB)

Scheme 2

chromatography treatment. The Table lists the isolated yields of the sulfinate esters; it also presents some diagnostic IR data for both the 1-alkenesulfinyl chlorides **9** and 3-phenylpropyl 1-alkenesulfinates **10**. Alkenyl sulfoxides **7** and **8** are clearly more consistently reliable sources of alkenesulfinyl chlorides than are 2-(trimethylsilyl)ethyl alkenyl sulfoxides.

Table. Capture of 1-Alkenesulfinyl Chlorides Generated by Oxidative Cleavage of Diphenylmethyl (DPM) and *para*-Methoxybenzyl (PMB) 1-Alkenyl Sulfoxides (Scheme 2)

entry	Starting Sulfoxide					Sulfinate	IR Stretching Frequencies (cm^{-1})[b]		
	#	Σ	R^1	R^2	R^3	(% Yield)[a]	C=C of 9[c]	S=O of 9[d]	S=O of **10**
1	**7a**	DPM	H	H	H	**10a** (65)	1611	1148	1128
2	**8a**	PMB				(65)			
3	**7b**	DPM	H	Me	H	**10b** (78)	1612	1146	1126
4	**8b**	PMB				(76)			
5	**7c**[e]	DPM	H	$Ph(CH_2)_2$	H	**10c** (69)	1611	1148	1124
6	**8c**	PMB				(62)			
7	**7d**	DPM	H	Ph	H	**10d** (75)	1609	1147[f]	1123
8	**8d**	PMB				(69)			
9	**7e**	DPM	Ph	H	H	**10e** (42)	1611	1152	1135
10	**8e**[e]	PMB				(69)			
11	**8f**	PMB	H	H	Ph	**10f** (65)	1609	1129	1112
12	**7g**	DPM	$-(CH_2)_4-$		H	**10g** (83)	1611	1144	1128
13	**8g**	PMB				(62)			

Footnotes. *a* Yields are of twice chromatographed material. *b* The IR spectra were run on a Bomem MB 100 instrument. *c* These values arise from the fragmentations of sulfoxides **8**; the C=C stretches of sulfinyl chlorides from **7** were not distinct. *d* The S=O stretching frequencies from both sources were within 1 cm^{-1} (usually < 0.6 cm^{-1}) of each other unless otherwise noted. *e* Complete consumption of this compound required 1.5 equiv. of SO_2Cl_2 rather than 1.2 equiv. *f* 1147 cm^{-1} is an average of readings of 1145 cm^{-1} (from **7d**) and 1149 cm^{-1} (from **8d**).

The PMB and DPM sulfoxides are both suitable sources of alkenesulfinyl chlorides. Sulfoxides **8** afford more consistent yields of ester, although in some instances, such as with **7d** and **g**, the DPM sulfoxides provide a better yield. The chlorinated by-products of the fragmentations of **7** and **8** are a hindrance during the purification of esters **10**, but are nevertheless sufficiently inert to allow selective functionalization of the alkenesulfinyl chlorides. The ability to selectively perform chemistry on sulfinyl chlorides **9** makes this first general preparation of 1-alkenesulfinyl chlorides an inviting one, since a number of ethenesulfinic acid derivatives are expected to be accessible through this chemistry. Indeed, the overall conversion of sulfoxide to sulfinate is one of the few synthetic routes available for 1-alkenesulfinic esters.[19] We plan to study the reactivity of the 1-alkenesulfinyl chlorides with other nucleophiles.

Acknowledgements

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9. Alkenyl sulfoxides **1a** and **1b** were prepared by the addition of $TMSCH_2CH_2SCl$ (see ref. 8) across 3-hexyne and 1,4-diacetoxy-2-butyne, respectively, followed by oxidation with MCPBA. Overall yields: **1a**, 56%; **1b**, 42%. Vinyl 2-(trimethylsilyl)ethyl sulfoxide (**4a**) was prepared by the addition of $TMSCH_2CH_2SCl$ across vinyl trimethylsilane followed by MCPBA oxidation and elimination of TMSCl with TBAF (43% overall). 1-Cyclopentenyl 2-(trimethylsilyl)ethyl sulfoxide was prepared by the addition of $TMSCH_2CH_2SCl$ across cyclopentene followed by MCPBA oxidation and elimination of HCl (NaI, DBU, 80 °C; 78% overall). Satisfactory ^1H and ^{13}C NMR, IR, MS and elemental analysis were obtained for compounds presented in this communication except **7d** for which appropriate ^1H and ^{13}C NMR, IR and MS were obtained.
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15. Sulfoxides **7a-c, g** and **8a-c, g** were prepared by reacting the appropriate alkenesulfenate (see ref. 16) with diphenylmethyl bromide and *p*-methoxybenzyl bromide (49-75%). Compounds **7d-e** and **8d-e** were prepared from the reaction of the phenyl substituted ethenesulfenates derived from phenylthiirane *S*-oxide (ref. 16) with the appropriate aforementioned bromides. One reaction produced **7d** (35%) and **7e** (12%) while a second reaction afforded **8d** (43%) and **8e** (24%). Sulfoxide **8f** was prepared by base catalyzed addition of *p*-methoxybenzyl mercaptan across phenylacetylene (cat. KOH, DMF, r.t.) followed by MCPBA oxidation (65% overall).
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17. Vacuum distillation was attempted for sulfinyl chlorides **9a** and **9b** (from **7a** and **7b**), but decomposition occurred upon concentration and mild heating of the samples.
18. The mixtures initially contain DPMCl or PMBCl as by-products. During and sometimes before chromatography, these chlorides undergo partial hydrolysis to their corresponding alcohols. Since the chlorides are less polar than the alkenesulfinates and the alcohols are more polar, the sulfinate containing fractions of the initial chromatographic separations usually contain some alcohol. The troublesome, labile hydrolytic behavior of PMBCl has literature precedent; see ref. 12.
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