

Oxidation of γ -Oxo Sulfides with Chlorine Dioxide

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Abstract— γ -Oxo sulfides were oxidized to the corresponding sulfoxides with an aqueous solution of chlorine dioxide.

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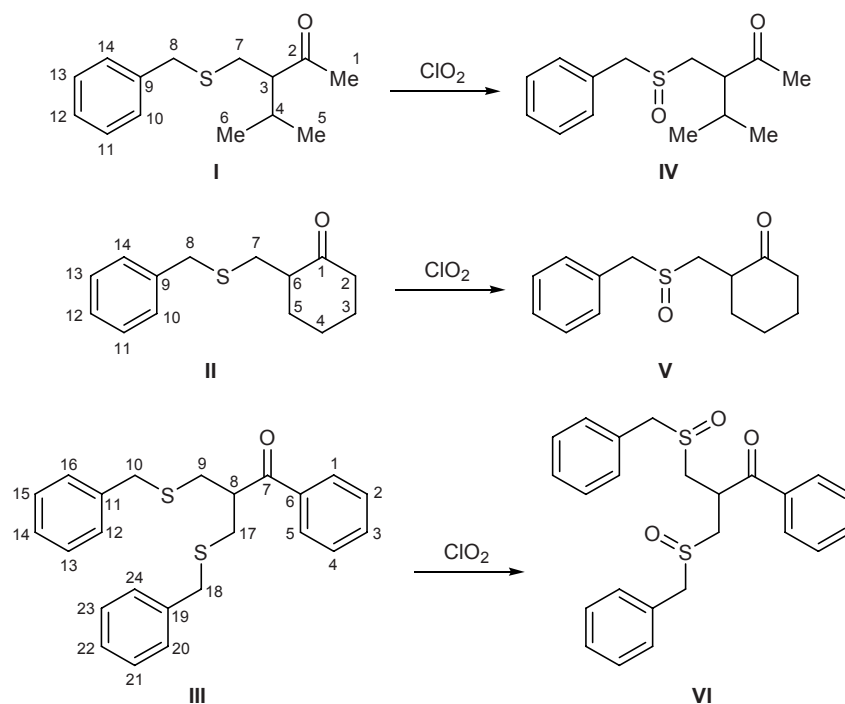
Oxidation of oxo sulfides to the corresponding sulfoxides and sulfones attracts increasing attention due to prospects in using oxo sulfoxides as reagents in asymmetric synthesis [1], palladium and platinum extractants, plant growth regulators, flotation agents [2], and metal complexes [3].

Oxo sulfoxides can be synthesized by condensation of sulfinyl anion with esters [4], oxidation of 6-substituted 2,3-dihydro-1,4-oxathiones with subsequent ring opening [5], and oxidation of oxo sulfides with various oxidants [6–9].

In the present article we report on the oxidation of some oxo sulfides to the corresponding oxo sulfoxides with the use of chlorine dioxide. We previously demonstrated high chemoselectivity in the oxidation of dialkyl, diaryl, alkyl aryl, and dibenzyl sulfides to sulfoxides with that reagent [10–14]. Initial γ -oxo sulfides **I–III** were synthesized according to the procedure described in [3] for methylsulfanylation of ketones [3].

The oxidation of sulfides **I–III** with an aqueous solution of chlorine dioxide was performed at 20°C, the substrate-to-oxidant molar ratio being 1:0.5 for com-

Scheme 1.



pounds **I** and **II** and 1:1 for **III**. The conversion of initial sulfides was 65–78%, and γ -oxo sulfoxides **IV**–**VI** were formed in 62–74% yield; the products contained no impurity of the corresponding sulfone.

The structure of sulfoxides **IV**–**VI** was confirmed by IR and NMR spectroscopy. The IR spectra of **IV**–**VI** contained absorption bands typical of sulfoxide group in the region 1020–1050 cm^{-1} . In the ^1H NMR spectra of these compounds, signals from the methylene protons displaced downfield relative to the corresponding signals of the initial sulfides. Compound **IV** displayed in the ^1H NMR spectrum signals belonging to protons in the methyl and phenyl groups; protons on C^8 gave two singlets at δ 3.94 and 4.11 ppm. The ^1H NMR spectrum of **V** contained signals from protons in the cyclohexane and benzene rings. As in the spectrum of **IV**, two singlets from methylene protons were present at δ 3.94 and 4.10 ppm.

The oxidation of oxo sulfide **III** involved both sulfur atoms and led to the formation of bis-sulfoxide **VI**. In the ^1H NMR spectrum of **VI**, aromatic protons resonated as multiplets at δ 7.29 and 7.92 ppm. The signal from the C^8H proton was retained, and protons in positions 10 and 18 gave singlets at δ 3.87 and 4.04 ppm. The presence of a couple of singlets in the ^1H NMR spectra of all oxidation products indicates that compounds **IV**–**VI** are mixtures of diastereoisomers. According to the signal intensities, the diastereoisomer ratio is 1:1. Presumably, the absence of differentiating effect of the oxo group in the initial sulfides is responsible for the lack of stereoselectivity. Molecules **IV** and **V** possess chiral carbon atoms (C^3 and C^6 , respectively), and a new chiral center appears on the sulfur atom. Compound **VI** has two sulfoxide groups, each being a chiral center. Splitting of the signal from protons in the α -position with respect to the sulfoxide group suggests diastereotopicity of these protons.

The use of chloride dioxide as oxidant in the synthesis of oxo sulfides seems to be fairly promising, despite the lack of stereoselectivity. The latter factor is a drawback intrinsic to most oxidants. Therefore, further improvement of the proposed procedure may be achieved via modification of the oxidant with chiral reagents.

EXPERIMENTAL

The IR spectra were recorded on a Specord M-80 spectrometer from solutions in carbon tetrachloride.

The ^1H and ^{13}C NMR spectra were measured on a Tesla BS467A spectrometer (80 MHz for ^1H) using CDCl_3 as solvent. The elemental compositions were determined on an EA1110 CHNS-O automatic analyzer. Column chromatography was performed on silica gel using gradient elution with benzene–ethanol. Silufol plates were used for thin-layer chromatography (benzene–ethanol, 4:1; the chromatograms were developed by treatment with a 5% solution of potassium permanganate).

3-(Benzylsulfanylmethyl)-4-methylpentan-2-one (I). Yield 65%, bp 170°C (2 mm). IR spectrum, ν , cm^{-1} : 700 (C–S), 1750 (C=O). ^1H NMR spectrum, δ , ppm: 0.78 m (3H, C^5H_3), 0.91 m (3H, C^6H_3), 1.11 m (1H, 4-H), 2.10 m (1H, 3-H), 2.17 s (3H, C^1H_3), 2.54 d (2H, 7-H, $J = 4$ Hz), 3.65 s (2H, 8-H), 7.25 m (5H, C_6H_5). ^{13}C NMR spectrum, δ_{C} , ppm: 21.85 (C^5), 22.22 (C^6), 22.24 (C^4), 29.23 (C^1), 29.78 (C^7), 52.25 (C^8), 95.95 (C^3), 126.56 (C^{12}), 127.07 (C^{13}), 127.26 (C^{11}), 127.56 (C^{14}), 128.42 (C^{10}), 137.27 (C^9), 208.13 (C^2). Found, %: C 71.22; H 8.52; S 13.61. $\text{C}_{14}\text{H}_{20}\text{OS}$. Calculated, %: C 71.19; H 8.47; S 13.56.

2-(Benzylsulfanylmethyl)cyclohexan-1-one (II). Yield 72%, bp 160°C (2 mm). IR spectrum, ν , cm^{-1} : 695 (C–S), 1750 (C=O). ^1H NMR spectrum, δ , ppm: 1.57 m (2H, 4-H), 1.81 m (2H, 3-H), 2.15 m (2H, 5-H), 2.33 m (2H, 2-H), 2.59 d (2H, 7-H, $J = 16.0$ Hz), 2.92 m (1H, 6-H), 3.59 d (2H, 8-H, $J = 8.3$ Hz), 7.28 m (5H, C_6H_5). ^{13}C NMR spectrum, δ_{C} , ppm: 24.67 (C^4), 26.53 (C^3 , C^5), 29.41 (C^7), 33.89 (C^8), 41.36 (C^2), 48.64 (C^6), 126.48 (C^{12}), 128.01 (C^{11} , C^{13}), 128.49 (C^{10} , C^{14}), 128.98 (C^9), 209.61 (C^1). Found, %: C 71.84; H 7.73; S 13.71. $\text{C}_{14}\text{H}_{18}\text{OS}$. Calculated, %: C 71.79; H 7.69; S 13.67.

3-(Benzylsulfanyl)-2-(benzylsulfanylmethyl)-1-phenylpropan-1-one (III). Yield 78%, bp 180°C (2 mm). IR spectrum, ν , cm^{-1} : 700 (C–S), 1700 (C=O). ^1H NMR spectrum, δ , ppm: 1.22 d (4H, 9-H, 17-H, $J = 7.0$ Hz), 2.61 s (4H, 10-H, 18-H), 3.77 m (1H, 8-H), 7.25 m (10H, C_6H_5), 7.88 m (5H, C_6H_5). ^{13}C NMR spectrum, δ_{C} , ppm: 25.15 (C^{11}), 25.90 (C^9), 75.83 (C^{18}), 78.37 (C^{10}), 95.92 (C^8), 127.19 (C^4 , C^{17}), 127.97 (C^{13} , C^{15} , C^{21} , C^{23}), 128.23 (C^1 , C^5), 128.75 (C^{12} , C^{16} , C^{20} , C^{24}), 132.56 (C^6), 129.02 (C^3), 137.16 (C^{11} , C^{19}), 196.69 (C^7). Found, %: C 73.43; H 6.18; S 16.27. $\text{C}_{24}\text{H}_{24}\text{OS}_2$. Calculated, %: C 73.47; H 6.12; S 16.33.

3-(Benzylsulfanylmethyl)-4-methylpentan-2-one (IV). An aqueous solution of chlorine dioxide, 15 ml

(1.1 mmol, $c = 5$ g/l) was added over a period of 1 h under stirring at 20°C to 0.5 g (2.1 mmol) of oxo sulfide **I**. The mixture was extracted with chloroform, the extract was evaporated, and the residue was subjected to column chromatography on silica gel using benzene–ethanol as eluent to isolate 0.35 g (65%) of compound **IV** as a yellow oily liquid. IR spectrum, ν , cm^{-1} : 1045 (S=O), 1750 (C=O). ^1H NMR spectrum, δ , ppm: 0.82 d (3H, C^6H_3 , $J = 2.4$ Hz), 0.92 d (3H, C^5H_3 , $J = 2.4$ Hz), 1.19 m (1H, 4-H), 2.16 s (3H, C^1H_3), 2.51 m (1H, 3-H), 2.81 d (2H, 7-H, $J = 3.2$ Hz), 3.94 s and 4.11 s (1H each, 8-H), 7.49 m (5H, C_6H_5). Found, %: C 66.75; H 8.02; S 12.65. $\text{C}_{14}\text{H}_{20}\text{O}_2\text{S}$. Calculated, %: C 66.67; H 7.94; S 12.70.

The oxidation of oxo sulfides **II** and **III** was carried out in a similar way.

2-(Benzylsulfinylmethyl)cyclohexan-1-one (V). Yield 72%, yellow oily liquid. IR spectrum, ν , cm^{-1} : 1035 (S=O), 1750 (C=O). ^1H NMR spectrum, δ , ppm: 1.17 m (2H, 3-H), 1.46 m (2H, 4-H), 2.11 m (2H, 5-H), 2.41 m (2H, 2-H), 2.58 d (2H, 7-H, $J = 13.4$ Hz), 2.74 m (1H, 6-H), 3.94 s and 4.10 s (1H each, 8-H), 7.25 m (5H, C_6H_5). Found, %: C 67.26; H 7.24; S 12.74. $\text{C}_{14}\text{H}_{18}\text{O}_2\text{S}$. Calculated, %: C 67.20; H 7.20; S 12.80.

3-(Benzylsulfinyl)-2-(benzylsulfinylmethyl)-1-phenylpropan-1-one (VI). Yield 78%, yellow oily liquid. IR spectrum, ν , cm^{-1} : 1050 (S=O), 1700 (C=O). ^1H NMR spectrum, δ , ppm: 2.57 d (4H, 9-H, 17-H, $J = 13.6$ Hz), 3.87 s and 4.04 s (2H each, 10-H, 18-H), 4.66 m (1H, 8-H), 7.29 m (10H, C_6H_5), 7.92 m (5H, C_6H_5). Found, %: C 67.87; H 5.72; S 15.15. $\text{C}_{24}\text{H}_{24}\text{O}_3\text{S}_2$. Calculated, %: C 67.92; H 5.66; S 15.09.

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