A Facile Synthesis of Symmetrical Alkanesulfonothioic *S*-Alkyl Esters (*S*-Alkyl Alkanethiosulfonates)

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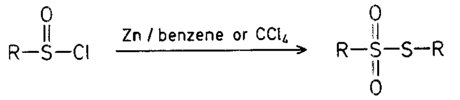
Although it has been reported that activated zinc powder reacts with benzenesulfinyl chloride (**1i**) and two alkanesulfinyl chlorides[2,3,4] to give benzenesulfonothioic *S*-phenyl ester (*S*-phenyl benzenethiosulfonate) (**2i**) and alkanesulfonothioic *S*-alkyl esters (*S*-alkyl alkanethiosulfonates), respectively, very little is known about the mechanism and synthetic scope of this potentially useful reaction.

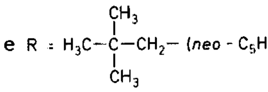
Benzenesulfinyl chloride (**1i**) and ethanesulfinyl chloride (**1a**) react with zinc powder in ether to yield *S*-phenyl benzenethiosulfonate (**2i**; 96%) and *S*-ethyl ethanethiosulfonate (**2a**; 54%), respectively[1-4]. In a preliminary study, it was observed that 2,2-dimethylpropanesulfinyl chloride (**1e**) reacted with activated zinc powder in benzene or tetrachloromethane as solvent to give *S*-(2,2-dimethylpropyl) 2,2-dimethylpropanesulfonothioate (**2e**) in 79% (^{1}H-N.M.R. assay; 40% **1e** recovered) or 78% yield of isolated product, respectively[2].



$$R-\overset{O}{\overset{\|}{S}}-Cl \xrightarrow{Zn\ /\ benzene\ or\ CCl_4} R-\underset{O}{\underset{\|}{\overset{O}{\overset{\|}{S}}}}-S-R$$

1 **2**

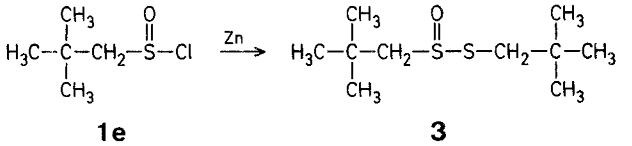
a R = C_2H_5



e R = $H_3C-\underset{CH_3}{\overset{CH_3}{C}}-CH_2-$ (*neo* - C_5H_{11})

i R = C_6H_5

Interestingly, the reaction of compound **1e** with zinc in diethyl ether, diethyl ether-d_{10}, or acetonitrile-d_3 gave *S*-(2,2-dimethylpropyl) 2,2-dimethylpropanethiosulfinate (**3**) as the major product[2].



$$H_3C-\underset{CH_3}{\overset{CH_3}{C}}-CH_2-\overset{O}{\overset{\|}{S}}-Cl \xrightarrow{Zn} H_3C-\underset{CH_3}{\overset{CH_3}{C}}-CH_2-\overset{O}{\overset{\|}{S}}-S-CH_2-\underset{CH_3}{\overset{CH_3}{C}}-CH_3$$

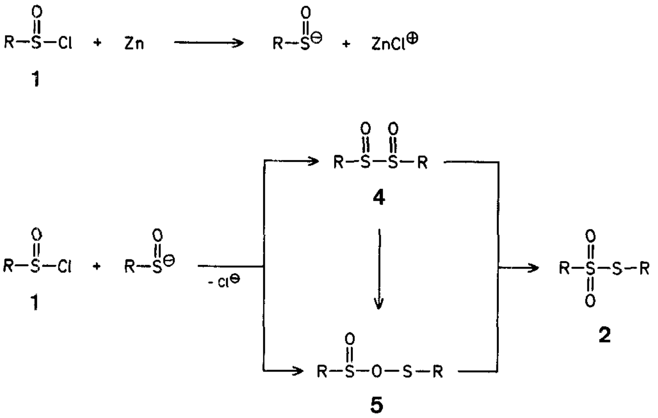
1e **3**

S-Esters of alkanesulfonothioic acids have previously been prepared mainly by oxidation of disulfides with peroxoic acids[5,6,7], by alkylation of alkali metal alkanethiosulfonates[6,8,9], and by thermolysis of alkanesulfinic acids[10,11]. We have investigated the conversion of alkanesulfinyl chlorides[12,13,14] to symmetrical alkanethiosulfonates with activated zinc powder[15] in dry tetrachloromethane in order to determine the synthetic scope of the reaction.

The eight symmetrical *S*-alkyl alkanesulfonothioates **2** listed in Tables 1 and 2[1,2,16] were prepared from the addition *(inverse addition)* of activated zinc powder[15] to the corresponding alkanesulfinyl chloride in tetrachloromethane. Slow addition of a solution of the alkanesulfinyl chloride to zinc in tetrachloromethane can give lower yields of alkanesulfonothioic *S*-esters, more exothermic reactions, and more side reactions. The chemical ionization (CI, 2-methylpropane) mass spectra (Table 2) of low molecular weight thiosulfonates generally show protonated molecular ions $[MH]^+$ as base peaks[17].

The yields of *S*-alkyl alkanesulfonothioates range from moderate to excellent (Table 2). The ready availability of alkanesulfinyl chlorides[12,13] and the simplicity of experimental conditions make this procedure a desirable method for the preparation of symmetrical alkanesulfonothioic *S*-alkyl esters. The moderate yield (45–55%) of **2a** is higher than that obtained via oxidation of diethyl disulfide (12%)[6] or alkylation of potassium ethanethiosulfonate (<30%)[6]. Even the moderate yield of *S*-dodecyl dodecanethiosulfonate (**2h**; 46%) compares favorably with its four-day preparation from oxidation of the corresponding disulfide [H_2O_2 (40%) and peroxy acetic acid (48%)][7].

Although the mechanism of the conversion of alkanesulfinyl chlorides to alkanesulfonothioic *S*-esters with zinc metal is not known, the reaction may involve *vic*-disulfoxides (**4**), sulfenyl sulfinates (**5**), and/or sulfinyl radicals[2,18].



^{1}H-N.M.R. spectra were obtained on a Varian FT-80A spectrometer. ^{13}C-N.M.R. spectra were taken at 22.63 MHz on a Bruker WH-90 Fourier transform N.M.R. spectrometer which was controlled by a B-NC-12 computer.

Thin layer chromatography (T.L.C.) was performed on silica gel glass plates which were developed in ethyl acetate/hexanes (1/9). After the solvent had risen to the top, the plates were immersed in phosphomolybdic acid and charred.

Flash column chromatography[19]: The alkanesulfonothioic *S*-esters are placed on an 46 cm × 50 mm diameter column which contained 15 cm of 100–200 mesh silica gel covered with 0.3 cm of sand. The alkanethiosulfonates are eluted with ethyl acetate/hexanes (1/9; 1000 ml) at a rate such that the eluant in the column falls ~5 cm/min. Fractions (50 ml) are collected and combined based on T.L.C. analysis. Removal of solvent gives the pure *S*-alkyl alkanesulfonothioates.

Activation of Zinc Metal[15]:

In a 25 ml Erlenmeyer flask, zinc (2.0 g, 0.03 mol) is stirred with 2% (v/v) hydrochloric acid (20 ml) for ~5 min until the zinc becomes silver-colored. After suction filtration, the zinc is washed successively with water (50 ml), 95% ethanol (20 ml), acetone (20 ml), and anhydrous ether (20 ml). The zinc is transferred to a 25 ml round-bottom flask. The flask is heated in a water bath at 90°C while the excess solvent is removed under reduced pressure (~20 min at 2 torr). The purified zinc is used within 20 min after drying.

Alkanesulfinyl chlorides were prepared as previously described[12,13]. [Boiling points and melting points agreed with literature values.]

Table 1. Symmetric *S*-Alkyl Alkanesulfonothioates (**2**) prepared from Alkanesulfinyl Chlorides (**1**) and Activated Zinc[a]

2	R	Reaction time [h]	Yield[b] [%]	b.p./torr or m.p. [°C]	Lit. data or Molecular formula	Mass spectra			
						chemical ionization[c]		electron impact	
						$[MH]^+$ *m/e*	% of base peak	$[M]^{+\bullet}$ *m/e*	% of base peak
a	C_2H_5	24	54[d]	102–103°/1–2	102–103°/1–2[16]	155	100	154	2.6
b	*n*-C_3H_7	24	68	112–114°/1–2	112–114°/1–2[16]	183	100	182	3.0
c	*n*-C_4H_9	24	73	128–130°/0.13	128–130°/0.13[10]	211	100	210	2.5
d	*n*-C_5H_{11}	24	78	176–180°/0.10	176–180°/0.10[10]	239	100	238	0.1
e	*neo*-C_5H_{11}	24	78[e]	55–57°	59–60°[20]	239	100		
f	*n*-C_6H_{13}	48	77	oil	$C_{12}H_{26}O_2S_2$ (266.47)[f]	267	100		
g	*n*-C_8H_{17}	48	78	oil	$C_{16}H_{34}O_2S_2$ (322.57)[g]	323	100		
h	*n*-$C_{12}H_{25}$	48	46[e]	42–43°	43.5–44°[7]	435	89		

[a] Reaction carried out in CCl_4 at 22–24°C.

[b] Product isolated via flash chromatography.

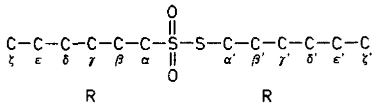
[c] 2-Methylpropane used as reactant gas.

[d] Diethyl ether solvent. In CCl_4 (4 h at −20°C followed by 20 h at 22–24°C), the yield of **2a** was 45% along with 4% diethyl disulfide. In diethyl ether (4 h at −20°C followed by 20 h at 22–24°C), the yield of **2a** was 49% along with 3% diethyl disulfide.

[e] Recrystallized from hexane.

		C	H	S
[f]	calc.	C 54.09	H 9.84	S 24.06
	found	53.92	9.73	23.90
[g]	calc.	C 59.58	H 10.62	S 19.88
	found	59.33	10.92	19.63

Table 2. I.R.- and ^{13}C-N.M.R.-Spectral Data of Compounds **2**



2	I.R. ($CDCl_3$) ν_{SO_2} [cm^{-1}]		^{13}C-N.M.R. ($CDCl_3/TMS_{int}$)[a] δ [ppm]											
	asym	sym	α	β	γ	δ	ε	ζ	α'	β'	γ'	δ'	ε'	ζ'
a	1310	1115	57.15	8.41					30.69	15.21				
b	1315	1120	64.68	17.63	13.36				38.36	23.45	12.89			
c	1315	1120	62.53	25.53	21.76	13.44			35.97	31.71	21.32	13.56		
d	1315	1120	62.84	30.24	29.51	22.31	13.97		36.36	30.83	23.38	22.22	13.84	
e	1321	1127	74.95	32.12	29.76				49.92	33.47	28.86			
f	1315	1122	62.47	31.01	29.48	28.08	22.28	13.76	36.04	31.07	27.48	23.41	22.17	13.76
g	1320	1122	62.90	29.83	29.13	29.13	28.73	23.62	36.36	31.85	29.08	29.08	28.13	23.33
h	1315	1122	63.03	31.86	29.86	29.86	29.86	29.59	36.48	32.18	29.86	29.86	29.59	29.59

[a] Central solvent resonance at $\delta = 77.27$ ppm at 22.63 MHz.

S-Butyl Butanesulfonothioate (2c, S-Butyl Butanethiosulfonate); Typical Procedure:

A solution of butanesulfinyl chloride (**1c**; 4.23 g, 30 mmol) in tetrachloromethane (12 ml) is placed in a 25 ml round-bottom flask equipped with stirrer and calcium chloride drying tube. The solution is stirred at room temperature (22–24 °C) while activated zinc powder (3.24 g, 49.5 mol) is added via a powder funnel during a 60 min period. Stirring is continued at 22–24 °C for 23 h. The organic layer is then decanted from the metal and washed with saturated ammonium chloride solution (25 ml). The organic layer is dried with sodium sulfate. After gravity filtration, the solvent is removed in vacuo, and the product is isolated via flash chromatography[19].

For alkanesulfonothioic S-alkyl esters **2d, f, g, h**, the zinc metal is removed via suction filtration instead of decantation. S-Dodecyl dodecanethiosulfonate (**2h**) is purified by recrystallization from hexane instead of via flash chromatography.

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[1] D. Barnard, *J. Chem. Soc.* **1957**, 4763.

[2] F. Freeman, C. N. Angeletakis, *Tetrahedron Lett.* **23**, 491 (1982).

[3] F. Freeman, M. C. Keindl, unpublished data.

[4] F. Freeman, C. N. Angeletakis, unpublished data.

[5] G. Leandri, A. Tundo, *Ann. Chim. (Roma)* **44**, 875 (1954); *C. A.* **49**, 15785 (1955).

[6] L. D. Small, J. H. Bailey, C. J. Cavallito, *J. Am. Chem. Soc.* **71**, 3565 (1949).

[7] P. Allen, J. W. Brook, *J. Org. Chem.* **27**, 1019 (1962).

[8] R. Otto, *Ber. Dtsch. Chem. Ges.* **13**, 1282 (1880).

[9] J. P. Weidner, S. S. Block, *J. Med. Chem.* **7**, 671 (1964).

[10] J. von Braun, K. Weissbach, *Ber. Dtsch. Chem. Ges.* **63**, 2836 (1930).

[11] W. G. Filby, R. D. Penzhorn, *Z. Naturforsch.* [b] **31**, 463 (1976).

[12] I. B. Douglass, B. S. Farah, *J. Org. Chem.* **24**, 973 (1959).

[13] I. B. Douglass, R. V. Norton, *J. Org. Chem.* **33**, 2104 (1968).

[14] J. D. Buckman, M. Bellas, H. K. Kim, L. Field, *J. Org. Chem.* **32**, 1626 (1967).

[15] R. L. Shriner, W. F. Neumann, *Org. Synth. Coll. Vol.* III, 73 (1955).

[16] B. G. Boldyrev, L. P. Slesarchuk, T. A. Trofimova, *Khim. Seraorg. Soedin. Soderzh. Neftyak Nefteprod.* **8**, 108 (1968); *C. A.* **72**, 54934 (1970).

[17] F. Freeman, C. N. Angeletakis, *Org. Mass. Spectrom.* **17**, 114 (1982); **105**, 4039 (1983).

[18] F. Freeman, C. N. Angeletakis, *J. Am. Chem. Soc.* **103**, 6232 (1981); **104**, 5766 (1982); **105**, 4039 (1983).

[19] W. C. Still, M. Kahn, A. Mitra, *J. Org. Chem.* **43**, 2923 (1978).

[20] F. Freeman, C. N. Angeletakis, T. J. Maricich, *Tetrahedron Lett.* **22**, 1867 (1981).