

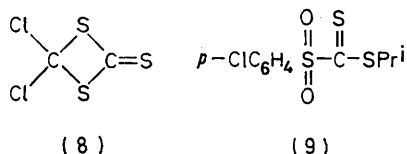
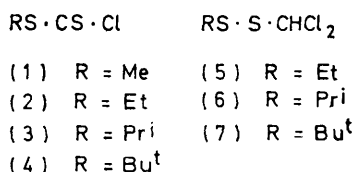
## Lewis Acid Catalysed Reaction of Aliphatic Thiols with Thiophosgene

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2-Methylpropane-2-thiol adds in the presence of catalytic amounts of aluminium chloride or trifluoroacetic acid to thiophosgene with the formation of dichloromethyl t-butyl disulphide (7). 4,4-Dichloro-1,3-dithietan-2-thione (8) which was isolated in minor amounts, was independently synthesised from 2,2,4,4-tetrachloro-1,3-dithietan (thiophosgene dimer) and 2-methylpropane-2-thiol. The reaction of methane-, ethane-, and propane-2-thiol with thiophosgene has been re-examined.

THE reaction of thiophosgene with aliphatic thiols under acidic conditions with<sup>1</sup> or without<sup>2-8</sup> added Lewis acid catalyst is a well established method for the preparation of chlorodithioformate esters. In no case have products corresponding to thiophilic† attack at the thionosulphur atom been reported.

In current work on electron-depleted thiocarbonyl compounds<sup>10-12</sup> the sterically hindered t-butyl chlorodithioformate (4) was needed. Whereas the preparation



of the chlorodithioformates (1) and (2) presented no difficulties when the method suggested by Arndt *et al.*<sup>1</sup> for the synthesis of (1) was followed, attempts to prepare

thiophosgene in the presence of a catalytic amount of aluminium chloride, instead of the expected (4) an 80% yield of dichloromethyl t-butyl disulphide (7) was obtained together with small amounts of 4,4-dichloro-1,3-dithietan-2-thione (8). This finding prompted me to investigate the reaction in more detail.

Following the normal procedure for the preparation of chlorodithioformates without a catalyst<sup>5</sup> no reaction was observed between 2-methylpropane-2-thiol and thiophosgene. As hydrogen chloride was generated during the aluminium chloride catalysed reaction, its catalytic properties were checked. However, only traces of (7) were detected after five days in a hydrogen chloride saturated solution of the reactants. On the other hand, trifluoroacetic acid was found to be a very potent catalyst as judged from n.m.r. experiments.

Minor amounts of dichloromethyl isopropyl disulphide (6) were obtained in the aluminium chloride catalysed reaction between propane-2-thiol and thiophosgene. The formation of isopropyl chlorodithioformate (3) was proved indirectly by its conversion to isopropyl *p*-chlorophenylsulphonyldithioformate (9).<sup>11</sup>

Diisopropyl trithiocarbonate which was isolated as the main product was found not to react with the *p*-chlorobenzenesulphinate anion.

Ethanthiol has been reported to add thiophilically to

Product distribution in the reaction of thiols with thiophosgene

Thiol	Solvent	Scale (mol)	Temp. (°C)	Time (h)	Catalyst	Yield <sup>a</sup> (%)	
						RS·CS·Cl	RSSCHCl <sub>2</sub>
MeSH	None	1.3	-18 to 0	24	AlCl <sub>3</sub>	73	0
EtSH	None	0.4	0	24	AlCl <sub>3</sub>	48	0
Pri <sup>t</sup> SH	CS <sub>2</sub>	0.25	-5 to 20	48	AlCl <sub>3</sub>	5-20	14
Bu <sup>t</sup> SH	CS <sub>2</sub>	0.50	20	72	None	0	0
Bu <sup>t</sup> SH	CS <sub>2</sub>	0.25	20	96	HCl	0	<2
Bu <sup>t</sup> SH	CS <sub>2</sub>	0.036	46	2.5	CF <sub>3</sub> CO <sub>2</sub> H	0	30
Bu <sup>t</sup> SH	C <sub>6</sub> H <sub>6</sub>	0.5	20	24	CF <sub>3</sub> CO <sub>2</sub> H <sup>b</sup>	0	<1
Bu <sup>t</sup> SH	None	0.3	0	36	AlCl <sub>3</sub>	0	69
Bu <sup>t</sup> SH	None	0.5	20	72	AlCl <sub>3</sub>	0	80
Bu <sup>t</sup> SH	C <sub>6</sub> H <sub>6</sub>	0.1	0	2	NaOH	0	90

<sup>a</sup> Trithiocarbonate RS·CS·SR was detected as by-product in the reaction of MeSH, EtSH, and Pri<sup>t</sup>SH with thiophosgene. In the Lewis acid catalysed reactions of Bu<sup>t</sup>SH, 4,4-dichloro-1,3-dithietan-2-thione (8) was invariably formed in low yields. <sup>b</sup> One equiv. used.

(4) using the same procedure failed. Thus, by mixing equivalent amounts of 2-methylpropane-2-thiol and

† Sulphur-nucleophilic. The term is used throughout the paper according to the definition in ref. 9 and in W. A. Pryor, *Mechanisms of Sulfur Reactions*, McGraw-Hill, London, 1962.

<sup>1</sup> F. Arndt, E. Milde, and G. Eckert, *Ber.*, 1923, **56**, 1976.

<sup>2</sup> P. Klason, *Ber.*, 1887, **20**, 2376.

<sup>3</sup> J. v. Braun, *Ber.*, 1902, **35**, 3377.

<sup>4</sup> H. Rivier and P. Richard, *Helv. Chim. Acta*, 1925, **8**, 499.

<sup>5</sup> K. A. Jensen, *J. prakt. Chem.*, 1937, **148**, 101.

<sup>6</sup> H. C. Godt, jun., and R. E. Wann, *J. Org. Chem.*, 1961, **26**, 4047.

thiophosgene in the presence of sodium hydroxide with the formation of dichloromethyl ethyl disulphide (5) in

<sup>7</sup> D. M. McKinnon and A. Queen, *Canad. J. Chem.*, 1972, **50**, 1401.

<sup>8</sup> J. Goerdeler and H. Hohage, *Chem. Ber.*, 1973, **106**, 1487.

<sup>9</sup> P. Beak and J. W. Worley, *J. Amer. Chem. Soc.*, 1972, **94**, 597.

<sup>10</sup> N. H. Nilsson, C. Jacobsen, and A. Senning, *Chem. Comm.*, 1970, 658.

<sup>11</sup> N. H. Nilsson, C. Jacobsen, and A. Senning, *Chem. Comm.*, 1971, 314.

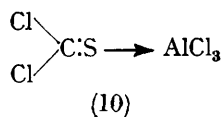
<sup>12</sup> N. H. Nilsson, C. Jacobsen, O. N. Sørensen, N. K. Haunsøe, and A. Senning, *Chem. Ber.*, 1972, **105**, 2854.

82% yield.<sup>13</sup> In a control experiment I checked this procedure with 2-methylpropane-2-thiol. An excellent yield of pure disulphide (7) was indeed isolated. The Table summarises the results obtained.

Dichloromethyl *t*-butyl disulphide (7) has recently been prepared by treating di-*t*-butyl disulphide with dichlorocarbene.<sup>14</sup> As a single attempt to prepare (7) by this method (using equivalent amounts of reactants) failed, the structure of (7) was further established by <sup>13</sup>C n.m.r. using the single-frequency off-resonance decoupling technique. Thus, by irradiation at 637 Hz [the resonance frequency assigned to the methine proton of the dichloromethyl group of (7)], the signal at 1967.9 Hz in the <sup>13</sup>C spectrum of (7) was completely decoupled. By moving the irradiation frequency 100 Hz downfield, the signal at 1967.9 Hz was split into a doublet. Having thus established that the signal at δ 6.37 in the <sup>1</sup>H n.m.r. spectrum of (7) originated from a methine proton, the isomeric structure, *i.e.* dichloro-*t*-butylthiomethane-thiol is ruled out. The i.r., u.v., and mass spectra of 4,4-dichloro-1,3-dithietan-2-thione (8) were in accord with those reported in the literature.<sup>15</sup> Furthermore, the 25.16 MHz <sup>13</sup>C n.m.r. spectrum of (8) in CDCl<sub>3</sub> showed as expected two signals corresponding to C-4 (δ 73.1) and C-2 (δ 197.2).

Thiophilic addition to thiocarbonyl compounds seems to be a rather general reaction.<sup>9</sup> Especially, the reaction of thioketones with organometallic reagents has been the subject of several recent investigations.<sup>9,16-18</sup>

However, no earlier studies have been carried out on Lewis acid catalysed thiophilic additions to thiocarbonyl compounds. As thiophilic additions to the thiono-group are facilitated by electron-withdrawing substituents on the thiono-carbon<sup>19</sup> or on the thiono-sulphur atom (*e.g.* >C:S:O),<sup>20,21</sup> a reasonable explanation of the catalytic action of the aluminium chloride is the formation of the covalent complex (10) which obviously makes the sulphur (as well as the thiono-carbon) more prone to nucleophilic attack. Although there has been

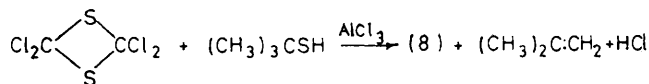


no report on Lewis acid complexes with thiophosgene, aluminium chloride complexes with phosgene have been studied in detail<sup>22</sup> and it was found that phosgene acts exclusively as a weak oxygen base.

The catalytic effect of trifluoroacetic acid might in an

equal manner be explained by initial protonation of the thiono-sulphur atom.<sup>23</sup>

The formation of 4,4-dichloro-1,3-dithietan-2-thione (8) probably involves an initial Lewis acid induced dimerisation of thiophosgene. Thus (8) was directly synthesised from thiophosgene dimer and 2-methylpropane-2-thiol. The formation of isobutene was evidenced by the decolouring of a bromine-water solution.



The structure of the attacking thiol is of crucial importance for the reaction course. Steric hindrance as well as softness of the thiol was found to promote thiophilic attack. Thus, 2-methylpropane-2-thiol which besides being the most crowded of the investigated thiols has the lowest ionisation potential,<sup>24</sup> gave the highest yield of thiophilic adduct. Furthermore, the thiophilicity of unbranched thiols towards thiophosgene as expected is enhanced under basic conditions.<sup>13</sup> More work has to be done to clear up the relative importance of steric and electronic effects for nucleophilic attack at the thiono-sulphur atom of thiocarbonyl compounds. Probably Lewis acid catalysed thiophilic addition of sterically hindered sulphur nucleophiles is a general reaction which is applicable to other electron-depleted thiocarbonyl compounds as well.

#### EXPERIMENTAL

M.p.s were determined with a Mettler FP instrument. U.v. absorption spectra were measured with a Perkin-Elmer 402 u.v. spectrometer, whilst i.r. absorption spectra were recorded on Beckman IR-18A and on Perkin-Elmer 180 instruments. Mass spectra were taken on a CEC mass spectrometer MS-21-104 (only base peaks and *m/e* >100 corresponding to the <sup>35</sup>Cl isotope are reported). <sup>1</sup>H N.m.r. spectra were obtained with a Varian A-60 spectrometer and <sup>13</sup>C n.m.r. spectra with a Varian XL-100-15 spectrometer, with tetramethylsilane as internal standard for both cases. Column chromatography was performed on water-cooled columns using Merck silica gel 60. Light petroleum refers to a fraction with b.p. 60–80°. Unless otherwise stated, yields refer to overall yields.

**Materials.**—Thiophosgene was prepared from trichloromethanesulphenyl chloride<sup>25</sup> and fractionated twice through a Vigreux column (30 cm) before use. The fraction with b.p. 74–76° was collected and used in the reactions.

**Reaction of Methane- and Ethane-thiol with Thiophosgene.**—Both reactions were carried out according to the procedure of Arndt *et al.*<sup>1</sup> to afford methyl chlorodithioformate (1), b.p. 49–51° at 12 mmHg (lit.,<sup>1</sup> 50–52° at 15 mmHg), and

<sup>20</sup> B. Zwanenburg, L. Thijs, and J. Strating, *Rec. Trav. chim.*, 1970, **89**, 687.

<sup>21</sup> A. G. Schultz and R. H. Schlessinger, *Chem. Comm.*, 1970, 747.

<sup>22</sup> D. P. N. Satchell and R. S. Satchell, in 'The Chemistry of Acyl Halides,' ed. S. Patai, Interscience, London, 1972, p. 128.

<sup>23</sup> M. J. Janssen, *Rec. Trav. chim.*, 1960, **79**, 464.

<sup>24</sup> L. S. Lewitt and B. W. Lewitt, *J. Org. Chem.*, 1972, **37**, 332.

<sup>25</sup> E. F. Orwol, U.S.P. 2,668,853/1954 (*Chem. Abs.*, 1955, **49**, 2496d).

<sup>13</sup> G. H. Birum, U.S.P. 3,116,335/1963 (*Chem. Abs.*, 1964, **60**, 10,549d).

<sup>14</sup> S. Searles, jun., and R. E. Wann, *Tetrahedron Letters*, 1965, 2899.

<sup>15</sup> J. Wortmann, G. Kiel, and G. Gattow, *Z. anorg. Chem.*, 1970, **376**(1), 64.

<sup>16</sup> M. Dagonneau and J. Vialle, *Bull. Soc. chim. France*, 1972, 2067.

<sup>17</sup> M. Dagonneau, *Compt. rend.*, 1973, **276C**, 1683.

<sup>18</sup> P. Metzner and J. Vialle, *Bull. Soc. chim. France*, 1973, 1703.

<sup>19</sup> W. J. Middleton and W. H. Sharkey, *J. Org. Chem.*, 1965, **30**, 1384.

ethyl chlorodithioformate (2), b.p. 66° at 10 mmHg (lit.,<sup>5</sup> 69–70° at 12 mmHg) in yields of 73 and 48%, respectively. N.m.r. spectra of the distillation residues as well as of the distillates confirmed that no dichloromethyl disulphides were present.

*Reaction of Propane-2-thiol with Thiophosgene.*—Propane-2-thiol (18.75 g, 0.25 mol) was added during 30 min to a stirred mixture of thiophosgene (28.75 g, 0.25 mol), aluminium chloride (0.5 g), and carbon disulphide (25 ml) cooled to –5° and kept under nitrogen. The mixture was stirred for a further 48 h at room temperature and was then poured into ice–water (400 ml) and extracted with ether (2 × 125 ml). The combined ether layers were further washed with saturated brine (2 × 200 ml) and dried over CaCl<sub>2</sub>. Evaporation of the ether gave a crude yield of 23.2 g.

As purification by distillation or by g.l.c. failed, a minor part of the crude product (1.50 g) was subjected to column chromatography on silica gel. Elution with light petroleum gave after evaporation *dichloromethyl isopropyl disulphide* (6) (432 mg, 14%),  $n_D^{26}$  1.5357 [after molecular distillation (80° at 14 mmHg)] (Found: C, 25.05; H, 4.2; Cl, 37.7; S, 33.35. C<sub>4</sub>H<sub>8</sub>Cl<sub>2</sub>S<sub>2</sub> requires C, 25.15; H, 4.2; Cl, 37.1; S, 33.55%),  $\lambda_{max}$  218 nm (log  $\epsilon$  3.46),  $\nu_{max}$  2965, 2925, 2865, 1450m, 1380w, 1365w, 1240m, 1200w, 1150m, 1050m, 730s, 505–480 (triplet), and 385m cm<sup>-1</sup>,  $\delta$  (CCl<sub>4</sub>) 1.35 (6H, d), 3.35 (1H, septet), and 6.47 (1H, s), *m/e* 190 (M<sup>+</sup>), \* 155 (M<sup>+</sup> – Cl), 148 (M<sup>+</sup> – C<sub>3</sub>H<sub>8</sub>), 115 (Cl<sub>2</sub>CHS<sup>+</sup>), 114 (Cl<sub>2</sub>CS<sup>+</sup>), 113 (M<sup>+</sup> – Cl – C<sub>3</sub>H<sub>8</sub>), 112 (CHClS<sub>2</sub><sup>+</sup>), and 43 (C<sub>3</sub>H<sub>7</sub><sup>+</sup>, base peak), and then di-isopropyl trithiocarbonate (510 mg, 32%) as a yellow heavy oil which slowly solidified, m.p. 31° (lit.,<sup>26</sup> 32°). The n.m.r. and u.v. spectra were identical with those of an authentic sample. As the isopropyl chlorodithioformate (3) was apparently unstable to chromatography, its presence was established by its conversion into the more stable isopropyl *p*-chlorophenylsulphonyldithioformate (9). Thus, the crude product (6.18 g) was stirred with sodium *p*-chlorobenzenesulphinate (6.00 g) in benzene–water 1 : 1 (80 ml) at 45° for 3 h. The benzene layer was separated and dried over CaCl<sub>2</sub>. After evaporation, the crude product (6.57 g) was chromatographed on a column packed with silica gel (eluant ether–light petroleum 2 : 98). After elution of the first fraction (3.88 g), which according to the n.m.r. and u.v. spectra was a mixture of dichloromethyl isopropyl disulphide (6) and di-isopropyl trithiocarbonate in the ratio 1 : 1, the column was sucked dry and the red zone extracted with methylene chloride. After evaporation of the solvent, the *sulphonyldithioformate* (9) (0.80 g, 5%) was obtained as a slowly crystallising red oil, m.p. 51° (after digestion with cold EtOH) (Found: C, 40.85; H, 3.9; S, 32.2. C<sub>10</sub>H<sub>11</sub>ClO<sub>2</sub>S<sub>3</sub> requires C, 40.7; H, 3.75; S, 32.65%). As the yields in this reaction normally are in the order of 25%,<sup>10</sup> it is reasonable to assume that the overall yield of isopropyl chlorodithioformate (3) is *ca.* 20%.

*Reaction of 2-Methylpropane-2-thiol with Thiophosgene.*—

*Method (a).* 2-Methylpropane-2-thiol (45.0 g, 0.5 mol) was added during 1 h to a stirred mixture of thiophosgene (57.5 g, 0.5 mol) and a catalytic amount of aluminium chloride (1.0 g), cooled to 0°, and kept under nitrogen. The mixture was stirred a further 72 h at room temperature. Work-up as previously described gave a yellow oil (87.0 g). This

was distilled through a Vigreux column (30 cm) and the fraction with b.p. 96–97° at 15 mmHg ( $n_D^{24}$  1.5322) was collected (85.6 g). Although this product gave a satisfactory analysis for dichloromethyl *t*-butyl disulphide (7), the u.v. spectrum revealed a small admixture of a thiocarbonyl compound. Thus, a minor fraction of the distillate (6.00 g) was chromatographed on a column of silica gel. Elution with petroleum gave after evaporation, first 4,4-dichloro-1,3-dithietan-2-thione (8) (176 mg, 5%), m.p. 56° [after sublimation (45° at 10 mmHg)] (lit.,<sup>15</sup> 57°) and then dichloromethyl *t*-butyl disulphide (7) as a pale yellow oil (5.65 g, 80%),  $n_D^{26}$  1.5270 [after molecular distillation (90° at 14 mmHg)] (lit.,<sup>14</sup>  $n_D^{20}$  1.5308; b.p. 114° at 32 mmHg) (Found: C, 29.65; H, 4.95; Cl, 33.85. Calc. for C<sub>5</sub>H<sub>10</sub>Cl<sub>2</sub>S<sub>2</sub>: C, 29.25; H, 4.91; Cl, 34.55%),  $\lambda_{max}$  218 nm (log  $\epsilon$  3.47);  $\nu_{max}$  2970, 2945, 2925, 2900, 2865, 1455m, 1390w, 1365m, 1205m, 1160s, 735s, 505s, 470s, and 385m cm<sup>-1</sup>, <sup>1</sup>H  $\delta$  (CCl<sub>4</sub>) 1.38 (9H, s), and 6.37 (1H, s), <sup>13</sup>C  $\delta$  (CDCl<sub>3</sub>) 30.17 (3 CH<sub>3</sub>), 49.18 [C(CH<sub>3</sub>)<sub>3</sub>], and 78.22 (Cl<sub>2</sub>CH), *m/e* 204 (M<sup>+</sup>), 169 (M<sup>+</sup> – Cl), 115 (Cl<sub>2</sub>CHS<sup>+</sup>), 114 (Cl<sub>2</sub>CS<sup>+</sup>), 113 [M<sup>+</sup> – Cl – (CH<sub>3</sub>)<sub>2</sub>C:CH<sub>2</sub>], 112 (CHClS<sub>2</sub><sup>+</sup>), and 57 (C<sub>4</sub>H<sub>9</sub><sup>+</sup>, base peak). From the extinction coefficients of the pure compound, the distillate was calculated to consist of 94.5% (7) and 5.5% (8) (by weight).

*Method (b).* 2-Methylpropane-2-thiol (4 ml, 36 mmol) was added over 5 min to a solution of thiophosgene (4 ml, 52 mmol) and trifluoroacetic acid (1 ml) in carbon disulphide (10 ml) at room temperature. The mixture was heated under reflux for 2.5 h and was left over night. The usual work-up gave dichloromethyl *t*-butyl disulphide (7) (2.14 g, 30%) containing (8) (4% determined from the u.v. spectrum) as an impurity.

*Method (c).* The reaction was carried out according to the method of Birum.<sup>13</sup> Sodium hydroxide (1N; 20 ml) was added during 15 min to a stirred solution of 2-methylpropane-2-thiol (9.0 g, 0.1 mol) and thiophosgene (11.5 g, 0.1 mol) dissolved in benzene (25 ml) and kept at 0–5°. The mixture was stirred for a further 2 h. The benzene layer was washed twice with saturated brine and dried over CaCl<sub>2</sub>. Evaporation of the solvent and distillation afforded pure dichloromethyl *t*-butyl disulphide (7) (18.55 g, 90%), b.p. 96° at 14 mmHg;  $n_D^{21}$  1.5301.

*Reaction of 2-Methylpropane-2-thiol with 2,2,4,4-Tetrachloro-1,3-dithietan (Thiophosgene Dimer).*—2-Methylpropane-2-thiol (1.80 g, 20 mmol) dissolved in benzene (30 ml) was added to a mixture of 2,2,4,4-tetrachloro-1,3-dithietan (4.60 g, 20 mmol) and aluminium chloride (300 mg) in benzene (50 ml) at 0° during 30 min. The evolution of isobutene was followed by its reaction with bromine–water. After stirring the solution for a further 4 h at 0°, the solution was extracted with ice–water (250 ml) and the benzene layer was dried over CaCl<sub>2</sub>. Evaporation *in vacuo* and column chromatography (silica gel; eluant light petroleum) of the crude product (3.53 g) gave pure 4,4-dichloro-1,3-dithietan-2-thione (8) (2.20 g, 58%), m.p. 57–58° (from EtOH).

*N.m.r. Experiments.*—The thiols (1 ml) (except methane-thiol) were refluxed with a slight excess of thiophosgene (1–2 ml) and trifluoroacetic acid (250  $\mu$ l) for 2.5 h. The solutions were filtered through cotton-wool and diluted with carbon tetrachloride. From the integrals of the methine protons at  $\delta$  *ca.* 6.5 it could be concluded that in the case of

\* Peaks corresponding to the <sup>37</sup>Cl isotope were present in the expected intensities.

<sup>26</sup> F. Runge, Zaki El-Hewehi, H.-J. Renner, and E. Taeger, *J. prakt. Chem.*, 1960, **11**, 284.

ethanethiol <1% of dichloromethyl ethyl disulphide (5) was formed while, in the reaction of propane-2-thiol <10% of dichloromethyl isopropyl disulphide (6) was formed. The solution from the reaction of 2-methylpropane-2-thiol with thiophosgene gave a spectrum identical with that of pure dichloromethyl t-butyl disulphide (7), but the presence

of 4,4-dichloro-1,3-dithietan-2-thione (8) would of course not be revealed by the n.m.r. spectrum.

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