

Chloro(phenylthio)methyltrimethylsilane: Preparation and some Synthetic Reactions

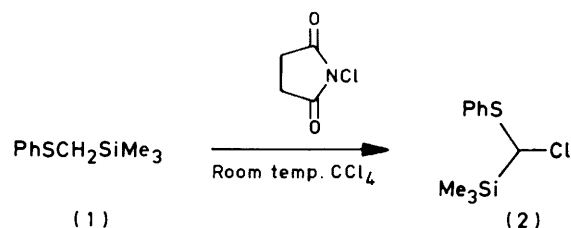
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Reaction of the title compound (2) with lead thiocyanate gave phenylthio(trimethylsilyl)methyl isothiocyanate (3a) which further reacted with aromatic aldehydes in the presence of fluoride ion to afford oxazoles in good yields. Compound (2) also reacted with silyl enol ethers to give β -silyl ketones which were capable of being converted into β -functionalized vinylsilanes.

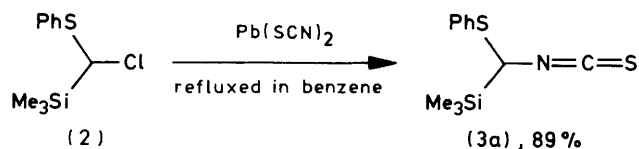
Since the lithiation of methylthiomethyltrimethylsilane was reported by Peterson¹ in 1968, its widespread application in organic synthesis as a formyl anion equivalent² and as a precursor of olefins³ has been reported. Considerable broadening of the synthetic scope for alkyl- or aryl-thio-methyltrimethylsilane might be expected if the nucleophilic centre carbon could be converted into an electrophilic carbon. In this paper, we report both the preparation and some synthetic reactions of chloro(phenylthio)methyltrimethylsilane.†

Chloro(phenylthio)methyltrimethylsilane (2) was prepared quantitatively by reaction of phenylthiomethyltrimethylsilane⁵ (1) with *N*-chlorosuccinimide in carbon tetrachloride at room temperature.



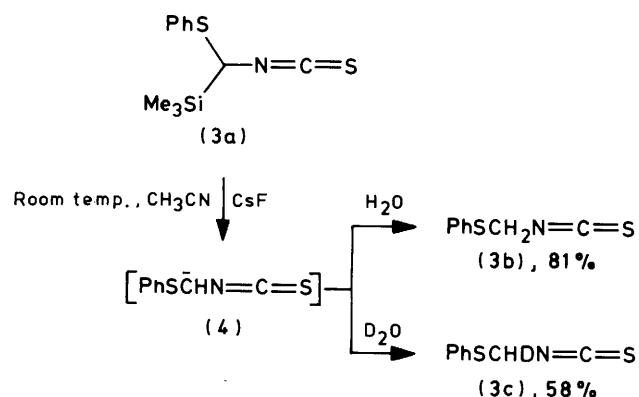
The silane (2) was obtained in better than 98% purity as a colourless or pale yellow liquid, but it could not be purified by distillation because of its thermal lability.

Reaction of (2) with lead thiocyanate proceeded smoothly in boiling benzene to give a phenylthio(trimethylsilyl)methyl isothiocyanate (3a) [ν_{max} , 2 200 cm^{-1}] in good yield.

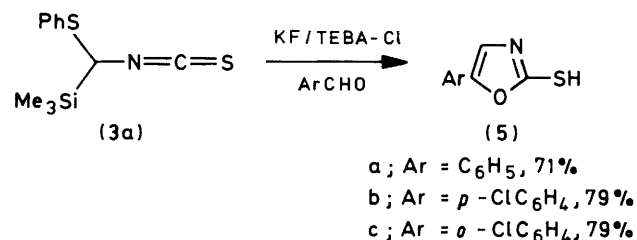


Compound (3a) is a stable, pale yellow liquid and can be stored under nitrogen at room temperature for several weeks without decomposition. Liberation of the trimethylsilyl group on (3a) was easily induced by fluoride ion to form the carbanion (4); thus, reaction of (3a) with water in the presence of cesium fluoride at room temperature gave phenylthiomethyl isothiocyanate (3b) in 81% yield. When deuterium

oxide was used instead of water, mono-deuteriated phenylthiomethyl isothiocyanate (3c) was obtained in 58% yield.



The silylmethyl isothiocyanate (3a) also reacted with aromatic aldehydes in the presence of potassium fluoride-triethylbenzylammonium chloride (TEBA-Cl) to give 2-mercapto-5-aryloxazoles (5a—c) in good yields.



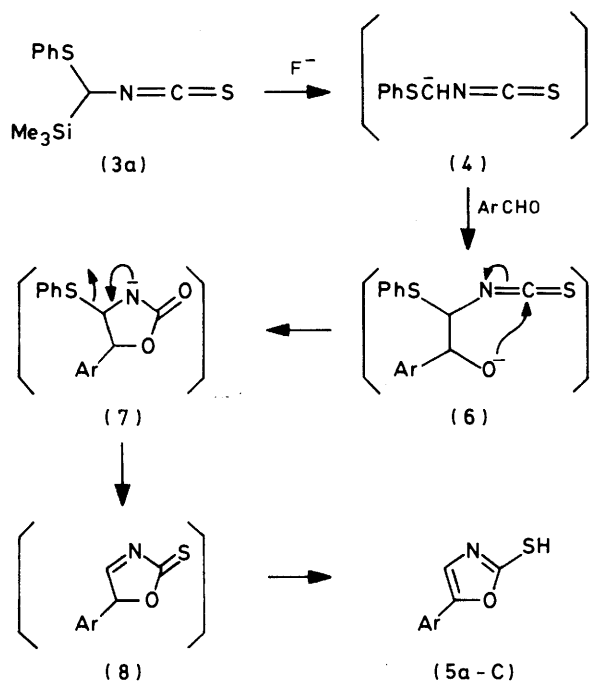
Silylmethyl isothiocyanates were first prepared by Agawa and his co-workers,^{6,7} who reported that trimethylsilyl and bistrimethylsilylmethyl isothiocyanate reacted with carbonyl compounds to give 1,3-oxazolidine-2-thiones. To our knowledge, however, there has been no report regarding the preparation and reactions of the phenylthio derivatives of silylmethyl isothiocyanates.

The structure of (5) was confirmed on the basis of micro-analytical and spectral data; in particular, the ¹³C n.m.r. spectrum for (5a) contained signals at δ 177.3 (C-2),[†] 112.0 (C-4), and 128.4 (C-5) p.p.m.

† Recently, chloro(phenylthio)methyltrimethylsilane reactions have been reported by Fleming but the experimental details for the compound's preparation have not been described.⁴

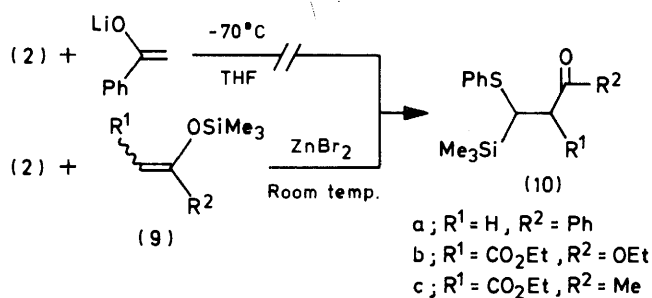
‡ The chemical shift of the thiocarbonyl carbon for 1,3-oxazolidine-2-thiones appeared at ca. 190 p.p.m.; T. Agawa, personal communication.

The formation of (5) can be explained as shown in Scheme 1, *i.e.*, the initially formed intermediate (4) attacks the aldehyde carbon to give (6), and this is followed by cyclization of (6) to (7) and rearrangement to form the products (5).



Scheme 1.

On the other hand, the silane (2) although not reacting with the lithium enolate of acetophenone at $-70^\circ C$ in THF, in the presence of zinc bromide reacted smoothly with the silyl enol ether (9) to give β-phenylthio-β-trimethylsilylpropio-phenone (10a) (Table).



Sakurai *et al.*⁸ reported that the reaction of a β-silyl ester with dibromomethane in the presence of sodium hydride gave rise to bromomethylation on the carbon α to the carbonyl group. In contrast, reaction of the lithium enolate (13) [from the β-silyl ketone (10a)] with methyl iodide gave thioanisole (14) and the vinylsilane (11a), but no α-methylated silyl ketone (12) (Scheme 2). Similarly, using the sodium enolate of the β-silyl ester (10b) instead of (10a), the vinylsilane (11b) was obtained. These vinylsilanes would come from the intermediate (13) *via* retro-Michael reactions.

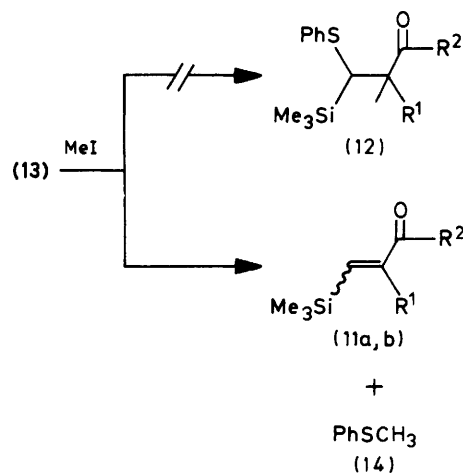
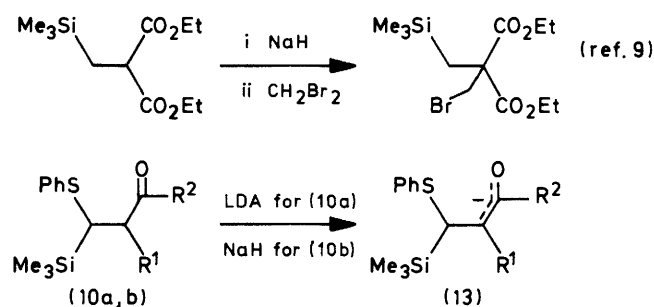
Vinylsilanes are useful intermediates for organic synthesis, and the most widely used method for the preparation of vinylsilanes have involved either the reaction of vinyl anion

Table.

The reaction scheme shows the conversion of compound (2) and silyl enol ether (9a-c) to intermediate (10a-c), which then yields products (11a,b).

Silyl enolate	R^1	R^2	Yields (%)	
			(10)	(11)
(9a)	H	Ph	86	44
(9b)	CO_2Et	OEt	77	66
(9c)	CO_2Et	Me	62	—

intermediates with chlorosilanes or the reduction of alkynylsilanes.⁹ Our present method would be a very convenient one for elaboration of β-functionalized vinylsilanes.



Scheme 2.

Experimental

B.p.s and m.p.s are uncorrected. I.r. spectra were obtained using JASCO IR-E and JASCO IR-A 100 spectrometers. 1H N.m.r. spectra were recorded with JEOL JNM-C-60HL and JNM-PMX-60si spectrometers. ^{13}C N.m.r. spectra were taken with a JNM-FX-90Q spectrometer using tetramethylsilane as internal reference. Mass spectra were obtained from JEOL-JMS 01SG-2 and JEOL-JMS-D300 spectrometers.

Chloro(phenylthio)methyltrimethylsilane (2).—A solution of phenylthiomethyltrimethylsilane⁵ (9.8 g, 50 mmol) in carbon tetrachloride (30 ml) was added to a suspension of *N*-chloro-

succinimide (8.1 g, 60 mmol) in carbon tetrachloride (170 ml), and the mixture was stirred for 3 h at room temperature under nitrogen. Then the insoluble materials were removed by filtration and the filtrate was concentrated. The residue was diluted with *n*-hexane (30 ml), chilled, and the precipitate so obtained filtered off. The hexane was removed under reduced pressure to give chloro(phenylthio)methyltrimethylsilane (2) as a colourless liquid: δ (CCl₄) 0.26 (9 H, s, SiMe₃) 4.76 (1 H, s, CH), and 7.05–7.55 (5 H, m, Ph); m/z (75 eV) 230 (M^+) and 232 ($M + 2$). This chlorosilane (2) was used without further purification because of its thermal lability.

Phenylthio(trimethylsilyl)methyl Isothiocyanate (3a).—A solution of chloro(phenylthio)methyltrimethylsilane (2) (5.11 g, 22.1 mmol) in benzene (60 ml) was added dropwise to a suspension of lead thiocyanate (8.57 g, 26.5 mmol) in benzene (40 ml) at room temperature under nitrogen; the mixture was then refluxed for 4 h and cooled. Solid materials were filtered off and the filtrate concentrated; the residue was distilled on a Kugelrohr (oven temp. 120 °C/0.65 mmHg) apparatus to afford (3a) (4.97 g, 89%) (Found: M^+ , m/z 253.042. C₁₁H₁₅NS₂Si requires M , 253.042); ν_{\max} 2 200 cm⁻¹ (N=C=S); δ (CCl₄) 0.225 (9 H, s, SiMe₃), 4.2 (1 H, s, CH), and 7.13–7.65 (5 H, m, Ph).

Reaction of (3a) with Water.—A mixture of (3a) (2.5 g, 10 mmol) and water (1.8 g, 10 mmol) in acetonitrile (29 ml) was added dropwise to a suspension of cesium fluoride (1.8 g, 12 mmol) in acetonitrile (30 ml). The mixture was stirred for 31.5 h at room temperature after which the solvent was evaporated under reduced pressure and the residue extracted with chloroform; the organic layer was dried (Na₂SO₄) and the chloroform evaporated under reduced pressure. The crude product was distilled on a Kugelrohr apparatus (oven temp. 120 °C/1.5 mmHg) to give a pure *phenylthiomethyl isothiocyanate* (3b) (1.47 g, 81%) (Found: M^+ , m/z 180.9991. C₈H₇NS requires M , 181.0020). ν_{\max} 2 200 cm⁻¹ (N=C=S); δ (CCl₄) 4.725 (2 H, s, CH₂) and 7.15–7.8 (5 H, m, Ph).

When deuterium oxide (10 mmol) was used instead of water, monodeuterated isothiocyanate (3c) was obtained in 58% (1.06 g) yield (Found: M^+ , m/z 182.0070. C₈H₆DNS requires M , 182.0098), ν_{\max} 2 200 cm⁻¹ (N=C=S); δ (CCl₄) 4.6 (2 H, s, CHD) and 6.8–7.575 (5 H, m, Ph).

2-Mercapto-5-phenyloxazole (5a).—A solution of silyl-methyl isothiocyanate (3a) (2.5 g, 10 mmol) in acetonitrile (30 ml) was added to a mixture of potassium fluoride (0.6 g, 10 mmol), triethylbenzylammonium chloride (0.23 g, 1 mmol), and benzaldehyde (1.3 g, 12 mmol) in acetonitrile (30 ml), and the mixture was stirred for 28 h at room temperature under nitrogen. It was then diluted with a little water and the acetonitrile evaporated under reduced pressure; the residue was extracted with chloroform (100 ml × 2). The combined organic layer was dried (Na₂SO₄) and the chloroform evaporated under reduced pressure to give the oxazole (5a) (71%, 1.25 g), m.p. 225–226 °C (Found: C, 61.0; H, 4.0; N, 7.9. C₉H₇NOS requires C, 60.7; H, 3.9; N, 7.8); δ_H [(CD₃)₂SO] 7.2–7.9 (5 H, m, C₆H₅), 8.0 (1 H, s, CH), 12.9–13.5 (1 H, br, SH); δ_C [(CD₃)₂SO] 177.4, 147.3, 128.8, 128.4, 126.3, 123.1, and 120.0.

Similarly, *5-p-chlorophenyl-2-mercapto-oxazole* (5b) [from potassium fluoride (0.6 g, 10 mmol), TEBA-Cl (0.23 g, 1 mmol), *p*-chlorobenzaldehyde (1.4 g, 10 mmol), and the isothiocyanate (3a) (2.5 g, 10 mmol)] was obtained (79%, 1.66 g), m.p. 250–251 °C (Found: C, 51.0; H, 2.8; N, 6.5. C₉H₆ClNOS requires C, 51.1; H, 2.9; N, 6.6); δ_H [(CD₃)₂SO] 7.25–7.8 (4 H, m, C₆H₄), 7.83 (1 H, s, CH), and 12.7–13.5 (1 H, br, SH).

Similarly, *5-o-chlorophenyl-2-mercapto-oxazole* (5c) [from KF (0.6 g, 10 mmol), TEBA-Cl (0.23 g, 1 mmol), *o*-chlorobenzaldehyde (1.4 g, 10 mmol), and the isothiocyanate (3a) (2.5 g, 10 mmol)] was obtained (79%, 1.66 g), m.p. 205.5–206.5 °C (Found: M^+ , m/z 210.9866. C₉H₆³⁵ClNOS requires M , 210.9865). δ [(CD₃)₂SO] 6.75–7.45 (4 H, m, C₆H₄), 7.83 (1 H, m, CH), and 12.7–13.5 (1 H, br, SH).

β -Phenylthio- β -trimethylsilylpropiofenone (10a).—A solution of chloro(phenylthio)methyltrimethylsilane (2) (4.6 g, 20 mmol) in dichloromethane (15 ml) was added to a mixture of β -trimethylsilyloxystyrene (9a) (3.2 g, 16.7 mmol) and zinc bromide (0.1 g, 0.4 mmol) in anhydrous dichloromethane (15 ml), and the mixture was stirred for 20 h at room temperature. The solvent was evaporated and the residue diluted with hexane (20 ml). The insoluble material was filtered off, and the filtrate concentrated; the residue was distilled on a Kugelrohr apparatus (oven temp. 170 °C/0.3 mmHg) to give pure (10a) (86%, 4.5 g), m.p. 44–45 °C (Found: C, 68.6; H, 6.7. C₁₈H₂₃OSSi requires C, 68.8; H, 7.1); ν_{\max} 1 680 cm⁻¹ (C=O); δ (CCl₄) 0.10 (9 H, s, Me₃Si), 3.10–3.27 (3 H, m, CH₂CH), and 6.82–7.87 (10 H, m, Ph); m/z 314 (M^+).

Similarly, *diethyl phenylthio(trimethylsilyl)methylmalonate* (10b) [from ethoxycarbonylketene ethyltrimethylsilyl acetal¹⁰ (6.95 g, 30 mmol), zinc bromide (0.07 g, 0.3 mmol), and chlorosilane (3a) (8.30 g, 36 mmol)] was obtained (77%, 8.17 g) as a colourless liquid (b.p. 150–170 °C/0.3 mmHg Kugelrohr apparatus) (Found: M^+ , m/z 354.1350. C₁₇H₂₆O₄SSi requires M , 354.1350); ν_{\max} 1 740 cm⁻¹ (C=O); δ (CCl₄) 0.16 (9 H, s, Me₃Si), 1.25 (t) and 1.29 (t) (6 H, 2 Me), 2.98 (1 H, d, CH), 3.48 (1 H, d, CH), 4.08 (q) and 4.11 (q) (4 H, 2 × CH₂), and 7.0–7.3 (5 H, m, Ph).

Similarly, *ethyl phenylthio(trimethylsilyl)methylacetate* (10c) [from acetylketene ethyltrimethylsilyl acetal¹¹ (4.04 g, 20 mmol), zinc bromide (0.05 g, 0.2 mmol), and chlorosilane (3a) (5.07 g, 22 mmol)] was obtained (62%, 4.02 g) as a 1 : 1 mixture of stereoisomers, b.p. 100–120 °C/0.3 mmHg (Kugelrohr) (Found: M^+ , m/z 324.121 60. C₁₆H₂₄O₃SSi requires M , 324.121 60); ν_{\max} 1 720 and 1 740 cm⁻¹ (C=O); δ (CCl₄) 0.15 (9 H, s, Me₃Si), 1.20 (t) and 1.28 (t) (3 H, Me), 2.06 (s) and 2.60 (s) (3 H, Me), 3.05 (d) and 3.08 (d) (1 H, CH), 3.46 (d) and 3.65 (s) (1 H, CH), 4.03 (q) and 4.10 (q) (2 H, CH₂), and 7.00–7.35 (5 H, m, Ph).

β -Trimethylsilylacrylophenone (11a).—A solution of *n*-butyl-lithium (15% in *n*-hexane; 6.2 ml, 10 mmol) was added to a solution of di-isopropylamine (1.1 g, 10 mmol) in THF (10 ml), and the mixture was stirred for 30 min at room temperature. A solution of silyl ketone (11a) (3.1 g, 10 mmol) in THF was then added dropwise to the mixture. After 2 h, a solution of methyl iodide (1.7 g, 12 mmol) in THF (10 ml) was added and the resultant mixture was stirred overnight. The mixture was diluted with water (50 ml) and extracted with ether (50 ml × 3). The combined organic extracts were washed with brine, dried (Na₂SO₄), and concentrated. The residue was distilled (Kugelrohr; oven temp. 108 °C/0.6 mmHg) to give the vinylsilane (11a) (0.9 g, 44%) and thioanisole (1.0 g, 81%). Compound (11a) (Found: M^+ , m/z 204.0954. C₁₂H₁₆OSi requires M , 204.0952), ν_{\max} 1 600 (C=C) and 1 670 (C=O) cm⁻¹; δ (CCl₄) 0.20 (9 H, s, Me₃Si) and 7.22–8.00 (7 H, m, vinyl and Ph).

Similarly, *diethyl trimethylsilylmethylenemalonate* (11b) [from sodium hydride (60% oil, 0.5 g, 12 mmol), the silyl ester (10b) (3.6 g, 12 mmol), and methyl iodide (1.7 g, 12 mmol)] was obtained in 66% yield (Found: M^+ – Me, m/z 229.0918. C₁₀H₁₇O₄Si requires M – Me, 229.0897), ν_{\max} 1 610 (C=C) and 1 730 (C=O) cm⁻¹; δ (CCl₄) 0.2 (9 H, s, Me₃Si), 1.3 (t) and

1.33 (t) (6 H, $2 \times \text{Me}$), 4.15 (q) and 4.18 (q) (4 H, $2 \times \text{CH}_2$), and 7.0 (s, 1 H, vinyl proton).

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