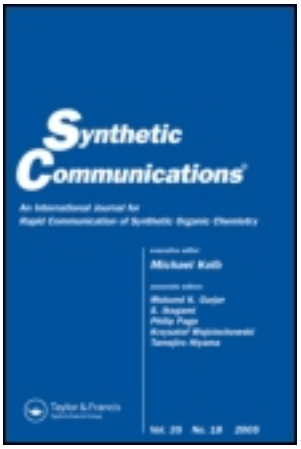

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One-Pot Tandem Synthesis of β-Trimethylsilyloxy Thioesters from Thioacids, Epoxides, and HMDS Catalyzed by Silica Gel Under Solvent-Free Conditions

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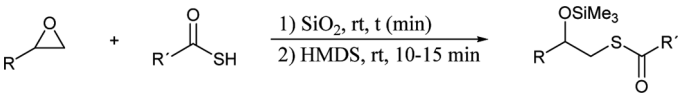
ONE-POT TANDEM SYNTHESIS OF β-TRIMETHYLSILYLOXY THIOESTERS FROM THIOACIDS, EPOXIDES, AND HMDS CATALYZED BY SILICA GEL UNDER SOLVENT-FREE CONDITIONS

Mohammad Abbasi

Department of Chemistry, Faculty of Science, Persian Gulf University, Bushehr, Iran

GRAPHICAL ABSTRACT



Abstract *A procedure for one-pot preparation of β-trimethylsilyloxy thioesters from epoxides, thioacids, and hexamethyl disilazane (HMDS) in the presence of silica gel under solvent-free condition was developed. The desired silylated products were isolated in good to excellent yields after silica-gel column chromatography.*

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Keywords Epoxide; hexamethyl disilazane; silica gel; solvent-free; thioacid; thioester

INTRODUCTION

The addition of sulfur nucleophiles to epoxides is a powerful tool for the synthesis of β-hydroxy organosulfur compounds in organic synthesis. In this regard, the addition of thioacids to epoxides has been applied for the preparation of β-hydroxy thioesters in organosulfur synthesis. This reaction is important because β-hydroxy thioesters are essential intermediates for the preparation of some bioactive molecules.[1] In addition, thioester molecules are recognized as mild acyl transfer agents[2] and important intermediates in the synthesis of acyl radicals,[3] ketones,[4] heterocycles,[5] asymmetric aldols,[6] and biologically active compounds[7] in organic synthesis. On the other hand, because of the ease of thioester linkage hydrolysis, the addition of thioacids to epoxides provides a simple, mild, and efficient access to precursors of β-hydroxy mercaptans in organic synthesis.[8] However, the reaction of thioacids with oxiranes is limited to a few scattered reports in the literature.[9–12] In this regard, the ring opening of cyclopentene oxides with thioacids in the presence

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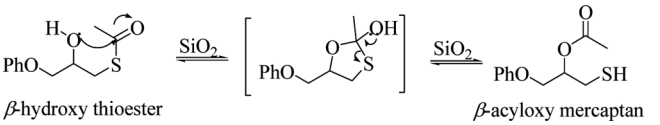
of alumina,[9] ring opening of an epoxy ring in a steroidal molecule with thioacetic acid,[10] and addition of potassium ethyl monothiocarbonate to cyclopentene oxide and 1-butene oxide catalyzed by a Brønsted acid[11] are among the reports dealing with this important reaction. The regioselective ring opening of structurally diverse oxiranes with thioacids in water in the presence of β-cyclodextrin[12a] and in the absence of any catalysts[12b] has been also reported in recent years.

In continuation of our interest in the development of organosulfur synthesis,[13] we now report a novel and facile method for one-pot preparation of β-trimethylsilyloxy thioesters from thioacids, epoxides, and hexamethyl disilazane (HMDS) on a silica-gel surface.

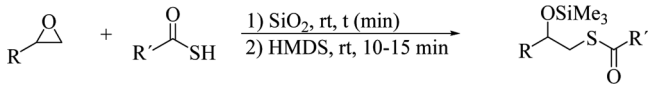
RESULTS AND DISCUSSION

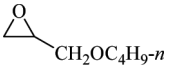
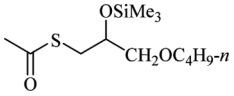
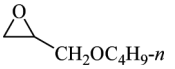
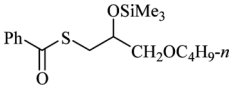
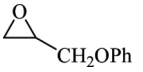
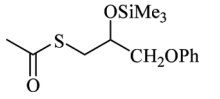
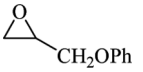
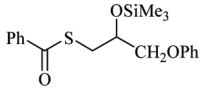
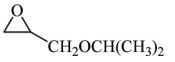
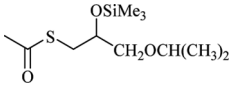
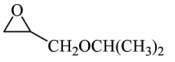
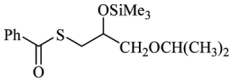
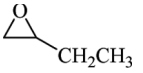
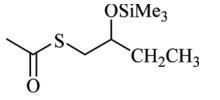
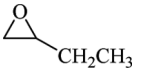
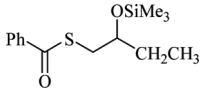
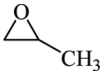
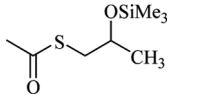
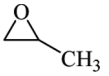
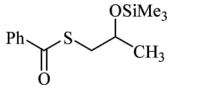
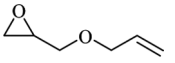
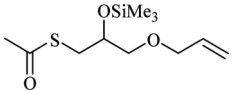
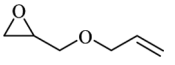
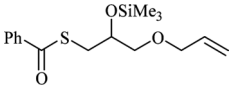
The development of efficient, economical, and environmentally benign procedures for organic reactions has received increased attention in recent years. The accomplishment of organic reactions under solvent-free conditions is certainly valuable from ecological and economical points of view. Meanwhile, solvent-free organic reactions studies in the past three decades show that many synthetic processes in the absence of solvents are faster, more efficient, and more convenient.[14] Therefore, we studied the catalyst-free addition of thioacetic acid (2.1 mmol) to 2-(phenoxymethyl)oxirane (2 mmol) as a model reaction under solvent-free conditions at room temperature. The reaction proceeded sluggishly, and after a prolonged reaction time (24 h) the starting epoxide was recovered from the reaction mixture in nearly 55% yield. Silica gel as an ecofriendly compound has been widely used as a heterogeneous, cheap and mild catalyst in organic synthesis.[15] Hence, we studied the previously mentioned reaction under similar conditions in the presence of silica gel 60 (70–230 mesh) (200 mg). The addition reaction proceeded cleanly and completed within 2 h, which after extraction with EtOAc and neutralization with aqueous solution of $NaHCO_3$ gave the corresponding β-hydroxy thioester (0.443 g) in good purity (as shown by thin-layer chromatography, TLC). The infrared (IR) spectrum of the crude product showed a broad peak at 3450 cm^{-1} (alcoholic OH stretching) and a sharp peak at 1693 cm^{-1} (thioesteric C=O stretching). However, further purification by column chromatography on silica gel failed because the product was contaminated with its β-acyloxy mercaptan isomer during the process. The ^1H NMR and IR spectra analysis of the mixture showed the presence of –OH, -SH, esteric, and thioesteric C=O functionalities. This isomerization process was a general trend for the reaction of structurally diverse epoxides and thioacids. A likely pathway for this rearrangement is presented in Scheme 1.



Scheme 1. Proposed pathway for the conversion of β-hydroxy thioester to β-acyloxy mercaptan and vice versa.

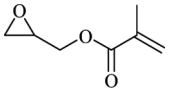
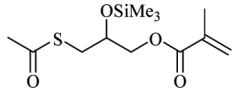
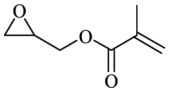
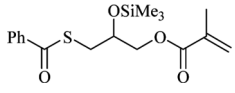
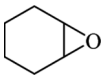
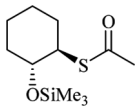
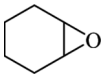
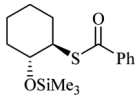
Table 1. One-pot tandem synthesis of β-trimethylsilyloxy thioesters from thioacids, epoxides, and HMDS catalyzed by SiO_2



Entry	Epoxide	R’	t (min)	Product	Yield (%)
1		CH_3	90 **(1)**		93
2		Ph	100 **(2)**		89
3		CH_3	120 **(3)**		91
4		Ph	120 **(4)**		90
5		CH_3	90 **(5)**		95
6		Ph	90 **(6)**		91
7		CH_3	60 **(7)**		84
8		Ph	70 **(8)**		82
9		CH_3	60 **(9)**		88
10		Ph	60 **(10)**		85
11		CH_3	60 **(11)**		86
12		Ph	60 **(12)**		90

(*Continued*)

Table 1. Continued

Entry	Epoxide	R'	t (min)	Product	Yield (%)
13		CH_3	75 **(13)**		85
14		Ph	70 **(14)**		84
15		CH_3	60 **(15)**		85
16		Ph	70 **(16)**		83

To eliminate side reactions under the purification process, the hydroxyl function of β-hydroxy thioester was first protected as β-trimethylsilyloxy thioester. In this regard, hexamethyldisilazane (HMDS) (2 mmol) was added to the mixture at the end of the reaction between 2-(phenoxymethyl)oxirane (2 mmol) and thioacetic acid (2.1 mmol), and the stirring was continued for another 10–15 min at room temperature. The corresponding β-trimethylsilyloxy thioester was successfully isolated in 91% yield after silica-gel column chromatography. The scope and generality of this process is illustrated with respect to various epoxides, thioacetic, and thiobenzoic acids in Table 1.

As is evident, the ring opening of the terminal epoxides with thioacids was mostly achieved regioselectively by preferential attack at the less-hindered carbon atom of the epoxide. 2,3-Epoxypropyl methacrylate (Table 1, entries 13 and 14) under similar reaction conditions produced selectively the product from the ring-opening reaction of the epoxide instead of the expected Michael addition reaction.

In conclusion, we have developed a mild, efficient, and convenient procedure for one-pot synthesis of β-trimethylsilyloxy thioesters from the reaction of thioacids, epoxides, and HMDS under solvent-free conditions at room temperature. The process was efficiently catalyzed by a small portion of silica gel, which produces the corresponding β-trimethylsilyloxy thioesters in good to excellent yields. The β-trimethylsilyloxy thioesters can be easily deprotected to the corresponding β-hydroxy thioesters under mild conditions.[15]

EXPERIMENTAL

All yields refer to the pure isolated products. Chemicals were purchased from different chemical companies. IR spectra were run on a Shimadzu Fourier transform (FT)–IR 8300 spectrophotometer. ^{1}H NMR and ^{13}C NMR spectra were recorded in

$CDCl_3$ using a Bruker Avance DPX instrument (^{1}H NMR 250 MHz, ^{13}C NMR 62.5 MHz). Chemical shifts are reported in parts per million (δ) downfield from tetramathylsilane (TMS). Coupling constants (*J*) are in hertz. Elemental analyses were run on a Thermo Finnigan Flash EA-1112 series. Thin-layer chromatography (TLC) was carried out on silica-gel 254 analytical sheets obtained from Fluka. Column chromatography was performed on Merck silica gel 60 (70–230 mesh).

General Procedure for One-Pot Preparation of β-Trimethylsilyloxy Thioesters Using Epoxides, Thioacids, and HMDS at Room Temperature in the Absence of Solvent

Thioacid (2.1 mmol), epoxide (2 mmol), and silica gel 60 (70–230 mesh) (200 mg) were added together, and the mixture were stirred magnetically at room temperature for the appropriate reaction time as indicated in Table 1. The progress of the reaction was monitored by TLC and gas chromatography (GC). After completion of the reaction, HMDS (2 mmol) was added, and the resulting mixture was stirred magnetically for 10–15 min. Then, the crude product was directly purified by silica-gel chromatography, using petroleum ether/ethyl acetate (20/1) as eluent to provide the desired product in good to excellent yields (Table 1).

S-{3-Butoxy-2-[(trimethylsilyl)oxy]propyl}ethanethioate (1)

Colorless oil; ^{1}H NMR (250 MHz, CDCl3) δ: 3.79–3.70 (m, 1H), 3.29 (t, $J = 6.5$ Hz, 2H), 3.22 (d, $J = 5.3$ Hz, 2H), 2.98 (dd, $J = 13.7$, 5.2 Hz, 1H), 2.80 (dd, $J = 13.7$, 6.9 Hz, 1H), 2.19 (s, 3H), 1.47–1.36 (m, 2H), 1.31–1.19 (m, 2H), 0.78 (t, $J = 7.3$ Hz, 3H), 0.00 (s, 9H); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ: 194.8, 73.9, 71.1, 70.7, 33.1, 31.6, 30.2, 19.1, 13.7, 0.0; IR (neat): ν (cm^{-1}) = 1695 (C=O thioester). Anal. calcd. for ($C_{12}H_{26}O_3SSi$): C, 51.75; H, 9.41; S, 11.51. Found: C, 51.57; H, 9.43; S, 11.39.

S-{3-Butoxy-2-[(trimethylsilyl)oxy]propyl}benzenecarbothioate (2)

Colorless oil; ^{1}H NMR (250 MHz, $CDCl_3$) δ: 7.84–7.80 (m, 2H), 7.41–7.35 (m, 1H), 7.29–7.23 (m, 2H), 3.89–3.80 (m, 1H), 3.32–3.27 (m, 4H), 3.18 (dd, $J = 13.5$, 5.2 Hz, 1H), 3.00 (dd, $J = 13.5$, 6.8 Hz, 1H), 1.47–1.35 (m, 2H), 1.30–1.15 (m, 2H), 0.76 (t, $J = 7.3$ Hz, 3H), 0.00 (s, 9H); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ: 191.2, 136.9, 133.0, 128.3, 126.9, 73.9, 71.1, 70.4, 33.0, 31.5, 19.0, 13.6, 0.0; IR (neat): ν (cm^{-1}) = 1666 (C=O thioester), 1597 (C=C aromatic). Anal. calcd. for ($C_{17}H_{28}O_3SSi$): C, 59.96; H, 8.29; S, 9.42. Found: C, 59.91; H, 8.46; S, 9.59.

S-{3-Phenoxy-2-[(trimethylsilyl)oxy]propyl}ethanethioate (3)

Colorless oil; ^{1}H NMR (250 MHz, $CDCl_3$) δ: 7.12–7.05 (m, 2H), 6.78–6.68 (m, 3H), 3.98–3.90 (m, 1H), 3.79–3.66 (m, 2H), 3.00 (dd, $J = 13.7$, 5.5 Hz, 1H), 2.86 (dd, $J = 13.7$, 6.4 Hz, 1H), 2.14 (s, 3H), 0.00 (s, 9H); ^{13}C NMR (62.5 MHz, $CDCl_3$)

δ: 194.6, 158.3, 129.2, 120.6, 114.3, 70.6, 69.8, 32.9, 30.2, 0.0; IR (neat): ν (cm^{-1}) = 1695 (C=O thioester), 1601 (C=C aromatic). Anal. calcd. for ($C_{14}H_{22}O_3SSi$): C, 56.34; H, 7.43; S, 10.74. Found: C, 56.42; H, 7.30; S, 10.56.

SUPPLEMENTAL MATERIAL

^{1}H NMR, ^{13}C NMR, and IR spectra and elemental analysis data of all products are provided as Supplemental Material available online.

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REFERENCES

1. (a) Zimmer, R.; Schefzig, L.; Peritz, A.; Dekaris, V.; Reissig, H.-U. *Synthesis* **2004**, 1439–1445; (b) Zimmer, R.; Peritz, A.; Czerwonka, R.; Schefzig, L.; Reissig, H.-U. *Eur. J. Org. Chem.* **2002**, 3419; (c) Adger, B.; Bes, M. T.; Grogan, G.; McCague, R.; Pedragosa-Moreau, S.; Roberts, S. M.; Villa, R.; Wan, P. W. H.; Willetts, A. J. *J. Chem. Soc., Chem. Commun.* **1995**, 1563; (d) Evans, D. A.; Fitch, D. M.; Smith, T. E.; Cee, V. J. *J. Am. Chem. Soc*. **2000**, *122*, 10033–10046.
2. (a) Patai, S. *The Chemistry of Thiol Group*; Wiley: New York, 1974; (b) Koval, I. V. *Russ. Chem. Rev.* **1994**, *63*, 147–168; (c) Mukaiyama, T.; Araki, M.; Takei, H. *J. Am. Chem. Soc.* **1973**, *95*, 4763–4765 (d) McGarvey, G. *J. Am. Chem. Soc.* **1986**, *108*, 4943–4956; (e) Conrow, R.; Portoghese, P. *J. Org. Chem.* **1986**, *51*, 938–940.
3. Ozaki, S.; Adachi, M.; Sekiya, S.; Kamikawa, R. *J. Org. Chem.* **2003**, *68*, 4586–4589.
4. (a) Hayashi, Y.; Itoh, T.; Fukuyama, T. *Org. Lett.* **2003**, *5*, 2235–2238; (b) Shimizu, T.; Seki, M. *Tetrahedron Lett.* **2002**, *43*, 1039–1042; (c) McGarvey, G. J.; Williams, M.; Hiner, R. N.; Matsubara, Y.; Oh, T. *J. Am. Chem. Soc.* **1986**, *108*, 4943–4952.
5. (a) Brule, C.; Bouillon, J.-P.; Nicolaï, E.; Portella, C. *Synthesis* **2003**, 436–442; (b) Chen, J.; Forsyth, C. J. *Org. Lett.* **2003**, *5*, 1281–1283.
6. (a) Kobayashi, S.; Uchiro, H.; Fujishita, Y.; Shiina, I.; Mukaiyama, T. *J. Am. Chem. Soc.* **1991**, *113*, 4247–4252; (b) Suh, K.-H.; Choo, D.-J. *Tetrahadron Lett.* **1995**, *36*, 6109–6112.
7. Turpin, J. M.; Song, Y.; Inman, J. K.; Huang, M.; Wallqvist, A.; Maynard, A.; Covell, D. G.; Rice, W. G.; Appella, E. *J. Med. Chem.* **1999**, *42*, 67–86.
8. Greene, T. W.; Wuts, P. G. M. *Protective Groups in Organic Synthesis*; John Wiley and Sons: New York, 2007.
9. Jin, Y.; Ghaffari, M. A.; Schwartz, M. A. *Tetrahedron Lett.* **2002**, *43*, 7319–7321.
10. Lesuisse, D.; Gourvest, J. F.; Hartmann, C.; Tric, B.; Benslimane, O.; Philibert, D.; Vevert, J. P. *J. Med. Chem.* **1992**, *35*, 1588–1597.
11. Beanla, M.; Kohn, H. *J. Org. Chem.* **1983**, *48*, 5033–5041.
12. (a) Srinivas, B.; Sridhar, R.; Surendra, K.; Krishnaveni, N. S.; Pavan Kumar, V.; Nageswar, Y. V. D.; Rama Rao, K. *Synth. Commun.* **2006**, *36*, 3455–3459; (b) Ziyaei Halimehjani, A.; Jalali, A.; Khalesi, M.; Ashouri, A.; Marjani, K. *Synth. Commun.* **2011**, *41*, 1638–1643.

13. (a) Firouzabadi, H.; Iranpoor, N.; Abbasi, M. *Adv. Synth. Catal.* **2009**, *351*, 755–766; (b) Firouzabadi, H.; Iranpoor, N.; Abbasi, M. *Tetrahedron* **2009**, *65*, 5293–5301; (c) Firouzabadi, H.; Iranpoor, N.; Abbasi, M. *Tetrahedron Lett.* **2010**, *51*, 508–509; (d) Firouzabadi, H.; Iranpoor, N.; Abbasi, M. *Bull. Chem. Soc. Jpn.* **2010**, *83*, 698–702; (e) Firouzabadi, H.; Iranpoor, N.; Khoshnood, A.; Abbasi, M. *J. Sulfur Chem.* **2007**, *28*, 351–356.
14. Tanaka, K.; Toda, F. *Chem. Rev.* **2000**, *100*, 1025–1074.
15. Banerjee, A. K.; Mimo, M. S. L.; Vegas, W. J. V. *Russ. Chem. Rev.* **2001**, *70*, 971–990; (a) Greene, T. W.; Wuts, P. G. M. Protective Groups in Organic Synthesis, 3rd ed.; John Wiley and Sons: New York, 1999; (b) Kocienski, P. J. Protecting Groups; Georg Thieme Verlag: Stuttgart, 1994.