Reaction of (Trimethylgermyl)copper(I)–Dimethyl Sulfide with Acyl Chlorides: Efficient Syntheses of **Functionalized Acyltrimethylgermanes**

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Summary: (Trimethylgermyl)copper(I)-dimethyl sulfide (2) reacts with acyl chlorides at low temperature in the presence of chlorotrimethylsilane to produce acyltrimethylgermanes in excellent yields.

Introduction. In connection with an ongoing research program aimed at developing the use of organogermanes as reagents for organic synthesis, 1-4 we required a convenient general method for the preparation of functionalized acyltrimethylgermanes. Interestingly, the chemical literature contains very few reports regarding the synthesis of acylgermanes.⁵⁻⁹ Although, collectively, these accounts disclose a variety of protocols for making these substances, the reported yields are generally poor to moderate⁶⁻⁸ or the methods lack generality.⁵⁻⁹ We report herein (a) that $Me_3GeLi(1)$ is readily prepared from Me₃GeH, (b) that treatment (THF, -78 °C) of 1 with 1 equiv of CuBr·Me₂S produces a solution of $Me_3GeCu \cdot Me_2S$ (2),^{10,11} and (c) that reaction of reagent 2 with acyl chlorides in the presence of Me₃SiCl provides excellent yields of acyltrimethylgermanes.¹²

Results and Discussion. Treatment of Me₃GeH⁴ $(\sim 1.2 \text{ equiv})$ with t-BuLi (1 equiv) in a minimum amount (\sim 5 equiv) of dry tetrahydrofuran (THF) at -10°C produced Me₃GeLi (1) in a yield of $\geq 97\%^{13}$ (Scheme 1).¹⁴ Addition of the resultant solution to a stirred suspension of $CuBr \cdot Me_2S$ (1 equiv) in dry THF at -78

* Abstract published in Advance ACS Abstracts, November 1, 1995. (1) Piers, E.; Marais, P. C. J. Chem. Soc., Chem. Commun. 1989, 1222

1222.
(2) Piers, E.; Marais, P. C. J. Org. Chem. 1990, 55, 3454.
(3) Piers, E.; Renaud, J. J. Org. Chem. 1993, 58, 11.
(4) Piers, E.; Lemieux, R. J. Chem. Soc., Perkin Trans. 1 1995, 3.
(5) Nicholson, D. A.; Allred, A. L. Inorg. Chem. 1965, 4, 1747.
(6) Brook, A. G.; Duff, J. M.; Jones, P. F.; Davis, N. R. J. Am. Chem.
Soc. 1967, 89, 431.

(7) Bravo-Zhivotovskii, D. A.; Pigarev, S. D.; Kalikhman, I. D.; Vyazankina, O. A.; Vyazankin, N. S. J. Organomet. Chem. **1983**, 248, 51.

(8) Yamamoto, K.; Hayashi, A.; Suzuki, S.; Tsuji, J. Organometallics **1987**, *6*, 974.

(9) Kiyooka, S.; Shibuya, T.; Shiota, F.; Fujiyama, R. Bull. Chem. Soc. Jpn. 1989, 62, 1361.

(10) This formulation is analogous to that used for the corresponding trimethylstannyl reagent: (a) Piers, E.; Morton, H. E.; Chong, J. M. Can. J. Chem. 1987, 65, 78. (b) Piers, E.; Chong, J. M. Can. J. Chem. 1988, 66, 1425.

(11) (Triethylgermyl)copper(I) reagents have been prepared and used sporadically: (a) See ref 7. (b) Oda, H.; Morizawa, Y.; Oshima, K.; Nozaki, H. Tetrahedron Lett. **1984**, 25, 3217. (c) Yamaguchi, J.; Tamada, Y.; Takeda, T. Bull. Chem. Soc. Jpn. **1993**, 66, 607. The reaction of (trialkylgermyl)copper(I) reagents with electrophilic substrates has received very little attention.

(12) Although a general method for the synthesis of acyltrimethylgermanes has not been described previously, a few members of this class of substances have been reported. See, for example: (a) Reference 8. (b) Soderquist, J. A.; Hassner, A. J. Am. Chem. Soc. 1980, 102, 1577. (c) Kruithof, K. J. H.; Schmitz, R. F.; Klumpp, G. W. Tetrahedron 1983, 39, 3073. (d) Maruoka, K.; Banno, H.; Yamamoto, H. Tetrahedron: Asymmetry 1991, 2, 647. (e) Nishimura, T.; Inoue-Ando, S.; Sato, Y. J. Chem. Soc., Perkin Trans. 1 1994, 1589.



°C gave a dark red solution of the (trimethylgermyl)copper(I) reagent 2.

The acyl chlorides 3-10 employed as substrates in this study are formulated in Chart 1.¹⁵ 4, 5, and 7 are commercially available, while 3, 6, 9, and 10 were prepared efficiently (yields >90%) by reaction of the parent carboxylic acids with refluxing SOCl₂. Treatment of potassium (4-methoxybenzyloxy)acetate with oxalyl chloride (3 equiv) in Et₂O containing a small amount of dry N,N-dimethylformamide¹⁶ gave 8 in 92% yield.

Initial investigations were carried out using substrate 3. After considerable experimentation, it was found that reaction of 3 with reagent 2 (1.5 equiv) in dry THF (-78 °C, 1 h; -30 °C, 2 h) in the presence of Me₃SiCl (1 $equiv)^{17}$ afforded decanoyltrimethylgermane (11; Chart 1) in 92% yield (Table 1, entry 1). This protocol also proved to be excellent for conversion of the acyl chlorides 4-10 (Chart 1) into the corresponding acylgermanes 12-18. The results are summarized in Table 1.

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⁽¹³⁾ The yield of Me₃GeLi (1) was determined by quantitative gasliquid chromatographic analysis (internal standard) of the mixture derived from alkylation of the reagent with 1-bromodecane.

⁽¹⁴⁾ To our knowledge, this is the only reported in situ preparation of Me₃GeLi (1) from Me₃GeH. For alternative preparations of 1, see: (a) Schumann, H.; Nickel, S.; Loebel, J.; Pickardt, J. Organometallics 1988, 7, 2004. (b) Bulten, E. J.; Noltes, J. G. J. Organomet. Chem. 1971, 29, 397.

⁽¹⁵⁾ All compounds reported herein exhibit spectra consistent with structural assignments, and new compounds gave satisfactory elemental analyses and (or) molecular mass determinations (mass spectrometry)

⁽¹⁶⁾ Beeby, P. J. Tetrahedron Lett. 1977, 3379.

⁽¹⁷⁾ In the absence of Me₃SiCl, the formation of side products resulted in lower yields (\sim 80%) of the acyltrimethylgermane 11. The role of Me₃SiCl in these reactions will be discussed in a full account of this work.



Table 1. Preparation of Acyltrimethylgermanes

The data given in Table 1 show that the method is compatible with the presence of a variety of functional groups, including a primary chloride (entry 3), a carboncarbon double bond (entry 4), and benzyl ether functions (entries 5 and 6). Furthermore, the efficient conversion of adipoyl chloride 9 into the structurally novel diketone 17 is particularly noteworthy. In this transformation 3 equiv of reagent 2 and 2 equiv of Me_3SiCl were employed.

20

21

19

The experiment summarized in entry 8 of Table 1 requires additional comment. Since terminal alkynes are known to serve as good substrates for addition of organocopper(I) reagents, it was of interest to determine whether reagent 2 would react preferentially with an acyl chloride function or a terminal alkyne unit. Reaction of 4-pentynoyl chloride (19; Scheme 2) with 2 (1.05 equiv) and Me₃SiCl (1.05 equiv) in dry THF at -78 °C, followed by workup with aqueous NH₄Cl-NH₄OH, gave two products; the major product (42%) was shown to be the amide **20**. No acyltrimethylgermane corresponding to 19 was isolated. Clearly, reagent 2 had reacted preferentially with the alkyne function of 19 and the resultant intermediate was converted into 20 during the workup procedure.18

Interestingly, the chemoselectivity inherent in the reaction summarized in Scheme 2 was reversed when the terminal alkyne proton in **19** was replaced by a Me₃-

Si group. Reaction of substrate 10 with 2 under the normal reaction conditions provided the acyltrimethylgermane 18 in very good yield (Table 1, entry 8).

Conclusion. In summary, a practical procedure for preparing Me₃GeLi (1) from Me₃GeH has been developed and it has been shown that $Me_3GeCu \cdot Me_2S$ (2) (easily prepared from 1) is a valuable reagent for the preparation of acyltrimethylgermanes from readily accessible acyl chlorides. Investigations into the transformation of the acylgermanes into synthetically useful bifunctional reagents are underway.

Experimental Section. A typical experimental procedure, involving the conversion of 8 into 16, is as follows. To a stirred solution of Me₃GeH (8.55 g, 72.0 mmol) in dry THF (25 mL) at -10 °C under an atmosphere of argon was added t-BuLi (33.9 mL, 1.77 M in pentane, 60.0 mmol) over a period of 3 min (Warning! gas evolution). After the light yellow solution had been stirred for 5 min, it was added via a cannula to a stirred suspension of CuBr·Me₂S (12.34 g, 60.0 mmol) in THF (325 mL, argon atmosphere) at -78 °C. The resulting suspension was stirred at -78 °C for 1 h to afford a dark red solution. Me₃SiCl (4.35 g, 40.0 mmol) was added to the mixture, and stirring was continued for 5 min. A solution of ((4-methoxybenzyl)oxy)acetyl chloride (8; 8.59 g, 40.0 mmol) in dry THF (30 mL) was added via a cannula. The black reaction mixture was stirred at -78 °C for 1 h and at -30 °C for 2 h. The mixture was poured into aqueous NH₄Cl-NH₄-OH (pH 8-9, 400 mL), and the resultant mixture was diluted with Et₂O (400 mL). The heterogeneous mixture was vigorously stirred until the aqueous phase was deep blue. The layers were separated, and the aqueous layer was extracted with Et_2O (3 \times 200 mL). The combined organic solutions were washed (water, brine), dried $(MgSO_4)$, and concentrated. Subjection of the crude product to chromatography (silica gel), followed by bulbto-bulb distillation (75-84 °C/0.005 Torr) of the acquired liquid, afforded 9.76 g (82%) of 16 as a light yellow oil. ¹H NMR (400 MHz, CDCl₃): δ 7.25 (2 H, d, J = 8.7 Hz), 6.87 (2 H, d, J = 8.7 Hz), 4.50 (2 H, s), 3.99 (2 H, s),3.79 (3 H, s), 0.33 (9 H, s).

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Supporting Information Available: Text giving spectral data for compounds 11-18, 20, and 21 (4 pages). This material is contained in many libraries on microfiche, immediately follows this article in the microfilm version of the journal, can be ordered from the ACS, and can be downloaded from the Internet; see any current masthead page for ordering information and Internet access instructions.

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⁽¹⁸⁾ The minor product (13% yield) from this reaction, 1-((trimethylsilyl)oxy)-2-(bis(trimethylgermyl)methyl)cyclobutene (21; Scheme 2), was evidently also derived from initial chemoselective addition of 2 to the triple bond of 19. The details of this transformation will be discussed in a full account of this study.