Notes

A Nitrogen-Containing Stannane for Free Radical Chemistry

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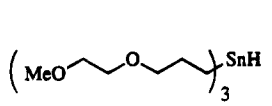
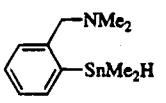
Tributyl- and triphenyltin hydrides are important reagents in preparative free radical chemistry[1] but product isolation is sometimes difficult because tin-containing materials formed in these reactions are nonpolar and cannot easily be separated from nonpolar organic products. Although a number of workup procedures have been proposed in order to deal with these isolation problems,[2] further effort is clearly warranted. The water-soluble stannane **1**[3] should be of general use in these situations, although it does not seem to have been fully evaluated in this respect. More recently, stannane **2** was reported.[4] Its most characteristic property appears to be high reactivity in both ionic and radical reductions,[5] and its polarity does indeed facilitate product isolation.



1



2

We report that stannane **6** is a useful reagent for typical radical chemistry, because both **6** and the derived bromide and phenyl selenide are much more polar than corresponding tributyl- or triphenyltin species. Compound **6** was prepared as shown in Scheme 1. It is stable in CD_2Cl_2 for at least one day (^1H NMR), and both CD_2Cl_2 and $CDCl_3$ can be used as NMR solvents. Compound **6** should be stored in a refrigerator as a neat liquid or, better, as a frozen benzene solution. We have always used the material within two weeks of its preparation. The compound is not fully extracted from ether solutions by 6 N HCl; consequently, when **6** is used, chromatographic separation is required, but the separation is easy because of the high polarity of **6** and its derivatives.

Compound **6** may be used in radical chemistry in the same way as tributyl- and triphenyltin hydrides, and typical examples are shown in Table 1 for a number of bromides and selenides. We generally use refluxing benzene or toluene, being guided by the choice of solvent made for the corresponding conventional stannane reductions reported in the literature. Yields and conditions are comparable to those for the traditional reagents (Bu_3SnH and Ph_3SnH), but chromatographic separation is simplified in those cases where the desired product is nonpolar. For example, in the case of entries 2, 3, and 7, product isolation by flash chromatography (silica gel, 1:3 ethyl acetate–hexane) was much easier for reductions done with **6** than those accomplished with triphenyltin hydride. This was due to the fact that the R_f-values of the desired products and the contaminating tin species from triphenyltin hydride were all in the range 0.4 to 0.5. However, tin species derived from **6** were chromatographically much less mobile (R_f *ca.* 0). Compound **6** itself has an R_f of *ca.* 0.2 on silica gel, with 1:3 ethyl acetate–hexane, while the value for triphenyltin hydride is *ca.* 0.9.

In two experiments (entries 1 and 6) we have also examined the triethylborane–air method of initiation, and found that it too works well, at room temperature. Consequently, our results indicate that the nitrogen-containing stannane **6** should be considered for use in stannane reductions leading to nonpolar compounds, where separation problems have been experienced with tributyl- or triphenyltin hydrides. Stannane **6** can also be used for hydrostannylation (entry 9).

Experimental Section

General. The same general techniques were used as reported previously.[13] The symbols s′, d′, t′, and q′ used for ^{13}C NMR signals indicate 0, 1, 2, or 3 attached hydrogens, respectively. Where ^{119}Sn and ^{117}Sn couplings are resolved both values are given.

Triphenyl[2-(4-pyridyl)ethyl]tin (4). The general literature procedure[14] was followed. 4-Vinylpyridine (Aldrich, used as received, 1.55 mL, 14.4 mmol) was added to Ph_3SnH (Aldrich, used as received, 2.52 g, 7.18 mmol), and AIBN (1 mg) was added to the mixture. The mixture was lowered into a preheated oil bath (80 °C) and stirred for 4 h under a slow stream of dry Ar.

(1) E.g. Motherwell, W. B.; Crich, D. *Free Radical Chain Reactions in Organic Synthesis*; Academic Press: London, 1992. Giese, B. *Radicals in Organic Synthesis: Formation of Carbon-Carbon Bonds*; Pergamon Press: Oxford, 1986.

(2) E.g. (a) Macmullin, E. C.; Peach, M. E. *J. Organomet. Chem.* **1973**, *52*, 355. (b) Berge, J. M.; Roberts, S. M. *Synthesis* **1979**, 471. (c) Leibner, J. E.; Jacobus, J. *J. Org. Chem.* **1979**, *44*, 449. (d) Barton, D. H. R.; Motherwell, W. B.; Stange, A. *Synthesis* **1981**, 743. (e) Tanner, D. D.; Blackburn, E. V.; Diaz, G. E. *J. Am. Chem. Soc.* **1981**, *103*, 1557.

(3) (a) Light, J.; Breslow, R. *Org. Synth.* **1993**, *72*, 199. (b) Light, J.; Breslow, R. *Tetrahedron Lett.* **1990**, *31*, 2957.

(4) Vedejs, E.; Duncan, S. M.; Haight, A. R. *J. Org. Chem.* **1993**, *58*, 3046.

(5) An unusual stannane (which is generated in situ) for radical reactions in aqueous base has been reported: Rai, R.; Collum, D. B. *Tetrahedron Lett.* **1994**, *35*, 6221.

(6) Miura, K.; Ichinose, Y.; Nozaki, K.; Fugami, K.; Oshima, K.; Utimoto, K. *Bull. Chem. Soc. Jpn.* **1989**, *62*, 143.

(7) Abeywickrema, A. N.; Beckwith, A. L. J.; Gerba, S. *J. Org. Chem.* **1987**, *52*, 4072.

(8) Clive, D. L. J.; Chittattu, G. J.; Farina, V.; Kiel, W. A.; Menchen, S. M.; Russell, C. G.; Singh, A.; Wong, C. K.; Curtis, N. J. *J. Am. Chem. Soc.* **1980**, *102*, 4438.

(9) Clive, D. L. J.; Manning, H. W.; Boivin, T. L. B.; Postema, M. H. D. *J. Org. Chem.* **1993**, *58*, 6857.

(10) Robins, M. J.; Wilson, J. S.; Hanske, F. *J. Am. Chem. Soc.* **1983**, *105*, 4059.

(11) Eggert, H.; VanAntwerp, C. L.; Bhacca, N. S.; Djerassi, C. *J. Org. Chem.* **1976**, *41*, 71.

(12) van der Kerk, G. J. M.; Noltes, J. G.; Luijten, J. G. A. *J. Appl. Chem.* **1957**, *7*, 356.

(13) Clive, D. L. J.; Cole, D. C.; Tao, Y. *J. Org. Chem.* **1994**, *59*, 1396.

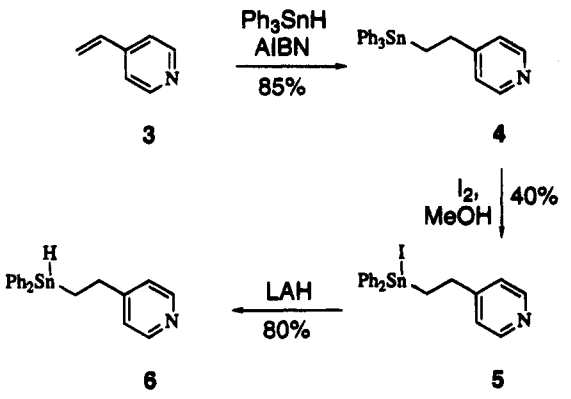
(14) van der Kerk, G. J. M.; Noltes, J. G. *J. Appl. Chem.* **1959**, *9*, 106.

(15) From a spectrum run in $CDCl_3$ at 50.324 MHz.

(16) From a spectrum run in CD_2Cl_2 at 100.614 MHz.

0022-3263/95/1960-2607$09.00/0

Scheme 1



At this stage the excess of 4-vinylpyridine was evaporated (rotary evaporator, *ca.* 80 °C). Flash chromatography of the residue over silica gel (4 × 40 cm), using 1:1 EtOAc–hexane, gave **4** (2.78 g, 85%) as a pure (^{1}H NMR, 200 MHz), white solid: mp 112–112.5 °C (lit.[14] 112–113 °C); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.68–2.06 (m, $^2J_{SnCH}$ = 53 Hz, 2 H), 2.85–3.22 (m, $^3J_{SnCCH}$ = 47 Hz, 2 H), 7.12 (dd, J = 6.0, 1.5 Hz, 2 H), 7.35–7.76 (m, 15 H), 8.49 (dd, J = 6.0, 1.5 Hz, 2 H); ^{13}C NMR (75.496 MHz, C_6D_6) δ 11.4 (t'), 31.9 (t'), 123.3 (d'), 129.0 (d', $^3J_{SnCCC}$ = 48 Hz), 129.3 (d', $^4J_{SnCCCC}$ = 10.5 Hz), 137.3 (d', $^2J_{SnCC}$ = 35 Hz), 138.5 (s'), 150.3 (d'), 152.8 (s'); broadband proton-decoupled ^{119}Sn NMR (149.213 MHz, $CDCl_3$, Me_4Sn as internal standard) δ −100.53; exact mass m/z calcd for $C_{25}H_{23}N^{120}Sn$ 457.08524, found 457.08471. Anal. Calcd for $C_{25}H_{23}NSn$: C 65.83, H 5.08, N 3.07. Found: C 65.51, H 5.05, N 3.03.

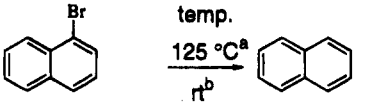
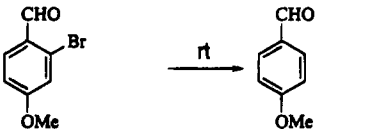
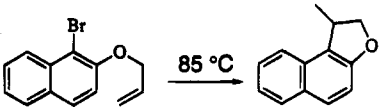
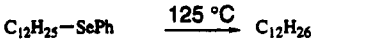
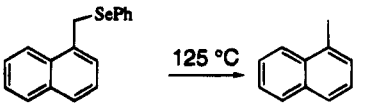
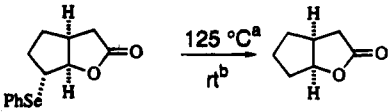
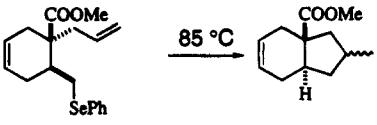
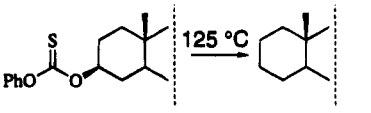
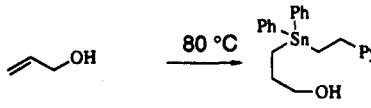
Diphenyl[2-(4-pyridyl)ethyl]tin Iodide (5). I_2 (1.51 g, 5.94 mmol) was added over *ca.* 30 min from a solid addition sidearm tube to a stirred solution of **4** (2.52 g, 5.51 mmol) in bench MeOH (40 mL) (Ar atmosphere). After 4 h (TLC control, silica, 1:3 EtOAc–hexane) the solvent was evaporated, and flash chromatography of the residue over silica gel (4 × 12 cm), using first 1:3 EtOAc–hexane, and then MeOH, gave **5** (1.12 g, 40%) as a pure (^{1}H NMR, 200 MHz), white solid: mp 180–181 °C; ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.80–2.20 (m, $^2J_{SnCH}$ = 51 Hz, 2 H), 2.82–3.28 (m, $^3J_{SnCCH}$ = 68 Hz, 2 H), 7.12 (dd, J = 6.0, 1.5 Hz, 2 H), 7.35–7.73 (m, 10 H), 8.42 (dd, J = 6.0, 1.5 Hz, 2 H); ^{13}C NMR ($CDCl_3$, 100.614 MHz) δ 18.0 (t'), 32.3 (t'), 123.8 (d'), 129.3 (d', $^3J_{SnCCC}$ = 60 Hz[15]), 130.4 (d'), 136.4 (d', $^2J_{SnCC}$ = 47 Hz[15]), 137.7 (s'), 150.1 (d'), 152.8 (s'); broadband proton-decoupled ^{119}Sn NMR (149.213 MHz, $CDCl_3$, Me_4Sn as internal standard) δ − 61.59; exact mass m/z calcd for $C_{19}H_{18}IN^{120}Sn$ 506.95078, found 506.96477.

Diphenyl[2-(4-pyridyl)ethyl]tin Hydride (6). A solution of **5** (183.6 mg, 0.36 mmol) in dry THF (10 mL) was added dropwise over *ca.* 15 min to a stirred and cooled (0 °C) suspension of $LiAlH_4$ (13.7 mg, 0.36 mmol) in dry Et_2O (10 mL) (Ar atmosphere). Stirring was continued for 15 min at 0 °C. The mixture was then quenched by slow addition of ice–water (*ca.* 5 mL) and extracted with Et_2O (3 × 15 mL). The extract was dried ($MgSO_4$) and evaporated at rt. Flash chromatography of the residue over silica gel (4 x 40 cm), using 1:1 EtOAc–hexane, gave **6** (110 mg, 80%) as a pure (^{1}H NMR, 200 MHz) liquid which can be stored under Ar in the refrigerator for several weeks: FTIR (cast from CH_2Cl_2) 1836 cm^1; ^{1}H NMR (400 MHz, C_6D_6) δ 1.12–1.32 (m, $^2J_{SnCH}$ = 53 Hz, 2 H), 2.40–2.61 (m, $^3J_{SnCCH}$ = 54 Hz, 2 H), 6.19 (t, J = 1.75 Hz, $^1J_{(119)SnH}$ = 1851 Hz, $^1J_{(117)SnH}$ = 1776 Hz, 1 H), 6.55 (dd, J = 6.0, 1.5 Hz, 2 H), 7.05–7.20 (m, 6 H), 7.27–7.44 (m, 4 H), 8.45 (dd, J = 6.0, 1.5 Hz, 2 H); ^{13}C NMR (50.323 MHz, C_6D_6) δ 10.6 (t', $^1J_{(119)SnC}$ = 382 Hz, $^1J_{(117)SnC}$ = 366 Hz), 32.3 (t', $^2J_{(119)SnCC}$ = 38 Hz, $^2J_{(117)SnCC}$ = 17 Hz), 123.3 (d'), 128.9 (d', $^3J_{SnCCC}$ = 49 Hz[16]), 129.3 (d', $^4J_{SnCCCC}$ = 16 Hz[16]), 137.4 (d', $^2J_{SnCC}$ = 37 Hz[16]), 137.6 (s', $^1J_{SnC}$ = 490 Hz[16]), 150.4 (d'), 152.6 (s'); broadband proton-decoupled ^{119}Sn NMR (149.212 MHz, C_6D_6, Me_4Sn as internal standard) δ −137.006; exact mass m/z calcd for $C_{19}H_{19}N^{120}Sn$ 381.05396, found 381.05319. Anal. Calcd for $C_{19}H_{19}NSn$: C 60.05, H 5.04, N 3.69. Found: C 60.27, H 5.02, N 3.70.

Typical Radical Reaction Conditions. (a) Thermal Method. The substrate (1 mmol) was placed in a round-bottomed flask carrying a reflux condenser closed by a septum. The flask was flushed with Ar, and the contents were kept under a slight positive pressure of Ar. PhH or PhMe (5.0 mL) was injected, and the flask was lowered into a preheated oil bath set at 85 °C, or at 125 °C in the case of PhMe. A solution of both **6** (1.4 mmol) and AIBN (2.0 mg) in the same solvent (3 mL plus 1 mL as a rinse) was injected in one portion (except for the cyclization reaction, in which case the addition was made over 28 h). Refluxing was continued for 2–10 h after the addition. The mixture was cooled and evaporated. Flash chromatography of the residue over silica gel then gave the product.

(b) Room Temperature Method. The stannane **6** (1.4 mmol) in hexane (4 mL) and Et_3B (1 M solution in hexane, 1.1 mL) were added to a stirred solution of the substrate (1.0 mmol) in hexane (5 mL) contained in a flask fitted with a calcium sulfate guard tube. Stirring with exposure to air was continued for 11 h, and the solution was then evaporated. Flash chromatography of the residue then gave the product.

Table 1. Reductions Using Stannane 6

		Bath temp.	Yield with 6	Lit.
1		125 °C[a] / rt[b]	75%[a] 77%[b]	78- 85%[c]
2		rt	70%[b]	69%[b,d,e]
3		85 °C	76%[a]	<71%[f]
4		125 °C	70%[a]	73%[g]
5		125 °C	85%[a]	-[d]
6		125 °C[a] / rt[b]	75%[a] 80%[b]	74%[g]
7		85 °C	80%[a]	92%[h]
8		125 °C	90%[a,i]	-[d]
9		80 °C	65%	93%[j]

[a]Thermal reaction. A bath temperature of 85 °C was used for reactions run in PhH, and 125 °C for those done in PhMe. [b]Triethylborane method. [c]Use of Ph_3SnH and Et_3B at 80 °C gave 85% yield (ref 6). Use of Ph_3SnH in refluxing PhH (thermal method) gave 78% yield (present work). [d]Stannane reduction of the starting material does not seem to have been reported previously. [e]We used KF workup (*cf.* ref 2c). [f]Use of Ph_3SnH in refluxing PhH gave <71% yield (ref 7). [g]Use of Ph_3SnH in refluxing PhMe (ref 8). [h]Use of Ph_3SnH in refluxing PhH (ref 9). [i]*Cf.* Reference 10 for preparation of the starting material, and ref 11 for ^{13}C NMR data of the product. [j]Using Ph_3SnH (ref 12).

3-[Diphenyl[2-(4-pyridyl)ethyl]stannyl]propanol by Hydrostannylation of Allyl Alcohol. Stannane **6** (140.0 mg, 0.37 mmol), allyl alcohol (0.3 mL, 4.4 mmol), and AIBN (2.5 mg) were dissolved in dry Et_2O (4.0 mL), and the solution was evaporated at rt under water-pump vacuum. The residual oil was stirred at 80 °C for 4 h in a preheated oil bath (Ar atmosphere). Flash chromatography of the residue over silica gel (4 × 30 cm), using 1:1 EtOAc–hexane, gave the product (104.7 mg, 65%) as a pure (^{1}H NMR, 200 MHz) oil: ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.08–2.10 (m, 6 H), 2.46 (br s, 1 H), 2.72–3.10 (m, $^3J_{SnCCH}$ = 46 Hz, 2 H), 3.61 (t, J = 6.0 Hz, 2 H), 7.08 (dd, J = 6.0, 1.5 Hz, 2 H), 7.30–7.63 (m, 10 H), 8.39 (dd, J = 6.0, 1.5 Hz, 2 H); ^{13}C NMR (50.323 MHz, $CDCl_3$) δ 6.4 (s', $^1J_{(119)SnC}$ = 378 Hz, $^1J_{(117)SnC}$ = 361 Hz), 11.0 (t', $^1J_{(119)SnC}$ = 354 Hz, $^1J_{(117)SnC}$ = 339 Hz), 29.4 (t', $^2J_{(119)SnCC}$ = 21 Hz), 32.00 (t'), 65.4 (t', $^3J_{(119)SnCCC}$ = 62 Hz), 123.4 (d'), 128.5 (d', $^3J_{SnCCC}$ = 46 Hz), 128.8 (d', $^4J_{SnCCCC}$ = 16 Hz), 136.7 (d', $^2J_{SnCC}$ = 34 Hz), 139.5 (s'), 149.5 (d'), 154.1 (s'); exact mass m/z calcd for $C_{22}H_{25}ON^{120}Sn$ 439.09583, found 439.09639.

Acknowledgment. We thank NSERC and Merck Frosst Canada Inc. for financial support.

Supplementary Material Available: NMR spectra for **5** and 3-[diphenyl[2-(4-pyridyl)ethyl]stannyl]propanol (2 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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