Reactions of Lithiostannanes with 6-Halo-1-hexenes

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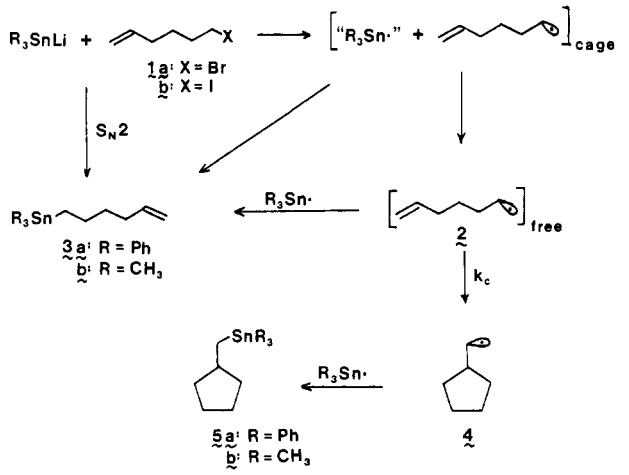
The reactions of tin anionoid species with organic halides are particularly useful for the synthesis of new carbon–tin bonds since they proceed in high yield with a wide variety of organic substrates. Despite the utility of these reactions for the synthesis of organometallic compounds, the details of their reaction mechanisms are still uncertain. The observation of predominant inversion at carbon in the products suggests that the major pathway of these reactions involves an S_N2 process,[1] but other results require the existence of alternative mechanisms.[2] Recently San Filippo et al. have studied the mechanistic details of these reactions and concluded that alkyl free radicals are intermediates. Based on the observed products from reactions of tin anionoids with cyclopropylcarbinyl halides (used as probes for free-radical intermediates), they concluded that in selected reactions up to 80% of the products may be formed via free-radical pathways for reactions of primary halides with tin anionoids.[3] We now report the results of studies with a different free-radical probe which do not indicate that free radicals are formed as intermediates in reactions of lithiotin anionoids with primary halides.

We have used 6-halo-1-hexenes (**1**) as free-radical probes in reactions with lithiotin anionoids. The utility of such a probe is exemplified in the study of Garst and Smith of the reactions of benzophenone ketyls with alkyl iodides.[4] If a 5-hexen-1-yl free radical (**2**) is formed it may be intercepted by tin radicals or clusters to give 5-hexenyltin products (**3**). Compounds **3** may also arise from collapse of caged radicals or direct S_N2 displacement on **1**. Alternatively, if bimolecular reactions of **2** are slow, irreversible cyclization to the cyclopentylcarbinyl radical **4** would occur at a known rate. Subsequent bimolecular coupling reactions of **4** would produce (cyclopentylcarbinyl)tin compounds (**5**). This simplified model of possible reactions is shown in Scheme I.

Upon consideration of the apparent relative rates of the processes studied by San Filippo (vida infra), we expected that reactions of **1** with tin anionoids at appropriate dilution would produce some cyclized product **5**. We found, however, that the reaction of (triphenylstannyl)lithium (0.05 M) with 6-bromo-1-hexene (**1a**) at 0 °C in tetrahydrofuran (THF) led to the formation of 6-(triphenylstannyl)-1-hexene (**3a**) in 67.5% isolated yield after column chromatography. Analysis of the crude and purified product by ^1H NMR spectroscopy indicated that no (<5%) **5a** could have been formed in this reaction.

Accordingly, we investigated the reaction of (trimethylstannyl)lithium with both **1a** and **1b**. In these cases products were analyzed by gas chromatography. For comparison, authentic [(trimethylstannyl)methyl]cyclopentane (**5b**) was synthesized by the reaction of (trimethylstannyl)lithium with the mesylate of cyclopentanemethanol. In several reactions of (trimethylstannyl)lithium (0.01–0.8 M) with **1a**, and one reaction of (trimethylstannyl)lithium (0.26 M) with **1b**, acyclic **3b** was formed in 50–84% yield but no (<1%) cyclized product **5b** was detected.

Scheme I



Our basis for expecting that cyclized product **5** would form under our reaction conditions is the following: The conclusion from the cyclopropylcarbinyl halide studies was that ca. 20% of the reaction of primary alkyl bromides and ca. 50% of the reaction of primary alkyl iodides with (trimethylstannyl)lithium proceed through free radicals.[3b] The rate constant for ring opening of the cyclopropylcarbinyl free radical at 0 °C is 5.3×10^7 s^{-1}.[5] If the bimolecular capture process involves reaction of the cyclopropylcarbinyl free radical with a tin radical, radical cation, or ionic species, then this process will occur with a rate constant of $k_2[X] < 5 \times 10^6$ s^{-1}, where [X] represents the concentration of trapping agent, and we allow ring opening to be at least 10 times faster than capture of the cyclic free radical, since changing the concentration of lithiostannane did not affect the product ratio.[3b] The rate constant for cyclization of the 5-hexenyl radical at 0 °C is 2.8×10^4 s^{-1}.[6] In the case of **1a** reacting with (trimethylstannyl)lithium, trapping of the acyclic radical would have to be at least 20 times faster than cyclization to preclude formation of 1% of **5**, and thus $k_2[Y] > 6 \times 10^5$ s^{-1}, where [Y] is the concentration of trapping agent, since we assume that ca. 20% of the reaction proceeds via free radicals.[3b] The constants k_2 in each expression should be similar since they describe the rates of the reactions of primary radicals. Mixing is probably the slow process in these reactions and the concentrations of X and Y will reflect the initial concentrations of tin anionoid species. Thus, by lowering the concentration of tin anionoid to 0.025 times that used in the cyclopropylcarbinyl reactions, we expected to find cyclized product **5**. In fact, since we added stoichiometric amounts of the halides to the organometal, the concentration of stannyllithium reagent at the end of each reaction was extremely low and cylization of **2** should have become increasingly competitive.

Our results cannot disprove the intermediacy of free radicals in the reactions of stannyllithium with primary alkyl halides since radical capture may be faster than the results with the cyclopropylcarbinyl probe suggest. We

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intend by this note to point out the mechanistic discrepancy which arises when the two probes are compared and to present a caveat for the application of cyclopropylcarbinyl halides as free-radical probes in reactions with nucleophiles. Noteworthy in the latter regard is the recent report by Kinney, Jones, and Bergman,[7] who obtained anomalous results from the reactions of cyclopropylcarbinyl halides with the anionic vanadium carbonyl hydride $[(\eta^5\text{-}C_5H_5)V(CO)_3H]^-$, which was shown by other means to react with organic halides to give free radicals.

Experimental Section

All reactions involving organometallic species were conducted under nitrogen or argon atmospheres and employed syringe transfers. Tetrahydrofuran (THF) was distilled from sodium–benzophenone under nitrogen immediately before use. Gas chromatography (GC) was performed on a Varian 920 chromatograph on a 3 ft by 0.25 in. column of 5% SE-30 on 60/80 Chromosorb W. ^{1}H NMR spectra were recorded on a Varian T-60 spectrometer on samples with an internal standard of Me_4Si unless otherwise noted. IR spectra were recorded on a Beckman IR-8 spectrometer.

Materials. 6-Bromo-1-hexene (Fluka) containing <5% of impurities of 6-bromo-2-hexenes was used without purification. 6-Iodo-1-hexene was prepared from the bromohexene and sodium iodide (fivefold excess) in acetone (25 °C, 48 h) in 77% yield. (Triphenylstannyl)lithium and (trimethylstannyl)lithium were prepared by standard procedures from the corresponding chloride and bromide, respectively.

[(Trimethylstannyl)methyl]cyclopentane (5b). Cyclopentanemethanol was prepared from cyclopentylmagnesium bromide and excess gaseous formaldehyde by the method of Zelinsky.[8] Mesylation was effected by the method of Crossland and Servis.[9] Treatment of 1.0 g (10 mmol) of cyclopentanemethanol in 5.6 mL of methylene chloride with 1.2 mL of pyridine and 1.3 g (11.1 mmol) of methanesulfonyl chloride at −10 °C for 20 min followed by an extractive workup (consecutive extractions with water, 10% aqueous hydrochloric acid, saturated aqueous sodium bicarbonate solution, and saturated aqueous sodium chloride solution, all at 0 °C) and drying ($MgSO_4$) gave, upon distillation of the solvent, a residue of 1.2 g (67% yield) of (mesyloxymethyl)cyclopentane which was used without further purification: ^{1}H NMR ($CDCl_3$) δ 1.0–2.0 (m, 8 H), 2.2–2.4 (m, 1 H), 3.0 (s, 3 H), 4.1 (d, 2 H, J = 7 Hz); IR (film) 1350, 1165, 945 cm^{-1}. A solution of (trimethylstannyl)lithium prepared from 4.1 mmol of trimethyltin bromide in 10 mL of THF was maintained at 0 °C as a solution of 0.7 g (4 mmol) of (mesyloxymethyl)cyclopentane in 5 mL of THF was added dropwise. The stirred reaction mixture was maintained at 0 °C for 2 h and then allowed to warm to 25 °C. After 12 h at 25 °C, saturated aqueous ammonium chloride was added and the phases were separated. The aqueous phase was extracted twice with methylene chloride, and the combined organic phases were dried ($MgSO_4$) and concentrated in vacuo. The residue was chromatographed on silica gel (methylene chloride elution) to give 0.6 g (62% yield) of [(trimethylstannyl)methyl]cyclopentane (**5b**) which was further purified by preparative GC to give spectroscopically and chromatographically pure **5b**: ^{1}H NMR ($CDCl_3$, CH_2Cl_2 reference) δ 0.1 (s, 9 H), 0.9–1.1 (m, 2 H), 1.5–1.9 (m, 9 H).

Reactions of Lithiostannanes with 6-Halo-1-hexenes. The following reaction is representative. A solution of 4.1 mmol of 6-bromo-1-hexene in 5 mL of THF was added dropwise to 10 mL of a 0.41 M solution of (trimethylstannyl)lithium at 0 °C over ca. 30 min. After 60 min of additional stirring at 0 °C, the mixture was quenched by addition of an aqueous saturated ammonium chloride solution. An extractive workup (methylene chloride) followed by drying ($MgSO_4$) and solvent distillation gave a residue which was shown by GC to contain no (<1%) [(trimethylstannyl)methyl]cyclopentane. Chromatography of the residue on silica gel (hexane elution) gave 0.5 g (50% yield) of 6-(trimethylstannyl)-1-hexene (**3b**) which was chromatographically and spectroscopically pure: ^{1}H NMR ($CDCl_3$, $CHCl_3$ reference) δ 0.17 (s, 9 H), 0.85–0.95 (m, 2 H), 1.0–1.7 (m, 4 H), 1.8–2.2 (m, 2 H), 4.7–5.1 (m, 2 H), 5.2–6.1 (m, 1 H). The corresponding product from the reaction of (triphenylstannyl)lithium, 6-(triphenylstannyl)-1-hexene (**3a**), had the following ^{1}H NMR spectrum: ($CDCl_3$) δ 1.1–1.7 (m, 8 H), 4.7–5.1 (m, 2 H), 5.2–5.9 (m, 1 H), 7.0–7.6 (m, 15 H).

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Registry No. **1a**, 2695-47-8; **1b**, 18922-04-8; **3a**, 73017-73-9; **3b**, 73017-74-0; **5b**, 73017-75-1; cyclopentanemethanol, 3637-61-4; [(mesyloxy)methyl]cyclopentane, 73017-76-2; (trimethylstannyl)lithium, 17946-71-3; trimethyltin bromide, 1066-44-0; (triphenylstannyl)lithium, 4167-90-2.

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General Catalyzed Condensation of Nitrosobenzene and Phenylhydroxylamine in Aqueous Solution

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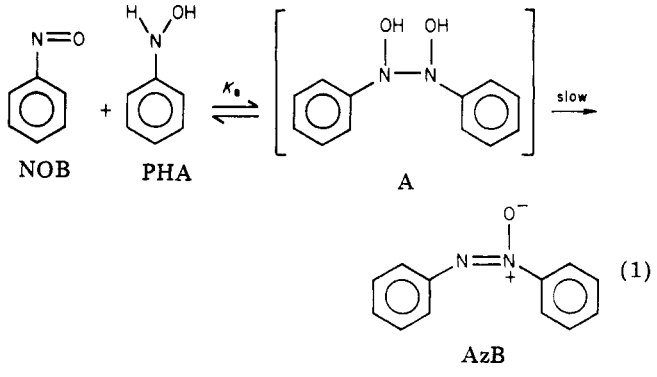
The condensation of *N*-arylhydroxylamines with aromatic nitroso compounds to form substituted azoxybenzenes has been studied in a variety of solvent systems.[1-6] Evidence[7,8] suggests that PHA and NOB in the absence of added bases (ethanol and 70% aqueous methanol solvent) react to produce a symmetrical intermediate (A) which is in rapid equilibrium with starting materials (eq 1). In ethanolic Britton–Robinson buffer, Darchen



(1)

and Moinet[9] have shown that the reaction exhibits *specific* acid and base catalysis and an undefined spontaneous term. Because of the potential importance of this con-

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