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Determination of the Effect of Cation−π Interactions on the Stability of α-Oxy-Organolithium Compounds

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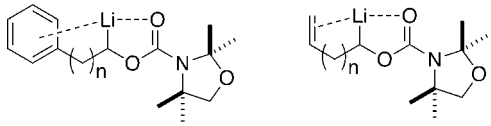

Li-π interaction energy = up to 2.2 Kcal mol^{-1}

Sn−Li exchange equilibria have allowed the quantification of the stabilizing effect of cation−π interactions in organolithium chemistry. Stabilization energy data on the effect of Li−π complexation of an aromatic ring or a C=C double bond in organolithium compounds are presented. The amount of stabilization gained by complexation of the Li atom with a π system in α-oxy-organolithium compounds is quite comparable to the one observed in systems containing Li−N or Li−O interactions.

Noncovalent interactions involving unsaturated systems[1] play a dominant role in many forefront areas of modern chemistry[2] and molecular biology.[3] Together with other attractive interactions, cation−π interactions[4] are playing a key role in both chemical and biological recognition,[1,5] the structural and functional properties of proteins,[6] and enzymatic catalysis.[7] The cation−π interaction is fundamentally an electrostatic interaction between a positively charged species (a cation) and the electrons that make up one or more π bonds. Theoretical investigations[8] and experimental evidence[9] for cation−π interactions are well-documented and place it among the strongest of noncovalent binding forces. From a synthetic point of view, cation−π interactions have been occasionally proposed to explain the stereochemical outcome of several organic transformations.[10] For instance, five-membered rings have been prepared in a very stereoselective manner by anionic cyclizations of different alkenyllithiums.[11] The stereoselectivity of this reaction is a consequence of an energetically favorable coordination of the lithium atom with the remote π bond. More recent applications[12] of cation−π interactions include their use as a conformation-controlling tool[13] in a variety of regio- and stereoselective syntheses, as well as in the design of chiral metal catalysts for enantioselective Diels−Alder and Mukaiyama−Michael reactions.[14]

We have recently reported[15] the measurement of the relative stabilities of α-heterosubstituted benzylic organolithium compounds and secondary α-oxy-organolithium compounds in THF, where the effects of alkyl substituents and Li−O and Li−N chelation on carbanion stability were quantified. Our approach is based on the establishment of a Sn−Li exchange between the organolithium under study and a reference compound (as shown in eq 1 in Figure 1), an equilibrium reaction which favors the pairing of the most stable carbanion with the more electropositive Li atom.[16,17]

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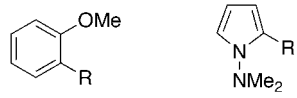
$R^1SnR^3_3 + R^2Li \rightleftharpoons R^1Li + R^2SnR^3_3$ (1)

Reference Compounds (R^2Li):



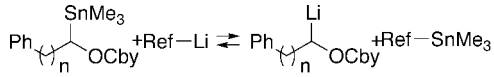
1 **2**

ΔG_{eq}: 7.7 5.7

a. R = $SnMe_3$ **b**. R = Li **c**. R = H

FIGURE 1. Sn−Li exchange equilibrium and reference compounds used.

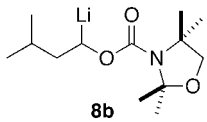
SCHEME 1. Effect of Cation−π Interaction on α-Oxy-Organolithium Stability



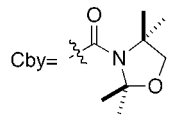
3-7a **1-2b** **3-7b** **1-2a**

Entry	Anion	n	Ref-Li	*T* (°C)/*t* (h)	ΔG_{eq}[a]
1	**3b**	1	**2b**	-65/16	**5.5-5.6**
2	**4b**	2	**2b**	-65/24-48	**6.0**
3[b]	**4b**	2	**2b**	-65/24-48	**6.0**
4	**5b**	3	**1b**	-70/24	**7.5**
5	**6b**	4	**1b**	-50/24	**7.5**
6	**7b**	7	**1b**	-50/24	**7.7**
7	**8b**	-	**1b**	-65/16	**7.5**

[a] ΔG_{eq} values in kcalmol^{-1} [b] Relative stability obtained by Pb-Li exchange.



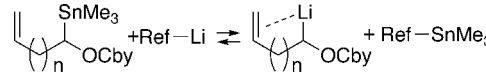
8b



Since quantification of the thermodynamic effect of cation−π interactions on simple organic systems would put the development of new synthetic uses for them on firmer ground, we decided to apply our methodology for determining the relative stabilities of organolithium compounds to establish if cation−π interactions can exert a significant stabilization on organolithiums possessing an unsaturated system on the side chain. We report herein the application of this Sn−Li exchange equilibrium methodology to the quantification of the cation−π interaction effects on the stability of phenyl- and vinyl-substituted organolithiums.

We have prepared a series of α-oxy-organolithium compounds with different phenyl-group-containing side chains from the appropriate stannanes and measured their relative stabilities. To set up the tin−lithium exchange equilibria, equimolar amounts of stannanes **3**−**7a** and organolithium reagents **1**−**2b** (obtained from the corresponding stannanes **1**−**2a** and 100 mol % of BuLi) were mixed and kept for the time and at the appropriate temperature as indicated in Scheme 1. The equilibrium concentrations were determined after low-temperature quenching of the reactions with methanol and quantitative analysis of the resulting mixtures of hydrocarbons **3**−**7c** (arising from the protonation of the corresponding organolithium species present in the equilibria) and stannanes **3**−**7a** by ^{1}H NMR. The reverse reaction (organolithium reagents **3**−**7b** and stannanes **1**−**2a**) was performed in each case to establish that the equilibrium had been reached. The conditions for each particular reaction were optimized until the same K_{eq} value from the forward and reverse reactions was obtained. The data obtained from the tin−lithium equilibration with the reference compounds are displayed in Scheme 1 (the reference level of 0.0 kcal mol^{-1} was assigned to 9-xanthenyllithium, the most stable reference compound used in our previous studies).[15] These data clearly show the presence of sizable stabilizing effects when the phenyl group is located two or three carbon atoms away from the Li, when compared with compounds possessing the phenyl group at a greater distance or an alkyl side chain[15b] ($\Delta\Delta G_{eq} = 1.5-2.2$ kcal mol^{-1}, compare entries 1 and 2 with 4−6 of Scheme 1). This stabilization can be explained by the formation of a pseudo-four- (**3b**) or pseudo-five-membered ring chelate (**4b**) by interaction of the Li cation with the aromatic ring. Apparently, cation−π stabilizing interactions through the formation of pseudo-six-membered and larger rings are not taking place since these systems show the same relative stabilities as those possessing a purely alkyl side chain (compound **8**) ($\Delta\Delta G_{eq} = 0-0.2$ kcal mol^{-1}, compare entries 4−6 with entry 7, Scheme 1).

SCHEME 2. Relative Stability Data of α-Oxy-Organolithium Compounds 9−12b



9-12a **1-2b** **9-12b** **1-2a**

Entry	Anion	n	Ref-Li	*T* (°C)/*t* (h)	ΔG_{eq}[a]
1	**9b**	1	**2b**	-50/24	**6.0**
2	**10b**	2	**2b**	-50/24	**6.2**
3	**11b**	3	**1b**	-65/24	**7.5**
4	**12b**	7	**1b**	-50/16	**7.7**

[a] ΔG_{eq} values in kcalmol^{-1}

Pb−Li exchange equilibrium[15b] was showed to be a useful alternative to Sn−Li for the determination of relative stabilities of organolithium compounds, especially for those more sterically hindered. We decided to determine the relative stability of compound **4** by using both Sn−Li and Pb−Li exchange methodologies, and we were pleased to see that the same value for its relative stability was obtained (see entries 2 and 3, Scheme 1).

The values for the observed K_{eq} are temperature and concentration independent, as the same value was obtained when the equilibrium constant for **4b** was measured at different temperatures (−35, −50, and −65 °C) and concentrations (0.02, 0.1, and 0.2 M), which suggest that these compounds have definite aggregation states under the experimental conditions used. We[15b] and others[18] have established that *O*-carbamoyl-organolithiums are monomers in THF solution at low temperature based on NMR data.

To check the general validity of these results, we have also prepared a similar set of stannanes and organolithium compounds now containing an alkene substituent instead of a phenyl ring (**9**−**12**) and studied their Sn−Li exchange equilibria with reference compounds of known stability (**1** and **2**). The results obtained are collected in Scheme 2 and indicate that these carbanions are displaying a behavior similar to their phenyl-substituted counterparts: when a pseudo-four- or pseudo-five-membered ring chelate can be established by interaction between the lithium cation and the C=C π-system, the corresponding

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organolithium is 1.3−1.7 kcal mol^{-1} more stable than when the side chain does not possess an unsaturated substituent or when the C=C moiety is separated by more than two methylene groups from the negatively charged carbon atom (compare entries 1 and 2 and 3 and 4, Scheme 2). As was the case with the phenyl-substituted compounds, the possibility of forming a pseudo-six-membered ring chelate gave no appreciable stabilization to the organolithium, as the stabilization observed in this case is similar to that of **12b** ($\Delta\Delta G_{eq}$ = 0.2 kcal mol,$^{-1}$ compare entries 3 and 4, Scheme 2) or **8b**[15b] ($\Delta\Delta G_{eq}$ = 0 kcal mol,$^{-1}$ compare entry 3, Scheme 2 with entry 7, Scheme 1).

To the best of our knowledge, these results can be considered the first quantitative evidence of the importance of the cation−π interactions in organolithium chemistry. It is interesting to note that the amount of stabilization gained by complexation of the Li atom with a π-system is quite comparable to the one shown by systems containing Li−N or Li−O interactions.[19,20]

Experimental Section

Preparation of 2,2,4,4-Tetramethyloxazolidine-3-carboxylates 3−7c and 9−12c. General Procedure. A suspension of NaH (60% in mineral oil, 0.3 g, 7.5 mmol) in THF (6 mL) was treated with the corresponding alcohol (5 mmol) and stirred at room temperature for 30 min. A solution of 2,2,4,4-tetramethyloxazolidine-3-carbonyl chloride[21] (1.1 g, 6.0 mmol) in THF (6 mL) was then added, and the resulting mixture was stirred at room temperature for 5 days, quenched by addition of pH 7.0 phosphate buffer (5 mL), and partitioned between CH_2Cl_2 (10 mL) and phosphate buffer (10 mL). The aqueous phase was extracted with CH_2Cl_2 (3 × 10 mL), and the combined organic phase was washed with brine (15 mL), dried with anhydrous Na_2SO_4, filtered, and concentrated. The residue was purified by column chromatography (SiO_2, EtOAc/hexane 1:6) to give **3−7c** and **9−12c** as oils (87−99% yield).

General Procedure for the Synthesis of Organostannanes 3−7a and 9−12a. *s*-BuLi (1.25 mL, 1.50 mmol, 1.2 M in hexane) was added to a precooled solution (−78 °C) of the corresponding carbamate (1.00 mmol) and TMEDA (230 μL, 1.50 mmol) in Et_2O (3.0 mL). After stirring for 5 h at−78 °C, Me_3SnCl (1.5 mL, 1.5 mmol, 1.0 M in THF) was added to the reaction mixture. The resulting solution was stirred at the same temperature for 1 h, quenched by addition of pH 7.0 phosphate buffer, and then partitioned between Et_2O (10 mL) and phosphate buffer (10 mL). The aqueous phase was extracted with Et_2O (10 mL), and the combined organic phase was washed with brine (10 mL), dried with anhydrous Na_2SO_4, filtered, and concentrated. The residue was purified by column chromatography (grade III neutral Al_2O_3, hexane to EtOAc/hexane 1:50).

2-Phenyl-1-(trimethylstannanyl)ethyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (3a). Following the general procedure, **3c** (670 mg, 2.42 mmol) afforded **3a** as a pale yellow oil (969 mg, 91%): ^{1}H NMR (300 MHz, $CDCl_3$, rotamers) δ 7.24 (m, 5H), 4.78 (m, 1H), 3.65 (s, 2H), 3.23 (m, 1H), 3.06 (dd, J = 13.9, 6.9 Hz, 1H), 1.54 and 1.52 (2 s, 3H), 1.40, 1.37, 1.25, 1.22, and 1.12 (5 s, 9H), 0.05 (s, $J(^{117,119}Sn\text{-}^1H)$ = 52.8, 9H); ^{13}C NMR (75 MHz, $CDCl_3$, rotamers) δ 153.1/152.4, 139.5, 128.7, 128.2, 126.2, 95.5/94.6, 76.2/75.9, 71.6 ($J(^{117,119}Sn\text{-}^{13}C)$ = 429.5), 60.3/59.4, 39.7, 26.1/26.0, 25.2/25.1, 24.9/24.8, 24.0, −9.2 ($J(^{117}Sn\text{-}^{13}C)$ = 320.4, $J(^{119}Sn\text{-}^{13}C)$ = 335.4); IR (NaCl) ν 1681 cm^{-1}. Anal. Calcd for $C_{19}H_{31}NO_3Sn$: C, 51.85; H, 7.10; N, 3.18. Found: C, 52.04; H, 7.28; N, 3.22.

3-Phenyl-1-(trimethylstannanyl)propyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (4a). Following the general procedure, **4c** (1.0 g, 3.43 mmol) afforded **4a** as a pale yellow oil (1.52 g, 98%): ^{1}H NMR (300 MHz, $CDCl_3$, rotamers) δ 7.29 (m, 5H), 4.53 (m, 1H), 3.71 (s, 2H), 2.70 (m, 2H), 2.13 (m, 2H), 1.54 (s, 6H), 1.39 (s, 6H), 0.10 (s, $J(^{117,119}Sn\text{-}^1H)$ = 52.5, 9H); ^{13}C NMR (75 MHz, $CDCl_3$, rotamers) δ 153.2/152.5, 141.6, 128.3, 128.2, 125.8, 95.6/94.5, 76.1/76.0, 71.2 ($J(^{117}Sn\text{-}^{13}C)$ = 423.3, $J(^{119}Sn\text{-}^{13}C)$ = 442.9), 60.3/59.4, 35.9, 34.3 ($J(^{117,119}Sn\text{-}^{13}C)$ = 38.5), 26.6/26.5, 25.2, 25.3/25.1, 24.1/24.0, −9.1 ($J(^{117}Sn\text{-}^{13}C)$ = 318.1, $J(^{119}Sn\text{-}^{13}C)$ = 333.0); IR (NaCl) ν 1678 cm^{-1}. Anal. Calcd for $C_{20}H_{33}NO_3Sn$: C, 52.89; H, 7.32; N, 3.08. Found: C, 53.29; H, 7.52; N, 3.07.

4-Phenyl-1-(trimethylstannanyl)butyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (5a). Following the general procedure, 720 mg of **5c** (2.39 mmol) gave **5a** as a colorless oil (950 mg, 85%): ^{1}H NMR (250 MHz, $CDCl_3$, rotamers) δ 7.23 (m, 2H), 7.13 (m, 3H), 4.51 (m, 1H), 3.67 (s, 2H), 2.60 (m, 2H), 1.79 (m, 2H), 1.55 (s, 2H), 1.49 and 1.46 (2s, 6H), 1.35 and 1.30 (2s, 6H), 0.04 (s, $J(^{117,119}Sn\text{-}^1H)$ = 52.4, 9H); ^{13}C NMR (62.9 MHz, $CDCl_3$, rotamers) δ 153.1/152.4, 141.9, 128.1, 128.0, 125.5, 95.4/94.4, 76.0/75.8, 71.3 ($J(^{117}Sn\text{-}^{13}C)$ = 429.1, $J(^{119}Sn\text{-}^{13}C)$ = 448.9), 60.2/59.2, 35.4, 33.1, 29.5 ($J(^{117,119}Sn\text{-}^{13}C)$ = 35.8), 26.4/26.3, 25.2/25.1, 24.0/23.9, −9.3 ($J(^{117}Sn\text{-}^{13}C)$ = 316.8, $J(^{119}Sn\text{-}^{13}C)$ = 331.3); IR (NaCl) ν 1678 cm^{-1}. Anal. Calcd for $C_{21}H_{35}NO_3Sn$: C, 53.87; H, 7.53; N, 2.99. Found: C, 53.84; H, 7.88; N, 2.96.

5-Phenyl-1-(trimethylstannanyl)pentyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (6a). Following the general procedure, 780 mg of **6c** (2.44 mmol) gave **6a** as a colorless oil (969 mg, 82%): ^{1}H NMR (250 MHz, $CDCl_3$, rotamers) δ 7.26 (m, 2H), 7.16 (m, 3H), 4.51 (m, 1H), 3.71 (s, 2H), 2.62 (t, J = 7.5 Hz, 2H), 1.74 (m, 4H), 1.56−1.26 (m, 14H), 0.07 (s, $J(^{117}Sn\text{-}^1H)$ = 53.3, $J(^{119}Sn\text{-}^1H)$ = 51.4, 9H); ^{13}C NMR (62.9 MHz, $CDCl_3$, rotamers) δ 153.1/152.5, 142.1, 125.5, 95.5/94.4, 76.1/75.9, 71.6 ($J(^{117}Sn\text{-}^{13}C)$ = 430.9, $J(^{119}Sn\text{-}^{13}C)$ = 450.9), 60.2/59.3, 35.6, 33.5, 30.9, 27.3 ($J(^{117,119}Sn\text{-}^{13}C)$ = 35.0), 26.3, 25.2/25.1, 25.0, 24.0/23.9, −9.3 ($J(^{117}Sn\text{-}^{13}C)$ = 316.3, $J(^{119}Sn\text{-}^{13}C)$ = 331.0); IR (NaCl) ν 1678 cm^{-1}. Anal. Calcd for $C_{22}H_{37}NO_3Sn$: C, 54.79; H, 7.73; N, 2.90. Found: C, 54.52; H, 8.10; N, 2.79.

8-Phenyl-1-(trimethylstannanyl)octyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (7a). Following the general procedure, **7c** (553 mg, 1.53 mmol) afforded **7a** as a colorless oil (613 mg, 76%): ^{1}H NMR (250 MHz, $CDCl_3$, rotamers) δ 7.23 (m, 5H), 4.53 (m, 1H), 3.72 (s, 2H), 2.62 (t, J = 7.5 Hz, 2H), 1.87 (m, 2H), 1.58 (m, 8H), 1.40 (m, 14H), 0.14 (s, $J(^{117,119}Sn\text{-}^1H)$ = 53.0, 9H); ^{13}C NMR (62.9 MHz, $CDCl_3$, rotamers) δ 153.2/152.5, 142.5, 128.2, 128.0, 125.4, 95.5/94.5, 76.1/75.9, 71.7 ($J(^{117}Sn\text{-}^{13}C)$ = 432.6, $J(^{119}Sn\text{-}^{13}C)$ = 452.7), 60.2/59.3, 35.8, 33.6, 31.3, 29.2, 29.1, 29.0, 27.7 ($J(^{117,119}Sn\text{-}^{13}C)$ = 33.8), 26.4, 26.3, 25.2/25.1, 24.1/24.0, −9.2 ($J(^{117}Sn\text{-}^{13}C)$ = 315.7, $J(^{119}Sn\text{-}^{13}C)$ = 330.4); IR (NaCl) ν 1677 cm^{-1}. Anal. Calcd for $C_{25}H_{43}NO_3Sn$: C, 57.27; H, 8.27; N, 2.67. Found: C, 57.49; H, 8.49; N, 2.72.

1-(Trimethylstannanyl)but-3-enyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (9a). Following the general procedure, **9c** (638 mg, 2.81 mmol) afforded **9a** as a colorless oil (1.03 g, 94%): ^{1}H NMR (250 MHz, $CDCl_3$, rotamers) δ 5.79 (m, 1H), 5.08 (d, J = 24.7 Hz, 1H), 5.07 (s, 1H), 4.57 (m, 1H), 3.71 (s, 2H), 2.61 (m, 2H), 1.54 and 1.50 (2 s, 6H), 1.40 and 1.35 (2 s, 6H), 0.11 (s, $J(^{117,119}Sn\text{-}^1H)$ = 52.8, 9H); ^{13}C NMR (62.9 MHz, $CDCl_3$, rotamers) δ 153.2/152.5, 136.3 ($J(^{117,119}Sn\text{-}^{13}C)$ = 36.2), 116.7, 95.6/94.7, 76.3/76.0, 70.5 ($J(^{117}Sn\text{-}^{13}C)$ = 421.8, $J(^{119}Sn\text{-}^{13}C)$ = 441.4), 60.4/59.6, 38.1, 26.4, 25.2/25.1, 24.1/24.0, −9.0 ($J(^{117}Sn\text{-}^{13}C)$ = 319.2, $J(^{119}Sn\text{-}^{13}C)$ = 334.1); IR (NaCl) ν 1679 cm^{-1}. Anal. Calcd for $C_{15}H_{29}NO_3Sn$: C, 46.18; H, 7.49; N, 3.59. Found: C, 46.50; H, 7.56; N, 3.58.

1-(Trimethylstannanyl)pent-4-enyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (10a). Following the general procedure, **10c** (758 mg, 3.14 mmol) afforded **10a** as a colorless oil (1.23 g, 97%): ^{1}H NMR (250 MHz, $CDCl_3$, rotamers) δ 5.83 (m, 1H), 5.01 (d, J = 24.1 Hz, 1H), 5.00 (s, 1H), 4.52 (m, 1H), 3.72 (s, 2H), 2.01 (m,

(19) ΔG_{eq} (kcal/mol): $Me_2NCH_2CHLiOCby$ = 5.8; $Me_2N(CH_2)_2CHLiOCby$ = 5.0; $MeO(CH_2)_2CHLiOCby$ = 5.4−5.5.

(20) An approximate acidity scale can be derived from these data that should be of value in the planning of syntheses involving carbanions (compound/pK): **3c**/36.8−36.9, **4c**/37.3, **5c**/38.8, **6c**/38.8, **7c**/39.0, **8c**/38.8, **9c**/37.3, **10c**/37.5, **11c**/38.8, **12c**/39.0. See ref 15 for an explanation.

(21) Hintze, F.; Hoppe, D. *Synthesis* **1992**, 1216–1218.

4H), 1.54 and 1.53 (2 s, 6H), 1.40 and 1.37 (2 s, 6H), 0.10 (s, $J(^{117,119}Sn\text{-}^{1}H) = 52.4$, 9H); ^{13}C NMR (62.9 MHz, $CDCl_3$, rotamers) δ 153.0/152.4, 137.5, 114.8, 95.4/94.4, 76.0/75.8, 71.0 ($J(^{117}Sn\text{-}^{13}C) = 426.9$, $J(^{119}Sn\text{-}^{13}C) = 447.0$), 60.2/59.2, 33.0, 32.0 ($J(^{117,119}Sn\text{-}^{13}C) = 37.5$), 26.4/26.3, 25.1, 24.0/23.9, −9.3 ($J(^{117}Sn\text{-}^{13}C) = 318.2$, $J(^{119}Sn\text{-}^{13}C) = 333.0$); IR (NaCl) ν 1678 cm^{-1}. Anal. Calcd for $C_{16}H_{31}NO_3Sn$: C, 47.55; H, 7.73; N, 3.47. Found: C, 47.23; H, 7.59; N, 3.49.

1-(Trimethylstannanyl)hex-5-enyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (11a). Following the general procedure, **11c** (656 mg, 2.57 mmol) afforded **11a** as a colorless oil (967 mg, 90%): ^{1}H NMR (250 MHz, $CDCl_3$, rotamers) δ 5.80 (m, 1H), 4.99 (m, 2H), 4.53 (m, 1H), 3.72 (s, 2H), 2.09 (q, $J = 7.1$ Hz, 2H), 1.86 (m, 2H), 1.53 (m, 8H), 1.41, 1.40 and 1.36 (3s, 6H), 0.10 (s, $J(^{117}Sn\text{-}^{1}H) = 51.2$, $J(^{119}Sn\text{-}^{1}H) = 53.2$, 9H); ^{13}C NMR (62.9 MHz, $CDCl_3$, rotamers) δ 153.2/152.5, 138.3, 114.6, 95.6/94.5, 76.2/76.0, 71.5 ($J(^{117}Sn\text{-}^{13}C) = 429.6$, $J(^{119}Sn\text{-}^{13}C) = 449.8$), 60.3/59.4, 33.3, 33.0, 27.0 ($J(^{117,119}Sn\text{-}^{13}C) = 35.5$), 26.4/26.3, 25.2/25.1, 24.1/24.0, −9.3 ($J(^{117}Sn\text{-}^{13}C) = 316.5$, $J(^{119}Sn\text{-}^{13}C) = 331.3$); IR (NaCl) ν 1678 cm^{-1}. Anal. Calcd for $C_{17}H_{33}NO_3Sn$: C, 48.83; H, 7.95; N, 3.35. Found: C, 49.15; H, 8.25; N, 3.30.

1-(Trimethylstannanyl)dec-9-enyl 2,2,4,4-tetramethyloxazolidine-3-carboxylate (12a). Following the general procedure, **12c** (419 mg, 1.35 mmol) afforded **12a** as a colorless oil (544 mg, 85%): ^{1}H NMR (250 MHz, $CDCl_3$, rotamers) δ 5.80 (m, 1H), 4.95 (m, 2H), 4.53 (m, 1H), 3.72 (s, 2H), 2.03 (q, $J = 6.7$ Hz, 2H), 1.83 (m, 2H), 1.54 and 1.52 (2s, 6H), 1.36 (m, 16H), 0.09 (s, $J(^{117}Sn\text{-}^{1}H) = 51.2$, $J(^{119}Sn\text{-}^{1}H) = 53.4$, 9H); ^{13}C NMR (62.9 MHz, $CDCl_3$, rotamers) δ 153.3/152.7, 139.0, 114.1, 95.6/94.6, 76.3/76.1, 71.9 ($J(^{117}Sn\text{-}^{13}C) = 432.3$, $J(^{119}Sn\text{-}^{13}C) = 452.0$), 60.4/59.5, 33.8, 29.3, 29.2, 29.0, 28.8, 27.7 ($J(^{117,119}Sn\text{-}^{13}C) = 33.6$), 26.5/26.4, 25.3/25.2, 24.2/24.1, −9.3 ($J(^{117}Sn\text{-}^{13}C) = 315.4$, $J(^{119}Sn\text{-}^{13}C) = 329.9$); IR (CsI) ν 1679 cm^{-1}. Anal. Calcd for $C_{21}H_{41}NO_3Sn$: C, 53.18; H, 8.71; N, 2.95. Found: C, 53.20; H, 8.97; N, 2.93.

General Procedure for Sn−Li Exchange. A cold solution of stannane **3**−**7a** or **9**−**12a** (0.1 mmol) in THF was treated with BuLi (0.1 mmol) and stirred for 30 min. A solution of the reference stannane (**1**−**2a**) in THF was then added, and the resulting solution was allowed to equilibrate while stirring for the time and at the appropriate temperature as indicated in Schemes 1 and 2. The reaction mixture was treated with dry and deoxygenated MeOH followed by pH 7.0 phosphate buffer, then partitioned between CH_2Cl_2 (10 mL) and phosphate buffer (10 mL). The aqueous phase was extracted with CH_2Cl_2 (2 × 10 mL), and the combined organic phase was washed with brine (15 mL), dried with anhydrous Na_2SO_4, filtered, and concentrated. Analysis of the resulting mixtures of stannanes (**3**−**7a** or **9**−**12a**) and protonated compounds (**3**−**7c** or **9**−**12c**) by ^{1}H NMR spectroscopy allowed the determination of the equilibrium concentrations. To confirm that the equilibrium had been reached, the reverse reaction was performed starting from a THF solution of the reference organolithium **1**−**2b** which was then treated with a solution of stannane **3**−**7a** or **9**−**12a**.

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Supporting Information Available: General experimental methods, preparation and full characterization for compounds **3**−**7c** and **9**−**12c**, equilibria data, and copies of ^{1}H and ^{13}C NMR spectra for all new compounds are included. This material is available free of charge via the Internet at http://pubs.acs.org.

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