The diester **4b** has been reported[5] to result from the reaction of **1** with 1-ethoxysilatrane. It is likely that the pentacoordinate silicon atom enhances the reactivity of the ethoxy group toward the exchange reaction with **1** and with **3b** because the formation of **3b** was not reported.[5] In our systems, the uncatalyzed reactions of the three tetraalkoxysilanes **2a–c** with **1** proceed at different rates. Tetramethoxysilane (**2a**) is the most reactive toward **1**, whereas tetraisopropoxysilane (**2c**) is the least reactive. Steric interactions, which develop in the transition state leading to the alkyl phosphonofluoridate products, can be invoked to explain the observed order of relative reactivity.

Experimental Section

General Procedures. ^{1}H NMR spectra were obtained on a Varian EM-360A spectrometer, generally with carbon tetrachloride as the solvent, with tetramethylsilane as an external standard. ^{31}P and ^{19}F spectra were recorded on a Varian FT-80A or Varian XL-200 spectrometer using neat liquid samples. A positive chemical shift value (δ, ppm) is taken downfield from 85% phosphoric acid as an external reference for the ^{31}P NMR spectra and downfield from $\mathrm{CFCl_3}$ for the ^{19}F spectra. Tetramethoxysilane (**2a**), trimethoxysilane (**5**), trimethylmethoxysilane (**6**), and tetraethoxysilane (**2b**) were used as received from Petrarch. Methylphosphonic difluoride (**1**)[6] was distilled from dicyclohexylcarbodiimide prior to use. Tetraisopropoxysilane (**2c**) was prepared by Regis Chemical Company[7] according to the method of Sumrell and Ham.[8]

Fluorinated Methoxy Silanes (7 and 8). The mixture of **7** and **8** was prepared as described by Noskov.[4] Analysis of the crude distillate by ^{1}H and ^{19}F NMR revealed that the composition of the product mixture was 20% **2a**, 56% **7**, and 23% **8**. ^{19}F NMR: δ –157.05 (d, $J_{\text{Si-F}}$ = 196 Hz, **6**), –158.15 (d, $J_{\text{Si-F}}$ = 196 Hz, **7**). ^{1}H NMR: δ 3.38 (s, **2a**), 3.46 (s, **7**), 3.56 (s, **8**).

Reactions of Methylphosphonic Difluoride with the Alkoxy-Substituted Silanes. General Procedures. *WARNING! The alkyl phosphonofluoridates are highly toxic acetylcholineesterase inhibitors; trained medical personnel should be available and the proper safety procedures should be followed while synthesizing or performing other experiments with these compounds.*[9] It is recommended that the water catalysis of these reactions not be attempted and that the reaction flask never be filled above half-full in order to ensure the retention of the alkyl methylphosphonofluoridate product in the reaction flask during the emission of silicon tetrafluoride. These reactions were conducted by using 1 to 2 g (10–20 mmol) of **1**. The neat reaction mixtures were stirred for the times specified (Table I) in flasks fitted with calcium sulfate drying tubes. Reactions were monitored by ^{1}H NMR analysis of a small aliquot of the reaction mixture dissolved in carbon tetrachloride. In some cases, the reaction temperature was measured with a thermocouple inserted into a septum-fitted two-necked flask. At the end of the reactions, the product composition was determined by ^{1}H or ^{31}P NMR analysis. The results are summarized in Table I.

Methyl Methylphosphonofluoridate (3a). ^{31}P NMR: δ 33.4 (d, J = 1039 Hz). ^{1}H NMR: δ 1.55 (dd, $J_{\text{P-H}}$ = 18.4 Hz, 3 H, $\mathrm{CH_3{-}P}$, $^2J_{\text{F-H}}$ = 6.0 Hz), 3.80 (d, $J_{\text{P-H}}$ = 11.8 Hz, $\mathrm{CH_3OP}$).

Dimethyl Methylphosphonate (5). ^{31}P NMR: δ 37.8 ^{1}H NMR: δ 1.37 (d, J = 17.8 Hz, 3 H, $\mathrm{CH_3{-}P}$), 3.67 (d, J = 10.9 Hz, 6 H, $\mathrm{CH_3OP}$).

Isopropyl Methylphosphonofluoridate (11). ^{1}H NMR: δ 1.25 (d, J = 6.1 Hz, 6 H, $\mathrm{OCH(C}H_3)_2$), 1.45 (dd, $J_{\text{P-H}}$ = 18.3 Hz, 3 H, $\mathrm{CH_3{-}P}$, $^2J_{\text{F-H}}$ = 5.5 Hz), 4.4–5.1 (m, 1 H, $\mathrm{OC}H\mathrm{(CH_3)_2}$).

Methylphosphonofluoridic Acid (13). ^{1}H NMR: δ 1.49 (dd, $J_{\text{P-H}}$ = 18.8 Hz, 3 H, $\mathrm{CH_3{-}P}$, $^2J_{\text{F-H}}$ = 6.0 Hz), 9.75 (s, 1 H, P–OH).

Ethyl Methylphosphonofluoridate (2b). A preparative scale synthesis of this compound was performed by employing 14.5 g (69 mmol) of silane **2b** and 27.2 g (272 mmol) of **1**. The temperature of the reaction mixture rose gradually from room temperature to 33 °C over a period of 50 min. During the next 5–6 min the reaction temperature rose to 70 °C as the solution darkened and $\mathrm{SiF_4}$ was emitted. The resulting product was purified by vacuum distillation (bp 53–54 °C/12 mm) to afford 27.9 g (81%) of **3b**. The product was 97.4% pure by ^{31}P NMR and contained 2.1% of unreacted **1**. ^{31}P NMR: δ 31.2 (d, J = 1038 Hz). ^{1}H NMR: δ 1.39 (t, J = 6.9 Hz, 3 H, $\mathrm{OCH_2C}H_3$), 1.54 (dd, $J_{\text{P-H}}$ = 18.5 Hz, 3 H, $\mathrm{CH_3{-}P}$, $^2J_{\text{F-H}}$ = 5.8 Hz), 3.8–4.5 (m, 2 H, $\mathrm{OC}H_2\mathrm{CH_3}$).

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Registry No. **1**, 676-99-3; **2a**, 681-84-5; **2b**, 78-10-4; **2c**, 1992-48-9; **3a**, 353-88-8; **3b**, 673-97-2; **3c**, 107-44-8; **4a**, 756-79-6; **5**, 2487-90-3; **6**, 1825-61-2; **7**, 39486-13-0; **8**, 25111-12-0; **13**, 1511-67-7; antimony trifluoride, 7783-56-4.

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Facile Conversion of Chloromethylated Polystyrene to the Lithium or Potassium Derivatives

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Functionalization of chloromethylated polystyrene (Merrifield resin) is an important process in the synthesis of polymer-supported reagents or catalysts.[1] As pointed out recently by Frêchet et al.,[2] organometallic substituents on the polymer are ideal reagents for C–C bond formation. They were able to prepare an insoluble Grignard reagent directly from Merrifield resin by reaction with magnesium–anthracene/THF. However, they remark in their paper that the lithiated derivative of chloromethylated polystyrene "has never been prepared successfully", in contrast to polystyrene lithiated on the phenyl ring, which is readily available from the aryl bromide.[2] We now report that both the lithium and potassium derivatives can be prepared quantitatively from chloromethylated polystyrene by a simple two-step procedure.

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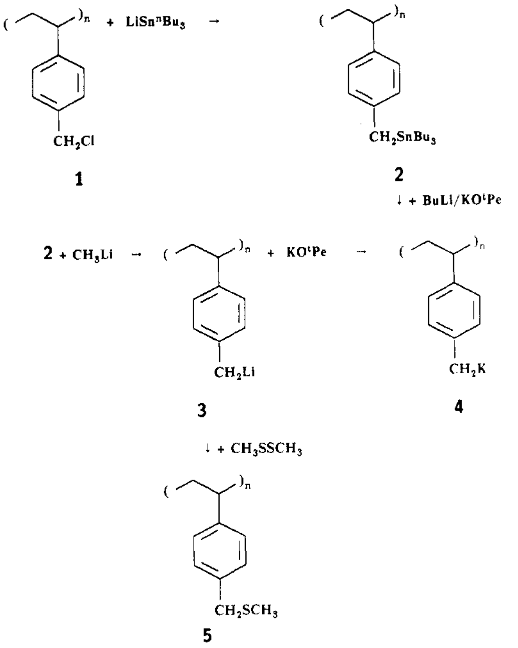
Scheme I



The two major routes[3] to organolithium reagents from chlorides, direct reaction with the metal and metal–halogen exchange with alkyllithiums, are not applicable to polymer-bound CH_2Cl groups. The former fails because both reagents are insoluble and the latter because Wurtz coupling is very effective in polymer systems. However, metal–metal exchange is also a valuable route to organolithium reagents[3] and can be applied successfully to chloromethylated polystyrenes by first substituting the polymer in a Wurtz-type step and then performing the metal–metal exchange reaction.

If a commercial Merrifield resin (1) is allowed to swell in THF and then reacted with LiSn-*n*-Bu_3 at 15 °C for 24 h, the reaction solution filtered off, and the polymer washed several times with THF, a slightly yellow tributyltin-substituted polymer (2) is obtained. This polymer is not only a valuable intermediate for organometallically substituted polymers but may also have considerable potential as a precursor for radical centers on the polymer. Polymer 2 is stable indefinitely under normal conditions and can therefore be made in large batches and stored for further use. The benzylic carbon–tin bond can be cleaved by a variety of reagents. For instance, reaction with methyllithium in THF at 20 °C for 3 h yields the benzyllithium derivative of the polymer (3) in quantitative yield (based on acid/base titration with standard alcohol[4] using the red color of the polymer as indicator and on microanalyses for Cl and Sn on the hydrolyzed polymer and for S on samples quenched with MeSSMe). Similarly, the potassium derivative 4 may be produced by direct cleavage of the tin polymer with butylpotassium (made by metal–metal exchange between butyllithium and potassium *tert*-pentanolate[5]) at −78 °C to prevent reaction of the butylpotassium with THF, but the conversion is not complete at this temperature. A better procedure is to perform the corresponding metal–metal exchange on the lithiated polymer (see Scheme I).

Experimental Section

Typical experimental procedures are as follows (all operations were carried out under an argon atmosphere):

(Tri-*n*-butylstannyl)lithium[6] was prepared by adding 40.8 mL (150 mmol) of tri-*n*-butyltin chloride to a suspension of 4.9 g (707 mmol) of lithium sand in 180 mL of THF (distilled from benzophenone/potassium) at 15 °C over 2 h. The suspension was stirred for 6 h, and the dark green solution was then filtered from the solids and stored under argon at 0 °C. The yield of (tri-*n*-butylstannyl)lithium was estimated by acid–base titration. Some hexa-*n*-butylditin is formed as a byproduct, but does not interfere with the subsequent reaction.

Poly[4-[(tri-*n*-butylstannyl)methyl]styrene] (2) was prepared by stirring 50 g of resin 1 [130 mequiv of CH_2Cl, prepared by chloromethylation[7] of 3% cross-linked polystyrene beads (Janssen)], swollen in 100 mL of THF with LiSn-*n*-Bu_3 (200 mmol) for 1 h at 15 °C. The mixture was allowed to stand in the refrigerator for 24 h and then stirred at 40 °C for 2 h. The polymer was filtered off, washed with THF, water, methanol, and ether, and dried under vacuum for 24 h to give 56.5 g of 2. Analyses for chlorine and tin gave 98% elimination of the former from the original polymer and 96% incorporation of tin. Commercial polymer 1 [1.5 mequiv of Cl/g, 2% cross-linked (Merck-Schuchardt)] gave the same results.

Poly[4-(lithiomethyl)styrene] (3) was obtained by adding 1.0 mL of 1.5 N methyllithium in ether at −78 °C to 500 mg (0.76 mmol of Sn-*n*-Bu_3) of resin 2 in 20 mL of THF. The mixture was allowed to warm to room temperature with stirring over 3 h to give orange-red polymer beads which were washed with precooled (0 °C) THF (2 × 10 mL). Analysis by direct titration with a standard 2-butanol solution in toluene[4] until the red color disappeared or by adding excess CH_3SSCH_3 to the polymer at −78 °C and warming to room temperature to give a colorless CH_2SCH_3-substituted polymer (5) followed by microanalysis for tin and sulfur indicated quantitative conversion of 2 to 3.

Poly[4-(potassiomethyl)styrene] (4). Method A. Polymer 3 (prepared and washed as above) was stirred in THF with 2 equiv of 1.6 M potassium *tert*-pentanolate in hexane for 2 h at 20 °C. The color of the polymer beads changes from orange-red to dark red.

Method B. Polymer 2, swollen in THF at room temperature, was cooled to −78 °C and stirred with an excess of a 1:1 mixture of 1.6 M *n*-butyllithium and 1.6 M potassium *tert*-pentanolate (both in hexane). Even for large excesses of the base and long reaction times, the percentage conversion was never higher than 90% (analysis as above).

Registry No. CH_3Li, 917-54-4; BuK, 6231-20-5.

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A New Isocyanide from a Sponge. Is the Formamide a Natural Product?

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Isocyanide metabolites have been isolated from several species of marine sponges.[1] In almost all cases, the isocyanide is accompanied by the corresponding isothio-

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