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POLYMER-SUPPORTED ORGANOALKALI COMPOUNDS BY RADICAL ANION INDUCED REDUCTIVE METALATION OF PHENYL THIOETHERS

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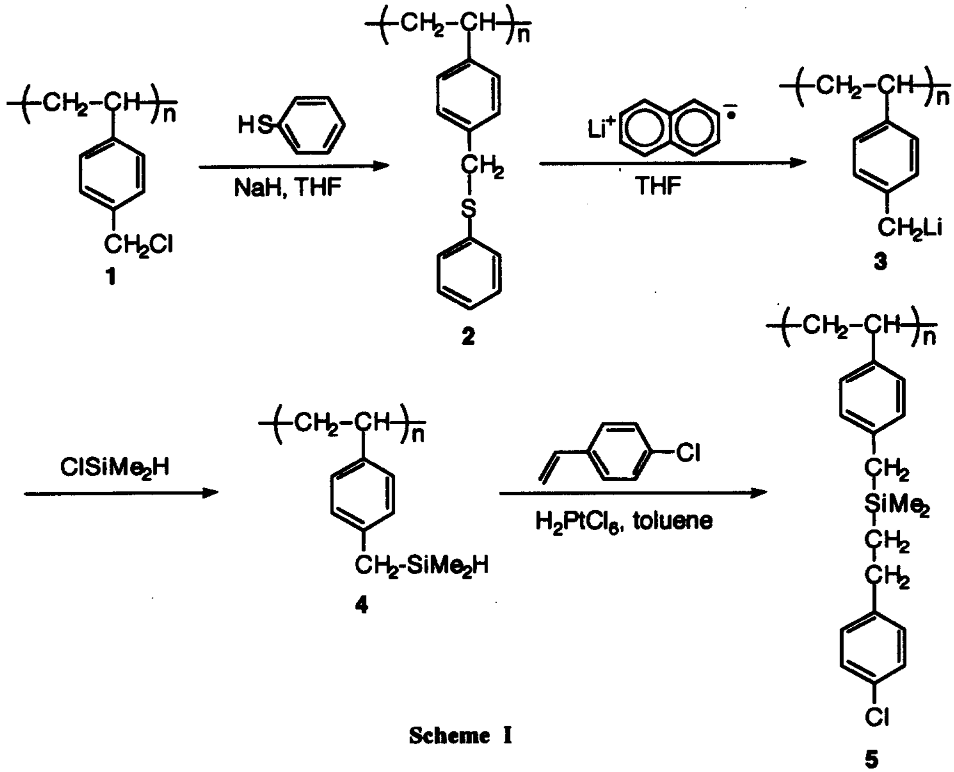
Summary: Cross-linked polymer-supported organoalkali compounds were successfully prepared by radical anion induced reductive metalation of polymeric phenyl thioethers. The resulting polymeric organometals serve as versatile reactive intermediates for further synthetic manipulations.

Although organometallic compounds are potentially very valuable synthetic reagents for organic synthesis, only a few examples of their polymeric analogues have been utilized for functional polymer synthesis,[1] except for polystyrene lithiated on the phenyl ring, which is readily available from the aryl bromide or through the direct lithiation of polystyrene resin.[2] There is a vast accumulation of useful synthetic methods for organoalkali compounds in solution organometallic chemistry.[3] These reactions are however often difficult to apply to polymers in general and to cross-linked ones in particular. For example, our attempts at lithiation of cross-linked (7-iodoheptyl)polystyrene using *tert*-butyllithium gave no lithiated product,[4] while several alkyl iodides in solution have been lithiated cleanly by this method.[5] Attempts at lithiation of (chloromethyl)polystyrene under a variety of conditions also met with failure as the reagent couples instantly to yield bibenzylic species thereby increasing the degree of cross-linking of the resin and destroying all desired functionality. On the other hand, Screttas and Micha-Screttas showed that simple phenyl thioethers could be reductively lithiated with lithium naphthalenide to give alkyllithium reagents.[6] Cohen has also demonstrated that reductive lithiation of phenyl thioethers using aromatic radical anions gave several useful organolithiums which are difficult to prepare by other methods.[7] These results encouraged us to apply the radical anion induced reductive metalation to the preparation of polymer-supported organoalkali compounds. We now present a general and convenient preparative method of polymeric organometallic reagents based on the reductive metalation.

Cross-linked (chloromethyl)polystyrene 1 was chosen as a starting material for the following reactive polymer synthesis. Cross-linked polymer 2 having phenylsulfide groups was easily prepared from reaction of 1 with thiophenol (Scheme I). Since the thioether formations were achieved quantitatively in a wide range of the content of the functionalities on the resin, degree of functionalization (DF)[8] of 2 was identical to the degree of chloromethylation which could be controlled easily by our improved method using chlorotrimethylsilane and trioxane.[9] Obtained phenylsulfide polymer was then treated with lithium naphthalenide in THF at 0°C. Immediate



Scheme I

color change to red-orange was observed on the resin, which supported the formation of polymeric benzyllithium species. After 1 h quenching of the lithiated resin with methanol afforded a white powder of the polymer containing no sulfur detected by sulfur analysis.[10] On the other hand, no metalation reaction occurred if **1** was directly used instead of **2**.[11] When chlorodimethylsilane was added as nucleophile to the metalated polymer **3**, the polymer **4** having hydrosilyl groups was obtained as shown in Scheme I. Incorporation of the hydrosilyl groups into the polymer was clearly detected by infrared spectra of **4**. Degrees of lithiation are taken as being synonymous with DF of the product polymer. In order to determine DF of the polymer by halogen analysis the silylated polymer was further allowed to react with 4-chlorostyrene in the presence of chloroplatinic acid as a catalyst to give **5**. Results of the polymer reactions are summarized in Table 1. High functional yields were obtained in the lithiation of **2** followed by silylation and hydrosilylation reactions on the insoluble polymers. In this method highly functionalized polymer could also be obtained in satisfactory functional yield (run 11). Although electron transfer process from radical anion to the sulfide polymer required 2 equiv of lithium naphthalenide, the use of excess (3 equiv) lithium naphthalenide gave somewhat better result in functional yield of the finished polymer (run 1, 2). Temperature has also an effect upon the metalation using lithium naphthalenide. Low functional yield was obtained at room temperature (run 9). Temperature should be maintained below 0°C during metalation. This simple procedure of metalation of cross-linked polymers could be applied not only to polymeric benzyl phenyl thioethers but also alkyl phenyl thioethers which were derived from (bromoalkyl)polystyrenes. As a result, polymer-supported butyllithium reagent was prepared in high yield from (bromobutyl)polystyrene (run 6). In addition, when sodium and potassium naphthalenide were used instead of lithium naphthalenide, corresponding polymer-supported organosodium and organopotassium were formed in high yield respectively (run 7, 8). After reaction of metalated polymer with the silyl nucleophile was completed naphthalene could be removed readily by simple filtration and wash of the polymer on a glass filter, while substantial difficulty was usually encountered in separating the naphthalene from the product in solution chemistry. These polymer-supported organoalkali compounds are attractive alternative to the conventional polymeric phenyllithium.

Table 1. Lithiation of phenylsulfide polymers followed by silylation and hydrosilylation

run	DF of 1	DF of 2	[LiN][a] / [2]	temp. °C	time h	DF of 5	FY[b] %
1	0.19	0.19	2	0	0.5	0.16	84
2	0.19	0.19	3	0	0.5	0.18	95
3	0.19	0.19	8	0	0.5	0.17	90
4	0.50	0.50	3	0	0.5	0.46	92
5	0.50	0.50	3	0	1.0	0.48	96
6	0.45[c]	0.45	3	0	1.0	0.43	96
7	0.50	0.50	3[d]	0	1.0	0.48	96
8	0.50	0.50	3[e]	0	1.0	0.50	100
9	0.50	0.50	3	r.t.	1.0	0.27	54
10	0.50	0.50	3	-80	1.0	0.40	80
11	0.76	0.76	3	0	1.0	0.70	92

[a] Lithium naphthalenide. [b] Functional yield indicates % conversion of functional groups of starting polymer to those of the final polymer. [c] (Bromobutyl)polystyrene was used. [d] Sodium naphthalenide was used. [e] Potassium naphthalenide was used.

Typical experimental procedure (Table 1, run 5) is as follows: Lithium (10 mmol) and naphthalene (9 mmol) were stirred in freshly distilled THF (15 mL) at 0°C under argon until the lithium was consumed. Cross-linked (phenylthiomethyl)polystyrene **2** (3.0 mmol of S, based on 3.02 mmol of S/g, DF=0.50, 2% cross-linking) was added to the THF solution of the lithium naphthalenide at 0°C. The resulting suspension was stirred for 1.0 h at 0°C. Chlorodimethylsilane (10 mmol) was then added to the lithiated polymer. The polymer was filtered and washed with 100 mL portions of THF, MeOH, H_2O, and MeOH and dried under vacuum for 24 h at room temperature, yielding 0.84 g of a white powder: IR (KBr) peaks present at 2100, 1250 cm^{-1}. Obtained polymer **4** having hydrosilyl group was then suspended in toluene. 4-Chlorostyrene (7.5 mmol) and chloroplatinic acid (40 μL, 0.13 M in isopropyl alcohol) were added and stirred for 4 h at 80°C. The polymer was filtered, washed, and dried as shown above, yielding 1.2 g of a white powder: IR (KBr) peak absent at 2100 cm^{-1}, peaks present at 1250, 840, 800 cm^{-1}. Halogen analysis of the product polymer **5** showed 2.33 mmol of Cl/g, DF=0.48, FY=96%.

In conclusion, a simple convenient preparative method of polymer-supported organoalkali compounds could be achieved using radical anion induced reductive cleavage of polymeric phenyl thioethers. The organoalkali compounds that result is highly reactive and can be used as a site for further synthetic manipulations.

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