THE 1,4 O→C SILEYL MIGRATIONS OF VARIOUS 3-[(TRIALKYLISILYL)-OXYMETHYL]-FURANS AND -THIOPHENS

Edward J. Bures and Brian A. Keay

Department of Chemistry and Biochemistry
University of Windsor, Windsor, Ontario, Canada, N9B 3P4

Summary: Numerous 3-[(trialkylsilyl)oxymethyl]-furans and -thiophenes undergo a 1,4 O→C silyl migration when treated with n-BuLi/HMPA in THF or DME to produce 2-(trialkylsilyl)-3-(hydroxymethyl)-furans and -thiophenes in good yields.

That 3-[(t-butyldimethylsilyl)oxymethyl]furan 1 can be lithiated at C-2 (n-BuLi/ether/r.t./6h) and the resulting anion quenched with electrophiles is well known. Treatment of the above anion with 1-bromo-3-chloropropane resulted in a poor yield of 2; however, changing the reaction conditions (n-BuLi/THF 0°C/6h) and then adding HMPA with the electrophile resulted in the isolation of 2 (40% by 1H NMR) and 2-(t-butyldimethylsilyl)-3-(hydroxymethyl)furans 3 (60% by 1H NMR) (Scheme 1). That the silyl group was indeed at C-2 was confirmed by treating 4 with 2.2 equivalents of n-butyllithium and quenching the resulting anion with 1.0 equivalent of t-butyldimethylsilyl chloride; the spectral data of 3 prepared from both 1 and 4 were identical. As 1,4 O→C silyl migrations are rare, we decided to investigate this unexpected result.

Optimized results were obtained by treating 1 with 1.1 equivalents of n-BuLi in the presence of HMPA in THF or DME at -20°C for 1 hour to produce 3 in 87% yield. This silyl migration turned out to be a general reaction.
TABLE 1: 1,4 O->C SYL SYL MIGRATIONS

\[
\text{OSiR}_2R_3\xrightarrow{-nBuLi,\text{THF, HMPA,} -20°C, 1h} \text{SiR}_2R_3\xrightarrow{\text{OH}}
\]

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>PRODUCT</th>
<th>YIELD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(Y=0; R_1=R_2=Me; R_3=t-Bu)</td>
<td>3 (87)</td>
</tr>
<tr>
<td>2</td>
<td>(Y=S; R_1=R_2=Me; R_3=t-Bu)</td>
<td>17 (87)</td>
</tr>
<tr>
<td>3</td>
<td>(Y=0; R_1=R_2=R_3=i\text{-propyl})</td>
<td>18 (86)</td>
</tr>
<tr>
<td>4</td>
<td>(Y=S; R_1=R_2=R_3=i\text{-propyl})</td>
<td>19 (89)</td>
</tr>
<tr>
<td>5</td>
<td>(Y=0; R_1=R_2=Ph; R_3=t-Bu)</td>
<td>20 (87)</td>
</tr>
<tr>
<td>6</td>
<td>(Y=S; R_1=R_2=Ph; R_3=t-Bu)</td>
<td>21 (63)</td>
</tr>
<tr>
<td>7</td>
<td>(Y=0; R_1=R_2=Ph; R_3=Me)</td>
<td>22 (75)</td>
</tr>
<tr>
<td>8</td>
<td>(Y=S; R_1=R_2=Ph; R_3=Me)</td>
<td>23 (24)</td>
</tr>
<tr>
<td>9</td>
<td>(Y=0; R_1=R_2=Me; R_3=i\text{-propyl})</td>
<td>24 (29)</td>
</tr>
<tr>
<td>10</td>
<td>(Y=S; R_1=R_2=Me; R_3=i\text{-propyl})</td>
<td>25 (27)</td>
</tr>
<tr>
<td>11</td>
<td>(Y=0; R_1=R_2=Me; R_3=Ph)</td>
<td>26 (38)</td>
</tr>
<tr>
<td>12</td>
<td>(Y=S; R_1=R_2=Me; R_3=Ph)</td>
<td>-- (--)</td>
</tr>
<tr>
<td>13</td>
<td>(Y=0; R_1=R_2=Me)</td>
<td>-- (--)</td>
</tr>
</tbody>
</table>

a) all yields refer to isolated, purified products
b) also isolated were the following:

\[
\text{STARTING MATERIAL, } R_1R_2R_3\xrightarrow{\text{OH}} \text{SiR}_2R_3
\]

reaction and was not limited to either the t-butyldimethylsilyl group or furans. Table 1 summarizes our results to date. The reaction is high yielding for both furans and thiophenes when the substituents on the silane are bulky (entries 1-7). As the silane substituents were reduced in size the expected products were obtained with concomitant formation of desilylated starting material \(27\), starting material \(11-14\) and 2,5-disilylated compounds \(28\) in varying ratios (entries 8-11). Treatment of \(15\) and \(16\) with n-BuLi resulted in cleavage of the silane to form \(4\) and \(27\) \((Y=S)\) respectively (entries 12 and 13).

A general experimental procedure follows. A solution of \(1\) (0.69 g, 3.3 mmol) and HMPA (0.62 mL, 3.6 mmol) in THF (10 mL) was cooled to \(-78\)°C under argon and treated with n-butyllithium (1.43 mL of 2.5 M in hexane, 3.6 mmol). The solution was stirred at \(-20\)°C for 1 hour and then treated with saturated
aqueous ammonium chloride. An ethyl acetate extraction, silica gel column (to remove the HMPA) followed by a distillation afforded 3 (87%).

Crossover experiments showed that the silyl migration probably occurs by an intramolecular nucleophilic substitution at silicon (Scheme 2). Thus an equimolar mixture of 1 and 7 yielded 3 and 19 only. Analogous intramolecular mechanisms have been proposed recently for 1,4 O→C₄, 1,4 O→C₆, 1,5 O→C₆ and 1,4 C→C₆ silyl migrations.

**SCHEME 2**

![Chemical structure](attachment:image)

Treatment of 1 (n-BuLi/THF/-20°C/1h) and quenching an aliquot with trimethylsilyl chloride provided a 1:2 ratio of 29 and 30 (Scheme 3): no 2,5-disilylated furan product was observed (by MS and ¹H NMR) indicating that a C-2/C-5 dianion of 1 was not occurring. Subsequent addition of HMPA to the above mixture of C-2 and C-5 anions resulted in the isolation of only 3 (87%, Scheme 3). Therefore an “equilibration-disproportionation” of the C-5 anion must be occurring in the cases where substituents on the silane are large (Table 1, entries 1-7).

**SCHEME 3**

![Chemical structure](attachment:image)

With the examples involving less bulky substituents on the silane, such as 11 (Table 1, entries 8-11) we envision the formation of a mixture of anions 31 and 32. Compound 32 then rearranges to produce, after workup, 23 (Scheme 4). Compound 31, on the other hand, presumably attacks 11 intramolecularly at silicon to form 33 and 4. If this latter reaction is faster than the anion forming reaction to produce 31 and 32, then 33 can react with
some remaining n-BuLi to form the C-5 anion of 33 which can then rearrange to give, after workup, 28. The utilization of some of the n-BuLi to form this latter C-5 anion of 33 explains the presence of starting material 11 in the product mixture.

Synthetic applications of these rearrangements are now under investigation. **Scheme 4**

Acknowledgements

We thank the Natural Science and Engineering Research Council of Canada and the University of Windsor Research Board for financial support.

References and Notes


3) Compound 3: colourless oil; bp 95-100°C/20 torr; $^1$H NMR (300 MHz, CDCl$_3$) δ 0.01 (s, 6H), 0.89 (s, 9H), 1.5 (s, 1H, OH), 4.57 (s, 2H), 6.46 (d, 1H, J=1.8 Hz) 7.57 (d, 1H, J=1.8 Hz); $^{13}$C NMR (75 MHz, CDCl$_3$) δ -5.7, 18.1, 25.7, 57.1, 110.5, 135.9, 146.7, 155.0; MS (EI) 212 (M$^+$).


5) All new compounds provided analytical and/or spectroscopic data consistent with their structures.


7) The spectral data of 29 and 30 were identical to those reported by D. Goldsmith (see reference 1).


(Received in USA 1 July 1987)