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Utilization of Neutral Alumina as a Mild Reagent for the Selective Cleavage of Primary and Secondary Silyl Ethers

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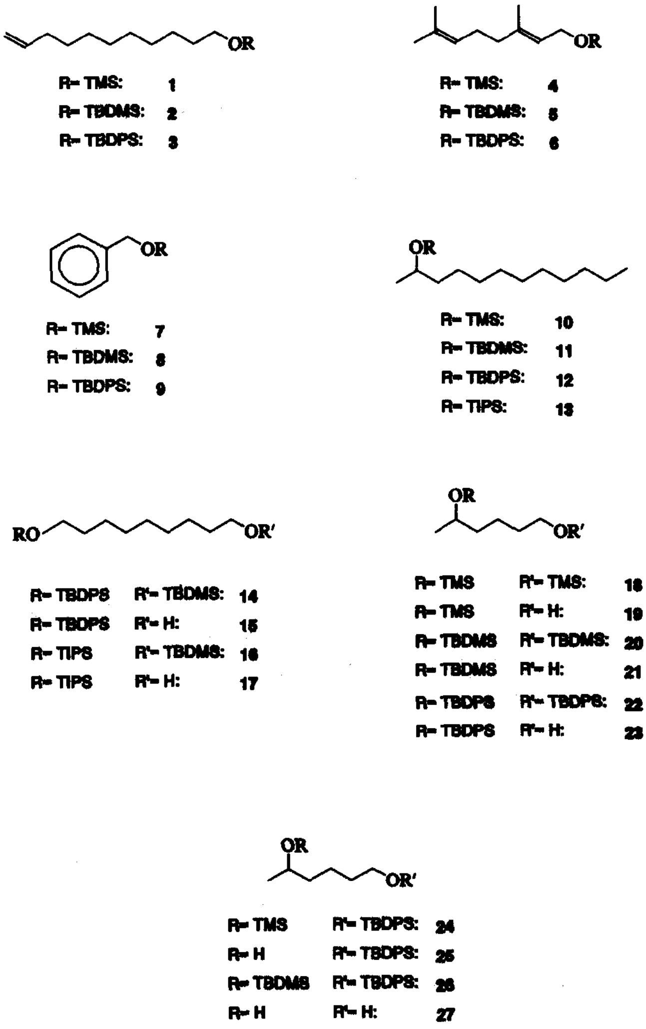
Abstract: The selective cleavage of primary and secondary trimethylsilyl (TMS), triisopropylsilyl (TIPS), *tert*-butyldimethylsilyl (TBDMS) and *tert*-butyldiphenylsilyl (TBDPS) ethers with neutral alumina under very mild conditions is described. The method involves utilization of the support, previously activated by heating at 80°C/0.1 torr for 16 h and later deactivated with variable amounts of water (1.5-4.5%), in 50:1 ratio with regard to the substrate and in the presence of non-polar solvents, like hexane. The deprotection rate depends on the steric bulkiness of the silicon substituents, following the order TMS > > TBDMS ≈ TIPS > TBDPS, as well as on the type of the attached carbon. The procedure can discriminate between different silyl groups located at equivalent positions of the same molecule affording the corresponding monoprotected alcohols in very good yields.

Derivatization of alcohols as silyl ethers is a widely used method of protection in organic chemistry[1]. In this regard, selective deprotection of silyl ethers in the presence of other silyl protecting groups or acid-sensitive moieties is of tremendous utility to the synthetic chemist. A variety of methods to cleave silyl-protected alcohols have been reported, being mostly those which utilize fluoride ion due to the high affinity for silicon shown by the fluorine atom (Si-F bond energy 540±13 kJ/mol). Among them, we can include tetrabutylammonium fluoride/THF[2], HF/CH_3CN[3], $LiBF_4/CH_3CN/CH_2Cl_2$[4], NH_4F/CH_3OH[5], SiF_4/CH_3CN[6], KF/18-crown-6[7] and $H_2SiF_6/CH_3CN/H_2O$[8]. Other procedures require acid hydrolysis, like citric acid/MeOH[9], AcOH/H_2O/THF[10], *p*-TsOH/THF/H_2O[11], or can be carried out under essentially neutral conditions, i.e. NBS/DMSO/H_2O[12], KO_2/DMSO/18-crown-6[13], $PdCl_2(CH_3CN)_2/Me_2CO$[14], DDQ/CH_3CN/H_2O[15] or Pd(II)O/cyclohexene/MeOH[16], among others. Utilization of pyridinium p-toluenesulfonate[17] and azide ion[18] has been reported to selectively remove *tert*-butyldimethylsilyl and methyldiphenylsilyl ethers in the presence of other silyl protecting groups. However, many methods present serious drawbacks when dealing with base-sensitive molecules, wherein fluoride ion cannot be used due to its very basic character, especially under anhydrous conditions[19,20]. Moreover, other procedures are obviously unacceptable if acid-sensitive moieties are present and, consequently, the development of alternative selective methods of deprotection under neutral conditions is highly desirable.



Scheme 1

The use of heterogeneous reactions on a solid support (silica, alumina,...) has been increasingly considered in the last few years because such reactions are often more selective and usually milder than the corresponding homogeneous processes. A large number of reactions involve utilization of supported reagents on an alumina surface, particularly water in the form of surface hydroxyl groups[21]. More recently, alumina has been used as catalyst for acetalization of aldehydes[22], in macrocyclization processes[23], Diels-Alder reactions[24] and Knoevenagel condensations[25]. In this context, we have recently described a preliminary report about the use of neutral alumina, deactivated with 1.5-3% water, for the selective cleavage of *tert*-butyl-

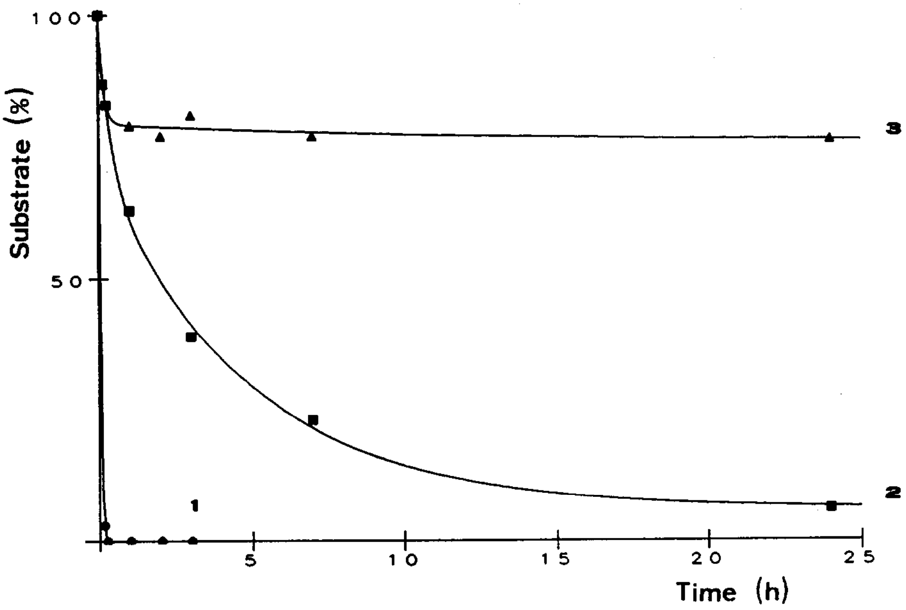


Figure 1

dimethylsilyl ethers in the presence of other acid-sensitive protective groups[26]. The deprotection takes place when the silyl ether is mixed with neutral alumina in the presence of non-polar solvents, i.e. hexane, while no desilylation occurs in more polar media like diethyl ether, ethyl acetate or methanol. This is in agreement with other reports in which no cleavage reaction was detected when TBDMS ethers were treated with basic alumina in CH_3CN[27] or upon column chromatography purification on alumina using $CH_2Cl_2/MeOH$[28]. Later on, Varma *et al.* reported deprotection of TBDMS ethers with alumina under microwave irradiation conditions[29]. We now want to report on the cleavage of a number of primary and secondary trimethylsilyl (TMS), triisopropylsilyl (TIPS), *tert*-butyldimethylsilyl (TBDMS) and *tert*-butyldiphenylsilyl (TBDPS) ethers with neutral alumina as well as the selective removal of the silyl protecting groups in *bis*-silyl derivatives under very mild conditions.

In preliminary experiments we tested cleavage of the TMS, TBDMS and TBDPS ethers of 10-undecen-1-ol (compounds **1**, **2** and **3**, respectively, Scheme 1) with alumina activity II in hexane, and noticed that when compound **1** was mixed with the support in 50:1 ratio with regard to the substrate, deprotection of the TMS group occurred in 15 min, while compound **2** required 24 h to yield 94% of the corresponding alcohol. Under these latter conditions, compound **3** remained essentially unaffected (Figure 1). The order of stability of the protecting groups (TMS < < TBDMS < TBDPS) followed the same trend as previously described for these groups towards acid hydrolysis[30], i.e. Me_3Si (1) < *t*-$BuMe_2Si$ ($2x10^4$) < *i*-Pr_3Si ($7x10^5$) < *t*-$BuPh_2Si$ ($5x10^6$), the number in brackets meaning the relative stability of the silyl groups in comparison to the less stable trimethylsilyl moiety. Therefore, the possibility of using deactivated neutral alumina to achieve selective

Table 1. Selective removal of primary and secondary silyl ethers **4-13**.

Entry	Substrate	Alumina[a] (% water)	Time	Alcohol[b]	
				Protected	Deprotected
1	**4**	3	5 min	0	90
2	**5**	3	5 min	83	10
3	**5**	3	6 h	0	81
4	**6**	3	6 h	73	21
5	**7**	3	15 min	3	90
6	**8**	3	15 min	94	0
7	**8**	3	15 h	0	98
8	**9**	3	15 h	88	5[c]
9	**9**	1.5	24 h	5	93
10	**10**	3	15 h	0	91
11	**11**	3	15 h	94	0
12	**11**	1.5	21 h	0	83
13	**12**	1.5	23 h	85	14[c]
14	**12**	0	48 h	52	36
15	**13**	0	48 h	60	28

[a] Commercial neutral alumina was activated by heating at 85°C at 0.1 torr for 16 h. When cooled, the specified amount of water was added and the mixture vigorously stirred to get the ready-to-use support.

[b] Isolated yield unless otherwise noted.

[c] Yield by GC.

deprotection of several types of primary allylic, benzylic and secondary silyl ethers was explored (Scheme 1).

As shown in Table 1, geranyl derivatives **4-6** were readily deprotected with alumina containing 3% water and selectively cleaved by simply changing the reaction time. Thus, whereas compound **4** needed only 5 min to be hydrolysed (entry 1), compound **5** remained essentially unaltered requiring 6 h to be effectively cleaved (entries 2,3). Under the latter conditions compound **6** was only slightly deprotected (entry 4). More differentiated results were obtained among benzyl derivatives **7-9**, since they were found to be less prone to cleavage than the corresponding compounds **4-6**. The most labile TMS derivative **7** was rapidly deprotected in 15 min, whereas TBDMS ether **8** needed 15 h for hydrolysis. Compound **9** was practically unaffected under these conditions and the use of a less deactivated alumina (1.5% water) and longer reaction time (24 h) were required to obtain the free alcohol (entry 9). The secondary silyl ethers **10** and **11** showed stability similar to the corresponding benzyl derivatives **8** and **9**, respectively, (entries 10-12 in comparison with entries 7-9), and could be effectively deprotected under essentially the same conditions. The more stable TBDPS ether **12** and TIPS ether **13** could not be completely cleaved even in the presence of non-deactivated alumina (0% water) (entries 14,15) but, nevertheless, the remarkable difference in reactivity compared with the TMS derivative **10** and TBDMS ether **11** can be exploited in an effective way to selectively cleave the latter protecting groups in the presence of the former ones.

We therefore decided to determine whether our method could discriminate between different silyl ethers located at equivalent positions of the same molecule. Thus, we prepared *bis*-silyl ethers **14, 16, 18, 20, 22, 24** and **26** in order to obtain selectively the corresponding monoalcohols **15, 17, 19, 21, 23** and **25**. The results are summarized in Table 2. According to our preliminary results, the rate of deprotection depends on the steric bulkiness of the silicon substituents and, therefore, we could expect that the cleavage rate of the silyl groups in compounds **14** and **16** would be substantially different. This turned out to be the case and the TBDMS group was preferentially cleaved over TBDPS and TIPS moieties, affording the corresponding alcohols **15** and **17** in very good yields (entries 1,2). Lower discrimination was observed when we tried to remove a primary TMS group in the presence of a secondary one (compound **18**, entry 3), using our standard alumina (3% water). However, the use of a more deactivated support (4.5% water) markedly increased the selectivity yielding monoprotected alcohol **19** in 85% yield with no *bis*-silyl derivative being detected (entry 4). In the same manner, the primary *bis*-TBDMS and *bis*-TIPS ethers of 1,5-hexanediol (compounds **20**, **22**) were successfully cleaved to yield the secondary silyl ethers **21** and **23** in almost quantitative yield by changing the water content of the support (entries 5,6). Here, again, the rate of deprotection depends on the accessibility of the Si-O bond.

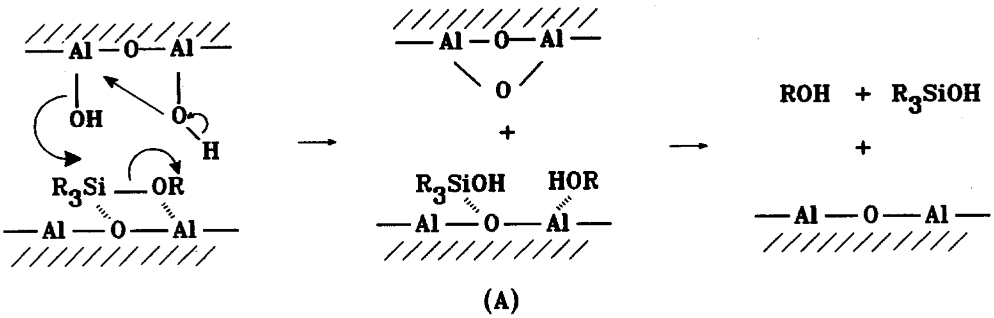
Finally, we turned our attention to the possibility of achieving the selective cleavage of different silyl moieties located in a primary and secondary position of the same molecule. While this process in principle should not represent any problem when the more labile silyl group (TMS) is on a primary carbon (see above), the reverse case, with the less resistant silyl moiety occupying a secondary position, should be much more troublesome because the higher accessibility of the more sterically hindered ether at the primary position can counterbalance the higher reactivity of the less sterically hindered secondary ether. However, when the difference of steric hindrance was big enough we were able to remove a *secondary* TMS group in the presence of a *primary* TBDPS moiety. Thus, compound **24** furnished monoprotected alcohol **25** in 90% yield upon reaction with 3% water-containing neutral alumina for 16 h (entry 7). No selective desilylation, however, could be attained when the secondary position was occupied by the TBDMS group (compound **26**), in which case mixtures of monoprotected secondary and primary alcohols **25** and **21** were obtained along with fully deprotected diol **27** (entry 8).

Table 2. Selective removal of primary and secondary silyl ethers **14-26** in the presence of other silyl protective groups.

Entry	Substrate	Alumina[a] (% water)	Time	Alcohol[b] Protected	Alcohol[b] Deprotected	Other
1	**14**	3	14 h	8	**15**: 89	
2	**16**	3	20 h	2	**17**: 90	
3	**18**	3	15 min	19	**19**: 75	--[c]
4	**18**	4.5	22 h	0	**19**: 85	
5	**20**	3	17 h	0	**21**: 97	--[c]
6	**22**	1.5	16 h	0	**23**: 97	
7	**24**	3	16 h	0	**25**: 90	
8	**26**	1.5	16 h	0	**25**: 15 **21**: 17	**27**:57

[a] Commercial neutral alumina was activated by heating at 85°C at 0.1 torr for 16 h. When cooled, the specified amount of water was added and the mixture vigorously stirred to get the ready-to-use support.
[b] Isolated yield.
[c] Traces of diol were also detected.

Although at present the mechanism of reactions on alumina surface is not understood, we can envision that the residual water adsorbed onto the support and/or the water added to deactivate the solid along with the Lewis acid sites created upon activation[24a] are involved in the desilylation process. The amount of water removed from the surface depends on the activation temperature of the support. Thus, at 300°C for example, ca. 50% of the OH groups still remains on the surface, 25% are aluminum cations and 25% oxide anions[24a]. The aluminum ions can behave as effective Lewis acids while the oxide anions can explain the basic character of the support[31]. In our process rather mild conditions have been used to activate the support, i.e. heating at 80°C/0.1 torr for 16 h., and it is likely that a major portion of the OH groups reside on the surface, since more astringent conditions, like drying at 800-1000°C under vacuum, still leave some hydroxyl groups[32]. In view of the above considerations we propose a model for the mechanism of the desilylation reaction, which is shown in Scheme 2. Basically, a formal addition of water from the support to silyl-adsorbed alumina molecules might give rise to a species of type (A), which would proceed yielding the deprotected alcohol along with the corresponding silanol. The very polar character of the alumina surface favors the ready adsorption of the silyl ethers when a non-polar solvent is used, thus making the reaction possible. The presence of a more polar solvent like ether, ethyl acetate or methanol, however, advantageously competes with the adsorption



Scheme 2

process thus precluding the deprotection reaction to occur.

In summary, a new procedure has been developed to cleave selectively primary and secondary silyl ethers under neutral conditions and with very high yields. Other advantageous features of the method comprise the ready availability and low price of the support as well as the very mild conditions required.

Experimental Section

IR spectra were recorded in $CHCl_3$ on a FT-IR Bomem MB120 apparatus. ^1H and ^{13}C NMR spectra were determined in $CDCl_3$ on a Varian Gemini 200 or a Varian Unity 300 spectrometer, operating at 200 and 300 MHz, respectively, for proton and 50 and 75 MHz, respectively, for carbon. Chemical shifts are reported in δ scale relative to the chloroform signal of $CDCl_3$ in the ^1H NMR and to the $CDCl_3$ triplet in the ^{13}C NMR spectra. Elemental analyses were determined on a Carlo Erba model 1108. GLC analyses were performed on a Carlo Erba 4130 gas chromatograph equipped with a FID detector, using a fused silica capillary column SPB-5 30 m x 0.32 μm i.d. and hydrogen as carrier gas. The high resolution mass spectra were determined on a VG Autospec Q instrument.

Unless otherwise noted, compounds were purified by column chromatography on silica gel eluting with hexane:ether mixtures. Monosilyl ethers **1-13** were prepared by reaction of the corresponding alcohols with TMS, TBDMS, TBDPS or TIPS chloride and imidazole[2]. Where required structural assignment was based on 2D HETCOR experiments.

Preparation of *bis*-silyl derivatives 14, 16, 18, 20, 22, 24 and 26. Compounds **14-16** were prepared by monoprotection of the corresponding diol with sodium hydride/TBDMS chloride[33] to yield the corresponding monoprotected alcohols, followed by silylation wih TBDPS or TIPS chloride and imidazole[2]. Compounds **18**, **20** and **22** were readily prepared by using 2-3 equivalents of the corresponding silyl chlorides, whereas compounds **24** and **26** were obtained through the intermediate alcohol **25** by the same silylation procedure.

9-*t*-Butyldimethylsilyloxy-1-*t*-butyldiphenylsilyloxynonane (14).

Yield 86% (97.3% purity by GC). IR ν 3070, 2929, 2856, 1255, 1110, 1099, 835, 700 cm^{-1}. ^{1}H NMR δ: 7.70-7.62 (c, 4H, 4H-*ortho*), 7.43-7.30 (c, 6H, 2H-*para* and 4H-*meta*), 3.63 (t, J=6.4 Hz, 2H, $TBDPSOCH_2$), 3.58 (t, J=6.6 Hz, 2H, $TBDMSOCH_2$), 1.62-1.42 (m, 4H, $2C\underline{H}_2CH_2O$), 1.25 (b, 10H, $5CH_2$), 1.03 (s, 9H, $(CH_3)_3CPh_2Si$), 0.88 (s, 9H, $(CH_3)_3CMe_2Si$), 0.03 (s, 6H, $(CH_3)_3C(C\underline{H}_3)_2Si$). ^{13}C NMR δ: 135.56 (C-*ortho*), 134.18 (C-*ipso*), 129.44 (C-*para*), 127.53 (C-*meta*), 63.9 (C-9), 63.3 (C-1), 33.0 (C-8), 32.8 (C-2), 29.5, 29.3, 29.3, 26.8 ($(\underline{C}H_3)_3CPh_2Si$), 25.9 ($(\underline{C}H_3)_3CMe_2Si$), 25.8, 25.7, 19.2 ($(CH_3)_3\underline{C}Ph_2Si$), 18.3 ($(CH_3)_3\underline{C}Me_2Si$), -5.2 ($(CH_3)_2Si$).

9-*t*-Butyldimethylsilyloxy-1-triisopropylsilyloxynonane (16).

Yield 97% (100% purity by GC). IR ν 2929, 2864, 1463, 1255, 1101, 835, 775 cm^{-1}. ^{1}H NMR δ: 3.65 (t, J=6.4 Hz, 2H, $TIPSOCH_2$), 3.58 (t, J=6.6 Hz, $TBDMSOCH_2$), 1.45 (m, 4H, $2C\underline{H}_2CH_2O$), 1.27 (b, 10H, $5CH_2$), 1.05 (b, 18H, $3(C\underline{H}_3)_2CHSi$), 1.05 (m, 3H $3(CH_3)_2C\underline{H}Si$), 0.88 (s, 9H, $(CH_3)_3CSi$), 0.03 (s, 6H, $(CH_3)_2SiO$). ^{13}C NMR δ: 63.5 (C-9), 63.3 (C-1), 33.0 (C-8), 32.8 (C-2), 29.6, 29.4, 25.9 ($(\underline{C}H_3)_3CMe_2Si$), 25.7, 18.3 ($(CH_3)_3\underline{C}Me_2Si$), 18.0 ($(\underline{C}H_3)_2CHSi$), 17.6 ($(CH_3)_2\underline{C}HSi$), -5.2 ($(CH_3)_2Si$).

1,5-*bis*-Trimethylsilyloxyhexane (18).

Yield 70% (100% purity by GC). IR ν 2956, 2864, 1259, 1249, 1097, 875, 840 cm^{-1}. ^{1}H NMR δ: 3.73 (m, 1H, $CH_3C\underline{H}O$), 3.54 (t, J=6.6 Hz, 2H, CH_2O), 1.58-1.15 (c, 6H, $3CH_2$), 1.10 (d, J=6.3 Hz, 3H, $C\underline{H}_3CHO$), 0.08 (s, 18H, $2(CH_3)_3Si$). ^{13}C NMR δ: 68.4 (C-5), 62.5 (C-1), 39.3 (C-4), 32.6 (C-2), 23.8 (C-6), 22.2 (C-3), 0.2 ($(\underline{C}H_3)_3SiOCH$), -0.5 ($(\underline{C}H_3)_3SiOCH_2$).

1,5-*bis*-*t*-Butyldimethylsilyloxyhexane (20).

Yield 72% (99.4% purity by GC). IR ν 2954, 2929, 2856, 1471, 1255, 1101, 835, 773 cm^{-1}. ^{1}H NMR δ: 3.76 (m, 1H, $CH_3C\underline{H}O$), 3.59 (t, J=6.6 Hz, 2H, CH_2O), 1.56-1.25 (dm, 6H, $3CH_2$), 1.11 (d, J=6.0 Hz, 3H, $C\underline{H}_3CHO$), 0.88 (s, 9H, $(CH_3)_3CSi$), 0.87 (s, 9H, $(CH_3)_3CSi$), 0.04 (s, 12H, $2(CH_3)_2Si$). ^{13}C NMR δ: 68.6 (C-5), 63.1 (C-1), 39.6 (C-4), 32.9 (C-2), 25.9 ($2(\underline{C}H_3)_3CSi$), 23.8 (C-6), 22.1 (C-3), 18.3 and 18.1 ($2(CH_3)_2SiO$), -4.3 and -4.6 ($(\underline{C}H_3)_2SiOCH$), -5.2 ($(\underline{C}H_3)_2SiOCH_2$).

1,5-*bis*-*t*-Butyldiphenylsilyloxyhexane (22).

Yield 58%. IR ν 3070, 2931, 2856, 1470, 1427, 1110, 701 cm^{-1}. ^{1}H NMR δ: 7.70-7.62 (c, 8H, 8H-*ortho*), 7.42-7.30 (c, 12H, 8H-*meta* and 4H-*para*), 3.80 (m, 1H, $CH_3C\underline{H}O$), 3.58 (t, J=6.2 Hz, 2H, CH_2O), 1.55-1.25 (c, 6H, $3CH_2$), 1.05-1.03 (overlapping signal with $(CH_3)_3CSi$ groups, 3H, $C\underline{H}_3CHO$), 1.04 (s, 9H, $(CH_3)_3CSi$), 1.03 (s, 9H, $(CH_3)_3CSi$). ^{13}C NMR δ: 135.86 and 135.84 (CHOSiArH-*ortho*), 135.5 ($CH_2OSiArH$-*ortho*), 134.9 and 134.5 (CHOSiArH-*ipso*), 134.1 ($CH_2OSiArH$-*ipso*), 129.46 ($CH_2OSiArH$-*para*), 129.41 and 129.3 (CHOSiArH-*para*), 127.5 ($CH_2OSiArH$-*meta*), 127.4 and 127.3 (CHOSiArH-*meta*), 69.5 (C-5), 63.8 (C-1), 39.1 (C-4), 32.6 (C-2), 27.0 and 26.8 ($(\underline{C}H_3)_3CSi$), 23.1 C-6), 21.4 (C-3), 19.2 and 19.1 ($2(CH_3)_3\underline{C}Si$). Elemental Analysis: Calculated for $C_{38}H_{50}Si_2O_2$: C 76.77%, H 8.42%; Found: C 76.79%, H 8.63%.

1-*t*-Butyldiphenylsilyloxy-5-trimethylsilyloxyhexane (24).

Yield 62% (98.3% purity by GC). IR ν 3070, 3049, 2951, 2858, 1426, 1251, 1110, 836, 700 cm^{-1}. ^1H NMR δ: 7.71-7.64 (c, 4H, H-*ortho*), 7.46-7.32 (c, 6H, 4H-*meta* and 2H-*para*), 3.72 (m, 1H, $CH_3C\underline{H}O$), 3.65 (t, J= 6.2 Hz, 2H, CH_2O), 1.62-1.24 (c, 6H, $3CH_2$), 1.11 (d, J=6.2 Hz, 3H, $C\underline{H_3}CHO$), 1.04 (s, 9H, $(CH_3)_3CSi$), 0.10 (s, 9H, $(CH_3)_3Si$). ^{13}C NMR δ: 135.5 (C-*ortho*), 134.0 (C-*ipso*), 129.4 (C-*para*), 127.5 (C-*meta*), 68.5 (C-5), 63.8 (C-1), 39.3 (C-4), 32.5 (C-2), 26.8 ($(\underline{C}H_3)_3CSi$), 23.9 (C-6), 22.3 (C-3), 19.1 ($(CH_3)_3\underline{C}Si$), 0.2 ($(CH_3)_3Si$).

5-*t*-butyldimethylsilyloxy-1-*t*-butyldiphenylsilyloxyhexane (26).

Yield 96% (98.9% purity by GC). IR ν 3075, 2929, 2856, 1471, 1427, 1253, 1110, 835, 701 cm^{-1}. ^1H NMR δ: 7.70-7.64 (c, 4H, 4H-*ortho*), 7.44-7.34 (c, 6H, 4H-*meta* and 2H-*para*), 3.74 (m, 1H, $CH_3C\underline{H}$), 3.65 (t, J=6.2 Hz, 2H, CH_2O), 1.64-1.25 (dm, 6H, $3CH_2$), 1.10 (d, J=6.0 Hz, 3H, $C\underline{H_3}CHO$), 1.04 (s, 9H, $(CH_3)_3CSiPh_2$), 0.88 (s, 9H, $(C\underline{H_3})_3CSi(CH_3)_2$), 0.03 (s, 6H, $(CH_3)_2Si$).^{13}C NMR δ: 135.5 (C-*ortho*), 134.1 (C-*ipso*), 129.4 (C-*para*), 127.5 (C-*meta*), 68.6 (C-5), 63.8 (C-1), 39.5 (C-4), 32.6 (C-2), 26.8 ($(\underline{C}H_3)_3CSiPh_2$), 25.9 ($(\underline{C}H_3)_3CSi(CH_3)_2$), 23.8 (C-6), 22.1 (C-3), 19.1 ($(CH_3)_3\underline{C}SiPh_2$), 18.1 ($(CH_3)_3\underline{C}Si(CH_3)_2$), -4.4 and -4.6 ($(CH_3)_2Si$).

General procedure for the desilylation reaction. In a typical deprotection reaction, to a solution of 200 mg of the silyl ether in 20 ml of hexane was added neutral alumina (70-230 mesh) (10 g, 50:1 with regard to the substrate) and 2 μl of n-pentadecane as internal standard. The support was prepared by heating the alumina at 85°C and 0.1 torr for 16 h, cooling and adding the specified amounts of water (1.5, 3.0 or 4.5%) and vigorously shaking the mixture. The slurry was stirred at room temperature and the progress of the reaction (disappearance of the silyl ether since the resulting alcohol remains adsorbed onto the support) monitored by GC analysis on a SPB-5 fused silica capillary column. When the reaction was over, the mixture was filtered through a sintered glass funnel (No. 4) and washed with hexane to remove traces of unreacted starting material. Further washings with ethyl acetate or methanol followed by evaporation of the solvent, furnished the expected alcohol which was purified by column chromatography on silica gel eluting with hexane:ether or hexane:ethyl acetate mixtures.

9-*t*-Butyldiphenylsilyloxy-1-nonanol (15)[34].

Yield 89% (99.9% purity by GC). IR ν 3350, 3075, 2929, 2856, 1427, 1110, 700 cm^{-1}. ^1H NMR δ: 7.70-7.65 (c, 4H, 4H-*ortho*), 7.46-7.34 (c, 6H, 4H-*meta* and 2H-*para*), 3.65 (t, J=6.3 Hz, 2H, CH_2OH), 3.63 (t, J=6.6 Hz, 2H, CH_2OSi), 1.55 (m, 4H, $2C\underline{H_2}CH_2O$), 1.28 (b, 10H, $5CH_2$), 1.05 (s, 9H, $(CH_3)_3CSi$). ^{13}C NMR δ: 135.5 (C-*ortho*), 134.1 (C-*ipso*), 129.4 (C-*para*), 127.5 (C-*meta*), 63.9 (C-9), 63.0 (C-1), 32.7 (C-2), 32.5 (C-8), 29.5, 29.3, 29.2, 26.8 ($(\underline{C}H_3)_3CSi$), 25.7, 25.6, 19.1 ($(CH_3)_2Si$).

9-Triisopropylsilyloxy-1-nonanol (17).

Yield 90% (99.9% purity by GC). IR ν 3338, 2929, 2864, 1463, 1103, 881, 680 cm^{-1}. ^1H NMR δ: 3.64 (t, J=6.4 Hz, 2H, CH_2OH), 3.61 (t, J=6.4 Hz, 2H, CH_2OSi), 1.51 (m, 4H, $2\ C\underline{H_2}CH_2O$), 1.28 (b, 10H, $5CH_2$), 1.04 (m, 3H, $(CH_3)_2C\underline{H}Si$), 1.04 (b, 18H, $3(C\underline{H_3})_2CHSi$). ^{13}C NMR δ: 63.4 (C-9), 63.0 (C-1), 33.0 (C-8), 32.7

(C-2), 29.5, 29.3, 25.7, 18.0 ($(\underline{C}H_3)_2CHSi$), 11.9 ($(CH_3)_2C\underline{H}Si$). **Elemental Analysis: Calculated for $C_{18}H_{40}O_2Si$: C 68.35%, H 12.66%; Found: C 68.42%, H 12.85%.**

5-Trimethylsilyloxy-1-hexanol (19).

Yield 85% (100% purity by GC). IR ν 3375, 2954, 1249, 1058, 838 cm^{-1}. ^{1}H NMR δ: 3.73 (m, 1H, $CH_3C\underline{H}$), 3.61 (t, J=6.4 Hz, 2H, CH_2OH), 1.62-1.20 (c, 6H, $3CH_2$), 1.11 (d, J=6.2 Hz, 3H, $C\underline{H}_3CHO$), 0.08 (s, 9H, $(CH_3)_3Si$). ^{13}C NMR δ: 68.[illegible] (C-5), 62.9 (C-1), 39.2 (C-4), 32.7 (C-2), 23.8 (C-6), 22.0 (C-3), 0.2 ($(CH_3)_3Si$). Elemental Analysis: Calculated for $C_9H_{22}O_2Si$: C 56.79%, H 11.65%; Found: C 56.83%, H 11.74%.

5-*t*-Butyldimethylsilyloxy-1-hexanol (21).

Yield 97% (100% purity by GC). IR ν 3350, 2929, 2858, 1255, 1058, 835, 773 cm^{-1}. ^{1}H NMR δ: 3.77 (m, 1H, $CH_3C\underline{H}O$), 3.64 (t, J=6.3 Hz, 2H, CH_2OH), 1.54 (m, 2H, $C\underline{H}_2CH_2OH$), 1.45 (c, 1H, $OCHC\underline{H}_aH_b$), 1.39 (c, 1H, $OCHCH_2C\underline{H}_aH_b$), 1.36 (c, 1H, $OCHCH_a\underline{H}_b$), 1.30 (c, 1H, $OCHCH_2CH_a\underline{H}_b$), 1.09 (d, J=6.1 Hz, 3H, $C\underline{H}_3CH$), 0.87 (s, 9H, $(CH_3)_3CSi$), 0.04 (s, 6H, $(CH_3)_2Si$). ^{13}C NMR δ: 68.5 (C-5), 62.8 (C-1), 39.3 (C-4), 32.7 (C-2), 25.8 ($(\underline{C}H_3)_3CSi$), 23.7 (C-6), 21.8 (C-3), 18.1 ($(CH_3)_3\underline{C}Si$), -4.4 and -4.7 ($(CH_3)_2Si$). Elemental Analysis: Calculated for $C_{12}H_{28}SiO_2$: C 62.00%, H 12.14%; Found: C 61.93%, H 12.15%.

5-*t*-Butyldiphenylsilyloxy-1-hexanol (23)[35].

Yield 97% (100% purity by GC). IR ν 3350, 2931, 1589, 1471, 1427, 1110, 702 cm^{-1}. ^{1}H NMR δ: 7.72-7.65 (c, 4H, 4H-*ortho*), 7.45-7.30 (c, 6H, 4H-*meta* and 2H-*para*), 3.84 (m, 1H, $CH_3C\underline{H}O$), 3.54 (t, J=6.2 Hz, 2H, CH_2O), 1.45 (m, 2H, $CH_3CHOC\underline{H}_2$), 1.43 (m, 2H, $C\underline{H}_2CH_2OH$), 1.31 (m, 2H, $C\underline{H}_2CH_2CH_2OH$), 1.07 (d, J=6.4 Hz, 3H, $C\underline{H}_3CHO$), 1.05 (s, 9H, $(CH_3)_3CSi$). ^{13}C NMR δ: 135.84 and 135.82 (C-*ortho*), 134.8 and 134.5 (C-*ipso*), 129.4 and 129.3 (C-*para*), 127.4 and 127.3 (C-*meta*), 69.3 (C-5), 62.8 (C-1), 39.0 (C-4), 32.6 (C-2), 26.9 ($(\underline{C}H_3)_3CSi$), 23.1 (C-6), 21.3 (C-3), 19.2 ($(CH_3)_3\underline{C}Si$).

6-*t*-Butyldiphenylsilyloxy-2-hexanol (25)[35].

Yield 69% (100% purity by GC). IR ν 3350, 3075, 2931, 2858, 1427, 1110, 701 cm^{-1}. ^{1}H NMR δ: 7.72-7.65 (c, 4H, H-*ortho*), 7.46-7.32 (c, 6H, 4H-*meta* and 2H-*para*), 3.75 (m, 1H, $CH_3C\underline{H}O$), 3.68 (t, J=6.2 Hz, 2H, CH_2O), 1.64-1.38 (dm, 6H, $3CH_2$), 1.17 (d, J=6.2 Hz, 3H, $C\underline{H}_3CHO$), 1.06 (s, 9H, $(CH_3)_3CSi$).

^{13}C NMR δ: 135.5 (C-*ortho*), 134.0 (C-*ipso*), 129.5 (C-*para*), 127.5 (C-*meta*), 68.0 (C-5), 63.7 (C-1), 38.9 (C-4), 32.4 (C-2), 26.8 ($(\underline{C}H_3)_3CSi$), 23.4 C-6), 21.9 (C-3), 19.1 ($(CH_3)_3\underline{C}Si$).

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