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Triethylsiloxymethyl-*N*-*N*-dimethylamine, $Et_3SiOCH_2NMe_2$: A new dimethylaminomethylation (Mannich) reagent for O-H, S-H, P-H and aromatic C-H systems

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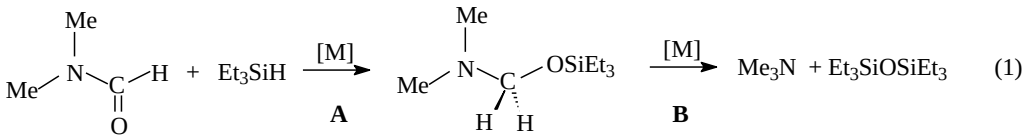
Abstract

Triethylsiloxymethylamine, $Et_3SiOCH_2NMe_2$, readily synthesized in high yield by the hydrosilylation reaction between Et_3SiH and DMF, is an excellent (*N*,*N*-dimethylamino)methyl transfer agent to a representative range of aliphatic alcohol, thiol and Ph_2PH (E-H) materials. The reactions are almost instantaneous at room temperature in inert solvents and require no activating agents to produce E-CH_2NMe_2 products in high yield and illustrate the title compound as an excellent addition to the family of organic reagents. For aromatic alcohols electrophilic substitution of the aromatic ring occurs in high yield. Crystal structures of new materials such as the cholesteryl –CH_2NMe_2 derivative, 2-4-[bis(*N*,*N*-dimethylamino)methyl]-1-naphthol, and the phosphine oxide derived from $Ph_2PCH_2NMe_2$ are reported.

Introduction

We recently reported that when catalyzed by $(Me_3N)Mo(CO)_5$ (M), the organosilane (R_3SiH) reduction of amides,[1] (leading to the formation of Me_3N and the corresponding disiloxane),[2,3] involved the intermediacy of siloxymethyldimethylamines, $R_3SiOCH_2NMe_2$, **1**, eq. 1, R = Et (**1a**).[4]



We were able to observe, isolate in good yield, characterize, and study the chemistry of these intermediates.[4] The degree to which this is a generally applicable mechanism is, however, unclear and probably, depending upon both catalyst and substrate, other reaction pathways are operative.[5]

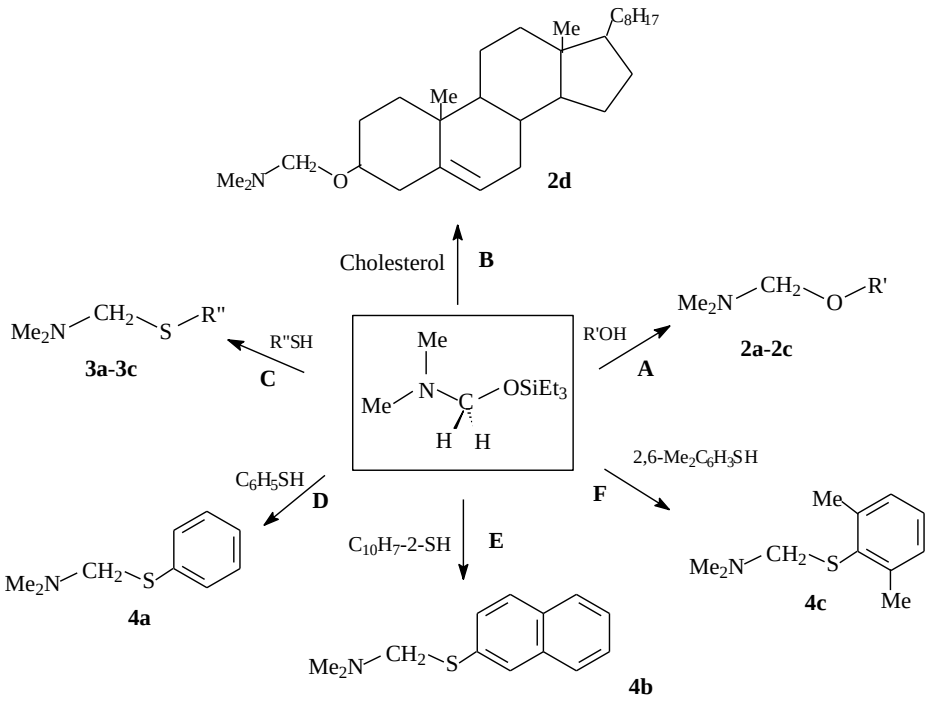
The discovery that **1a** could undergo a facile reaction with the active $R_3Si^{\delta+}$-$H^{\delta-}$ and $R_3Si^{\delta+}$-$Cl^{\delta-}$ bonds, resulting in the formation of Me_3N (or $ClCH_2NMe_2$) and $R_3SiOSiR_3$,[6,7] respectively, suggests that **1**, which can be termed O-silylated aminol ethers, are masked analogs of Eschenmoser's salt,[8] eq. 2, and thereby act as aminomethyl transfer agents (Mannich reagents).

$$R_3SiO\text{-}CH_2NMe_2 \rightleftharpoons [R_3SiO]^- [CH_2{=}NMe_2]^+ \qquad (2)$$

Aminol ethers and aminals are reported to function best in the presence of an activating species, e.g. SO_2, chlorosilanes, acetyl chloride, trifluoroacetic acid, trimethylamine oxide etc., and thus facilitating the Mannich reaction in convenient non-protic solvents is a useful new synthetic tool.[9] We previously reported the utility of **1a** to react with amines, R_2NH, in benzene, to form new diaminomethanes, $R_2NCH_2NMe_2$, and bis-(dimethylamino)amines $(Me_2NCH_2)_2NPh$ which possess interesting lability properties.[10] We now report the reactions of **1a** with a representative group of element-hydrogen bonds, E-H (E = O, S, N, P), and aromatic C-H bonds, which illustrate that **1a** is a general, useful and reliable $[CH_2NMe_2]$ transfer reagent requiring no activating co-reactants, occurs at room temperature and gives high yields.

Results and Discussion

It is well-established that Mannich reagents can react with E-H (E = O, S) bonded compounds;[9a] thus, our initial studies concentrated upon the reactions of **1a** with simple alcohols and thiols to form the corresponding E-CH_2NMe_2 products. In each case there is a very rapid reaction involving transfer the aminomethyl group with concomitant formation of R_3SiOH. As previously known, the Mannich reaction products with alcohols depend upon the nature of the R group attached to O, aliphatic or aromatic;[9] this is not the case for thio-alcohols.[11] For the aliphatic alcohols studied, MeOH, EtOH, ^{i}PrOH and cholesterol, the products are the corresponding aminol ethers, Me_2NCH_2OR',**2**, formed in good yields, Scheme 1 (routes A and B). Similar chemistry was observed for the reactions with both aliphatic and aromatic thiols, Scheme 1 (routes C-F).



Scheme 1. Reactions of **1a** with aliphatic alcohols (route A, R' = Me (**2a**), Et (**2b**), ^{i}Pr (**2c**)), -thiols (route C, R" = Et (**3a**), Pr (**3b**), Bu (**3c**)), aromatic thiols (routes D-F), and cholesterol (route B).

The structure of the aminomethyl cholesterol derivative, a previously unknown material, is illustrated in Figure 1.

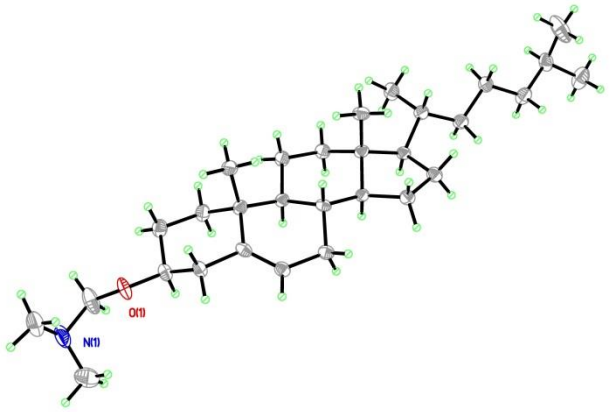
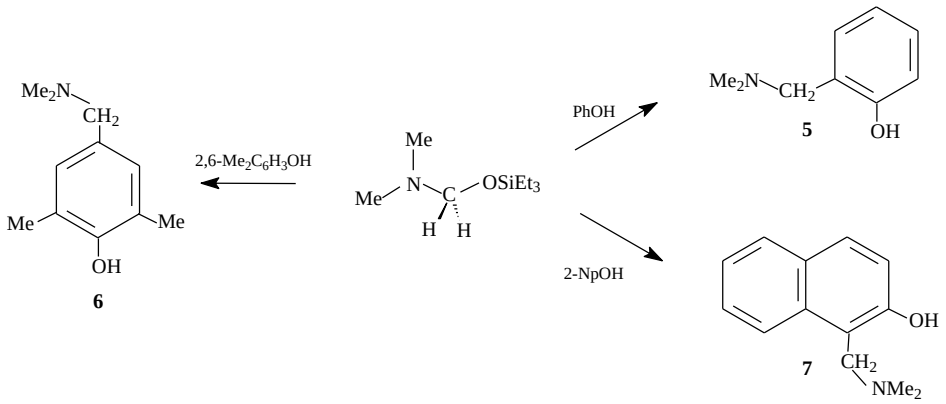


Figure 1: Structure of cholesteromethyl(dimethyl)amine, **2d**, CCDC # 1428932

With respect to the structure, the most reported cholesterol derivatives are those with modifications in the aliphatic chain;[12a] however, there are also some with the alcohol functionalized.[12b] The substitution of the alcohol in the compound **2d** has no effect in the C-O bond distance, neither on the cholesterol conformation.

For the aromatic alcohols investigated, phenol, 2,6-dimethylphenol, and α- and β-naphthol, simple aromatic electrophilic substitution reactions take preference,[9f] with no indication of substitution of the OH group, Scheme 2.[9b] *O*-aminomethylphenols, e.g. **5**, have recently been used for *o*-quinone methide synthesis, species with an important and interesting chemistry.[9e]



Scheme 2. Reactions of **1a** with aromatic alcohols.

The initial substitution is very selective and always *ortho* with respect to the OH group on the aromatic core when possible, as is well-established.[9b] However, if this position is blocked, as in 2,6-dimethylphenol, *para* substitution occurs. The same *ortho*-(*N*,*N*-dimethylamino)methylation of phenol has been achieved using both Eschenmoser's salt[9g] and bis-(*N*,*N*-dimethylamino)methane;[9d] however, the experimental conditions involved required an activation system involving two or more equivalents of $MgCl_2$-Et_3N or SO_2, respectively.

The structures of 4-[(*N*,*N*-dimethylamino)methyl]-2,6-dimethyl-phenol, **6**, and 1-[(N,*N*-dimethylamino)methyl]-2--naphthalenol, **7**, are illustrated in Figure 2. For **7**, the anticipated formation of an intramolecular HB [r(OH···N) = 1.56(3)] can be observed, which is statistically similar to the interaction found and studied for 4,5-dimethyl-2-[(*N*,*N*-dimethylaminomethyl)phenol and 3,5,6-trimethyl-2-(*N*,*N*-dimethylamino)methyl]phenol [r(OH···N) = 1.73(6) and 1.73(3) Å respectively.[13a]

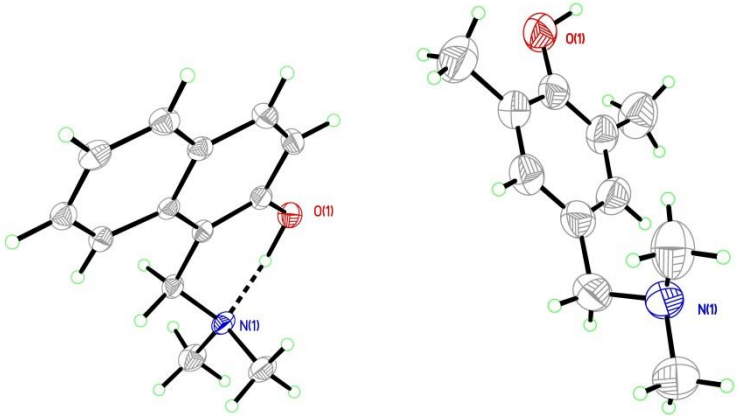
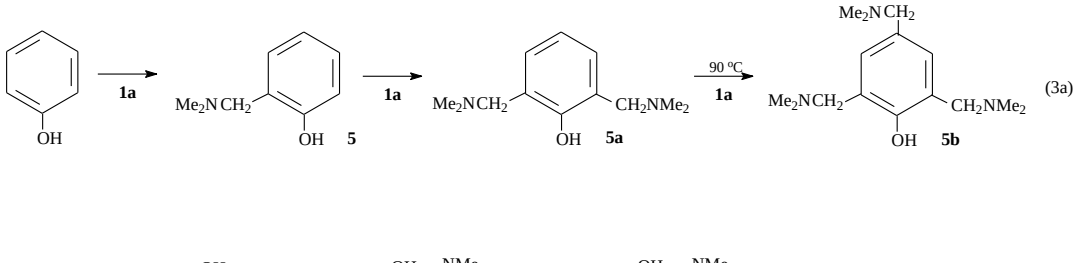


Figure 2: Structure of 1-[*N*,*N*-dimethylamino)methyl-2--naphthalenol. **7**, CCDC # 1428933; and 2,5-dimethyl-4-(*N*,*N*-dimethylamino)methyl]-phenol, **6**, CCDC # 1428937.

When the stoichiometry of the phenol + **1a** reaction is changed from 1:1 to 1:2 the reaction leads to the di-substituted product, 2,6-bis-[(*N*,*N*-dimethylamino)methyl]phenol, **5a**, *via* the intermediacy of **5**; however, at that stoichiometry a mixture of the two products was obtained. With a larger excess of **1a** (1:4 equivalents) product **5a** can be obtained pure when the reaction is performed at room temperature. Using at least a 1:3 ratio of reactants, the tri-substituted material 2,4,6-tris-[(*N*,*N*-dimethylamino)methyl)]phenol, **5b**, can be readily formed in high yield when the reaction is performed at 80 °C, eq. 3a. Thus **1a** is a simple and effective reagent to form all three (*N*,*N*-dimethylamino)methyl in high yields under the appropriate conditions. It is of interest that the reported reaction of phenol with $Me_2NCH_2NMe_2$, using SO_2 as an activator, produced primarily **5** and smaller amounts of the 2,4-bis[(*N*,*N*-dimethylamino)methyl]phenol, a product we did not observe.[9d] Both the bis-and tris-[(*N*,*N*-dimethylamino)methyl]phenols are well-established materials;[13c] ^{13}C and ^{1}H NMR spectra were in accord with expectation.[13d]

Similar chemistry occurs during the reaction of **1a** with α-naphthol; initial rapid formation of the ortho-substituion product with a slower secondary reaction leading to the di-substituted *ortho* and *para* product, eq. 3b.



We could find only a single previous report on **9** in the literature, and its single crystal structure is presented in Figure 3.[13b]

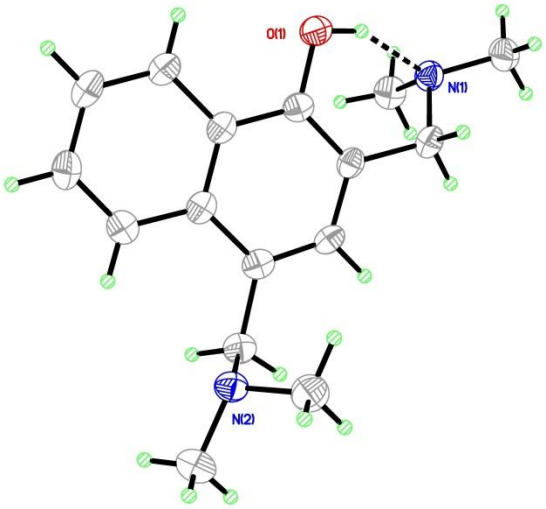


Figure 3. Structure of 2,4-dimethylaminomethyl-1-naphthol, **9**, CCDC # 1535575

As expected, the crystal structure involves formation of an intramolecular HB between the amino and the alcohol function as in **7,** [r(OH···N) = 1.83(2)]. This HB is longer in 9 because of the introduction of a second amino group, and results in a the less dense packing, 1.172 g/cm^3 for **9** vs 1.215 g/cm^3 for **7.**

Initial studies on the reaction between **1a** and Ph_2PH illustrated that no reaction was occurring, even at temperatures considerably elevated compared to those of the OH and SH reactions reported above (70 °C cf. 25 °C) and the reactions with NH compounds.[10] However, addition of ~5% of (η^5-C_5H_5)Mo(CO)$_3$Me to a reaction mixture in C_6D_6 at 30 °C, resulted in a transformation to the expected dimethylaminomethyl transfer species, $Ph_2PCH_2NMe_2$ (**10**). This is a previously reported species, obtained from the reaction of Ph_2PLi and $ClCH_2NMe_2$,[14a] or from the acid catalyzed reaction of Ph_2PH with tetramethyldiaminomethane.[14b] The ^{31}P NMR chemical shift of our product appears at -26.6 ppm, consistent with the ^{31}P NMR chemical shift reported for diphenylphosphino group of diphenylphosphino(dimethylphoshino)methane, $Ph_2PCH_2PMe_2$, at ~ -22.8 ppm.[15] However, our value is significantly at variance with a reported literature value of

27.5 ppm ppm,[14b] but in accord with another literature value of -25.3 ppm.[14c] Studies on our sample illustrated that upon mild exposure to air it rapidly transforms to the corresponding phosphine oxide, $Ph_2P(O)CH_2NMe_2$ (**11**) which indeed exhibits a ^{31}P NMR resonance at 26.9 ppm! This latter value is comparable with the ^{31}P NMR chemical shift of the $Ph_2P{=}O$ group of $Ph_2P(O)CH_2PPh_2$ at 27.6 ppm,[16] thus we conclude that one of the original reports of $Ph_2CH_2NMe_2$ resulted in the isolation of the phosphine oxide derivative **11**.[14b] This is a crystalline material and we have been able to determine its single crystal structure, Figure 4, hence proving the suggested formulation.

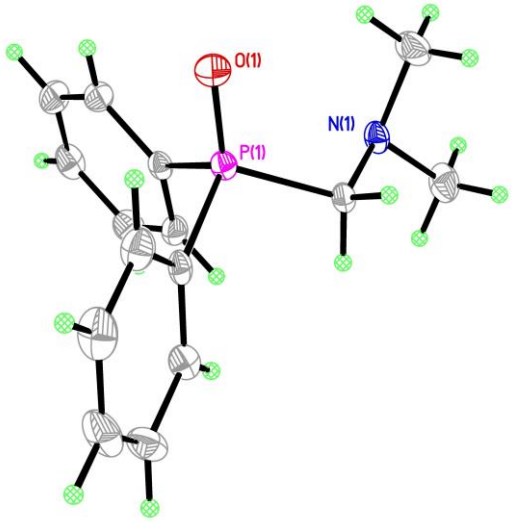


Figure 4: Structure of [$Ph_2P(O)CH_2NMe_2$], **11**, CCDC # 1535574

The space group for this molecule is Pbca, a centrosymmetric structure with two orthogonal H-bonding motifs. One network is associated with the N lone pair and an aromatic *para*-C-H, Figure 5 (left). The other, a chain like pattern is formed *via* three P=O···H bonds, two *ortho*-C-H units and a single H-bond with a methylene H atom, Figure 5 (right).

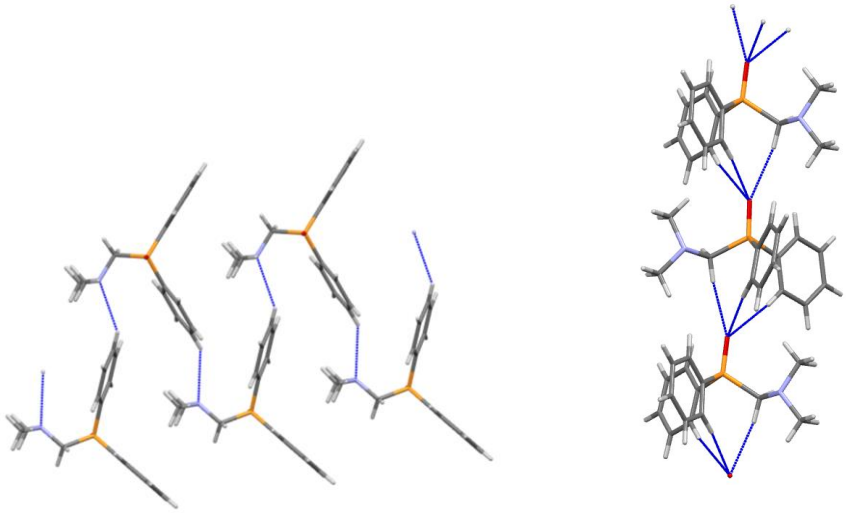


Figure 5. HB chain of **11** formed by interaction of the amino group with one C-H from the aromatic ring on the phosphine [2.724 Å], left; and a chain formed by a triple HB to the phosphine oxygen with the following distances 2.301, 2.312 and 2.473 Å, right.

The sulfur analog, $Ph_2P(S)CH_2NMe_2$, has been obtained from the Mannich reaction of $Ph_2P(S)H$ with DMF.[17]

Initial attempts to obtain transition metal derivatives of this bidentate PC_1N ligand $Ph_2PCH_2NMe_2$, a member of the interesting class of hemilabile ligands, PC_nN,[18] have not been successful. Given the ready formation of $R'_2NCH_2NR_2$ complexes,[10] this is surprising, but a search of the literature reveals a handful of such complexes; a dimeric palladium complex where each ligand atom binds a separate metal centre;[19] and three complexes of bis(tris(*N*-piperidinomethyl)phosphine oxide)- with zinc and cadmium dinitrate, and zinc dichloride.[20]

Conclusions

We have demonstrated that triethylsiloxymethyl-*N*-*N*-dimethylamine, $Et_3SiOCH_2NMe_2$, **1a**, readily formed in high yield from the reaction of Et_3SiH and DMF, is an excellent new Mannich reagent and transfers Me_2NCH_2 group to reactive E-H bonds (E = O, S, N, P, and aromatic C-H) in high yields. The reagent is soluble in most organic solvents permitting homogeneous reaction conditions which also involve relatively low temperatures and short reaction times, and, in general

for E = O, S and N, useful in the absence of any activating reagents or catalysts. Where appropriate the side product, Et_3SiOH, can be readily removed under vacuum at 60 °C, thus facilitating product purification for all but low boiling materials.

Experimental

All manipulations were carried out under Argon atmosphere using Schlenk or vacuum line techniques. THF was distilled under nitrogen from benzophenone ketyl prior to use. Other solvents, hexanes, benzene and toluene were dried over sodium metal and distilled before use. All alcohols and thiols, were purchased from Sigma-Aldrich. NMR spectra were recorded on either a JEOL 600 MHz or Bruker 300 MHz spectrometer in either $CDCl_3$ or C_6D_6 and recorded in ppm. Column chromatography was performed on small columns (5 x 60 mm) of Silica Gel (Aldrich), 70-230 mesh, 60 Å, Pore Volume 0.75 cm^3/g.

Single crystal X-ray diffraction. Crystals of compounds **2d**, **6**, **7**, **9**, and **11**, were each mounted on a glass fiber in a random orientation using paratone oil. The X-ray intensity data were collected with APEX2 suite [APEX2 v2010.7-0 Bruker AXS 2005-2010] on a Bruker APEX CCD diffractometer with monochromatized MoKα radiation (λ = 0.71073 Å) at room temperature.

Synthesis of $Et_3SiOCH_2NMe_2$, 1a.[4b]

A 25 mL Schlenk tube with a HI-VAC valve was charged with 3.64 g (31.4 mmol) of Et_3SiH, 2.3 g (31.5 mmol) DMF and 2 mole % of the $Mo(CO)_6$ as a catalyst. The tube was sealed under vacuum and heated at 60 °C for 12 h. The tube was opened under Ar and the catalyst was removed by repeatedly freezing the tube in liquid N_2 and decanting the liquid into another flask. The crude product was distilled at 60-62 °C at 20 mm/Hg. Yield: 4.45g (76 %). ^1H NMR: 0.55 (q, 6 H, CH_2), 0.97(t, 9H, CH_3), 2.31, (s, 6 H, Me_2N), 4.28 (s, 2 H, CH_2). ^{13}C NMR: 5.03, 7.15 (Et), 41.1 (Me_2N), 82.3 (CH_2). ^{29}Si NMR: 15.3 ppm; HRMS(ESI): Calcd. for $C_9H_{22}SiNO$: (M^+-

1): 188.1470, Found 188.1445. Anal. Calcd. for $C_9H_{23}NOSi$: C, 57.1; H, 12.2. Found: C, 55.9; H, 12.2.

Reactions of $Et_3SiOCH_2NMe_2$ with alcohols and thiols, 2-3.

In a typical experiment, a Pyrex NMR tube or 15-mL round-bottom flask was charged with a 10% excess of **1a**, and R′EH (E = O, R′ = Me, Et, *t*-Bu, Ph, 2,6-$Me_2C_6H_3$, cholesterol; E = S, R″ = Et, 1-Pr, 1-Bu, Ph, 2,6-Me_2Ph) and 0.5 mL of C_6D_6 or $CDCl_3$ and sealed under vacuum or under inert atmosphere. The reactions were performed at room temperature and progress was monitored by ^{13}C, ^{29}Si NMR spectroscopy; however, the formation of the products was essentially instantaneous. The products were purified by distillation or in the case of **4c** and **2d**, simply washed with cold hexanes and recrystallized.

MeO-CH_2NMe_2, **2a.**[21] Yield 53%, b.p. 25 °C/30 mm Hg. ^1H NMR (C_6D_6, 300 MHz): 2.31 (s, 6 H, (Me_2N), 3.15 (s, 3 H, Me), 3.85 (CH_2). ^{13}C NMR (C_6D_6, 300 MHz): 41.50 (Me_2N), 55.57 (Me), 90.82 (CH_2).

EtO-CH_2NMe_2, **2b.**[22] Yield: 62%, b.p. 30 °C/25 mm Hg. ^1H NMR (C_6D_6, 300 MHz): 1.52 (t, 3 H, -CH_2*Me*), 2.68 (s, 6 H, Me_2N), 3.82 (q, 2 H, -*CH_2*Me), 4.31 (CH_2). ^{13}C NMR (C_6D_6, 300 MHz): 15.1, 63.4 (Et), 41.2 (Me_2N), 89.1 (CH_2).

***i*PrO-CH_2NMe_2**, **2c.**[22] Yield 67%, b.p. 24 °C/30 mm Hg. ^1H NMR (C_6D_6, 300 MHz): 1.04 (d, 6 H, CH(*Me*)$_2$), 2.23 (s, 6 H, Me_2N), 3.52 (sept, 1 H, *CH*Me_2), 3.89 (s, 2 H, CH_2) ppm. ^{13}C NMR (C_6D_6, 300 MHz): 22.5 (CH(*Me*)$_2$), 41.5 (Me_2N), 69.2 (*CH*Me_2), 87.3 (CH_2).

Reaction of $Et_3SiOCH_2NMe_2$ with cholesterol to form 2d.

In a typical experiment, a 15-mL round-bottom flask was charged with cholesterol (1.78 g (4.60 mmol) dissolved in 2 mL of benzene, and **1a** (1.0 g (5.28 mmol) under an inert atmosphere at room temperature. The reaction was monitoring by NMR spectroscopy using C_6D_6 or $CDCl_3$ as

solvent and once the reaction finished, the benzene was evaporated, the solid was washed with cold hexanes and recrystallized to yield the product.

Cholesteromethyl(*N*,*N*-dimethyl)amine, 2d: yield: 73%, m.p. 103-105 °C, white crystals. ^{13}C NMR ($CDCl_3$, 300 MHz): 12.07, 19.03, 13.54, 21.44, 22.76, 23.00, 24.34, 24.60, 28.39, 28.62, 29.33, 32.23, 32.38, 36.20, 36.67, 37.13, 37.72, 39.92, 40.16, 40.20, 41.68, 42.60, 50.67, 56.56, 57.03, 77.12, 87.46, 121.55, 141.39 ppm; Calcd. for $C_{30}H_{53}ON$: C, 81.19; H, 12.05; Found: C, 81.72; H, 12.67

EtSCH$_2$NMe$_2$, 3a.[23] Yield: 67%, b.p. 44-45 °C/25 mm Hg. ^{1}H NMR (C_6D_6, 300 MHz): 1.66 (t, 3 H, -CH$_2$*Me*), 2.68 (s, 6 H, Me$_2$N), 3.03 (q, 2 H, -*CH$_2$*Me), 4.27 (CH$_2$). ^{13}C NMR (C_6D_6, 300 MHz): 16.1, 27.6 (Et), 43.2 (Me$_2$N), 64.5 (CH$_2$).

PrSCH$_2$NMe$_2$, 3b. Yield: 75%, b.p. 48-50 °C/20 mm Hg. ^{1}H NMR (C_6D_6, 300 MHz): 1.37 (t, 3 H, -CH$_2$CH$_2$*Me*, 2.00 (sext, 2 H, -CH$_2$*CH$_2$*Me), 2.64 (s, 6 H, Me$_2$N), 2.93 (t, 2 H, -*CH$_2$*CH$_2$Me), 4.24 (s, 2 H, CH$_2$). ^{13}C NMR (C_6D_6, 300 MHz): 13.9, 24.4, 35.9 (Pr), 43.1 (Me$_2$N), 65.0 (CH$_2$).

BuSCH$_2$NMe$_2$, 3c.[24] Yield: 80%, b.p. 34-35 °C/3 mm Hg. ^{1}H NMR (C_6D_6, 300 MHz): 1.29 (t, 3 H, -CH$_2$CH$_2$CH$_2$*Me*), 1.79 (sext, 2 H, -CH$_2$CH$_2$*CH$_2$*Me), 1.93 (quint, 2 H, -CH$_2$*CH$_2$*CH$_2$Me), 2.63 (s, 6 H, Me$_2$N), 2.93 (t, 2 H, -*CH$_2$*CH$_2$CH$_2$Me), 4.22 (s, 2 H, CH$_2$). ^{13}C NMR (C_6D_6, 300 MHz): 14.2, 22.60, 33.3, 33.5 (Bu), 43.1 (Me$_2$N), 64.9 (CH$_2$). HRMS (DART), Calcd. for $C_7H_{18}NS$, M+1, 148.11599, Found 148.1143.

[(*N*,*N*-dimethylamino)methyl]thio-benzene, 4a.[24] Yield: 79%, b.p. 97 °C/3 mm Hg. ^{1}H NMR ($CDCl_3$, 300 MHz): 2.32 (s, 6 H, Me$_2$N), 4.52 (s, 2 H, CH$_2$), 7.17 (t, 1 H, CH), 7.26 (t, 2 H, CH), 7.55 (d, 2 H, CH). ^{13}C NMR ($CDCl_3$, 300 MHz): 40.0 (Me$_2$N), 68.2 (CH$_2$), 125.7, 128.4, 131.1, 137.9 (Ph).

Synthesis of 2-[(*N*,*N*-dimethylamino)methyl]thio-napthalene, 4b.[27] 2-Naphthalene thiol, 0.2 g (1.25 mmol) was dissolved in 1 ml of benzene and 0.24 g of **1a** (1.26 mmol) was added to the solution. After evaporation of solvent the crude mixture was left under vacuum at 60 ºC for 2 h to remove Et_3SiOH and the oily product was isolated in 61 % yield.

^1H (300 MHz, $CDCl_3$) 2.4 (s, 6H), 4.6 (s, 2H), 7.4-8.1 (Ar-H, complex, 7H) ^{13}C (75, $CDCl_3$) 42.8, 69.0, 125.8, 126.5, 127.2, 127.7, 128. 5, 129.5, 130.0, 132.0, 134.0, 135.7; Anal. Calcd. for $C_{13}H_{15}NS$: C, 71.84; H, 6.96; Found: C, 71.71; H, 7.25.

1- [(*N*,*N*-dimethylamino)methyl]thio-2,6-dimethylbenzene, 4c. Yield: 74%, b.p. 105-108 °C/3 mm Hg. ^1H NMR ($CDCl_3$, 600 MHz): 2.39 (s, 6 H, Me_2N), 2.65 (s, 6 H, Me_2), 4.30 (s, 2 H, CH_2), 7.11 (s, 3 H, Ph). ^{13}C NMR ($CDCl_3$, 600 MHz): 22.4 (Me), 42.6 (Me_2N), 69.3 (CH_2), 127.6, 128.3, 135.9, 142.2 (Ph). HRMS (DART), Calcd. for $C_{11}H_{18}NS$, M+1, 196.11599, Found 196.1193.

2-[(*N*,*N*-dimethylamino)methyl]-phenol, **5.**[25] Yield: 51%, b.p. 75 °C/3 mm Hg. ^1H NMR ($CDCl_3$, 300 MHz): 2.26 (s, 6 H, Me_2N), 3.58 (s, 2 H, CH_2), 6.75 (t, 1 H, C-4), 6.83 (d, 1 H, C-6), 6.93 (d, 1 H, C-3), 7.15 (t, 1 H, C-5), 11.00 (s, 1 H, OH). ^{13}C NMR ($CDCl_3$, 300 MHz): 44.13 (Me_2N), 62.6 (CH_2), 115.8, 118.7, 121.8, 128.1, 128.5, 158.06 (Ph).

2,6-*bis*-[(*N*,*N*-dimethylamino)methyl]-phenol, 5a.[13d] Yield: 75%, ^1H NMR: 1.97 (s, 12 H, $((CH_3)_2N)$, 3.38 (s, 4 H, CH_2), 6.69 (t, 1H), 6.98 (d, 2H), Ph. ^{13}C NMR: 44.5 $((CH_3)_2N)$, 59.9 (CH_2), 118.7, 123.4, 129.1, 157.1 (Ph).

2,4,6-*tris*-[(*N*,*N*-dimethylamino)methyl]-phenol, 5b.[13d] Yield: 90%, ^1H NMR (C_6D_6, 300 MHz): 2.00 (s, 12 H, *p*-Me_2N), 2.13 (s, 6 H, *o*-Me_2N), 3.30 (s, 2 H, CH_2), 3.47 (s, 4 H, CH_2), 7.23 (s, 2H (Ph). ^{13}C NMR (C_6D_6, 300 MHz): 44.8 (*o*-$(CH_3)_2N$), 45.4 (*p*-Me_2N), 60.2 (*o*-CH_2), 64.4 (*p*-CH_2), 123.7, 129.3, 129.6, 156.0 (Ph).

4-[(*N*,*N*-dimethylamino)methyl]-2,6-dimethylphenol, **6.**[25c, 9d] Yield 78%, m.p. 116-117 °C, colorless crystals. ^{1}H NMR ($CDCl_3$, 600 MHz): 2.17 (s, 6 H, Me_2), 2.21 (s, 6 H, Me_2N), 3.29 (s, 2 H, CH_2), 6.87 (s, 2 H, Ph). ^{13}C NMR ($CDCl_3$, 600 MHz): 16.13 (Me_2), 45.3 (Me_2N), 63.9 (CH_2), 123.7, 129.6, 129.9, 151.7 (Ph).

Reactions of $Et_3SiOCH_2NMe_2$ with 1- and 2-Naphthol

1-[(*N*,*N*-dimethylamino)methyl]-2-naphthalenol, **7**,[25] 2-Naphthol (0.3 g, 2.08 mmol) and **1a** (0.4 g, 2.1 mmol) were dissolved in 2 mL of benzene. After 10 minutes the solvent was removed under vacuum and the residual oil was dissolved in small amount of hexane and left at 5 ºC overnight. The yellow-brown crystals formed were washed with cold hexane to remove any residual silanol. The final yield of the product was 63%, m.p. 71-72 ºC; NMR, ^{1}H (C_6D_6): 1.9 (s, 6H), 3.7 (s, 2H), 7.3-7.9 (Ar-H, complex, 6H), 12.1 (s, 1H).^{13}C (C_6D_6): 44.0 (Me_2N), 57.8 (CH_2-N), 111.7, 119.8, 121.2, 122.4, 126.4, 129.0, 129.3, 129.6, 133.3, 157.7.

2-[(*N*,*N*-dimethylamino)methyl]-1-naphthalenol, **8**.[26] 1-Naphthol (0.3 g, 2.08 mmol) and **1a** (0.4 g, 2.1 mmol) were dissolved in 2 mL of benzene. After 10 minutes the solvent was removed under vacuum, and the residue was passed through a small silica gel column. The column was eluded with hexane followed by (1:2) hexane-THF mixture. The final yield of the product was 57%. NMR, ^{1}H (C_6D_6): 1.8 (s, 6H), 3.3 (s, 2H), 6.9-7.9 (Ar-H, complex, 6H), 8.9 (1H).^{13}C ($CDCl_3$): 44.6 (Me_2N), 63.2 (CH_2-N), 114.4, 118.2, 122.2, 124.9, 125.1, 126.1, 126.5, 127.4, 134.1, 153.9.

2,4-bis[(*N*,*N*-dimethylamino)methyl]-1-naphthalenol, **9**.[26] In a typical experiment, a 15-mL round-bottom flask was charged with 1-naphthol (0.5g, 0.35 mmol) and **1a** (1.31g, 0.73 mmol) dissolved in 4 mL of benzene, under an inert atmosphere at room temperature. The reaction was agitated and monitored by NMR spectroscopy and when the reaction was finished, the solvent was

evaporated and the residual solid washed with cold hexanes, and recrystallized to yield the product. Yield: 73%, m.p. 75-77 °C. ^{1}H NMR ($CDCl_3$, 600 MHz): 2.28 (s, 6 H, Me_2N), 2.37 (s, 6 H, Me_2N), 3.71 (s, 2 H, CH_2), 3.77 (s, 2 H, CH_2), 6.99 (s, 1 H, aromat. H), 7.43-7.46 (t, 1 H, aromat. H), 7.48-7.50 (t, 1 H, aromat. H), 8.11-8.12 (d, 1 H, aromat. H), 8.26-8.27 (d, 1 H, aromat. H) ppm. ^{13}C NMR ($CDCl_3$, 600 MHz): 44.7 (Me_2N), 45.6 (Me_2N), 62.0 (CH_2), 63.0 (CH_2), 113.3, 122.4, 124.1, 124.6, 125.4, 126.2, 128.2, 132.8, 153.6 (aromat.).

Synthesis of [(*N*,*N*-dimethylamino)methyl)]-diphenylphosphine, 10. A 5 mm Pyrex NMR tube was charged with 0.1 g (0.53 mmol) of $Et_3SiOCH_2NMe_2$, 0.1 g (0.53 mmol) of Ph_2PH, and 0.5 mL of C_6D_6 and 5 mole% of $(\eta^5\text{-}C_5H_5)Mo(CO)_3\text{-}Me$ as a catalyst. The tube was sealed under vacuum and the NMR monitoring after 15 h of the reaction by ^{1}H, ^{29}Si and ^{13}C NMR spectroscopy showed the formation of $Ph_2PCH_2NMe_2$ and Et_3SiOH. Et_3SiOH was removed leaving the reaction mixture under vacuum at 70 ^{o}C for 2 hrs. An oil of pure $Ph_2CH_2NMe_2$, **12**, was obtained in 85% yield. ^{1}H NMR: 2.23 (s, 6 H, Me_2N), 2.97, (d, 2 H, ($^{2}J_{P\text{-}H}$ =4 Hz, CH_2), 7.04, 7.42-7.47 (m, 10 H, Ph). ^{13}C NMR: 46.8 (d, $^{3}J_{P\text{-}C}$ =9 Hz, Me_2N), 63.4 (d, $^{1}J_{P\text{-}C}$ =2.3 Hz, CH_2) 128.6 (d) 128.6, (s), 133.3 (d), 139.4 (d); ^{31}P NMR: -26.6.

Synthesis of [(*N*,*N*-dimethylamino)methyl]-diphenylphosphine oxide, 11. A sample of pure $Ph_2PCH_2NMe_2$ exposed to air for 2 minutes immediately forms a white solid $Ph_2P(O)CH_2NMe_2$, which was recrystallized from CH_2Cl_2/hexane mixture. ^{1}H NMR ($CDCl_3$): 2.38 (s, 6 H, Me_2N), 3.12, (d, 2 H, ($^{2}J_{P\text{-}H}$ = 6 Hz, CH_2), 7.44-7.48,7.74-7.78 (m, 10 H, Ph). ^{13}C NMR: δ ppm, 48.1 (d, $^{3}J_{P\text{-}C}$ = 9 Hz, NMe), 59.5 (d, $^{1}J_{P\text{-}C}$ = 88 Hz, CH_2) 128.5 (d) 131.1 (d),131.8 (s), 133.1 (d); ^{31}P NMR: 26.9.

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Supplementary Material

^{1}H and ^{13}C NMR data for materials; cif data for CCDC-1428932 for **2d**, 1428937 for **6**, 1428933 for **7**, 1535575 for **9** and 1535574 for **11** which can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

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Graphical Abstract