Straightforward One-Pot Syntheses of Silylamides of Magnesium and Calcium via an In Situ Grignard Metalation Method

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Abstract Calcium bis[bis(trimethylsilyl)amide] (Ca(HMDS)₂) is a widely used reagent in diverse stoichiometric and catalytic applications. These processes necessitate a straightforward and large-scale access of this complex. Calcium does not react with primary and secondary amines, but the addition of excess bromoethane to a mixture of calcium turnings and amines in THF at room temperature yields the corresponding calcium bis(amides), calcium bromide and ethane. This in situ Grignard metalation method (iGMM) allows the preparation of calcium bis(amides) from secondary and primary trialkylsilyl-substituted amines and anilines on a multigram scale.

1 Background

The development of diverse procedures for the synthesis of calcium bis[bis(trimethylsilyl)amide] (Ca(HMDS)₂) is based on the desperate need of soluble organocalcium complexes for various applications. Therefore, different strategies were developed independently at the beginning of the 1990s. The first syntheses of calcium bis[bis(trimethylsilyl)amide] (Ca(HMDS)₂) were performed via transmetalation of Hg(HMDS)₂ or Sn(HMDS)₂ via metathetical approaches of AHMDS (A = alkali metal) with calcium alkoxides or pseudoaldehydes such as trifluoromethanesulfonates (triflates) or arenesulfonates. The metathesis reaction of KHMDS with CaI₂ in tetrahydrofuran and toluene yields thf adducts and unsolvated Ca(HMDS)₂, respectively. Direct metalation of (H)HMDS with calcium is very challenging and requires activation of the alkaline earth metal via metal vapor synthesis and co-condensation with the organic solvent. Alternatively, ammonia-saturated solvents can be used for the direct metalation of (H)HMDS with calcium turnings. These procedures are depicted in Scheme 1.

Scheme 1 Common established procedures for the synthesis of Mg(HMDS)₂ and Ca(HMDS)₂ involving several preparation and purification steps

All these procedures are related to severe drawbacks. Transmetalation protocols require the preparation, isolation and distillation of the precursor organometallics (Hg(HMDS)₂ or Sn(HMDS)₂). Metathetical approaches necessitate an exact stoichiometry to avoid formation of calciates of the type [Ca(HMDS)₃]⁻ (excess of AHMDS) and halide-containing product mixtures (substoichiometric AHMDS). The Ca(HMDS)₂ product commonly contains at least traces of potassium (potassium calciate formation...
and/or traces of potassium iodide) that have to be removed by repeated recrystallization efforts. Prior to the direct metalation of \((\text{H})\text{HMDS}\) the calcium metal has to be activated to apply pyrophoric metal powders. In our hands, calcium pieces are sluggish in reactions in ammonia-saturated solutions and dull, grayish reaction mixtures are obtained which prohibit the isolation of a pure product. These initial investigations are summarized and evaluated in more detail elsewhere.\(^{10}\)

Due to these reasons, diverse strategies have been developed to accelerate the synthesis of highly pure \(\text{Ca}(\text{HMDS})_2\). The reaction of calcium with \((\text{H})\text{HMDS}\) in THF can be ensured via addition of \(\text{BiPh}_3\) under ultrasonication.\(^ {11}\) The organometallic metalation of \((\text{H})\text{HMDS}\) with dibenzylcalcium\(^ {12}\) circumvents the necessity of metal activation prior to use. Arylcalcium reagents (heavy Grignard reagents)\(^ {13}\) are easily available and represent suitable metalation reagents for the syntheses of calcium amides.\(^ {14}\)

Drawbacks of these procedures are obvious because another metalorganic precursor is required to prepare the metalation reagent.

The bis(trimethylsilyl)amido ligands guarantee not only solubility of the respective metal complexes in common organic solvents, but variations of this anion allow modification of the electronic and (especially) steric properties. Transmetalation of \(\text{Sn}[\text{N}(\text{SiMe}_2\text{CH}_2)_2]_2\) with calcium in THF yields the corresponding tris(THF) adduct of calcium bis(2,2,5,5-tetramethyl-1-aza-2,5-disilylcyclopentanide).\(^ {15}\) In contrast, enlargement of the amido ligand and the use of \(\text{Sn}[\text{N}(\text{SiMe}_3)\text{Si}(\text{SiMe}_3)_2]_2\) in the transmetalation procedure only gives the aminyl radicals and finally the amine \(\text{HN}(\text{SiMe}_3)\text{Si}(\text{SiMe}_3)_2\), but a calcium bis(amide) cannot be isolated. Suitable procedures for the preparation of \(\text{Ca}[\text{N}(\text{SiHMe}_2)_2]_2\) are the metathetical approach with \(\text{KN}(\text{SiHMe}_2)_2\) and \(\text{CaI}_2\) as well as the transamination of \(\text{Ca}(\text{HMDS})_2\) with \(\text{HN}(\text{SiHMe}_2)_2\).\(^ {16}\) The metathesis reaction of the potassium amides with calcium iodide offers access to solvated bulky calcium bis(amides) with amido ligands like

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**Biographical Sketches**

**Sven Krieck** (left) studied chemistry at Friedrich Schiller University Jena, Germany, and graduated in 2007 with his diploma thesis in the field of electrochemical studies on hetrosupramolecular aggregates in the group of Professor Günter Kreisel. He then joined the group of Professor Matthias Westerhausen and completed his Ph.D. in April 2010 working on the stabilization of organocalcium compounds. His thesis was awarded with the university prize as best thesis in 2010. After a postdoctoral fellowship with Professor Nadia Mösch-Zanetti at Karl Franzens University in Graz, Austria, he returned to the Westerhausen group in 2011. Today he is lecturer at the Institute of Inorganic and Analytical Chemistry at Friedrich Schiller University Jena, Germany.

**Philipp Schüler** (second from left) studied the synthesis and coordination chemistry of alkaline earth metal bis(bis(trimethylsilyl)amides) at Friedrich Schiller University Jena, Germany, and obtained his M.Sc. degree in 2018. He is currently a Ph.D. student in the Westerhausen group at the same institute.

**Jan M. Peschel** (second from right) studied chemistry at Friedrich Schiller University Jena, Germany, and obtained his B.Sc. degree in 2017. During his laboratory courses he investigated the synthesis and coordination chemistry of alkaline earth metal bis(bis(trimethylsilyl)amides).

**Matthias Westerhausen** (right) obtained his diploma degree in chemistry in 1983 from Philipps University in Marburg, Germany, and studied for his Ph.D. thesis at the University of Stuttgart, Germany, under the supervision of Professor Gerd Becker. In 1987/88, he worked as a postdoctoral fellow with Professor Robert T. Paine at the University of New Mexico in Albuquerque, USA, in the field of phosphanylboranes. Back at the University of Stuttgart, he finished his habilitation in the Institute of Inorganic Chemistry in December 1994 and received the venia legendi for Inorganic Chemistry in February 1995. From 1996 to 2004 he was a professor at Ludwig Maximilians University Munich where he was also vice rector from 2001 to 2004. He was awarded the Teaching Excellence Award of the State of Bavaria in 1998. Since 2004, he has been teaching and researching at Friedrich Schiller University Jena, Germany.
Calcium readily forms heavy Grignard reagents via the straightforward synthesis of the Hauser base on the one side and homometallic Mg(HMDS)$_2$ can be prepared by an organometallic metalation of Mg(HMDS)$_2$ and magnesium bromide on the other (see the Supporting Information). In the past, these Hauser bases had to be prepared via metalation of bis(trimethylsilyl)amine with previously prepared alkylmagnesium bromide. Alternatively, homometallic Mg(HMDS)$_2$ can be prepared by an organometallic metalation of Mg(HMDS)$_2$ with commercially available dibutylmagnesium, thereby avoiding formation of the Hauser base reagent.

The results with respect to the reaction conditions are summarized in Table 1. An equimolar amount of calcium granules and bromoethane leads to a conversion of only 43% (entry 1) because ether cleavage (formation of R–H)
and Wurtz-type coupling reactions (formation of R–R) com-
pete with the deprotonation of (H)HMDS. If another half
equivalent of EtBr is added after two hours almost complete
conversion is obtained (entry 2). Activation of the calcium
metal and the use of pyrophoric activated calcium powder
accelerates the reaction and higher yields are achieved (en-
tries 3 and 4). The use of iodoethane gave a very similar
yield (entry 5). Larger alkyl groups lower the yields signifi-
cantly, whereas the calcination of (H)HMDS cannot be initi-
ated amides of calcium are accessible via this novel
method. Moreover, primary and secondary phosphanes are not calciat-
ted under these reaction conditions, but phosphonium bro-
moethane, hampering the calciation reaction. For the same
reason, primary and secondary phosphinites are not calcu-
lized under these reaction conditions, but phosphonium bro-
mides are formed during the addition of bromoethane.
In summary, aryl- (anilides) and trialkylsilyl-substitut-
ed amides of calcium are accessible via this novel iGMM.
Commercially available calcium granules are a suitable sub-
strate for the calciation of these primary and secondary

These refined reaction conditions were applied to
screen the generality of this iGMM (Scheme 4). Commer-
cially available calcium chunks and primary or secondary
amines are combined in THF at room temperature. Then
bromoethane, dissolved in THF, was added dropwise. A gen-
tle metalation reaction starts yielding the calcium bis(am-
ide) and calcium bromide.

The results are listed in Table 2 together with the stan-
dardized reaction conditions. In all cases, 1.5 equivalents of
calcium turnings were used and combined with 1 equiva-
 lent of the amine in THF. Then bromoethane was added dropwise over a period of 30 minutes at room temperature.
The presence of one trialkysilsilyl substituent on the nitrogen
atom ensures a smooth reaction with high yields, regardless
of the bulkiness of the trialkysilyl group (entries 1 and 4–
6). Also, mixed alkyl-trimethylsilylamine (entry 5) rep-
presents a suitable substrate under these reaction condi-
tions. Anilines can also be calciated under these conditions
(entry 3), however, the yield is lower and longer reaction
times are required. Dialkylamines (entry 2) immediately
form ammonium bromides during the addition of bro-
moethane, hampering the calciation reaction. For the same
reason, primary and secondary phosphates are not calcu-
lized under these reaction conditions, but phosphonium bro-
mides are formed during the addition of bromoethane.

The thus prepared solutions of [(thf)2Ca(HMDS)2] con-
tain small amounts of calcium bromide according to the
solubility of this salt (16 mg of CaBr2 in 1 mL of THF or 40
mg of [(thf)2CaBr2] in 1 mL of THF, respectively). Quantita-
tive removal of calcium bromide is possible via recrystall-
ization of Ca(HMDS)2 from a mixture of THF and alkanes.
Formation of CaBr2 proved to be advantageous because this
calcium halide precipitates much more easily than CaI2,
which also coats the calcium turnings decelerating the con-
version. Taking all these facts into account, the preferred
strategy uses bromoethane and 1.5 equivalents of calcium.
Iodo- and bromomethane are not suitable because the
formed methane carries out these volatile halides from the
reaction mixture.

### Table 1 Synthesis of [(thf)2Ca(HMDS)2] Using the In Situ Grignard Metalation Method (iGMM) and Different Alkyl Halides (R–X)

<table>
<thead>
<tr>
<th>Entry</th>
<th>Ca (equiv)</th>
<th>R–X</th>
<th>Conversion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ca</td>
<td>EtBr</td>
<td>43</td>
</tr>
<tr>
<td>2</td>
<td>Ca</td>
<td>1.5 EtBr</td>
<td>80*</td>
</tr>
<tr>
<td>3</td>
<td>Ca + 5% Ca</td>
<td>1   EtBr</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>Ca*</td>
<td>1   EtBr</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>Ca</td>
<td>1   PrBr</td>
<td>42</td>
</tr>
<tr>
<td>6</td>
<td>Ca</td>
<td>1   BuCl</td>
<td>–</td>
</tr>
<tr>
<td>7</td>
<td>Ca</td>
<td>1   BuBr</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>Ca</td>
<td>1   Bu</td>
<td>17</td>
</tr>
<tr>
<td>9</td>
<td>Ca</td>
<td>1   Bu3Si</td>
<td>–</td>
</tr>
<tr>
<td>10</td>
<td>Ca</td>
<td>1   1,4–Bu2Br</td>
<td>13</td>
</tr>
<tr>
<td>11</td>
<td>Ca</td>
<td>1   PhBr</td>
<td>–</td>
</tr>
<tr>
<td>12</td>
<td>Ca</td>
<td>1   Br</td>
<td>48</td>
</tr>
</tbody>
</table>

*General conditions: Ka (2 g, 50 mmol) in THF (45 mL) and (H)HMDS (9.8 mL, 45 mmol) were placed in a Schlenk flask. The hydrocarbyl halide (R–X) (50 mmol) in THF (5 mL) was added dropwise over 30 min and the mixture was stirred for 3 h at room temperature.

*The conversion was determined by acidimetric titration of an aliquot (1 mL) after hydrolyzation in EtOH/H2O (20 mL, 1:1) with H2SO4 (0.1 M) against thymolphthaleine.

Additional EtBr (1 equiv) was added after 2 h.

### Table 2 Synthesis of [(thf)2Ca(NR2)2] Using the In Situ Grignard Metalation Method (iGMM)

<table>
<thead>
<tr>
<th>Entry</th>
<th>R2NH</th>
<th>Conversion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(H)HMDS</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>Cy2NH</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>Ph2NH</td>
<td>43</td>
</tr>
<tr>
<td>4</td>
<td>Pr3SiNH2</td>
<td>86</td>
</tr>
<tr>
<td>5</td>
<td>tBu(NH)TMS</td>
<td>92</td>
</tr>
<tr>
<td>6</td>
<td>Ph3SiNH2</td>
<td>78</td>
</tr>
</tbody>
</table>

*General conditions: Ka (2.75 g, 65 mmol, 1.5 equiv) in THF (45 mL) and R2NH (45 mmol) were placed in a Schlenk flask. EtBr (3.4 mL, 45 mmol) in THF (5 mL) was added dropwise over 30 min and the mixture was stirred for 3 h at room temperature.

*The conversion was determined by acidimetric titration of an aliquot (1 mL) after hydrolyzation in EtOH/H2O (20 mL, 1:1) with H2SO4 (0.1 M) against thymolphthaleine.
amines. In contrast to the calcium-based procedure, Hauser bases form if magnesium turns are used in this reaction. Due to competing Wurtz-type coupling reactions a slight excess of calcium is beneficial. This synthesis of Ca(HMDS)_2 can easily be upscaled to multigram scale without preceding elaborate and time-consuming preparations (such as purification and activation of calcium, preparation of calcination reagents or dealing with ammonia-saturated ethereal solvents).

The results are depicted in Scheme 5. Direct metalation of [(H)HMDS] and other amines with calcium in THF is impossible. Addition of bromoethane to this mixture at room temperature initiates a gentle and smooth deprotonation and formation of Ca(HMDS)_2. Ethane escapes from this reaction and calcium bromide precipitates without disturbance of the ongoing calcination process. Heteroleptic (HMDS)CaBr cannot be observed whereas the use of magnesium turnings favors the formation of the Hauser base (HMDS)MgBr. Addition of 1,4-dioxane leads to an equilibrium between the heteroleptic Hauser base on the one side and the homoleptic complexes Mg(HMDS)_2 and MgBr_2 on the other.

The thus prepared Ca(HMDS)_2 is free of other metals, but the solution contains calcium bromide which does not interfere with the reactivity of the amide because Hauser-base-like products have not been observed in these ethereal solutions. Nevertheless, removal of calcium bromide can easily be achieved. For this purpose, all volatile materials are removed in vacuo and the remaining residue is extracted with pentane. Calcium bromide is insoluble in alkanes whereas the calcium amides precipitate as colorless crystals upon cooling of this alkane solution.

In summary, the iGMM is an extremely valuable and straightforward procedure to prepare quantitatively, on a multigram scale, new calcium bis(amides) with aryl or tris(hydrocarbyl)silyl substituents at the nitrogen atom and, also for the preparation of heteroleptic amidosilicon bromide (Hauser base) solutions. The magnesium-based Hauser bases and their calcium-based congeners can be used as strong metalation reagents and furthermore, amidomagnesium halides containing stoichiometric amounts of LiCl are known as Turbo-Hauser bases.

### 3 Properties of [(thf)_2M(HMDS)_2]

The bis(trimethylsilyl)amides of the alkaline earth metals magnesium, calcium, strontium, and barium form bis(thf) adducts with distorted tetrahedral coordination spheres of the metal centers. These bis(thf) adducts [(thf)_2M(HMDS)_2] show characteristic NMR parameters that are summarized in Table 3. With increasing electronegativity of the central metal atom, the resonances of the 29Si nucleus show a high-field shift due to back donation of negative charge from the nitrogen atom into the σ(Si–C) bonds, a property known as negative hyperconjugation. If only one trimethylsilyl group is bound at the nitrogen atom, this effect is enhanced leading to increased hyperconjugative effects and an even stronger high-field shift of the 29Si resonance as observed for [(thf)_2Ca(N(tBu)(SiMe_3))] with a value of δ = −20.7. The δ(15N{'H}) values of the [15N]-labeled complexes also strongly depend on the size and hardness of the alkaline earth metal.

#### Table 3 NMR data of the HMDS Ligand of the Alkaline Earth Metal [(thf)_2M(HMDS)_2] Complexes

<table>
<thead>
<tr>
<th>M</th>
<th>Mg</th>
<th>Ca</th>
<th>Sr</th>
<th>Ba</th>
</tr>
</thead>
<tbody>
<tr>
<td>δ(1H)</td>
<td>0.35</td>
<td>0.33</td>
<td>0.33</td>
<td>0.32</td>
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<tr>
<td>δ(13C{'H})</td>
<td>6.60</td>
<td>5.69</td>
<td>5.93</td>
<td>5.73</td>
</tr>
<tr>
<td>δ(29Si{'C})</td>
<td>52.8</td>
<td>51.5</td>
<td>51.8</td>
<td>51.9</td>
</tr>
<tr>
<td>δ(15N{'H})</td>
<td>2.3</td>
<td>2.5</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>δ(29Si{'H})</td>
<td>−345.5</td>
<td>−304.5</td>
<td>−301.9</td>
<td>−275.9</td>
</tr>
<tr>
<td>δ(15N{'H})</td>
<td>−8.6</td>
<td>−15.0</td>
<td>−16.7</td>
<td>−18.4</td>
</tr>
<tr>
<td>δ(29Si{'H})</td>
<td>8.1</td>
<td>9.0</td>
<td>9.1</td>
<td>9.9</td>
</tr>
</tbody>
</table>

* Chemical shifts (δ) are quoted in ppm and coupling constants (J) in Hz.

The molecular structures of the [(thf)_2M(HMDS)_2] complexes are very much alike with characteristic trends dependent on the size and electronegativity of the alkaline earth metal. Selected values are listed in Table 4. As expected, the M–N and M–O bond lengths increase with the radius of the metal. Decreasing intramolecular repulsion with increasing size of the metal center is evident from the decreasing N–M–N bond angles from Mg to Ba. The N–Si bond lengths are rather small due to negative hyperconjugation. This interaction leads to large Si–N–Si bond angles.

Due to steric shielding of the reactive M–N bonds by the bulky HMDS ligands, these complexes show only a moderate sensitivity toward air and hence, isolated crystalline...
material as well as stock solutions are very durable and can be used for stoichiometric and catalytic chemical conversions.

### Applications and Perspective

In the initial 15 years after the first preparation of these [(thf)₂M(HMDS)₂] complexes of magnesium and calcium, the physical and chemical properties have been elucidated in detail. For approximately 20 years, widespread stoichiometric and catalytic applications have been identified and explored, especially for these environmentally benign magnesium and calcium complexes. A few representative examples are discussed below.

The complexes [(thf)₂M(HMDS)₂] (M = Mg, Ca) are valuable synthons in metalation reactions of acidic compounds; early reactivity studies include examples of the synthesis of phosphinides, thiolates, tellurolates, and alkylnyl complexes. Lewis–acid–base reactions with trialkylalanes and –gallanes allowed the synthesis of Ca–C bonds to bridging alkyl groups. Very recently, dimethylcalcium was prepared via a ligand exchange between Ca(HMDS)₂ and methylithium. Addition of [(thf)₂Ca(HMDS)₂] to nitriles allows the synthesis of amidinites with high yields. Recently, these compounds also allowed the synthesis of calcium hydride cages.

Besides these stoichiometric conversions many catalytic applications have recently been elucidated. The non-toxic nature of Ca(HMDS)₂ accelerates its use for the synthesis of biopolymers such as polylactides. For diverse catalytic processes, Ca(HMDS)₂ is a valuable and easy-to-handle pre-catalyst. Representative examples include the calcium-mediated hydroamination of unsaturated compounds (like alkenes, alkynes, heterocumulenes) as well as the hydroacylenation of carbodiimides. Inorganic–organic hybrid materials have also been prepared and functionalized using this compound as a catalyst.

These selected examples demonstrate the necessity of a simple and straightforward synthesis of [(thf)₂M(HMDS)₂] (M = Mg, Ca) with high yields that can be safely performed without the requirement of sophisticated preparative skills. This novel GMM fulfills all preconditions for an easy access to widely use these environmentally benign reagents.

All manipulations were carried out under an inert nitrogen atmosphere using standard Schlenk techniques unless otherwise noted. All substrates were purchased from Alfa Aesar, abcr, Sigma Aldrich, or TCI and were used without further purification. The solvents were dried over KOH and subsequently distilled over sodium/benzophenone under a nitrogen atmosphere prior to use. Deuterated solvents were dried over sodium, distilled, degassed, and stored under nitrogen over sodium. HN(tBu)SiMe₃ and iPr₂SiNH₃ were prepared according to literature protocols. The yields given are crystalline yields and not optimized. IR spectra were recorded on a Bruker Alpha spectrometer. H, Si and ¹³C(¹H) NMR spectra were recorded on a Bruker Avance III 400 spectrometer. Chemical shifts are reported in parts per million relative to SiMe₃ as an external standard referenced to the residual proton signal of the solvent. The purity of the compounds was verified by NMR spectroscopy.

### Table 4

<table>
<thead>
<tr>
<th>M</th>
<th>Mg</th>
<th>Ca</th>
<th>Sr</th>
<th>Ba</th>
</tr>
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<tbody>
<tr>
<td>M–N</td>
<td>202.1</td>
<td>230.2</td>
<td>245.8</td>
<td>259.2</td>
</tr>
<tr>
<td>M–O</td>
<td>209.4</td>
<td>237.7</td>
<td>253.4</td>
<td>273.1</td>
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<tr>
<td>N–M–N</td>
<td>127.9</td>
<td>121.3</td>
<td>120.6</td>
<td>116.8</td>
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<tr>
<td>O–M–O</td>
<td>89.8</td>
<td>81.4</td>
<td>84.7</td>
<td>91.4</td>
</tr>
<tr>
<td>N–Si</td>
<td>170.6</td>
<td>168.6</td>
<td>167.4</td>
<td>168.0</td>
</tr>
<tr>
<td>Si–N–Si</td>
<td>121.0</td>
<td>126.3</td>
<td>132.3</td>
<td>131.7</td>
</tr>
<tr>
<td>Ref.</td>
<td>1</td>
<td>22</td>
<td>22</td>
<td>29</td>
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</table>
of EtBr (1.4 mL, 18 mmol, 1 equiv) was added in one portion and the reaction mixture was stirred overnight at room temperature. After decanting of the supernatant, one aliquot of the solution was titrated by acidimetric titration (0.51 M). The solution was removed under reduced pressure, the residue was redissolved in with n-hexane (40 mL) and filtered through a frit covered with diatomaceous earth. The clear filtrate was stored at –20 °C and the obtained precipitate was collected and dried in vacuo yielding the amide as a colorless powder (2.6 g, 5.5 mmol, 31%).

IR (ATR): 2938, 2887, 1460, 1347, 1235, 1194, 1056, 1029, 991, 917, 853, 816, 752, 687, 651, 611, 504, 476, 432 cm⁻¹.

^1H NMR (400 MHz, CD₆⁾⁺, 296 K): δ = 3.62 (t, J = 6.27 Hz, 8 H, thf), 1.53 (s, 18 H, tBu), 1.28 (m, 8 H, thf), 0.41 (s, 18 H, SiMe₃).

^13C NMR (101 MHz, CD₆⁾⁺, 296 K): δ = 24.8 (thf), 5.8 (SiMe₃).

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Supporting Information
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References


