Pergamon

Tetrahedron, Vol. 53, No. 29, pp. 9977-9988, 1997

0040-4020/97 $17.00 + 0.00

PII: S0040-4020(97)00340-2

Reactions of the Butyllithiums with Tertiary Oligoethylenepolyamines

Hendrikus Luitjes, Marius Schakel, Maxim P. Aarnts, Robert F. Schmitz, Franciscus J.J. de Kanter, Gerhard W. Klumpp*

Scheikundig Laboratorium Vrije Universiteit, De Boelelaan 1083, 1081 HV Amsterdam, The Netherlands

Abstract: *Complexes of t-BuLi monomer with 1,4,7-trimethyl-1,4,7-triazacyclononane (TMTAN,* ***3-CH$_3$****) and tris(N,N-dimethyl-2-aminoethyl)amine (****4-CH$_3$****) were identified by ^{13}C-NMR. Rapid elimination of LiN(CH$_2$CH$_2$NMe$_2$)$_2$ takes place from the free CH$_2$CH$_2$NMe$_2$ group of t-BuLi·* ***4-CH$_3$****. BuLi complexes of hexamethyltriethylenetetramine (****5-CH$_3$****) and octamethylpentaethylenehexamine (****6****) behave similarly, as does* ***4-CH$_2$Li****. Complexes of BuLi oligomers are lithiated at free N-CH$_3$.*

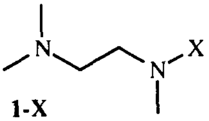
INTRODUCTION

By complexation of lithium, tertiary polyamines activate organolithiums to function as potent polymerization catalysts[1] and metalation agents.[2] Heteroatom-assisted lithiation[3] of the complexing polyamine may occur as a side-reaction. With the simplest and most frequently used of these agents, *N,N,N',N'*-tetramethylethylenediamine (TMEDA, **1-CH$_3$**), formation of **1-CH$_2$Li** (plus some lithiation of N-CH$_2$-C) is observed only at longer reaction times or at elevated temperatures.[4] By contrast, we found that the different methyl groups of the related triamine, *N,N,N',N'',N''*-pentamethyldiethylenetriamine (PMDTA, **2-CH$_3$**) are readily lithiated by the butyllithiums in hydrocarbon solutions at room temperature.[5] Reaction of **2-CH$_2$Li** with epoxides constitutes a new route to allyl alcohols.[6] In continuation of this work, we studied the behavior of polyamines **3(4,5)-CH$_3$** and **6** towards the isomeric butyllithiums. One finding, preparation of lithium amides **7-Li** and **2-Li** from **4-CH$_3$** and **5-CH$_3$** (or **6**), respectively, has already been communicated.[7] Here, we describe the behavior of **3-CH$_3$**, provide more details on **4(5)-CH$_3$** and sum up our results and our present views on butyllithium/polyamine chemistry (which, to a certain degree, may apply to alkyllithium/Lewis base chemistry in general). Proposals of structures of reactive complexes Bu$_m$Li$_m$-polyamine are based on the notion that attack on NC-H occurs at an *amino group initially uncomplexed to lithium*. In the absence of kinetic data, intracomplex reactions are assumed to take place. Bimolecular reaction between complexes should entail severe steric congestion and, therefore, is considered less likely.

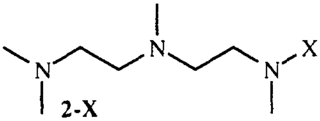
RESULTS

Polyamine-alkyllithium monomer complexes, elimination of lithium amide

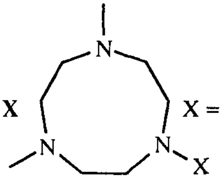
As the cornerstone of our present understanding of alkyllithium/polyamine chemistry we consider the different comportment towards t-BuLi of **3-CH$_3$** (TMTAN) on the one hand and **4-CH$_3$** on the other. Treating these polyamines with 0.6-0.9 equiv. of t-Bu^{6}Li in pentane at -78 °C led to greenish precipitates which dissolved upon replacement of pentane by THF/THF-d_8. As evidenced by 1:1:1 triplets in the ^{13}C-NMR spectra[8] (Table 1) of these solutions, at 165 K, both polyamines form 1:1 complexes with t-Bu^{6}Li monomer: t-Bu^{6}Li·**3-CH$_3$** (≡**8**) and t-Bu^{6}Li·**4-CH$_3$** (≡**9**), respectively.



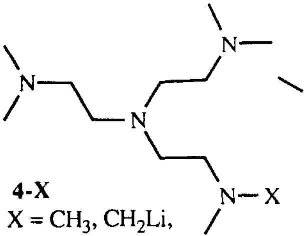
1-X
X = CH$_3$ (TMEDA), CH$_2$Li, H



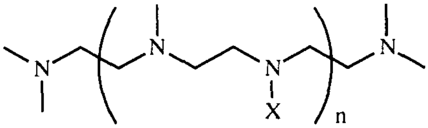
2-X
X = CH$_3$ (PMDTA), CH$_2$Li, Li, H, CH$_2$CPhHOH, CH$_2$SnMe$_3$



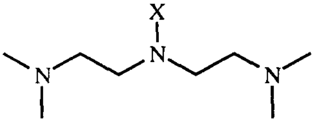
3-X
X = CH$_3$ (TMTAN), CH$_2$Li , CH$_2$SiMe$_3$



4-X
X = CH$_3$, CH$_2$Li, CH$_2$CPhHOH

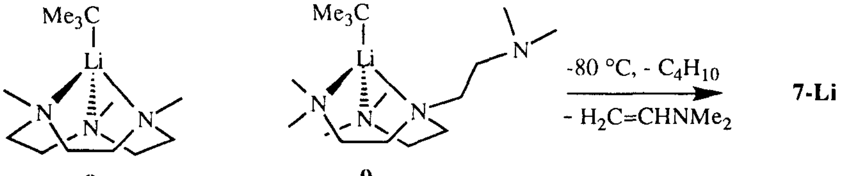


5-X: n = 1, X = CH$_3$, CH$_2$Li,
6: n =2, X = CH$_3$



7-X
X = CH$_2$Li, Li, H, CH$_2$CPhHOH, CH$_2$SnMe$_3$

In the case of t-Bu^{6}Li·**3-CH$_3$**, the ^{13}C chemical shifts of complexed and free (40%) **3-CH$_3$** were the same as those reported for THF-d_8 solutions of neopentyllithium-^{6}*Li*·**3-CH$_3$**[9] and structure **8**, corresponding to that proposed[9] for the latter, was assigned to t-BuLi·**3-CH$_3$**. By analogy, and in view of the preference of lithium for tetracoordination,[10] the t-BuLi complex of **4-CH$_3$** in THF was assigned structure **9**, with a free CH$_2$CH$_2$NMe$_2$ group which, according to the number of ^{13}C signals observed at 165 K (Table 1), exchanges rapidly, on the ^{13}C-NMR time scale, with the coordinated CH$_2$CH$_2$NMe$_2$ groups.



Scheme 1

Significantly, while **8** proved stable up to -20 °C, whence decomposition by attack on THF set in, **9** decomposed, even at -80 °C, to give lithium bis(*N*,*N*-dimethyl-2-aminoethyl)amide (**7-Li**), identified as **7-H**[7] after protonation, and dimethylvinylamine as evidenced by its ^{13}C-NMR signals[11] (Scheme 1).

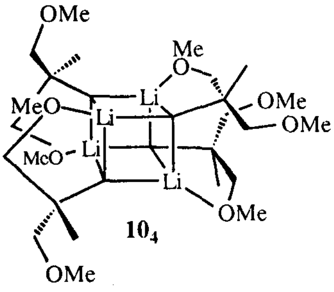
Table 1. Proton Decoupled ^{13}C-NMR Spectra of *t*-Bu^{6}Li·**3-CH$_3$** (**8**), *t*-Bu^{6}Li·**4-CH$_3$** (**9**), **3-CH$_3$** and **7-Li** [62.88 MHz, THF-*d*$_8$, TMS, δ, ppm, (multiplicity)].

T (K)		CLi	CH$_3$	NCH$_3$	NCH$_2$
165	*t*-Bu^{6}Li·**3-CH$_3$** (**8**)	17.49 (3)^a	39.85	45.45	50.60, 56.40^b
	free **3-CH$_3$**			43.50, 49.40	52.45, 59.10, 59.90
215	*t*-Bu^{6}Li·**3-CH$_3$**^{c} (**8**)	17.49	39.85	45.45	53.50
	free **3-CH$_3$**			47.20	57.60
165	*t*-Bu^{6}Li·**4-CH$_3$**^{d} (**9**)	16.90 (3)^e	40.17	46.26, 45.98	51.85, 57.91
210^{f,g}	**7-Li**	-	-	46.38	50.50, 58.16

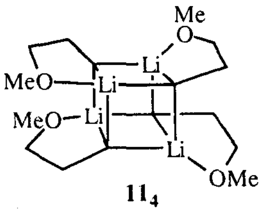
a $^1J(^{13}C,^6Li)$ = 14.3 Hz; ^{b} coalescence temperature: 171 K; $\Delta G^\ddagger$ (171) = 33 kJ·mol^{-1}; ^{c} ^{6}Li-NMR (36.80 MHz): 1.90 ppm; ^{d} ^{6}Li-NMR (36.80 MHz): 2.36 ppm; ^{e} $^1J(^{13}C,^6Li)$ = 13.0 Hz; ^{f}at this temperature, the sample also contains dimethylvinylamine (δ_{CH_2} = 76 ppm, δ_{CN} = 142 ppm); ^{g} data by G.L.J. van Vliet.

In pentane, the greenish precipitate formed by addition of *t*-BuLi to **3-CH$_3$** (TMTAN) even is stable at 20 °C, while, from the precipitate formed by **4-CH$_3$** and *t*-BuLi, **7-Li** is generated, practically quantitatively, at 0 °C within *ca.* 10 minutes.

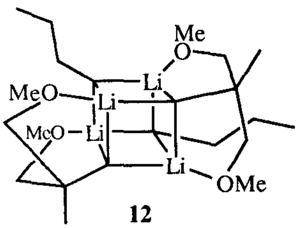
The feature most distinguishing relatively inert **8** from reactive **9** is the fact that in the former all nitrogen atoms are complexed to lithium while the latter possesses a free CH$_2$CH$_2$NMe$_2$ chain. Reduced reactivity of a RLi-complexed Lewis base (LB), where uncomplexed LB (for example, if present in excess), does react with R$_m$Li$_m$·n LB, has been observed before, by ourselves[12] and by others.[13] Thus, 2,2-bis(methoxymethyl)-1-propyllithium (**10**), prevailing in hydrocarbon solutions as the tetramer **10$_4$**[12a] in which one of the methoxy groups of each unit is free, decomposes above -10 °C to give LiOCH$_3$ and 1-methoxymethyl-1-methylcyclopropane, while the related tetramer **11$_4$**,[12b] containing only complexed methoxy groups, is stable. In similar vein, solutions of 1:1-mixtures of **10** and BuLi, containing, presumably, mixed tetramers of type **12** in which all methoxy groups are bonded to lithium,[12c] decompose much more slowly than **10$_4$**.



10$_4$



11$_4$

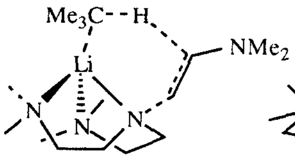


12

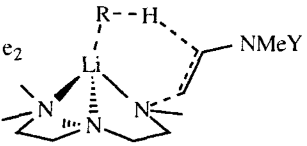
The Thomas group reports[13] that hydrocarbon solutions of *t*-BuLi containing 2 equivalents of ethyl ether or less, *i.e.* in which all ether is present as the di- or tetra-etherate of $t\text{-Bu}_2\text{Li}_2$, show no signs of decomposition, after several hours at -80 °C, whereas solutions containing free ether ($[\text{Et}_2\text{O}t]$:[-BuLi] > 2), begin to decompose immediately. On the basis of the foregoing and of our findings with **8**, **9** and (*vide infra*) **2-CH$_2$Li** and **4-CH$_2$Li**, respectively, we shall proceed in the interpretation of our results as follows: from the structure of a reaction product, a notion of the reactive uncomplexed tertiary amino group in the educt is obtained. From this, on the basis of the known relationships between Lewis base complexation and aggregation of σ-organolithiums,[10] the structure of a potential reacting Bu_mLi_m-polyamine complex is deduced.

In view of the lithiations of TMEDA[4] and PMDTA,[5] respectively, which, in accordance with the relative stability of primary alkyllithiums,[14] take place overwhelmingly at their *N*-methyl groups, exclusive carbanion attack at a free *N*-methylene group of **9** and formation of **7-Li** *cum* dimethylvinylamine was surprising. To account for the remarkable ease of this reaction mode which is novel for amines,[15] transition state **9≠** is proposed, having, to some degree, still the favorable features of concertedness although it is probably well on the E1*cB*-side of the range of variable elimination transition states.

Quite similar transition states **13≠** are possible for **5-CH$_3$** (→ **13a≠**) and **6** (→ **13b≠**) and, in fact, an isomer of **7-Li**, *N*-lithio-*N*,*N*',*N*'',*N*''-tetramethyldiethylenetriamine (**2-Li**) is the only product from these polyamines if they are treated with one equivalent of *n*- or *s*-BuLi in pentane, respectively (-40 °C, 10 min, 88 %, 85 %).[7] Support for **9≠** and **13≠** is derived from the observation that, under the same conditions, the 2,5,8-triaza-11-siladodecane derivative **14a** reacts with all three butyllithiums in a way analoguous to those of **5-CH$_3$** and **6** and that of **4-CH$_3$** with *t*-BuLi: carbanion attack on the *Si*-methylene group rather than on a *Si*-methyl group leads to **2-Li**. The three nitrogens of **14a** can complex to a monomeric organolithium like those of **4-CH$_3$**, while its $\text{CH}_2\text{CH}_2\text{SiMe}_3$ side-chain, which is attacked at SiCH_2, will be free.

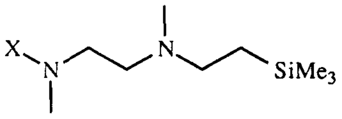


9≠



13≠

a Y = CH_3
b Y = $\text{CH}_2\text{CH}_2\text{N(CH}_3\text{)CH}_2\text{CH}_2\text{N(CH}_3\text{)}_2$
R = *n*-Bu, *s*-Bu, *t*-Bu



14

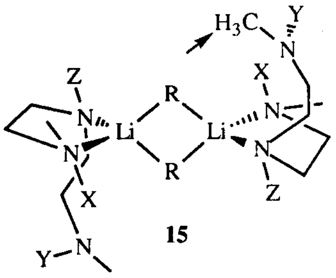
a X = $\text{CH}_2\text{CH}_2\text{N(CH}_3\text{)}_2$
b X = CH_3

Polyamine-alkyllithium oligomer complexes, formation of aminomethyllithiums

Unlike *t*-BuLi, its isomers *n*-BuLi and *s*-BuLi, respectively, in pentane, react readily with **3-CH$_3$** (TMTAN). With one equivalent of reagent, lithiation of N-CH$_3$ (→**3-CH$_2$Li**) is the exclusive reaction (*n*-BuLi, 80 %; *s*-BuLi, 85 %) as indicated by the formation of **3-CH$_2$SiMe$_3$**, isolated after silylation of the reaction mixture. As it seems unlikely that, contrary to **8**, its analogues in which *t*-Bu is replaced by *s*-Bu or *n*-Bu would form **3-CH$_2$Li**, we presume that the complexes formed between **3-CH$_3$** and *s*-BuLi or *n*-BuLi, respectively, differ from **8** and that they contain *uncomplexed N-CH$_3$*. Taking into account the decreasing tendency to form monomer on going from *t*-BuLi *via s*-BuLi to *n*-BuLi,[16] we propose, as the precursors of **3-CH$_2$Li**, TMTAN complexes of butyllithium oligomers, most probably those of dimers **15a**, reacting at the position marked by an arrow.

2-CH$_3$ (PMDTA), with *t*-BuLi in pentane, behaves neither like **3-CH$_3$** (TMTAN, formation of a relatively stable complex) nor like **4(5)-CH$_3$** and **6** (elimination of lithium amide). Instead, depending on the ratio of the reactants, mixtures of **2-CH_2Li** and **7-CH_2Li** are formed {93:7 (*t*-BuLi : **2-CH_3** = 1:1), 35:65 (*t*-BuLi : **2-CH_3** = 2:1)}. Results with *n*-BuLi and *s*-BuLi were similar (Table 2).[5]

The prevalent formation of **2-CH_2Li** for 1:1 ratios of BuLi and **2-CH_3** could be due to PMDTA complexes **15b** of the BuLi dimers. In genesis as well as in structure, **15b** bear a close analogy to *n*-Bu_2Li_2·2 TMEDA, whose solid-state structure has recently been elucidated.[18a]



15

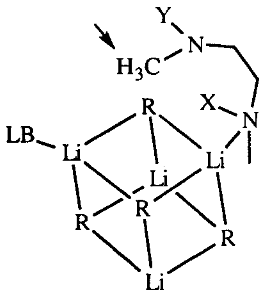
a R = *n*-Bu, *s*-Bu, X-Y = CH_2-CH_2, Z = Me
b R = *n*-Bu, *s*-Bu, *t*-Bu, X = Y = Z = Me
c R = *n*-Bu, *s*-Bu, X = Y = Me, Z = $CH_2CH_2NMe_2$
d R = *s*-Bu, X = Z = Me,Y = $CH_2CH_2NMe_2$

Table 2. Lithiation of **2-CH_3** (PMDTA) with the Isomeric Butyllithiums (pentane, 25°C; rel.-%, g.c., of trimethyltin derivatives).

BuLi	equiv.	Reaction time (h)	**2-CH_2Li** (%)	**7-CH_2Li** (%)
t-BuLi	1	2	93	7
	2	2	35	65
n-BuLi	1	2	80	20
	2	1	63	37
s-BuLi	1	2	98	2
	2	2	75	25

The notion that **2-CH_2Li** is formed by reaction of a free NMe_2 group of **15b** is supported by the quite analogous behavior of the 2,5-diaza-8-silanonane derivative **14b** which is expected to form complexes **15** (X = Z = Me, *SiMe₂* instead of *N-Y*). Unlike its triaza-analogue **14a**, **14b** did not react with *s*-BuLi by attack on the *Si*-methylene group and elimination of dimethylvinylamine. Rather, as evidenced by the ^{13}C-NMR spectrum of the resulting dimeric lithium compound, attack on a *Si*-methyl group, as in the case of **2-CH_3**, took place. This suggests that elimination *via* attack on methylene groups occurs only with monomeric alkyllithiums, whose occurrence becomes probable whenever lithium can be complexed intramolecularly by three nitrogens.[17]

According to our working hypothesis, **7-CH_2Li** is formed from complexes in which the central nitrogen atom of **2-CH_3** is free which could be the case in tetramer complexes **16a** reacting at the position marked by an arrow. Their structures resemble the recently determined solid-state structure of [*n*-Bu_4Li_4· TMEDA]$_\infty$[18a,b] and they should become more important when ratios of BuLi and **2-CH_3** are changed from 1:1 to 2:1. In the case of *t*-BuLi, formation of **7-CH_2Li** from complexes like **16** is improbable, since *t*-Bu_4Li_4 is known to be unable to complex triethylamine.[19] Polymers **17_n** may react at a position marked by an arrow.[20]

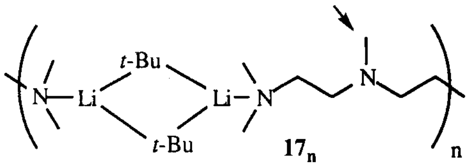


16

a R = *n*-Bu, *s*-Bu, X = Me, Y = $CH_2CH_2NMe_2$, LB = PMDTA

b R = *n*-Bu, *s*-Bu, X = Y = Me, LB = TMEDA

c R = *s*-Bu, X = Me, Y = $CH_2CH_2NMeCH_2CH_2NMe_2$, LB = **5-CH$_3$**



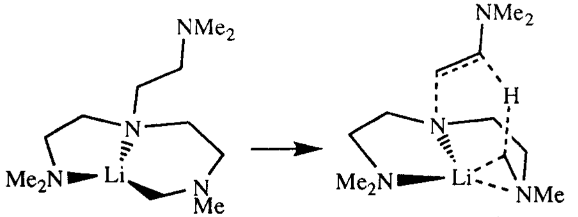
17$_n$

Analogous complexes **16b** are most probably involved in the lithiations of **1-CH$_3$** (TMEDA) with *n*- and *s*-BuLi, respectively,[4a] as may be analogues of **17$_n$** in the TMEDA/*t*-BuLi system.[4b]

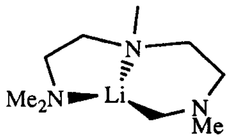
Besides some elimination producing **7-Li**, lithiation of N-CH_3 (→ **4-CH$_2$Li**) is the major reaction of **4-CH$_3$** with *n*-BuLi (70 % **4-CH$_2$Li** + 5 % **7-Li**) and *s*-BuLi (95 % **4-CH$_2$Li** + 5 % **7-Li**), as indicated by the formation of **4-CH$_2$CPhHOH**, isolated after treatment of the reaction mixture with benzaldehyde followed by hydrolysis. Dimer complexes **15c** can account for this. **7-Li** may arise from minor contributions by the *n*-Bu and *s*-Bu analogues of **9**.

After standing at 0 °C for one hour, **4-CH$_2$Li** in pentane had transformed into **7-Li**, probably *via* transition state **4-CH$_2$Li$^{\neq}$**. (In the rapid formation of **7-Li** from **4-CH$_3$** and *t*-BuLi in pentane (*vide supra*), **4-CH$_2$Li** cannot be an intermediate, since it forms **7-Li** more slowly). NMR indicates,[21] **4-CH$_2$Li**, in pentane, to be a monomer containing, most probably, tricoordinated lithium (*cf.* the structure calculated for **2-CH$_2$Li**)[5b] and a *free* $CH_2CH_2NMe_2$ group. The latter, according to our working hypothesis, is the cause of instability. In pentane at 20° C, **2-CH$_2$Li**, also a monomer,[5b] but lacking the free $CH_2CH_2NMe_2$ group, has a half-life of *ca.* 18 hours.

Some lithiation of an internal *N*-methyl group (→ **5-CH$_2$Li**, 31%) was indicated by the formation of **5-CH$_2$D** {together with 53 % **2-H** (from **2-Li** and **13a$^{\neq}$**)} when **5-CH$_3$** was reacted with *two* equivalents of *s*-BuLi (pentane, -40 °C, 10 min) followed by deuterolysis and aqueous work-up. **16c** (or **15d**) could be involved.



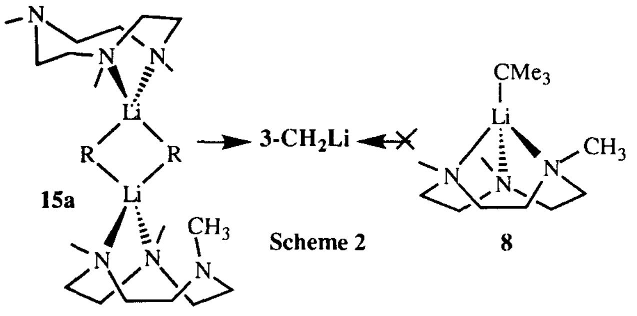
4-CH$_2$Li **4-CH$_2$Li$^{\neq}$**



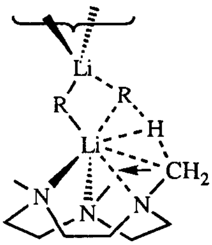
2-CH$_2$Li

DISCUSSION

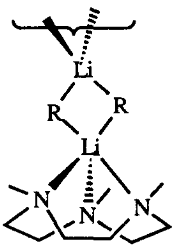
Two dichotomies are noted in this work: (1) If one (some) of the nitrogens of tertiary oligoethylenepolyamines is (are) uncomplexed to lithium, susceptibility to intracomplex (?) deprotonation by organolithiums at NC-H is greater than if uncomplexed nitrogen is altogether absent. (2) If complexes of alkyllithium *oligomers* are expected to prevail, (one of) their uncomplexed *N*-methyl group(s) is lithiated, whereas, if complexes of alkyllithium *monomers* are possible, attack at uncomplexed *N*-methylene leads to elimination of dimethylvinylamine.



Scheme 2



15a$^{\neq}$



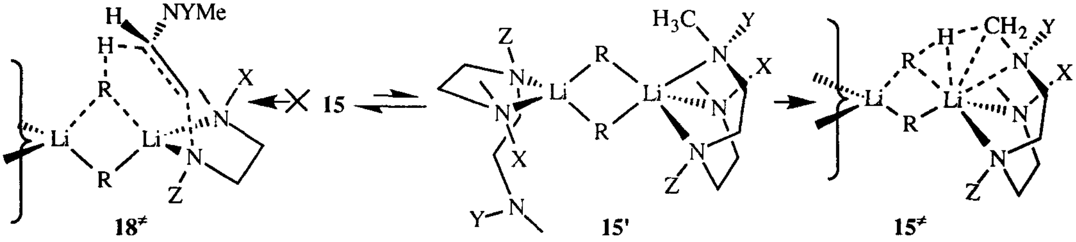
15a'

Notion (1) is counterintuitive on two accounts: complexation to lithium fixes N-CH in close vicinity of Li-R, which, in principle, should favor reaction; in addition, positive charge is induced on nitrogen which should facilitate deprotonation of one of its α-carbon atoms. Why is, in pentane at 20 °C, **3-CH$_2$Li** *not* formed from **8**, while, in the light of our working hypothesis, it does arise readily from **15a** (Scheme 2)?

At present, an answer can only be speculated upon. In the **8** *vs.* **15a** case, conformational differences may play a role. For attack on NMe to form **3-CH$_2$Li**, less motion is required for R in the conformation of **15a** shown, than for Me$_3$C in **8**. In addition, a very favorable coordination state of lithium in **8** will have to be given up for a less favorable one in **3-CH$_2$Li** (*cf.* the structure calculated for its open-chain analogue **2-CH$_2$Li**^{5b}). Clearly, conformational restrictions in *t*-Bu$_2$Li$_2$·nEt$_2$O (n = 2-4) should be less than in **8**, and, to explain the lesser reactivity of complexed ether as compared to *free* ether (in the presence of *t*-Bu$_2$Li$_2$·nEt$_2$O (n = 2-4), *vide supra*)[13], other factors may have to be invoked. These could also operate in the Bu$_m$Li$_m$-polyamine complexes studied here. As one possible general cause of the reactivity difference between complexed and free Lewis base, we suggest {on the basis of calculations of the Schleyer group on related lithiations at a position *ortho* to a heteroatom in benzene derivatives[3,22] (from which we also adopt the interaction between lithium and hydrogen indicated in **15a**$^{\neq}$)} that the free energy of activation of lithiation of initially uncomplexed NMe in **15-17** is lowered by the presence, in the respective transition states (*e.g.* **15a**$^{\neq}$), of a new bond between nitrogen and lithium (indicated in **15a**$^{\neq}$ by an arrow). This favorable factor will be unavailable if the NMe (OR$_2$) moiety is already complexed to lithium in the ground state, as in **8** (**11**$_4$, **12** and *t*-Bu$_2$Li$_2$·nEt$_2$O (n = 2-4)). Obvious precursors of **15a**$^{\neq}$ and its analogues from **15-17** would be complexes like **15a'** (see also **15'** Scheme 3). The normal coordination number of lithium in σ-organolithiums, 4,[10] is exceeded in such complexes and, therefore, we expect them to be less stable than **15-17**(**15a**). However, since organolithium transition states are stabilised by Lewis base coordination more strongly than ground states[23], we surmise that the extra bond, while destabilizing **15a'** and its analogues from **15-17**, still is stabilizing **15a**$^{\neq}$ (and its analogues from **15-17**). In addition, the possibility exists in **15a**$^{\neq}$ and its analogues from **15-17**, but not in a corresponding transition state derived from **8**, that the decrease of bonding between the lithiums and the "active" R (Me$_3$C) can be compensated for, to some degree, by an increase of bonding between the two lithiums and the "passive" R.[24a,b]

Under conditions where dimer complexes **15** are implied to prevail, E2-type elimination transition states **18**$^{\neq}$ do not compete with transition states of NYMe-lithiation **15**$^{\neq}$ (Scheme 3). This lends support to the notion that coordination of NYMe to lithium is a prerequisite for partial detachment of R$^-$ from the R$_m$Li$_m$ core in the transition states of *N*-Me lithiation in σ-organolithium *oligomer* complexes like **15**, **16** and **17**. By contrast, since LB-coordination of lithium is already extensive in most monomers, partial detachment of R$^-$ from the single lithium to which it is bound in σ-organolithium *monomer* complexes may occur without assistance by Li···NYMe bonding. Thus, conformers of monomer complexes BuLi-polyamine, in which H-C(NYMe) points towards Bu, can lead to transition states of concerted elimination (**9**$^{\neq}$, **13**$^{\neq}$ and SiMe$_3$ analogues formed from **14a**).[25, 26]

Scheme 3



In view of the rather similar propensities of ethers and tertiary amines for organolithium complexation, considerations related to those proffered above may also apply to the well-known lithiations (nearly always followed by cleavage or Wittig rearrangement)[27] of ethers.[12a,13,15]

EXPERIMENTAL SECTION

General

If not indicated otherwise, standard apparatus and conditions were used. ^{6}Li chemical shifts are based on 1 M LiBr in THF as external standard [δ (50% LiBr in H_2O): -1.04, δ (2-lithiobutane in C_6D_6): 0.77].

Most experimental details concerning the preparation of **7-Li** (**7-H**) and **2-Li** (**2-H**) from **4-CH$_3$** and **5-CH$_3$** (or **6**), respectively, have already been reported[7] as have the conditions of the reactions of **2-CH$_3$** (PMDTA) with the butyllithiums to give **2-CH$_2$Li** and **7-CH$_2$Li**, respectively (Table 2).[5] Spectral data of their derivatives:

2-CH$_2$SnMe$_3$ ^{1}H-NMR: 0.16 (9H, s, $J_{Sn\text{-}H}$ = 52.4/50.0 Hz, $SnCH_3$); 2.25 + 2.28 + 2.29 (12 H, s + s+ s, NCH_3); 2.36 - 2.56 (8H, m, NCH_2CH_2); 2.62 (2H, s, $J_{Sn\text{-}H}$ = 23.8 Hz, NCH_2Sn). ^{13}C-NMR: - 8.69 [$Sn(CH_3)_3$, $^1J_{Sn\text{-}C}$ = 299.4/285.9 Hz]; 42.75 [$CH_2N(\underline{C}H_3)CH_2$]; 45.71 [$CH_2N(CH_3)_2$]; 46.47 [$CH_2N(\underline{C}H_3)CH_2Sn$, $^3J_{Sn\text{-}C}$ = 30.8 Hz]; 48.14 (NCH_2Sn, $^1J_{Sn\text{-}C}$ = 377.1/358.3 Hz); 55.88 ($CH_2\underline{C}H_2N$); 56.10 ($CH_2\underline{C}H_2N$); 57.17 ($CH_2\underline{C}H_2N$); 58.46 [$\underline{C}H_2N(CH_3)CH_2Sn$, $^3J_{Sn\text{-}C}$ = 35.6 Hz]. MS(CI): 338 ([M+1]$^+$, 80), 267 (6), 172 (100).

2-CH$_2$CPhHOH ^{1}H-NMR: 2.20 [6H, s, $N(CH_3)_2$]; 2.23 (3H, s, NCH_3); 2.31 (3H, s, NCH_3); 2.32 - 2.72 (10 H, m, 5 x CH_2N); 4.53 - 4.68 (1H, m, CHOH); 7.10 - 7.37 (5H, m, $C_{arom}H$). ^{13}C-NMR: 42.23 (NCH_3); 43.26 (NCH_3); 45.72 [$N(CH_3)_2$]; 54.55 (CH_2N); 55.50 (CH_2N); 55.72 (CH_2N); 56.96 (CH_2N); 65.12 (CH_2N); 70.33 (CHOH); 125.70 (2 x C_{arom}); 126.96 (C_{arom}); 128.00 (2 x C_{arom}); 142.75 (C_{arom}). MS(CI): 280 ([M + 1]$^+$).

7-CH$_2$SnMe$_3$ ^{1}H-NMR: 0.20 (9H, s, $J_{Sn\text{-}H}$ = 52.4/50.0 Hz, $SnCH_3$); 2.30 (12H, s, $(CH_3)_2N$); 2.40 - 2.58 (8H, m, $N\underline{C}H_2CH_2$); 2.79 (2H, s, NCH_2Sn). MS(CI): 338 ([M+1]$^+$, 48), 172 (100).

7-CH$_2$CPhHOH ^{1}H-NMR: 2.25 [12H, s, 2 x $N(CH_3)_2$]; 2.31 - 2.82 (10H, m, 5 x CH_2N); 4.56 - 4.78 (1H, m, CHOH); 7.27 - 7.50 (m, 5H, $C_{arom}H$). MS(CI): 280 ([M + 1]$^+$).

Formation of *t*-Bu^{6}Li· 3-CH$_3$ (8)

At -78 °C, 0.30 mmol (0.970 M) *t*-Bu^{6}Li was slowly added to a solution of 0.09 g (0.5 mmol) **3-CH$_3$** (TMTAN) in 3 ml pentane contained in an NMR tube (∅ = 10 mm). Immediately, a green precipitate formed. When the addition was complete, the cooling bath was removed for 30 minutes while, by distillation at high vacuum, the reaction mixture was concentrated to a volume of *ca.* 0.5 ml. Subsequently, the sample was cooled with liquid nitrogen while a mixture of THF and THF-d_8 was distilled into it, whereupon ^{6}Li and ^{13}C-NMR spectra were taken at temperatures starting from 165 K (see Table 1).

Formation of *t*-Bu^{6}Li· 4-CH_3 (9)

At -78 °C, 0.60 mmol (0.970 M) *t*-Bu^{6}Li was slowly added to a solution of 0.151 g (0.66 mmol) **4-CH_3** in 6 ml pentane contained in an NMR tube (Ø = 10 mm). Immediately, a green precipitate formed. When the addition was complete, the sample was warmed to -40 °C and concentrated to a volume of *ca.* 0.5 ml by distillation at high vacuum. Subsequently, the sample was cooled with liquid nitrogen while a mixture of THF and THF-d_8 was distilled into it, whereupon ^{6}Li and ^{13}C-NMR spectra were taken at temperatures starting from 165 K (Table 1).

Formation of bis(*N*,*N*-dimethyl-2-aminoethyl)amine (7-H)[7] from 4-CH_3

(a) At -78 °C, 0.5 mmol (1.3 M) *t*-BuLi was slowly added to a solution of 0.115 g (0.5 mmol) **4-CH_3** in 10 ml pentane. When the addition was complete, the sample was stirred at 0 °C for 10 min, whereupon, first, methanol was added, then, 20 ml aqueous 5M NaOH. After extraction with CH_2Cl_2 (2 x 10 ml) and drying ($MgSO_4$), evaporation of the solvent yielded **7-H** as a colourless oil (0.072 g, 88 %). (b) As above, however, one equiv. of *s*-BuLi was used and the stirring time at 0 °C was 2 hours.

Formation of *N*,*N*',*N*'',*N*''-tetramethyldiethylenetriamine (2-H)[7,28] from 5-CH_3 and 6

At -78 °C, 0.5 mmol (1.3 M) *s*-BuLi was slowly added to a solution of 0.115 g (0.5 mmol) **5-CH_3** {0.172 g (0.5 mmol) **6**} in 10 ml pentane. When the addition was complete, the sample was stirred at 0 °C for one hour, whereupon, first, methanol was added, then, 20 ml aqueous 5M NaOH. After extraction with CH_2Cl_2 (2 x 10 ml) and drying ($MgSO_4$), evaporation of the solvent yielded **2-H** as a colourless oil {0.068 g, 85 %, GC-MS: 160 ($[M+1]^+$, 1.1), 128 (23.9), 115 (34.1), 101 (80.3), 72 98.6), 58 (100)}.

Preparation of 2,5,8,8-tetramethyl-2,5-diaza-8-silanonane (14b) and 2,5,8,11,11-pentamethyl-2,5,8-triaza-11-siladodecane (14a)

General route, R = $CH_2CH_2NMe_2$, $CH_2CH_2NMeCH_2CH_2NMe_2$: RNMeH → RNMeCOMe (**20**) → RNMeCOCH2SiMe3 (**21**) → **14a,b**.

(a) Preparation of **20** (R = $CH_2CH_2NMe_2$ and $CH_2CH_2NMeCH_2CH_2NMe_2$): To stirred aqueous solutions of **1-H** or **2-H**[28] (2.44 mmol/ml) were added at 0 °C, during 1 hour, concommitantly, equivalent amounts of acetyl chloride dissolved in CH_2Cl_2 (1.9 mmol/ml) and aqueous K_2CO_3 (0.5 M), respectively. Hereupon the reaction mixtures were stirred vigorously at room temperature for 3 hours and then extracted twice with CH_2Cl_2. After drying ($MgSO_4$), evaporation of the solvent yielded the reaction products as colorless oils. ^{1}H-NMR (δ, ppm): **20** (R = $CH_2CH_2NMe_2$, 38%) 2.05 + 2.06 (3H, s + s, CCH_3), 2.19 + 2.20 (6H, s + s, $N(CH_3)_2$), 2.4 (2H, m, NCH_2), 3.32 + 3.45 (2H, t + t, ^2J = 6.7 Hz, NCH_2); **20** (R = $CH_2CH_2NMeCH_2CH_2NMe_2$, 35 %) 2.04 + 2.08 (3H,s+s, CH_3), 2.19 (6H, s, NCH_3), 2.22 (3H, s, NCH_3), 2.3-2.6 (6H, m, NCH_2), 2.89 + 2.99 (3H, s+s, NCH_3), 3.33 + 3.45 (2H, t+t, ^2J = 7.2 Hz, NCH_2).

(b) Preparation of **21** (R = $CH_2CH_2NMe_2$ and $CH_2CH_2NMeCH_2CH_2NMe_2$): To freshly prepared solutions of LDA in THF (0.85 mmol/ml), equivalent amounts of **20** were slowly added at -78 °C. After stirring at -78 °C for 1.5 hours, equivalent amounts of neat ClSiMe3 were added and stirring continued at -78 °C for 2 hours whereafter 5M aqueous NaOH (0.53 ml/mmol **20**) was added to the reaction mixture. Twofold extraction (CH_2Cl_2), drying ($MgSO_4$) and evaporation of solvent gave the reaction products as a colorless oils. ^{1}H-NMR (δ, ppm): **21** (R = $CH_2CH_2NMe_2$, 77%) 0.10 (9H, s, $SiCH_3$), 1.93 (2H, s, NCH_2Si), 2.21 + 2.23 (6H, s + s, $N(CH_3)_2$), 2.38 (2H, m, NCH_2), 2.90 + 2.99 (3H, s + s, NCH_3), 3.3 - 3.5 (2H, m, NCH_2); **21** (R = $CH_2CH_2NMeCH_2CH_2NMe_2$, 81%) 0.09 (9H, s, $SiCH_3$), 1.95 + 2.05 (2H, s+s, $SiCH_2$), 2.20 (6H, s, NCH_2), 2.24 (3H, s, NCH_3), 2.3-2.6 (6H, b, NCH_2), 2.90 + 2.98 (3H, s, NCH_3), 3.32 + 3.48, (2H, t+t, ^2J = 7.2 Hz, NCH_2).

(c) Preparation of **14a** and **14b**: To stirred solutions of $LiAlH_4$ in THF (1.2 ml/mmol) were slowly added at 0 °C 0.6 equivalents of **21** in THF (1.7 ml/mmol). The reaction mixtures were refluxed for 1.5 hours, then quenched with water. After addition of 5M aqueous NaOH (0.7 ml/mmol **21**), twofold extraction (CH_2Cl_2), drying ($MgSO_4$), evaporation of solvent and evaporative distillation (70 °C, 10 Torr) yielded the reaction products as colourless oils·**14a** (55 %) GC-MS: 244 ([M-Me]$^+$, 0.9), 201 (25.4), 157 (48.8), 144 (60.6), 115 (70.3), 73 (100), 58 (62.4). ^{1}H-NMR (δ, ppm): 0.00 (9H, s, $SiCH_3$), 0.75 (2H, m, $SiCH_2$), 2.3 (12H, s, NCH_3), 2.35-2.50 (8H, m, NCH_2);**14b** (60%) ^{1}H-NMR (δ, ppm): 0.00 (9H, s, $SiCH_3$), 0.75 (2H, m, $SiCH_2$), 2.25 (3H, s, NCH_3), 2.27 (6H, s, $N(CH_3)_2$), 2.28 (2H, m, NCH_2), 2.35 - 2.50 (4H, m, NCH_2).

Formation of *N,N',N'',N''*-tetramethyldiethylenetriamine (2-H)^7 from 14a

The procedure followed was analogous to that leading to **2-H** from **5-CH_3** or **6**.

Formation of 1-lithiomethyl-4,7-dimethyl-1,4,7-triazacyclononane (3-CH_2Li) and of 1-(trimethylsilyl)methyl-4,7-dimethyl-1,4,7-triazacyclononane (3-CH_2SiMe_3) from 3-CH_3 (TMTAN)

At -78 °C, 1.92 ml 1.3 M *s*-BuLi was slowly added to a stirred solution of 0.43 g (2.5 mmol) **3-CH_3** (TMTAN) in 10 ml pentane. Immediately, a green precipitate formed. The sample was stirred at -78 °C for 3 hours, then, 0.33 g (3.0 mmol) $ClSiMe_3$ was added and stirring continued, at room temperature, for 2 hours. 20 ml aqueous 5M NaOH was added and, after extraction with CH_2Cl_2 (2 x 10 ml), drying ($MgSO_4$), evaporation of the solvent, evaporative distillation (70 °C, 10 Torr) yielded **3-CH_2SiMe_3** as a colourless oil (0.52 g, 85 %). ^{1}H-NMR (δ, ppm): 0.08 (9H, s, $SiCH_3$), 2.05 (2H, s, NCH_2Si), 2.35 (6H, s, NCH_3), 2.65 (8H, s, NCH_2), 2.78 (4H, s, NCH_2). An experiment with *n*-BuLi was carried out analogously (**3-CH_2SiMe_3**: 80% by GC).

Formation of 9-lithio-2,5,8,8-tetramethyl-2,5-diaza-8-silanonane from 14b

At -78 °C, 0.5 mmol (0.45 M) *s*-Bu^{6}Li was slowly added to a solution of 0.101 g (0.5 mmol) **14b** in 6 ml pentane contained in an NMR tube (Ø = 10 mm). The reaction mixture was stirred at 20 °C for one hour, then, by distillation in high vacuum, concentrated to a volume of *ca.* 1.8 ml. After addition of 0.2 ml pentane-d_{10}, ^{13}C-NMR spectra (δ, ppm) indicated a dimer with two magnetically non-equivalent lithiums to be present: -7.50 (C_α, 1:1:1 triplet of a 1:1:1 triplet, $^1J(^{13}C,^6Li)$ = 7.5 en 5.1 Hz), 2.13 ($SiMe_2$), 7.38 ($SiCH_2$), 41.83 (NCH_2), 44.75 (NMe), 46.13 (NMe), 48.95 (NMe), 53.30 (NCH_2), 57.20 (NCH_2), 57.30 (NCH_2).

Formation of 4-CH_2Li and 4-CH_2CPhHOH

At -78 °C, 0.93 mmol (0.45 M) *s*-Bu^{6}Li was slowly added to a solution of 0.214 g (0.93 mmol) **4-CH_3** in 8 ml pentane contained in an NMR tube (Ø = 10 mm). When the addition was complete, the mixture was stirred at 0 °C for 10 min, then concentrated to a volume of *ca.* 2 ml by distillation at high vacuum, whereupon 0.2 ml of pentane-d_{12} was distilled into it and ^{6}Li and ^{13}C-NMR spectra were taken. ^{6}Li-NMR (36.80 MHz, -53 °C, δ, ppm): 1.68 (s). ^{13}C-NMR (-13 °C, δ, ppm): 46.24, 46.34 (NMe_2), 52.49 (NMe), 54.24, 55.35, 58.7 (integrates for 2 carbon atoms), 58.89, 63.62 (NCH_2), 53.26 (C_α, 1:1:1 triplet, $^1J(^{13}C,^6Li)$ = 14.3 Hz). Subsequently, the sample was kept at 0 °C for 10 min, then, part of it was treated with benzaldehyde and worked up in the usual way to give **4-CH_2CPhHOH** in 95 % yield. ^{1}H-NMR: 2.23 [12H, s, 2 x $N(CH_3)_2$]; 2.37 (3H, s, NCH_3); 2.37 - 2.72 (10H, m, 5 x CH_2N); 4.62 - 4.71 (1H, m, CHOH); 7.10 - 7.37 (5H, m, C_{arom}H). ^{13}C-NMR: 42.78 (NCH_3); 45.51 [2 x $N(CH_3)_2$]; 52.28 (2 x CH_2N); 52.54 (CH_2N); 55.02 (CH_2N); 56.86 (2 x CH_2N); 65.61 (CH_2N); 70.09 (CHOH); 125.63 (2 x C_{arom}); 126.86 (C_{arom}); 127.89 (2 x C_{arom}); 142.77 (C_{arom}). MS(CI): 337 ([M + 1]$^+$, 100); 266 (8); 217 (42). The remaining part of the sample was kept at 0 °C for 1hour whereupon the usual work-up gave **7-H** (88%).

Formation of 5-CH$_2$Li from 5-CH$_3$

0.115 g (0.5 mmol) **5-CH$_3$** was reacted with *s*-BuLi as above, however, 1.0 mmol of the latter was used. Quenching with MeOD followed by the usual work-up gave **5-CH$_3$** (16%), **5-CH$_3$-d_1** (31%) and **2-H** (53%). GC-MS: **5-CH$_3$** 173 (0.14), 172 (12.1), 72 (100), 59 (0.62), 58 (97.1); **5-CH$_3$-d_1** 173 (11.7), 172 (5.5), 72 (100), 59 (0.63), 58 (62.2). Lithiation of NMe$_2$ would have led to an increase of the relative intensity of m/z = 59 in the case of **5-CH$_3$-d_1** as compared to **5-CH$_3$**, due to the occurrence of $[CH_2N(Me)CH_2D]^+$. This was not the case. By contrast, the relative intensity of m/z = 173 was much higher in the case of **5-CH$_3$-d_1**, in line with the occurrence of $[CH_2CH_2N(CH_2D)CH_2CH_2NMe_2]^+$ and lithiation of an internal methyl group.

REFERENCES AND NOTES

1 For recent examples and surveys of earlier literature, see: Endo, K., and Otsu, T. *Makromol. Chem., Rapid Commun.* **1993**, *14*, 1; Crassous, G., Abadie, M., and Schue, F., *European Polymer Journal* **1979**, *15*, 747.

2 Many examples involving *N,N,N',N'*-tetramethylethylenediamine (TMEDA, **1-CH$_3$**) are cited and discussed in: Collum, D.B. *Acc. Chem. Res.* **1992**, *10*, 448.

3 van Eikema Hommes, N.J.R.; von Ragué Schleyer, P. *Tetrahedron* **1994**, *50*, 5903.

4 (a) *n*-BuLi, *s*-BuLi (50 °C), Smith, W.N. *Adv. Chem. Ser.* **1974**, *130*, 23; (b) *t*-BuLi (23 °C), Köhler, F.; Hertkorn, N.; Blümel, J. *Chem. Ber.* **1987**, *120*, 2081; X-ray structure of a mixed aggregate RLi·**1**-Li·**1**-H: Harder, S.; Lutz, M. *Organometallics* **1994**, *131*, 5173.

5 (a) Schakel, M.; Aarnts, M.P.; Klumpp, G.W., *Recl. Trav. Chim. Pays-Bas* **1990**, *109*, 305; (b) monomeric nature of **2-CH$_2$Li**: Klumpp, G.W.; Luitjes, H.; Schakel, M.; de Kanter, F.J.J.; Schmitz, R.F.; van Eikema Hommes, N.J.R. *Angew. Chem.* **1992**, *104*, 624, *Angew. Chem. Int. Ed. Engl.* **1992**, *31*, 633.

6 Schakel, M.; Luitjes, H.; Dewever, F.L.M.; Scheele, J.; Klumpp, G.W. *J. Chem. Soc., Chem. Commun.* **1995**, 513.

7 Luitjes, H.; Schakel, M.; Klumpp, G.W. *Synth. Commun.* **1994**, *24*, 2257. In this paper reactions of **5-CH$_3$** and **6** with 2 equiv. of BuLi during 1 hour at 0 °C and 1 hour at 0 °C are described. Since then, it has been found that the conditions given here (see experimental section) suffice.

8 Günther, H.; Moskau, D.; Bast, P.; Schmalz, D. *Angew. Chem.* **1987**, *99*, 1242, *Angew. Chem. Int. Ed. Engl.* **1987**, *26*, 1212.

9 Fraenkel, G.; Chow, A.; Winchester, W.R. *J. Am. Chem. Soc.* **1990**, *112*, 6190.

10 Weiss, E.; *Angew. Chem.* **1993**, *105*, 1565, *Angew. Chem. Int. Ed. Engl.* **1993**, *32*, 1501.

11 *Cf.* Ahmed, Md.G., Hickmott, P.W. *J.C.S. Perkin II* **1977**, 838.

12 a) Moene, W.; Schakel, M.; Hoogland, G.J.M.; de Kanter, F.J.J.; Klumpp, G.W.; Spek, A.L. *Tetrahedron Lett.* **1990**, *31*, 2641; b) see refs. 6 and 7 in 12a; c) Moene, W. *Thesis*, Vrije Universiteit, Amsterdam, 1991.

13 Bates, T.F.; Clarke, M.T.; Thomas, R.D. *J. Am. Chem. Soc.* **1988**, *110*, 5109.

14 (a) Heats of protonation [*s*-BuOH, kJ/(mol of RLi), 25 °C, benzene] show most clearly the higher stability of primary alkyllithiums as compared to secondary ones: $(LiCH_2CH_2CH_2OMe)_4$: -190±2, $(LiCH(Me)CH_2CH_2OMe)_4$: -199±4 [Geurink, P.J.A.; Klumpp, G.W. *J. Am. Chem. Soc.* **1986**, *108*, 538; see also: Arnett, E.M.; Moe, K.D. *ibid.* **1991**, *113*, 7068, 7288]; (b) equilibrium stabilities in presence of ether: Applequist, D.E.; O'Brien, D.F. *J. Am. Chem. Soc.* **1963**, *85*, 743.

15 Formation of olefins by corresponding reactions of alkyllithiums with ethers is well-known, *cf.* Maercker, A. *Angew. Chem.* **1987**, *99*, 1002, *Angew. Chem. Int. Ed. Engl.* **1987**, *26*, 972.

16 *Cf.* Bauer, W.; Winchester, W.R.; von Ragué Schleyer, P. *Organometallics* **1987**, *6*, 2371.

17 *Cf.* Luitjes, H.; de Kanter, F.J.J.; Schakel, M.; Schmitz, R.F.; Klumpp, G.W. *J. Am. Chem. Soc.* **1995**, *117*, 4179.

18 (a) Nichols, M.A., Williard, P.G. *J. Am. Chem. Soc.* **1993**, *115*, 1568; (b) Barnett, N.D.R.; Mulvey, R.E.; Clegg, W.; O'Neil, P. *J. Am. Chem. Soc.* **1993**, *115*, 1573.

19 Lewis, H.L.; Brown, T.L. *J. Am. Chem. Soc.* **1970**, *92*, 4664.

20 *t*-BuLi dimer with tricoordinated lithium: Kottke, T.; Stalke, D. *Angew. Chem.* **1993**,*105*, 619 *Angew. Chem. Int. Ed. Engl.* **1993**, *32*, 580.

21 Luitjes, H. *to be published.*

22 Bauer, W.; von Ragué Schleyer, P. *J. Am. Chem. Soc.* **1989**, *111*, 7191.

23 Kammermeier, B.O.T.; Klumpp, G.W.; Kolthof, K.; Vos, M. *Tetrahedron Lett.* **1991**, *32*, 3111 and ref. 7 given there.

24 (a) See ref. 3; (b) rather analogous assistance of C-Li bond breaking by tighter binding of "passive" nitrogen is discussed in ref. 17.

25 The stability of **7-Li** and **2-Li**, respectively {pKa, 25 °C, THF: **7-H**: 25.2, **2-H**: 26.5 (van Vliet, G.L.J. *unpublished*), diisopropylamine: 35.7 (Fraser, R.R.; Mansour, T.S. *J. Org. Chem.* **1985**, *50*, 3232)} may be the driving force for olefin formation from **9**, **5-CH$_3$**, **6**, **14a** and **4-CH$_2$Li**.

26 Factors related to those discussed for **9**$^{\neq}$ and **18**$^{\neq}$ may also be the cause of the preference for enolate formation from ketones shown by Lewis base-complexed σ-organolithium monomers and and the preference for addition to C=O shown by the corresponding oligomers (see: Luitjes, H.; Schakel, M.; Schmitz, R.F.; Klumpp, G.W. *Angew. Chemie*, **1995**, *117*, 4179; *Angew. Chemie Int. Ed. Engl.*, **1995**, *34*, 2152). Rupture of the carbon-lithium bond with or without the energetic compensation arising from simultaneous formation of an oxygen-lithium bond {*i.e.* assistance of attack by R$^-$ by coordination to lithium of a heteroatom α to the site of attack (as in **15**$^{\neq}$ and analogues formed from **16** and **17**) *or* attack by R$^-$ without coordination of that heteroatom (as in **9**$^{\neq}$, **13**$^{\neq}$ and SiMe$_3$ analogues formed from **14a**)} was proffered as an explanation of the 1,2/1,4 competition in organolithium addition to enones (Cohen, T.; Abraham, W.D.; Myers, M. *J. Am. Chem. Soc.* **1987**, *109*, 7923). We thank Professor Cohen for drawing our attention to his work.

27 As first shown by Still, α-lithioethers obtained by tin-lithium exchange are stable at low temperatures in THF. Overview of the literature: Gawley, R.E., Zhang, Q. *Tetrahedron* **1994**, *50*, 6077.

28 Alder, R.W.; Coclough, D.; Mowlam, R.W. *Tetrahedron Lett.* **1991**, *32*, 7755.

(*Received* 4 *December* 1996)