Diastereoselective Self-Assembly of Chiral Diamine-Chelated Aryllithiums to Dimeric Aggregates

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Abstract: Aryllithium compounds [LiC$_6$H$_4$(CH$_2$N(Et)CH$_2$CH$_2$NEt$_2$)-2]$_2$ (**2b**), [LiC$_6$H$_4$(CH(Me)N(Me)CH$_2$-CH$_2$NMe$_2$-(*R*))-2]$_2$ ((*R*)-**3b**), and [LiC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$-(*rac*))-2]$_2$ ((*rac*)-**3b**) were synthesized and characterized in the solid state and in solution. X-ray crystallographic studies of **2b** and (*R*)-**3b** and molecular weight determinations of **2b**, (*R*)-**3b**, and (*rac*)-**3b** by cryoscopy in benzene showed that, both in the solid state and in apolar, noncoordinating solvents such as benzene, these compounds exist as discrete dimeric aggregates. For (*R*)-**3b** and (*rac*)-**3b** the aggregation process of two monomeric aryllithium units to one dimer is highly diastereoselective.

Introduction

Aryllithium compounds with intramolecular heteroatom coordination have proven to be very useful reagents and are of great interest to organic chemists.[1,2] Especially *ortho*-lithiated aminoarenes, synthesized via so-called directed *ortho* metalation (D*o*M), have been extensively used in organometallic chemistry and catalysis.[3–5] Monoanionic pincer ligands of the type C∧N ([C$_6$H$_4$(CH$_2$NMe$_2$)-2]$^-$), N∧C∧N ([C$_6$H$_3$(CH$_2$NMe$_2$)$_2$-2,6]$^-$) and C∧N∧N′ ([C$_6$H$_4$(CH$_2$N(Me)CH$_2$CH$_2$NMe$_2$)-2]$^-$) are examples of aryl compounds with an *ortho*-amino substituent that can act as an *ortho* directing group (*o*DG).[3,4,6] Although in each case the CH$_2$NMe$_2$ moiety is the same, it is the sequence of nitrogen atoms and C$_{ipso}$ that provides different chelation effects and thus determines the structural features of the resulting aryllithium species. The present study deals with the C∧N∧N′ type of *ortho*-diamine aryl ligand which has two specific features; i.e., the nitrogen atoms of the CH$_2$N(Me)CH$_2$CH$_2$-NMe$_2$)-2 sidearm can coordinate both monodentate and bidentate when chelating. In combination with C$_{ipso}$−Li bonding this results in terdendate C∧N∧N or bidentate C∧N bonding. However, even when the −CH$_2$CH$_2$NMe$_2$ part is noncoordinating, its flexibility still enables the terminal nitrogen atom to approach the metal and to become a spectator moiety.[6]

A unique feature of the C∧N∧N ligand is that N−Li coordination of the benzylic nitrogen atom renders it a stereogenic center. Previous studies showed that [Li(C$_6$H$_4$(CH$_2$N(Me)-CH$_2$CH$_2$NMe$_2$)-2)]$_2$, [LiC∧N∧N′]$_2$, occurs both in solution and in the solid state as a dimeric species in which the *ortho*-diamine substituent is chelate bonded.[6] The (*R*)$_N$(*R*)$_N$ and (*S*)$_N$(*S*)$_N$ enantiomeric pair is formed and isolated as the major isomer. Recently we prepared, in connection with our studies of bromo- and cyanocuprates,[7] also the ethyl analogue [BrC$_6$H$_4$(CH$_2$N(Et)-CH$_2$CH$_2$NEt$_2$)-2] and its corresponding aryllithium derivative. It was found that this compound had a more favorable conformational and configurational stability. In addition, we recently observed that the aryllithium compounds derived from the chiral monoanionic ligand [C$_6$H$_4$CH(Me)NMe$_2$-2]$^-$ show unique diastereoselective self-assembly to tetrameric aggregates.[8] This prompted us to prepare a chiral analogue of this

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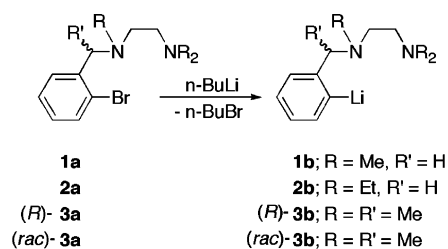
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Scheme 1

1a
2a
(*R*)- 3a
(*rac*)- 3a

1b; R = Me, R' = H
2b; R = Et, R' = H
(*R*)- 3b; R = R' = Me
(*rac*)- 3b; R = R' = Me

ligand, i.e., [C$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2]$^-$, and to study its stereoselective assembly during *ortho*-lithiation. Here we report the synthesis, characterization, and stereochemical features of these aryllithium compounds.

Results

Synthesis of Aryllithium Compounds [Li(C∧N∧N′)]$_2$ 1b, 2b, (*R*)-3b, and (*rac*)-3b. Aryllithium compounds [LiC$_6$H$_4$-(CH$_2$N(Me)CH$_2$CH$_2$NMe$_2$)-2]$_2$ (**1b**), [LiC$_6$H$_4$(CH$_2$N(Et)CH$_2$-CH$_2$NEt$_2$)-2]$_2$ (**2b**), [LiC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$-(*R*))-2]$_2$ ((*R*)-**3b**), and [LiC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$-(*rac*))-2]$_2$ ((*rac*)-**3b**) were prepared quantitatively via a lithium–bromine exchange reaction of the corresponding aryl bromides **1a**, **2a**, (*R*)-**3a**, and (*rac*)-**3a**, respectively, with *n*-BuLi in pentane at −78 °C (see Scheme 1). Aryl bromides **1a** and **2a** were prepared according to a procedure reported earlier,[6,7] while (*R*)-**3a** and (*rac*)-**3a** were prepared following an improved literature procedure.[9] (*R*)-**3a** was obtained with an enantiomeric purity of 98%.

The aryllithium compounds are colorless solids, which are sensitive toward moisture and oxygen, and are soluble in common organic solvents such as benzene and diethyl ether. Molecular weight determinations by cryoscopy in benzene indicated that **2b**, (*R*)-**3b**, and (*rac*)-**3b** exist as dimeric aggregates in solution, as already has been reported for **1b**.[6] Crystals, suitable for X-ray crystal structure determination, of **2b** and (*R*)-**3b** were obtained by crystallization of crude **2b** and (*R*)-**3b**, respectively, from diethyl ether at −30 °C.

Structures of [LiC$_6$H$_4$(CH$_2$N(Et)CH$_2$CH$_2$NEt$_2$)-2]$_2$ (2b), (*R*)-[LiC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2]$_2$ ((*R*)-3b), and (*rac*)-[LiC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2]$_2$ ((*rac*)-3b) in the Solid State. The molecular geometry of **2b** together with the adopted numbering scheme is shown in Figure 1A, while bond distances and bond angles are given in Table 1. The molecular structure of **2b** in the solid state consists of a centrosymmetric dimeric aggregate in which the two aryl units are bridge-bonded (C(1)−Li(1) 2.2707(19), C(1)−Li(1^i) 2.208(2) Å) via two-electron three-center bonds of C$_{ipso}$ between two lithium atoms. The two lithium atoms and the two bridging C$_{ipso}$ atoms are arranged in a perfectly planar arrangement. The two nitrogen atoms of each ethylenediamine substituent are coordinated to the same lithium atom (N(1)−Li(1) 2.1148(19), N(2)−Li(1) 2.1062(19) Å). One of the aryl units is oriented in such a way that its nitrogen atoms bind to the corresponding lithium atom from above the Li(1)−C(1)−Li(1^i)−C(1^i) plane, while for the other aryl unit the nitrogen atoms bind to the lithium atom from below this plane. Because pyramidal inver-

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sion at the benzylic nitrogen atoms is blocked as a result of coordination to the lithium atoms, these nitrogen atoms are stereogenic centers with a rigid configuration. In one-half of the dimer, the nitrogen (NMe) atom has a (*R*)-configuration, while in the other half the nitrogen (NMe) has a (*S*)-configuration. Because the two halves of the dimer are symmetry related by a center of symmetry, the dimer is a *meso*-compound.

The crystal structure of (*R*)-**3b** involves the packing of four dimeric molecules in the acentric unit cell (space group *P*2$_1$). The asymmetric unit contains two independent dimers A and B which are chemically identical but which differ slightly, though not significantly, in structure. The molecular geometry of (*R*)-**3b** (dimer A) together with the adopted numbering scheme is shown in Figure 1B, while bond distances and bond angles for both molecules are given in Table 1.

The overall structural features of (*R*)-**3b** are closely related to those of **2b**. Also in this structure the two bridging aryl groups are oriented in such a way that the benzylic nitrogen atoms approach the C(11)−Li(1)−C(12)−Li(2) plane from opposite sites. As outlined before for **2b**, the benzylic nitrogen atoms become rigid stereogenic centers as a consequence of Li−N coordination, one adopting an (*R*)-configuration while the other one has a (*S*)-configuration. Because the benzylic carbon atoms by definition have a chosen (*R*)-configuration, the dimer consists of two diastereoisomeric parts, having (*R*)$_C$(*R*)$_N$ and (*R*)$_C$(*S*)$_N$ stereochemistry, respectively. Furthermore, it is notable that in the (*R*)$_C$(*R*)$_N$ part of the dimer the benzylic methyl group is oriented anti-periplanar with respect to the aryl group, while in the (*R*)$_C$(*S*)$_N$ moiety this methyl group is in an energetically slightly less favorable in-plane conformation.

The observed ^{13}C CP-MAS NMR spectrum of **2b** is in agreement with the crystal structure; i.e., only one resonance pattern is observed. The observation of three Me resonances at 4.7, 6.1, and 13.5 ppm (for the NEt$_2$ and NEt groupings, respectively) is a consequence of the fact that the terminal NEt$_2$ groups are diastereotopic and thus give rise to two Et-resonance patterns (Figure 2). Unfortunately, no crystals suitable for an X-ray structure determination of (*rac*)-**3b** could be obtained. Therefore, the ^{13}C CP-MAS NMR spectra of (*R*)-**3b** and (*rac*)-**3b** were compared, see Figure 2.

The ^{13}C CP-MAS NMR spectrum of (*R*)-**3b** is rather complicated. This is not unexpected because the dimer contains two diastereoisomeric parts, (*R*)$_C$(*R*)$_N$ and (*R*)$_C$(*S*)$_N$. Moreover, the asymmetric unit contains two independent molecules. Therefore, in the solid-state in principle four sets of resonances are expected for the four different ligand environments. However, as shown in Figure 2, a number of peaks are overlapping. For the α-Me groups four resonances are indeed observed at 9.2, 11.6, 24.9, and 25.4 ppm. For the C$_{ipso}$ atoms two broad resonances are observed at 182.7 and 190.5 ppm. Due to line broadening, most likely as a consequence of ^{7}Li−^{13}C quadrupolar coupling, the splitting due to the two independent molecules in the unit cell is not observed.

The observed ^{13}C CP-MAS NMR spectrum of (*rac*)-**3b** is much less complicated; see Figure 2. Only one resonance pattern is observed of which seven resonances lie in the aliphatic range (25.1, CMe; 39.6, NMe; 47.1 and 48.8, NMe$_2$; 52.3, NCH$_2$; 64.9, NCH$_2$ and 72.0, benzyl-C). In the aromatic region four resonances are observed (183.5, C(1); 157.6, C(2); 142.4, C(6); and 124.5, C(3), C(4), and C(5)). The presence of only one
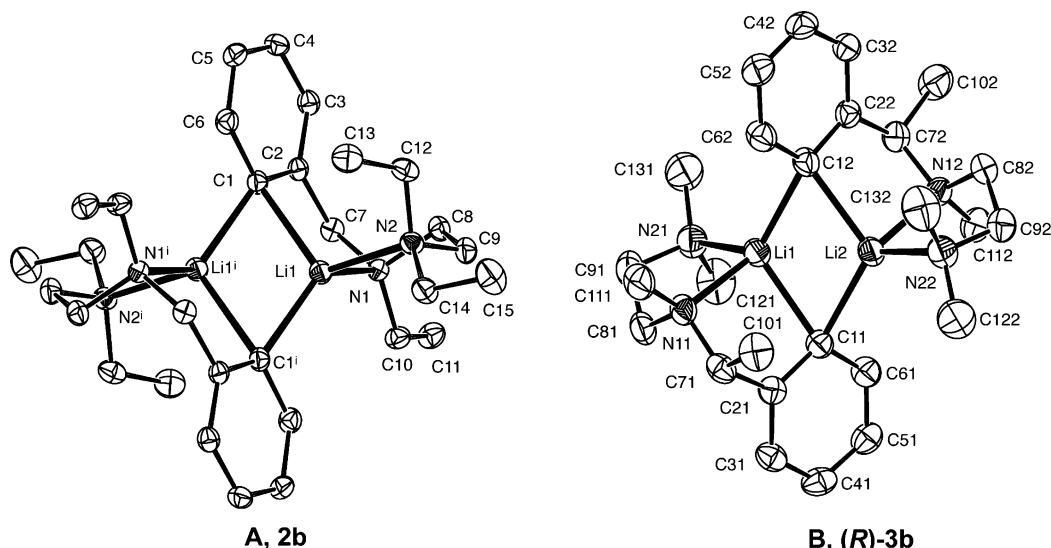
Figure 1. (A) Displacement ellipsoid plot of **2b**. Ellipsoids are drawn at the 50% probability level. Hydrogen atoms are omitted for clarity. Symmetry operation i: $1 - x$, $1 - y$, $1 - z$. (B) Displacement ellipsoid plot of one of the two independent molecules in the crystal structure of compound (*R*)-**3b**. Ellipsoids are drawn at the 50% probability level. Hydrogen atoms are omitted for clarity.
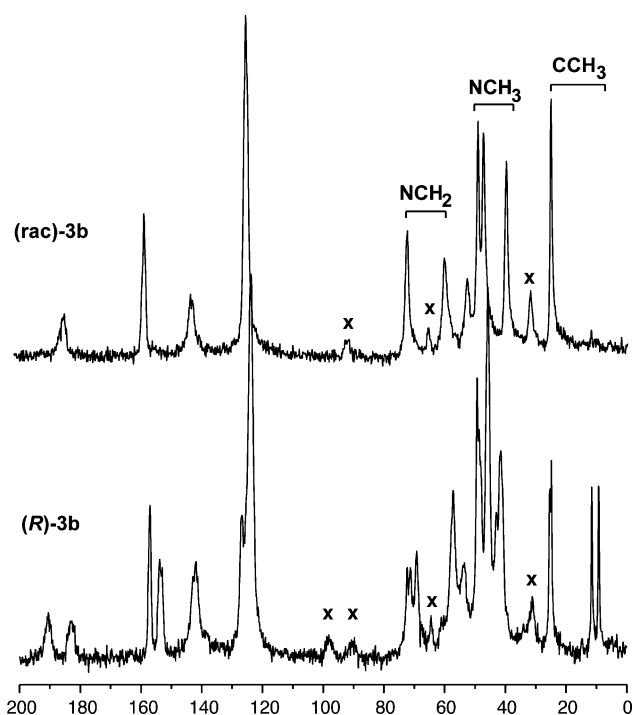
Table 1. Selected Bond Lengths [Å] and Angles and Torsion Angles [deg] for **2b**[a] and (*R*)-**3b**

2b		(*R*)-3b (molecule A)	
Bond Distances (Å)		Bond Distances (Å)	
Li(1)−N(2)	2.1062(19)	Li1−N11	2.119(4)
Li(1)−N(1)	2.1148(19)	Li1−N21	2.084(4)
Li(1)−C(1)	2.2707(19)	Li2−N12	2.130(4)
Li(1^i)−C(1)	2.208(2)	Li2−N22	2.125(4)
		Li1−C11	2.236(4)
		Li1−C12	2.157(4)
		Li2−C11	2.212(4)
		Li2−C12	2.230(4)
Bond Angles (deg)		Bond Angles (deg)	
N(1)−Li(1)−N(2)	88.26(7)	N11−Li1−N21	88.75(16)
C(1)−Li(1)−C(1^i)	115.89(8)	N12−Li2−N22	87.25(16)
C(1^i)−Li(1)−N(1)	128.31(9)	C11−Li1−C12	116.26(19)
Li(1)−C(1)−Li(1^i)	64.11(8)	C11−Li2−C12	114.26(18)
C(6)−C(1)−C(2)	112.73(9)	Li1−C11−Li2	64.25(14)
C(1)−Li(1)−N(1)	87.08(7)	Li1−C12−Li2	65.23(15)
C(1)−Li(1)−N(2)	114.74(8)		
		Torsion Angles (deg)	
		C11−C21−C71−C101	−66.1(3)
		C12−C22−C72−C102	174.2(2)

[a] Symmetry operation i: $1 - x$, $1 - y$, $1 - z$.

Figure 2. ^{13}C CP-MAS NMR spectra of (*rac*)-**3b** and (*R*)-**3b**; × symbols are spinning sidebands.

resonance pattern points to a highly symmetrical structure for (*rac*)-**3b** in the solid state. Most likely this is a dimeric structure in which a center of symmetry is present, like in **2b**, vide supra, suggesting that again a meso compound is formed; i.e., the dimer consists of a $(R)_C(R)_N/(S)_C(S)_N$ combination. However, by definition such a symmetry element cannot be present in (*R*)-**3b**.

A ^{1}H and ^{13}C NMR Study of the Structural Features of 1b,[6] 2b, (*R*)-3b, and (*rac*)-3b in Toluene Solution. The ^{1}H and ^{13}C NMR spectra of **2b** show two resonance patterns in an approximately 2:1 intensity ratio, indicating the presence of two different species in solution. This is especially obvious in the ^{1}H NMR spectrum by the observation of two H(6) resonances at 8.21 (major) and 8.27 ppm (minor) and two AB patterns (3.45 and 4.21 ppm for the major resonance pattern, 3.23 and 4.29 ppm for the minor) for the benzylic CH$_2$ protons. At room temperature the ^{1}H and ^{13}C NMR resonances of the NEt$_2$ groups

are broad. Below 0 °C decoalescence occurs indicating the diastereotopicity of these Et-groups. The presence of two different species in solution was furthermore confirmed by the observation of two resonances (0.46 ppm (major) and 0.36 ppm (minor)) in a 2:1 intensity ratio in the ^{6}Li spectrum of **2b**.

The observation of two resonance patterns in the ^{1}H and ^{13}C NMR spectra of **2b** prompted us to reinvestigate the data for **1b**, which have been reported earlier.[6] It appeared that also for this compound, both in the ^{1}H and ^{13}C NMR spectra two resonance patterns are present in an approximately 6:1 intensity ratio. The chemical shift differences are significantly less than those found for **2b**, but in the ^{1}H NMR spectrum of **1b** a second (low intensity) AB pattern for the benzylic protons is clearly observable.

The ^{1}H and ^{13}C NMR spectra of (*R*)-**3b** show two resonance patterns in a 1:1 intensity ratio. The diastereotopicity of the terminal NMe$_2$ methyl groups is reflected in the observation of two resonances for each pattern. At approximately 25 °C coalescence of each of these resonances begins. At a much higher temperature (100 °C) subsequent coalescence of the remaining two resonance patterns occurs.

Surprisingly, for (*rac*)-**3b** a simple, single resonance pattern is observed at room temperature, in both the ^{1}H and ^{13}C NMR spectra. Below 20 °C decoalescence of the NMe$_2$ resonance occurs into two resonances at 1.20 and 1.40 ppm. Apart from the major H(6) resonance at 8.25 ppm, additional resonances with low intensity (<5%) are observable, which point to the presence of minor amounts of (*R*)-**3b** (δ H(6) = 8.30 and 8.16 ppm) and its enantiomer (*S*)-**3b** in solution.

Discussion

It has been well-established that aryllithium compounds both in the solid-state and in (apolar) solution are aggregated species. The driving force for aggregation is the strong tendency of lithium to attain a tetrahedral coordination geometry, or in exceptional cases a trigonal one. Aggregation occurs via electron-deficient C$_{ipso}$–Li$_n$ (n = 2 or 3) multicenter bonding, while often coordination saturation at lithium is reached by the coordination of additional coordinating solvent molecules or intramolecular coordination of heteroatom-containing substituents (*o*DG).

Phenyllithium in the solid state is a polymer, consisting of [PhLi]$_2$ dimeric units as a leading structural motif, linked to infinite chains via η^6-coordination of lithium to the π-charge density of a phenyl group of an adjacent [LiPh]$_2$ dimeric unit.[10] Deaggregation of the polymer by donor molecules to discrete species is dependent on the donor strength and type of the specific donor molecule. For example in the presence of TMEDA a discrete dimer [PhLi(TMEDA)$_2$]$_2$ is formed,[11] while the presence of the more weakly coordinating diethyl ether gives rise to the formation of a tetramer [LiPh(OEt$_2$)]$_4$,[12] in which the four aryl groups are two-electron four-center bonded to each face of a central Li$_4$ tetrahedron and the fourth coordination site of each lithium atom is occupied by a coordinating diethyl ether molecule.

Aryllithium compounds containing one or more potentially coordinating heteroatoms, so-called *ortho* directing groups (*o*DG), may form of a variety of structural motifs, i.e., dimers,[5a–c,6,13] trimers,[14] tetramers,[13f,15] or higher aggregates.[16] Important factors that control the structure of the actual aggregate formed are (i) the nature of the potentially coordinating substituent, (ii) the position of this substituent relative to the lithium atom, and (iii) the presence (or absence) of coordinating solvent or additional donor molecules. For example, the presence of an *ortho*-CH(R)NMe$_2$ (R = H or Me) substituent produces a tetrameric [LiC$_6$H$_4$CH(R)NMe$_2$-2]$_4$ structure,[8,13f] of which the central aryllithium (hetero-cubane) structural motif is similar to that of [LiPh(OEt$_2$)]$_4$,[12] but with the coordinating diethyl ether molecules replaced by intramolecular coordinating NMe$_2$ groups. Recently we reported that [LiC$_6$H$_4$CH(Me)-NMe$_2$-2]$_4$ reacts with *n*-BuLi to give a [Li$_4$(C$_6$H$_4$CH(Me)NMe$_2$-2)$_2$(*n*-Bu)$_2$] hetero-aggregate also having a hetero-cubane structural motif comprising two assembled dimeric subunits, one aryllithium dimer and one butyllithium dimer.[17] Due to the presence of the chiral C$_6$H$_4$CH(Me)NMe$_2$-2 ligand, the self-assembly process leading to this structure is highly diastereoselective. In this respect it should be noted that it was shown earlier that the lithiation of the benzylic carbon atom in 1-[(benzyldimethylsilyl)-(*S*)-2-methoxymethylpyrrolidine] is highly diastereoselective,[18] as was evidenced by the X-ray structures of the TMEDA and DABCO complexes of the lithiated products.[19]

Furthermore, it has been shown that strongly coordinating solvents such as THF or additional donor molecules such as TMEDA[11,20c,d] and PMDTA[20d] are capable of breaking down such aggregates. Also in this case the presence of potentially intramolecular-coordinating substituents (*o*DG) will influence the remaining degree of aggregation. For example, considerable amounts of monomeric PhLi are present either in a THF solution of PhLi at low temperature[20] or in the presence of PMDTA.[20d] In the latter case, its monomeric structure has been established by an X-ray crystal structure determination.[21] In contrast, THF, TMEDA, or PMDTA are only capable of breaking down tetrameric [LiC$_6$H$_4$CH$_2$NMe$_2$-2]$_4$ into dimeric species,[5d,13f,h] indicating that in this process the *ortho*-(dimethylamino)methyl substituent plays a crucial role as an *o*DG.

X-ray crystallographic studies of **1b**,[6] **2b**, and (*R*)-**3b** and molecular weight determinations of **1b**,[6] **2b**, (*R*)-**3b**, and (*rac*)-**3b** by cryoscopy in benzene showed that both in the solid state and in apolar, noncoordinating solvents such as benzene these compounds exist as discrete dimeric aggregates. The overall structural motif as observed in the solid-state of these compounds, vide supra, closely resembles that of [LiPh(TME-

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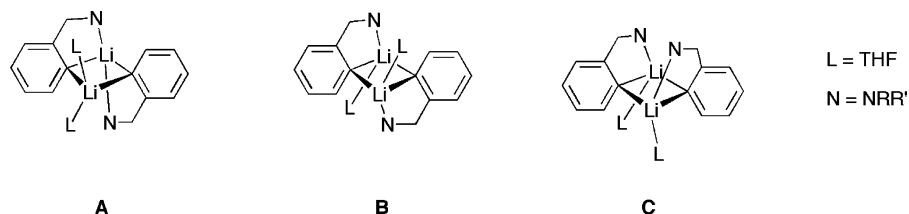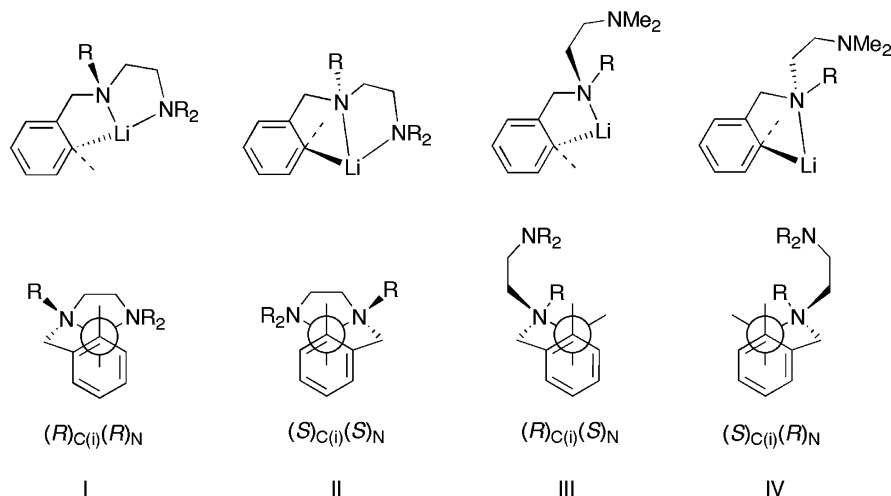
Figure 3.

Figure 4. Different stereochemical possibilities of C∧N∧N′-type aryllithium monomeric units.

DA)]₂.[11] (In fact these compounds may be regarded as PhLi containing an intramolecularly connected *ortho*-ethylenediamine unit.) A difference is the orientation of the aryl ring with respect to the C_{ipso}–Li–C_{ipso}–Li plane. In [LiPh(TMEDA)]₂ the aryl rings are oriented perpendicular to this plane.[11] In **1b**,[6] **2b**, and (*R*)-**3b**, the dihedral angles are 63.3(5)°/66.4(5)°, 53.53(7)° and 50.27(15)°/55.51(15)° (molecule A), 49.66(17)°/58.62(16)° (molecule B), respectively, which is not unexpected because they are a consequence of *ortho*-chelation.

Before discussing the observed data in detail, the various implications of the stereochemical aspects of this type of compounds will be outlined.

Elegant studies by Reich et al. have shown that 2-[(dialkyl-amino)methyl]phenyllithium compounds exist in polar, coor-dinating solvents such as THF as an equilibrium mixture of three geometrically different dimeric aggregates, A, B, and C, in each of which the dialkylamino substituent is coordinated to lithium; see Figure 3.[5b–e]

In the **A** type aggregate both dialkylamino substituents are coordinated to the same lithium atom, while they are positioned at opposite sites of the C_{ipso}–Li–C_{ipso}–Li plane. Coordination saturation of the second lithium atom is reached by coordination of two THF molecules. In the **B** and **C** type aggregates each lithium atom is coordinated to only one dialkylamino substituent and one THF molecule. The difference between **B** and **C** is the orientation of the dialkylamino substituents with respect to the C_{ipso}–Li–C_{ipso}–Li plane. In **B** these amino substituents lie on opposite sides of this plane, while in **C** both substituents lie on the same side. The ratio of **A**, **B**, and **C** in solution depends on the nature of R and R′. (For example, for R = R′ = Me in a THF/Me₂O/Et₂O mixture this ratio is 54:38:8, and for R = R′ = Et the major isomer is **B**.)[5c,d] An important feature of the present (LiC∧N∧N′)₂ structures is that when R and R′ are different and Li–N coordination is rigid, pyramidal inversion

at nitrogen is blocked and the nitrogen atoms become rigid chiral centers (labeled $(R)_N$ or $(S)_N$).

The dimers **A**, **B** and **C** may serve as models for the compounds discussed here, in which R = Me or Et and R′ is a CH₂CH₂NR₂ group. The structures of **1b** and **2b** in the solid state and their NMR data (vide supra) show that the terminal nitrogen atoms of the 2-(dialkylamino)ethyl substituents are involved in Li–N coordination and thus have replaced the coordinated THF molecules present in structures A, B, and C. Previous modeling studies[6] have shown that in a type **A** structure the terminal nitrogen atom of the 2-(dialkylamino)ethyl sub-stituent can never reach the second lithium atom. Therefore, such a structure can be a priori excluded, and only **B** and **C** type aggregates have to be considered as possible structures.

For a better understanding of the stereochemical aspects that may play a role in the formation of such aggregates, it is useful to discuss these aspects for a hypothetical monomeric unit. First, it should be noted that the bridging C_{ipso} atom is a stereogenic center in the rotation conformers (aryl rotation around C_4–C_{ipso}) shown in **A**–**C** (Figure 3, labeled $(R)_{C(i)}$ or $(S)_{C(i)}$).[22] Because a monomeric unit contains two chiral centers there are four different possibilities, $(R)_{C(i)}(R)_N$, $(S)_{C(i)}(S)_N$ (an enantiomeric pair), $(R)_{C(i)}(S)_N$, and $(S)_{C(i)}(R)_N$ (also an enantiomeric pair, but diastereoisomers with respect to the previous pair). In Figure 4 these four different stereochemical possibilities I, II, III, and IV are schematically shown, together with a Newman projection along the C_{ipso}–Li axis.

As a consequence of the different orientations in space of the two substituents at the benzylic nitrogen atoms, only in two

(22) (a) The configuration of the bridging C_{ipso} center in the rotamer having the aryl plane perpendicular to the Li–Li vector is determined by the priority of the atoms connected to C_{ipso} in the C,N-chelate ring, viewing in the direction of the second lithium atom. (b) van Koten, G.; Noltes, J. G. *J. Am. Chem. Soc.* **1979**, *101*, 6593.
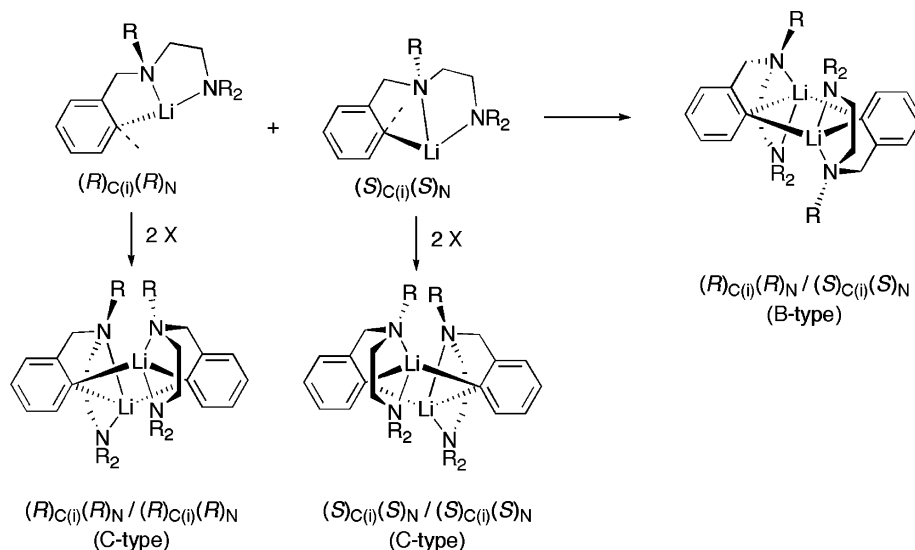
Figure 5. Possible combinations of two C∧N∧N′-type aryllithium monomeric units.

combinations of the two chiral centers, i.e., $(R)_{C(i)}(R)_N$ and $(S)_{C(i)}(S)_N$, the 2-(dialkylamino)ethyl substituent is oriented so that the terminal nitrogen atom can coordinate with the lithium atom (I and II in Figure 4). Therefore, in resting-state structures, i.e., when both nitrogen atoms are coordinated and the Li−N coordination-decoordination process is slow or blocked, only two structures (I and II) have to be considered.

There are two ways in which a dimeric molecule can be assembled from two monomeric units; see Figure 5. The first involves the combination of either two I-type or two II-type monomers, affording $(R)_{C(i)}(R)_N/(R)_{C(i)}(R)_N$ and $(S)_{C(i)}(S)_N/(S)_{C(i)}(S)_N$ overall stereochemistries (enantiomeric pairs). These are by definition dimers of the **C**-type; i.e., both benzylic nitrogen atoms lie at the same side of the C_{ipso}−Li−C_{ipso}−Li plane.

The second possibility is a combination of a I-type and II-type monomer, affording a **B**-type dimer, having $(R)_{C(i)}(R)_N/(S)_{C(i)}(S)_N$ stereochemistry. In this case the benzylic nitrogen atoms lie on opposite sides of the C_{ipso}−Li−C_{ipso}−Li plane. This dimer is a meso compound and a diastereoisomer of the previous two.

The X-ray crystal structure determination of **2b** reveals a **B**-type structure with $(R)_{C(i)}(R)_N/(S)_{C(i)}(S)_N$ stereochemistry. This is in contrast with the observed structure for **1b**, for which a **C**-type was established by an X-ray crystal structure determination.[6] For this latter compound both enantiomers, i.e., $(R)_{C(i)}(R)_N/(R)_{C(i)}(R)_N$ and $(S)_{C(i)}(S)_N/(S)_{C(i)}(S)_N$, are present in the crystal lattice. That **2b** exists as one diastereoisomer in the solid state became evident from its ^{13}C CP-MAS spectrum. In apolar solvents, however, the ^1H and ^{13}C NMR spectra of both **1b** and **2b** show in each case the presence of two resonance patterns for each compound (vide supra), indicating the existence of an equilibrium between a **B**-type and a **C**-type aggregate in solution. The NMR intensity ratios between the different aggregates, 6:1 and 2:1 for **1b** and **2b**, respectively, point to a relatively small difference in thermodynamic stability between a **B**-type and a **C**-type aggregate. Which aggregate finally crystallizes from solution is controlled by solubility differences and packing effects in the crystal lattice.

Based on the same arguments, outlined above, when a third rigid chiral center is introduced, i.e., the chiral benzylic carbon

atom (labeled $(R)_{C(b)}$ in (R)-**3b**), three different aggregated dimers should be considered. These will have $(R)_{C(i)}(R)_{C(b)}(R)_N/(S)_{C(i)}(R)_{C(b)}(S)_N$ (**B**-type), $(R)_{C(i)}(R)_{C(b)}(R)_N/(R)_{C(i)}(R)_{C(b)}(R)_N$, and $(S)_{C(i)}(R)_{C(b)}(S)_N/(S)_{C(i)}(R)_{C(b)}(S)_N$ (both **C**-type) stereochemistries, respectively, as shown in Figure 6. The latter two dimers are not enantiomers but diastereoisomers. It should be noted that the first aggregate (**B**-type) lacks a symmetry element, and therefore the two halves of the dimer are inequivalent. In both **C**-type aggregates the two halves of the dimer are symmetry related. Consequently, this would give rise to the observation of only one resonance pattern in the ^1H and ^{13}C NMR spectra. It is this **B**-type structure that is found for (R)-**3b** by an X-ray crystal structure determination (vide supra). The dissymmetry of this structure in the solid state was furthermore confirmed by its ^{13}C CP-MAS spectrum, showing two different resonance patterns (vide supra).

The solution ^1H and ^{13}C NMR spectra of (R)-**3b** also show two resonance patterns in a 1:1 intensity ratio indicating that this dissymmetric **B**-type structure is also present in solution. A variable temperature ^1H and ^{13}C NMR study of (R)-**3b** in toluene solution points to the occurrence of two different processes. The coalescence of the diastereotopic NMe_2 methyl resonances at 25 °C points to a process involving N−Li coordination−decoordination that becomes fast on the NMR time scale above this temperature. At this temperature still two different resonance patterns are observed for the two diastereoisomeric halves of the dimer. This indicates that the configuration of the stereogenic benzylic nitrogen atom is still rigid on the NMR time scale. However, at 100 °C coalescence of these two resonance patterns occurs to a single resonance pattern. The only explanation for this observation is a process involving Li−N coordination-decoordination of the benzylic nitrogen atom that becomes fast on the NMR time-scale. Such a process allows pyramidal inversion of configuration of this benzylic nitrogen atom and thus would render the two diastereoisomeric parts in the dimer homotopic.

For (rac)-**3b**, apart from the three different diastereoisomers (and their corresponding enantiomers) obtained from a combination of two hypothetical monomers having the same stereochemistry at the benzylic carbon center (vide supra), also the
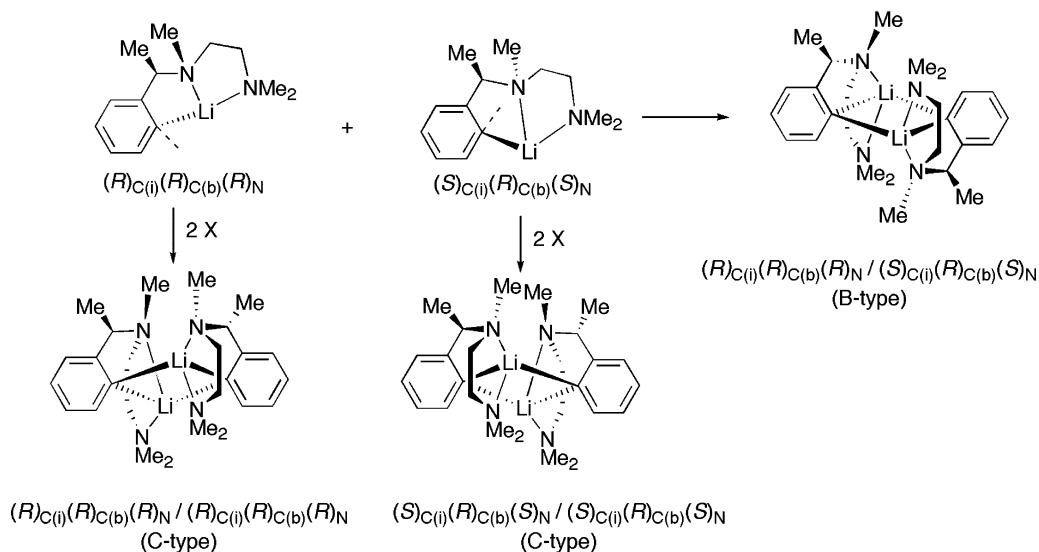
Figure 6. Possible combinations of two C∧N∧N′-type aryllithium monomeric units with a (R)-chiral benzylic carbon atom.
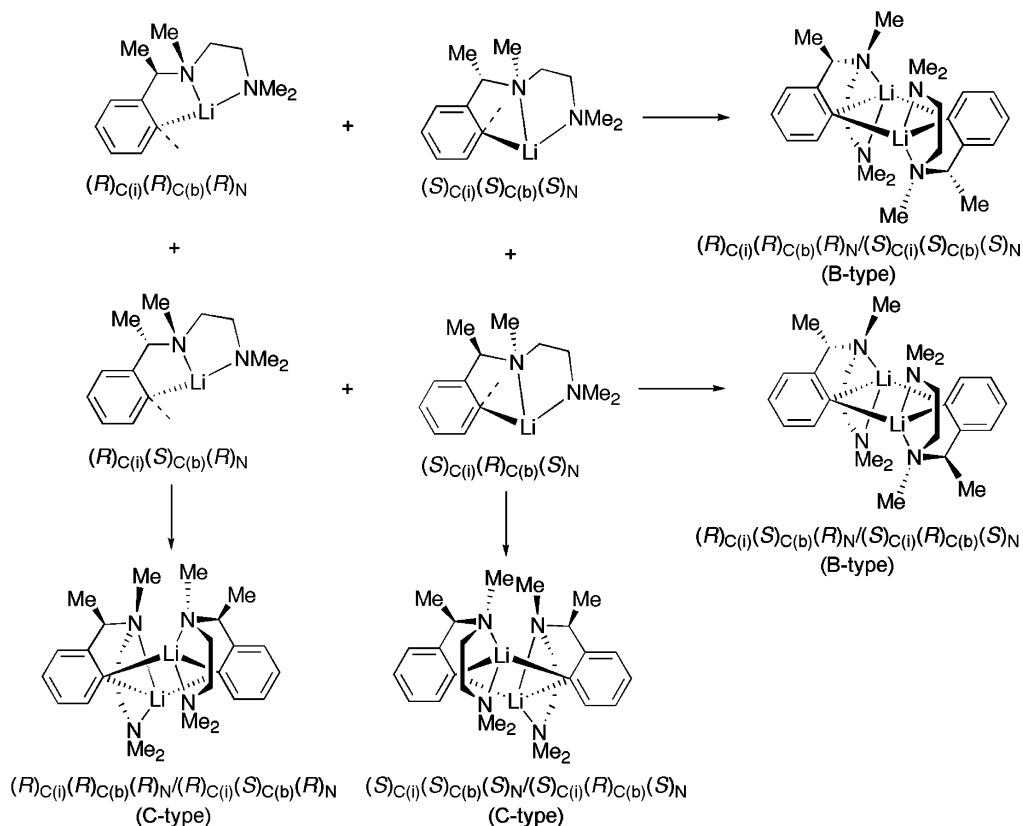
Figure 7. Possible combinations of two C∧N∧N′-type aryllithium monomeric units with one (R)- and one (S)-benzylic carbon atom.

formation of aggregated dimers in which the chiral benzylic carbon atoms have opposite stereochemistry must be considered; see Figure 7.

The various combinations afford four possible structures having $(R)_{C(i)}(R)_{C(b)}(R)_N/(R)_{C(i)}(S)_{C(b)}(R)_N$, $(S)_{C(i)}(R)_{C(b)}(S)_N/(S)_{C(i)}(S)_{C(b)}(S)_N$ (both **C**-type), $(R)_{C(i)}(R)_{C(b)}(R)_N/(S)_{C(i)}(S)_{C(b)}(S)_N$, and $(R)_{C(i)}(S)_{C(b)}(R)_N/(S)_{C(i)}(R)_{C(b)}(S)_N$ (both **B**-type) stereochemistries, respectively. The first two are enantiomers, but due to lack of a symmetry element, the dimers consists of two diastereoisomeric parts. In the latter two compounds, the two halves of the dimers are symmetry-related by a center of symmetry and therefore these dimers are meso compounds.

Based on the above-described arguments, for the racemic material six different diastereoisomeric dimers (three B-types and three C-types) and their corresponding enantiomers might be formed. Interestingly, the observation of relatively simple ^{1}H and ^{13}C NMR spectra in solution and ^{13}C CP-MAS spectrum in the solid state (vide supra) indicates that (*rac*)-**3b** exists in solution and in the solid state as a single diastereoisomer. Because single resonance patterns are observed in the NMR spectra, it is either the one with $(R)_{C(i)}(R)_{C(b)}(R)_N/(S)_{C(i)}(S)_{C(b)}(S)_N$ or the one with $(R)_{C(i)}(S)_{C(b)}(R)_N/(S)_{C(i)}(R)_{C(b)}(S)_N$ (both B-type) stereochemistry. It is obvious that in the first one the steric congestion between the various substituents present in

the molecule is more enhanced compared to that in the latter dimer. Therefore the latter proposed structure seems to be more likely. The low intensity resonance pattern (<5%) observed in the ^{1}H NMR spectrum of (*rac*)-**3b** is superimposed with that of (*R*)-**3b**. It is obvious that in solution an equilibrium exists between all possible diastereoisomers, but only one, most probably with $(R)_{C(i)}(S)_{C(b)}(R)_N/(S)_{C(i)}(R)_{C(b)}(S)_N$ stereochemistry, is the thermodynamically favored one, while a small amount of (*R*)-**3b** and its enantiomer (*S*)-**3b** is observable.

It can be concluded that, although for both (*R*)-**3b** and (*rac*)-**3b** a variety of diastereoisomeric dimers is possible, in both cases only one specific dimer is formed in excess, both in the solid state and in solution. This indicates that the aggregation process of two monomeric aryllithium units to one dimer is highly monomer−dimer diastereoselective.

Concluding Remarks

In previous work, Reich et al. have made extensive use of ^{6}Li and ^{13}C (VT) NMR spectroscopy to examine the solution properties of [RLi] species in polar solvents such as THF.[5b−d] This work effectively quantified (in solution) the relative ratios of monomers, dimers, and higher order aggregates with and without the addition of donor solvent molecules (e.g., HMPA). These studies have detailed the complex solution chemistry of many [RLi] species and include those compounds that contain a tertiary amine functionality that is capable of coordination to the Li atom(s).

The work herein entails an investigation of [RLi] compounds that are known to exist only as dimers in the solid state (X-ray) *and* in solution (NMR, cryoscopy) in exclusively nonpolar solvent environments. The central theme is concerned with the structural effect(s) (in both solid-state and solution) on *ortho*-lithiated aromatic benzylamines that contain a further tethered amine group. This group can be envisioned as representing a single donor "solvent" molecule that is kept in close proximity to the Li metal center(s). The advantage here is that these dimeric species do not undergo any observable secondary equilibrium processes resulting in the formation of monomeric, dimeric, or higher order aggregates. We therefore have the unique opportunity to study the structural ramifications of induced and/or predetermined chirality on the diastereomeric [RLi]$_2$ aggregation properties. The observations discussed above have been centered on providing information which is key to the understanding of the structural aspects which lead to selective formation of diastereomeric and enantiomeric [Li(CNN)]$_2$ species. That is, bonded *pairs* of organolithiums in which chirality has been rigorously defined by a secondary chiral center ((*R*)-**3b**) *and/or* induced chirality at Li and N (**1b**, **2b**, **rac-3b**). These chiral properties are shown to influence both the solution and solid-state formation of various possible diastereomers of the [RLi]$_2$ aggregates.

Let us now conclude and consider a brief summary of the effects of induced chirality at Li (and N) on the formation of the various complexes described herein. The self-assembly of two [Li(CNN)] fragments which comprise **1b** gives exclusively only the racemic mixture (1:1) of (*R*),(*R*)-[Li$_2$(CNN)$_2$] and (*S*),(*S*)-[Li$_2$(CNN)$_2$] (chirality in this case being defined only at the Li centers). The meso form of **1b** (i.e., (*R*),(*S*)-[Li$_2$(CNN)$_2$]) is not a thermodynamic aggregate. Steric effects appear to be responsible for the *opposite* result when the two [Li(CNN)]

pieces of **2b** combine; in this case only the meso form (*R*),(*S*)-[Li$_2$(CNN)$_2$] is observed.

Attempts to direct or modify the diastereomeric ratio of these dimers was addressed in a classical sense by the addition of a second fixed chiral center (one moiety of the (*R*)-**3b** dimer) and then comparing the self-assembly properties of this species with that of complex **1b**. In this case, secondary chirality at the benzylic position does not lead to modified diastereoselectivity ((*R*)-**3b** is "meso" with respect to chirality at Li when compared to **2b**). Thus, the overall stereochemical outcome at Li is identical to the purely steric (not enantiomeric) modifications of bulkier alkyl groups displayed by **2b**. That is to say that exchange of methyl groups on the N atoms of **1b** by ethyl groups (**2b**) has the identical stereochemical influence at Li in the resulting dimeric aggregate as does the introduction of an auxiliary chiral center ((*R*)-**3b**). Thus, steric effects (not auxiliary chirality) appear to be a primary gateway to controlling the diastereoisomeric ratios in these aggregates. This is further exemplified by our examination of (*rac*)-**3b**, where chiral (at Li) [Li(CNN)] fragments selectively self-assemble only with the fragments having opposite (at Li) chiral centers. Such unusual stereoselective self-assembly has been observed previously by us in the selective self-aggregation of [(*R*),(*R*),(*R*),(*R*)-{Li$_2$(NCN*)$_2$}] (NCN* = 1,3-[Me$_2$NCH(Me)]$_2$C$_6$H$_3$) isolated from mixtures of 1:1 rac/meso 1,3-bis[1-(dimethylamino)-ethyl]-2-lithio-benzene.[13i] Again, steric effects are likely playing a vital role. These experiments have further demonstrated the complex nature of organolithium aggregation phenomena in the solid state and *in apolar solvents*. In the latter situation, the formation of monomeric or other Li aggregates is excluded by the addition of a secondary (tertiary) N-donor group held in close proximity to the lithium nuclei. This additional binding fragment leads to kinetically and thermodynamically stable dimeric species [Li$_2$(CNN)$_2$]. Future work will entail attempts to control such aggregation properties in mixed aryl/alkyl organolithium and related species.

Experimental Section

All experiments were carried out under a dry, oxygen-free nitrogen atmosphere using standard Schlenk techniques. Solvents were dried and distilled prior to use. All standard chemicals were purchased from ACROS and Aldrich Chemical Co. and used as received. Reactions involving organolithium syntheses were carried out in flame-dried Schlenk flasks. The starting material (*S*)-(−)-2-bromo-α-methylbenzyl alcohol with an optical purity of 99% was obtained from Aldrich Chemical Co.. The starting materials C$_6$H$_4$Br(CH$_2$N(Et)CH$_2$CH$_2$NEt$_2$)-2[6] and (*rac*)-2-bromo-α-methylbenzyl-alcohol[9,23] were prepared according to a literature procedure. ^{1}H, ^{13}C, and ^{6}Li NMR spectra were recorded on a 300 MHz spectrometer at ambient temperature unless otherwise stated. Chemical shifts (δ) are given in ppm relative to SiMe$_4$ as an internal standard (^{1}H and ^{13}C) or to LiCl in D$_2$O (1 M) as an external standard. Coupling constants are in Hz.

^{13}C CP-MAS NMR spectra were recorded at 75 MHz on a Varian Inity Inova spectrometer equipped with a 7 mm VT CP-MAS probe. Samples were spun at 7000 Hz in silicon nitride rotors. Cross polarization contact times ranged from 1 to 3.5 ms. Spectra were averaged from 900 to 3000 FIDS. A line broadening factor of 10 Hz was applied. Chemical shifts are relative to SiMe$_4$. External adamantane (δ 29.2 and 38.3 ppm) was used as secondary chemical shift reference.

Elemental analyses were obtained from Kolbe Mikroanalytisches Laboratorium, Mülheim a.d. Ruhr, Germany. Cryoscopic measurements

(23) Reynolds, K. A.; Finn, M. G. *J. Org. Chem.* **1997**, *62*, 2574.

were carried out using a S2541 thermolyzer and a metal-mantled Pt-100 sensor.[24] For calibration, naphthalene was used to determine the cryoscopic constant K_f = 5.54 K kg mol^{-1}.

(*R*)-[BrC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2] ((*R*)-3a). (*S*)-(−)-2-Bromo-α-methyl-benzyl alcohol (5.03 g; 25.05 mmol) and triethyl-amine (7 mL; 50.03 mmol) were dissolved in CH$_2$Cl$_2$ (70 mL) and cooled to −78 °C. Methanesulfonyl chloride (2.15 mL; 27.52 mmol) was added dropwise within 30 min, and the mixture was stirred at low temperature for another 30 min. *N*,*N*,*N*′-Trimethylethylenediamine (3.5 mL; 27.52 mmol) was added in portions of 1 mL to the suspension. This mixture was stirred for an additional 2 h at low temperature and then left overnight to warm to room temperature slowly. The suspension formed was quenched with an aqueous HCl solution (2 M; 100 mL; until pH < 2) and separated from the organic layer. The aqueous layer was washed with Et$_2$O and subsequently made alkaline with solid KOH to pH > 12. The product was extracted with pentane (80 mL, 3×). The combined organic layers were washed with brine and dried over Na$_2$SO$_4$, and the solvent was removed in vacuo to yield (*R*)-3a as an almost colorless oil. Purification via Kugelrohr distillation yielded 2.34 g (33%) of (*R*)-3a as a colorless oil. The ee (98%) was determined by HPLC analysis: eluent 2% propan-2-ol in hexane; flow rate 1.0 mL min^{-1}; retention time 252 s for the (*S*)-enantiomer and 285 s for the (*R*)-enantiomer.

^{1}H NMR (C$_6$D$_6$, 300.105 MHz, 298 K): δ 1.15 (d, 3H, ^3J = 6.6 Hz, CH(*Me*)), 2.01 (s, 6H, N*Me*$_2$), 2.14 (s, 3H, N(*Me*)), 2.29, 2.51 (2 × m, 2H, NCH$_2$CH$_2$N), 3.99 (q, 1H, ^3J = 6.6 Hz, C*H*(Me)), 6.67 (t, 1H, Ar*H*(4)), 6.98 (t, 1H, Ar*H*(5)), 7.37 (d, 1H, Ar*H*(3)), 7.57 (d, 1H, Ar*H*(6)). ^{13}C NMR (C$_6$D$_6$, 75.469 MHz, 298 K): δ (in ppm) 19.9 (CH(*Me*)), 39.4 (N(*Me*)), 45.8 (N*Me*$_2$), 53.2, 58.0 (N*C*H$_2$CH$_2$N), 63.0 (*C*H(Me)), 124.3, 127.6, 128.1, 129.0, 132.9 (Ar(*2,3,4,5,6*)), 145.1 (Ar*C*$_{ipso}$). [α]$_D^{20}$ = +19.9° (*c* = 1 (MeOH)). Anal. Calcd for C$_{13}$H$_{21}$N$_2$Br: C, 54.74; H, 7.42; N, 9.82. Found: C, 54.70; H, 7.34; N, 9.68.

(*rac*)-[BrC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2] ((*rac*)-3a). The synthetic route is identical to that described for the chiral compound (*R*)-3a, starting from (*rac*)-2-bromo-α-methylbenzyl alcohol (6.78 g; 33.72 mmol) and *N*,*N*,*N*′-trimethylethylenediamine (4.5 mL; 35.42 mmol), yielding 3.99 g (42%).

^{1}H and ^{13}C NMR spectra are identical to that of (*R*)-3a. Anal. Calcd for C$_{13}$H$_{21}$N$_2$Br: C, 54.74; H, 7.42; N, 9.82. Found: C, 54.82; H, 7.52; N, 9.76.

[LiC$_6$H$_4$(CH$_2$N(Et)CH$_2$CH$_2$NEt$_2$)-2]$_2$ (2b). To a solution of BrC$_6$H$_4$(CH$_2$N(Et)CH$_2$CH$_2$NEt$_2$)-2 (2.67 g; 8.5 mmol) in pentane (30 mL) was added slowly *n*-butyllithium (6.8 mL of a 1.5 M solution in pentane; 10.2 mmol) in 45 min at −78 °C. The mixture was stirred for 45 min at −78 °C and was allowed to warm to room temperature in 1.5 h. The resulting suspension was centrifuged, and the supernatant was removed by decantation. The solid obtained was washed with pentane (2 × 10 mL) and then dried in vacuo to afford **2** as a white powder (1.90 g, 70% yield). Crystals suitable for an X-ray analysis were obtained from a saturated solution of **2b** in Et$_2$O at −30 °C.

The ^{1}H and ^{13}C NMR data of a solution of **2b** showed that two different species are present in a ~2:1 ratio (labeled **A** and **B**). ^{1}H NMR (300.105 MHz, toluene-d_8, 298 K): δ (in ppm) 0.59 (br s, 2 × 3H, N(CH$_2$CH$_3$)$_2$ (**A**)), 0.77 (t, 3H, NCH$_2$C*H$_3$* (**B**), ^3J = 6.9 Hz), 0.90 (br s, 2 × 3H, N(CH$_2$C*H$_3$*)$_2$ (**B**)), 1.08 (t, 3H, NCH$_2$C*H$_3$* (**A**), ^3J = 7.0 Hz), 1.44–2.86 (m, 4 × 2H, NCH$_2$CH$_2$N (**A**, **B**) and N(CH$_2$CH$_3$)$_2$ (**A**, **B**)), 2.39 (m, 1H, NCH$_2$CH$_3$ (**B**)), 2.51 (m, 1H, NCH$_2$CH$_3$ (**B**)), 3.02 (m, 1H, NCH$_2$CH$_3$ (**A**)), 3.17 (m, 1H, NCH$_2$CH$_3$ (**A**)), 3.23/4.29 (AB, 2H, C*H$_2$*N (**B**), J_{AB} = 12 Hz), 3.45/4.21 (AB, 2H, C*H$_2$*N (**A**), J_{AB} = 11.7 Hz), 7.10 (m, 1H, Ar*H* (**A**, **B**)), 7.20 (m, 2H, Ar*H* (**A**, **B**)), 8.21 (br d, 1H, Ar*H* (**B**), ^3J = 4.8 Hz), 8.27 (d, 1H, Ar*H* (**A**), ^3J = 6.0 Hz). ^{13}C NMR (75.469 MHz, toluene-d_8, 298 K): δ (in ppm) 8.77

(NCH$_2$*C*H$_3$ (**A**)), 10.20 (N(CH$_2$*C*H$_3$)$_2$ (**A**, **B**)), 10.71 (NCH$_2$*C*H$_3$ (**B**)), 45.8 (N(*C*H$_2$CH$_3$)$_2$ (**A**, **B**)), 46.3 (N*C*H$_2$CH$_2$N (**A**)), 48.4 (N*C*H$_2$CH$_2$N (**B**)), 49.7 (N*C*H$_2$CH$_3$ (**A**)), 50.2 (N*C*H$_2$CH$_3$ (**B**)), 52.0 (N*C*H$_2$CH$_2$N (**B**)), 52.3 (N*C*H$_2$CH$_2$N (**A**)), 67.4 (Ar*C*H$_2$N (**A**)), 68.6 (Ar*C*H$_2$N (**B**)), 124.5, 124.6 (Ar(*3*) and Ar(*4*) (**A**, **B**)), 126.2 (Ar(*5*) (**B**)), 126.4 (Ar(*5*) (**A**)), 143.4 (Ar(*6*) (**A**)), 144.1 (Ar(*6*) (**B**)), 151.3 (Ar(*2*) (**A**)), 152.1 (Ar(*2*) (**B**)), 187.5 (Ar(*1*), ^1J(^{7}Li–^{13}C) = 18 Hz (**A**) and (**B**)). ^{6}Li NMR (44.165 MHz, toluene-d_8): δ (in ppm) 0.36 (**B**), 0.46 (**A**). ^{13}C CP-MAS NMR: δ (in ppm) 4.7 and 6.1 (N(CH$_2$*C*H$_3$)$_2$), 13.5 (NCH$_2$*C*H$_3$), 42.4, 43.7, 47.5, 48.2 and 52.7 (N*C*H$_2$ 5 ×), 65.7 (Ar*C*H$_2$N), 123.0, 123.7 and 126.6 (Ar(*3,4,5*)), 142.7 (Ar(*6*)), 150.8 (Ar(*2*)), 188.5 (Ar(*1*)). Due to its extreme sensitivity no reliable elemental analysis could be abtained. Molecular weight determination by cryoscopy (0.21 g in 16.32 g C$_6$H$_6$). Calcd. for monomer: 240.3. Found: 436.

(*R*)-[LiC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2]$_2$ ((*R*)-3b). Prepared according to a published procedure,[6] (*R*)-3b was started from (*R*)-[1-BrC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2] ((*R*)-3a) (2.31 g; 8.10 mmol) and *n*-BuLi (5.2 mL of a 1.6 M solution in hexane, 8.20 mmol) in pentane (10 mL), yielding 1.57 g (87%). Crystals suitable for an X-ray analysis were obtained from a saturated solution of (*R*)-3b in Et$_2$O at −30 °C.

^{1}H NMR (toluene-d_8, 300.105 MHz, 233 K): δ (in ppm) Two ligand patterns are observed in a 1:1 ratio, labeled **A** and **B**. 1.02 (s, 3H, N*Me$_2$* (**A**)), 1.10–1.60 (m, 4H, NCH$_2$CH$_2$N (**A**, **B**)), 1.30 (d, 3H, CH(*Me*) (**B**)), 1.44 (s, 3H, N*Me$_2$* (**B**)), 1.46 (s, 3H, N*Me$_2$* (**A**)), 1.57 (s, 3H, N*Me$_2$* (**B**)), 1.59 (d, 3H, CH(*Me*) (**A**)), 2.04 (m, 3H, NCH$_2$CH$_2$N (**A**, **B**)), 2.30 (s, 3H, N(*Me*) (**B**)), 2.49 (s, 3H, N(*Me*) (**A**)), 2.92 (m, 1H, NCH$_2$CH$_2$N (**A** or **B**)), 3.16 (q, 1H, ArC*H* (**B**)), 4.08 (q, 1H, ArC*H* (**A**)), 7.08–7.35 (Ar*H*(*3,4,5*) (**A**, **B**)), 8.16 (d, 1H, Ar*H*(*6*) (**A**)), 8.33 (d, 1H, Ar*H*(*6*) (**B**)). ^{13}C NMR (toluene-d_8, 75.469 MHz, 233 K): δ (in ppm) 8.89 (CH(*Me*) (**A**)), 24.6 (CH(*Me*) (**B**)), 39.6, 41.5 (N*C*H$_2$CH$_2$N (**A** and **B**)), 42.8, 44.7 (N*Me$_2$* (**A**, **B**)), 45.2 (N*C*H$_2$CH$_2$N (**A**)), 47.9 (N*Me$_2$* (**A**, **B**)), 52.8 (N*C*H$_2$CH$_2$N (**B**)), 56.9, 57.3 (N(*Me*) (**A**, **B**)), 68.6 (Ar*C*H (**A**)), 72.0 (Ar*C*H (**B**)), 142.3, 143.1 (Ar(*2*) (**A**, **B**)), 154.0, 157.4 (Ar(*6*) (**A**, **B**)), 183.0, 190.0 (Ar*C*$_{ipso}$ (**A**, **B**)). ^{6}Li NMR (toluene-d_8, 44.165 MHz, 298 K): δ (in ppm) 0.87 and 0.60. ^{13}C CP-MAS NMR: see Figure 2 in the Results section. Due to its extreme sensitivity, no reliable elemental analysis could be obtained. Molecular weight determination by cryoscopy (0.29 g in 10.58 g C$_6$H$_6$), calcd for monomer: 212.3. Found: 430.

(*rac*)-[LiC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2]$_2$ ((*rac*)-3b). Prepared according to the procedure for ((*R*)-3b), (*rac*)-3b was started from (*rac*)-[1-BrC$_6$H$_4$(CH(Me)N(Me)CH$_2$CH$_2$NMe$_2$)-2] ((*rac*)-3a) (3.39 g; 11.89 mmol) and *n*-BuLi (7.5 mL of a 1.6 M solution in hexane, 12.00 mmol), yielding 2.50 g (99%).

^{1}H NMR (toluene-d_8, 300.105 MHz, 308 K): δ (in ppm) 1.10–1.60 (m, 2H, NCH$_2$CH$_2$N), 1.45 (br, 6H, N*Me$_2$*), 1.55 (d, 3H, CH(*Me*)), 2.20 (m, 1H, NCH$_2$CH$_2$N), 2.40 (s, 3H, N*Me*), 2.98 (m, 1H, NCH$_2$CH$_2$N), 3.20 (q, 1H, ArC*H*), 7.08–7.35 (Ar*H*(*3,4,5*)), 8.20 (d, 1H, Ar*H*(*6*)). ^{13}C NMR (toluene-d_8, 75.469 MHz, 233 K): δ (in ppm) 25.4 (CH(*Me*)), 40.5 (N*C*H$_2$CH$_2$N), 45.0 and 48.2 (N*Me$_2$*), 54.0 (N*C*H$_2$CH$_2$N), 58.7 (N(*Me*)), 72.6 (Ar*C*H), 124.0, 124.3 and 125.3 (Ar(*3,4,5*)), 143.4 (Ar(*2*)), 157.8 (Ar(*6*)), 184.0 (Ar(*1*)). ^{6}Li NMR (toluene-d_8, 44.165 MHz, 298K): δ (in ppm) 0.64. ^{13}C CP-MAS NMR: see also Figure 2 in the Results section. δ (in ppm) 25.1 (CH(*Me*)), 39.6, 47.0, 48.8 (NMe 3×), 52.3, 64.9 (N*C*H$_2$CH$_2$N), 72.0 (Ar*C*H), 124.5, (Ar(*3,4,5*)), 142.4 (Ar(*2*)), 157.6 (Ar(*6*)), 183.5 (Ar(*1*)). Due to its extreme sensitivity no reliable elemental analysis could be obtained. Molecular weight determination by cryoscopy (0.21 g in 10.73 g C$_6$H$_6$). Calcd for monomer: 212.3. Found: 440.

Structure Determinations and Refinement of 2b and (*R*)-3b. Compound **2b**: C$_{30}$H$_{50}$Li$_2$N$_2$, F_w = 480.62, colorless block, 0.36 × 0.33 × 0.21 mm^3, T = 110(2) K, monoclinic, $P2_1/c$ (no. 14), a = 9.9986(1) Å, b = 11.8266(1) Å, c = 13.6183(2) Å, $β$ = 113.4371(5)°, V = 1477.50(3) Å^3, Z = 2, $F(000)$ = 528, D_{calcd} = 1.080 g cm^{-3}, 22 188 reflections were measured on a Nonius KappaCCD diffracto-

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meter with rotating anode ($\lambda = 0.710\ 73$ Å). The data were merged using the program SortAV,[25] resulting in 3378 unique reflections (R_{int} = 0.036). An absorption correction was not considered necessary. The structure was solved with direct methods (SHELXS-97)[26] and refined against F^2 of all reflections (SHELXL-97).[27] 199 refined parameters, no restraints. $R\ [I > 2\sigma(I)]$: R1 = 0.0364, wR2 = 0.0902. R [all data]: R1 = 0.0524, wR2 = 0.0993. S = 0.955. Residual electron density (min/max) = $-0.21/0.21$ e/Å³. Structure calculations, drawings, and checking for higher symmetry were performed with the PLATON package.[28] An earlier structure determination of this compound is available from the Cambridge Structural Database.[29]

Compound (R)-**3b**: $C_{26}H_{42}Li_2N_2$, F_w = 424.52, colorless block, 0.40 × 0.40 × 0.30 mm³, T = 150(2) K, monoclinic, $P2_1$ (no. 4), a = 9.6895(1) Å, b = 17.2620(2) Å, c = 16.2017(2) Å, β = 94.7843(5)°, V = 2700.46(5) Å³, Z = 4, $F(000)$ = 928, D_{calcd} = 1.044 g cm⁻³,

28 269 reflections were measured on a Nonius KappaCCD diffractometer with rotating anode ($\lambda = 0.710\ 73$ Å). The data were merged using the program SortAV,[25] resulting in 4556 unique reflections (R_{int} = 0.073). An absorption correction was not considered necessary. The structure was solved with direct methods (SHELXS-97)[26] and refined against F^2 of all reflections (SHELXL-97).[27] 593 refined parameters, 1 restraint. The absolute structure could not be determined reliably and was assigned according to the synthesis. $R\ [I > 2\sigma(I)]$: R1 = 0.0365, wR2 = 0.0855. R [all data]: R1 = 0.0438, wR2 = 0.0904, S = 1.041. Residual electron density (min/max) = $-0.14/0.12$ e/Å³. Structure calculations, drawings, and checking for higher symmetry were performed with the PLATON package.[28]

Supporting Information Available: X-ray crystallographic data of **2b** and (R)-**3b** (CIF). This material is available free of charge via the Internet at http://pubs.acs.org.

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