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Highly Functionalized β-Enamino Esters via C-C Coupling Reactions of Lithium Enolates of Protected Glycine Esters and Isothiocyanates

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Abstract: Lithium enolates of N,N-diprotected glycine esters were reacted with isothiocyanates, affording Et_2O coordinated lithium thiolates $R^1N(H)$-C(SLi)=C(NR_2)-COOEt (**2a**: R_2 = -$Si(CH_3)_2$-CH_2CH_2-$Si(CH_3)_2$-; R^1 = Ph; **2b**: R_2 = -$Si(CH_3)_2$-CH_2CH_2-$Si(CH_3)_2$-; R^1 = -CH_2Ph; **2c**: R = Et; R^1 = Ph), in which the carboxyl oxygen atom is coordinated to lithium. Thiolate **2a** was shown to be dimeric in the solid state by X-ray crystal structure determination.
Hydrolysis of N-protected lithium thiolates **2a** and **2b** afforded 2-aminothiomalonamic esters **3a** and **3b**, resulting from C-protonation. N,N-diethyl substituted lithium thiolate **2c** afforded mainly [2-(N,N-diethyl)amino-3-mercapto]-β-enamino ester **3c'**, the S-protonated product, which is in slow equilibrium with the C-protonated tautomer. Ring closure to 4-thioxo-β-lactams was unsuccessful. Highly functionalized 3-methylthio-β-enamino esters were obtained via S-alkylation of the lithium thiolates **2** with iodomethane.

INTRODUCTION

In the past decades, much research has been devoted to the development of synthetic routes to β-lactam antibiotics. However, completely synthetic routes to penicillins cephalosporins have not found widespread application[1], due to problems encountered in the synthesis of β-lactam precursors with a C(4)-sulphur substituent and the availability of intermediates from biological sources[2]. Starting from thioimidates, both the classical Staudinger reaction[3] and the modified procedure using acid chlorides[4] commonly produce *trans*-substituted β-

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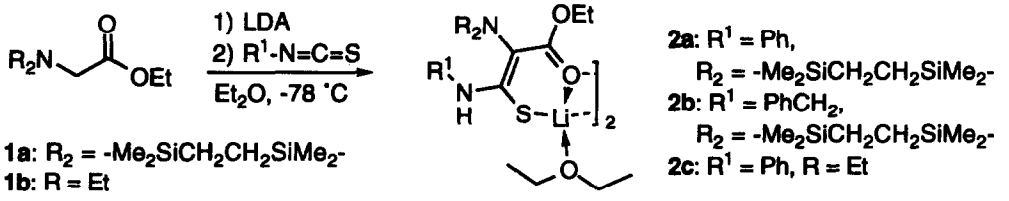
lactams,[5,6] whereas the *cis*-configuration is a prerequisite for antibacterial activity[1]. An alternative synthetic route is the condensation reaction of ester enolates and imines[7]. This route offers control of the diastereoselectivity of the reaction through the choice of the metal counterion. However, 4-alkylthio substituted β-lactams appear not to be accessible *via* this ester enolate-imine condensation route[7a].

4-Thioxo-β-lactams, which were first obtained via thermolysis[8] or photolysis[9] of sulfoxides of *trans*-4-alkylthio-β-lactams, were recognized as possible penem and cephem precursors. Furthermore, these compounds have been converted into 4-alkylidene-2-azetidinones[10], azetidine-2,4-diones[10] and 4-spirocyclopropyl-2-azetidinones[11]. Several miscellaneous routes to 4-thioxo-β-lactams have been published, *e.g.* a [2+2] cycloaddition of thioketenes and isothiocyanates[12], photocyclisation of N-acetyl-thiocarbamates[13] or selective thionation of azetidine-2,4-diones[13]. Recently, the synthesis of 4-thioxo-β-lactams from ester enolates has been reported, by reacting them with isothiocyanates instead of imines[14]. The intermediate thiomalonamic esters are cyclized to 4-thioxo-β-lactams, that are readily converted to 4-acetylthio-2-azetidinones. However, the cyclisation gave poor yields (<25 %) of 3-alkyl-β-lactams when monosubstituted ester enolates were employed. The reported 3,3-dialkyl-β-lactams are merely interesting from a scientific point of view.

As the biologically active cephems and penems possess an amidofunction at the 3-position of the β-lactam ring[15], we selected suitably protected glycine ester enolates as the starting compounds in the C-C coupling reaction with isothiocyanates. Not only the lithium enolates, but also the chlorozinc and dimethylaluminum enolates of protected glycine esters were studied. We have previously demonstrated[16], that these enolates combine excellent diastereoselectivity and a high reactivity in the ester enolate-imine condensation reaction.

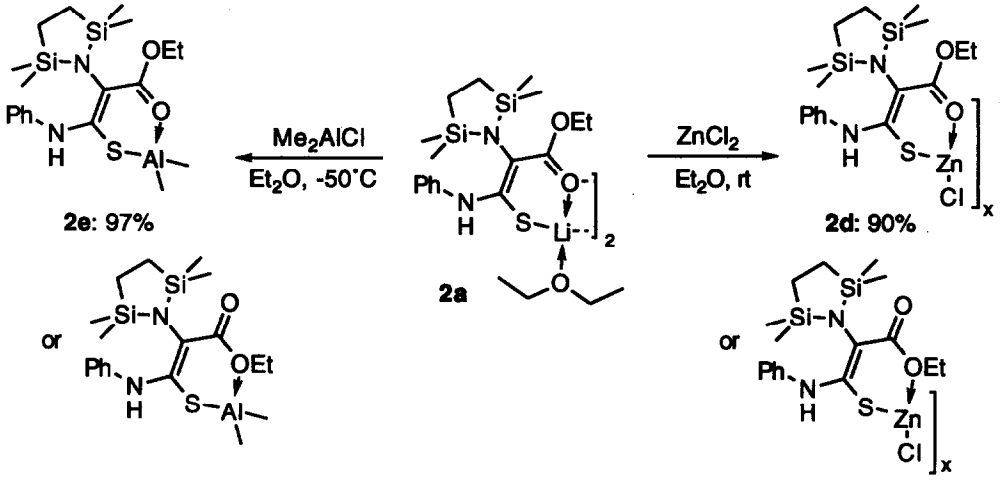
RESULTS & DISCUSSION

C-C coupling Reactions. The lithium enolate of ethyl ([2,2,5,5-tetramethyl-1-aza-2,5-disila]cyclopentyl)-acetate[17] **1a** was reacted with phenyl isothiocyanate in Et_2O at -78 °C to afford lithium thiolate **2a** (*scheme 1*). Recrystallisation from Et_2O/pentane afforded **2a** as light yellow disk-shaped crystals, in 80% yield. One equivalent of Et_2O was incorporated in the crystals, as was evidenced by ^1H and ^{13}C NMR and by X-ray diffraction (*vide infra*). Benzyl isothiocyanate reacted similarly with the lithium enolate of **1a** to give the C-C coupled product **2b** in a good yield[18].



scheme 1

The lithium enolate of ethyl (N,N-diethyl)glycinate **1b** reacts only at elevated temperatures, because it is stabilized by intramolecular coordination[16e]. The reaction with phenylisothiocyanate was therefore performed in refluxing THF and in the absence of diisopropylamine, since this adds readily to phenylisothiocyanate to give the corresponding thiourea[19]. Prior to the reaction, the diisopropylamine-free enolate was isolated by evacuating to dryness *in vacuo*. Alternatively, the lithium enolate was generated *in situ* by deprotonation with LiHMDS, because hexamethyldisilazane is not nucleophilic enough to react with phenyl isothiocyanate. Irrespective of the method, the conversion of the C-C coupling reaction was almost quantitative. Repeated crystallisation from Et_2O afforded the Et_2O adduct of the lithium thiolate **2c** as yellow disk-shaped crystals in 76 % yield.



scheme 2

The reaction of the chlorozinc enolate of **1a** with phenyl isothiocyanate was so slow, that decomposition of the enolate[16e,20] became competitive. To avoid thiourea formation, the enolate was generated with LHMDS instead of LDA. The dimethylaluminium enolate of **1a** did not react at all, even though 10 % excess of Me_2AlCl was used in the transmetallation step[16c]. Transmetallation of **2a** with zinc chloride or dimethylaluminum chloride in Et_2O afforded the corresponding chlorozinc (**2d**) and dimethylaluminum (**2e**) thiolates in almost quantitative yields (scheme 2). The dimethylaluminum compound **2e** crystallized readily from pentane as yellow disk-shaped crystals, containing no Et_2O. The chlorozinc thiolate **2d** could not be obtained in a crystalline form. Compounds **2a-e** were characterized by ^1H and ^{13}C NMR, cryoscopy and IR. The solid state structure of **2a** was determined *via* an X-ray crystal structure determination.

Molecular Structure of 2a.

Crystals of **2a**, suitable for X-ray crystal structure determination, were obtained by careful recrystallisation from Et_2O. The molecular structure of **2a** is shown in figure 1, while selected bond distances and angles are given

in table 1. Compound **2a** is a dimer bridged by the carboxyl oxygen atom. The organic moiety acts as a rigid, planar (S,O)-bidentate ligand to lithium, with a bite angle of 91.1(2)°. Noteworthy, N(1) is sp^2 hybridized, as the sum of angles for N(1) is 360° within experimental error. The shortened C(7)-N(1) bond length of 1.371(4) Å and the coplanarity of the plane of the N(1) substituents with the delocalized system of S-C(7)-C(8)-C(15)-O(1) shows that the p_z-orbital of N(1), and possibly also the phenyl ring, is conjugated with this delocalized system. The tilt angle of 35.30(13)° between the planes of the delocalized system and the phenyl ring might be a result of the crystal packing.

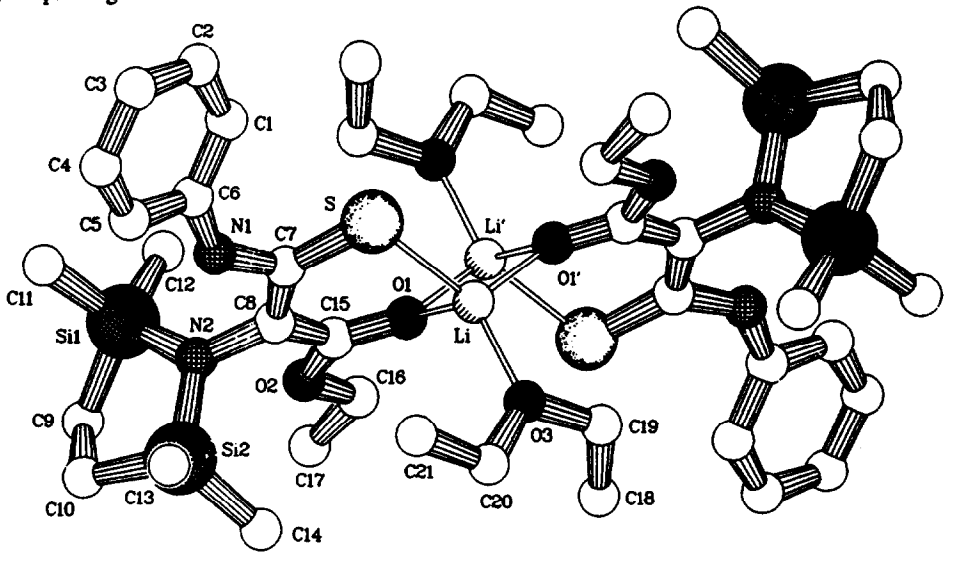


Figure 1: Molecular structure of **2a**, PLUTON drawing showing the adopted numbering scheme.

Table 1: Selected Geometrical Data for **2a**

bond lengths (Å)					
S-C(7)	1.708(3)	C(8)-C(15)	1.416(4)	O(1a)-Li	1.935(6)
S-Li	2.413(6)	O(1)-C(15)	1.249(4)	N(1)-C(7)	1.371(4)
C(7)-C(8)	1.424(4)	O(1)-Li	1.896(6)	N(2)-C(8)	1.441(4)

bond angles (°)			
C(7)-S-Li	102.7(2)	C(6)-N(1)-C(7)	132.9(3)
S-Li-O(1)	91.1(2)	C(6)-N(1)-H(14)	113(3)
C(15)-O(1)-Li	127.0(3)	C(7)-N(1)-H(14)	114(3)
O(1)-C(15)-C(8)	128.7(3)	C(8)-N(2)-Si(1)	124.9(2)
S-C(7)-C(8)	127.6(2)	C(8)-N(2)-Si(2)	119.3(2)
C(7)-C(8)-C(15)	124.4(3)	Si(1)-N(2)-Si(2)	113.2(1)

torsion angles (°)			
C(8)-C(15)-O(1)-Li	29.6(5)	C(1)-C(6)-N(1)-C(7)	35.30(13)
C(8)-C(7)-S-Li	-15.0(3)	O(1)-C(15)-O(2)-C(16)	-1.7(4)
S-C(7)-C(8)-C(15)	-12.4(5)	C(7)-C(8)-C(15)-O(1)	11.6(5)

The other nitrogen atom N(2) is also sp^2 hybridized. However, it is not part of the aforementioned delocalized system, because this is nearly perpendicular to the p_z-orbital of N(2). The sp^2 hybridisation is not uncommon for nitrogen atoms bound to two silicon atoms.[16a] It has been generally accepted that the overlap of the filled p_z orbital of N(2) with empty, low-lying orbitals on silicon is a stabilizing factor, although the nature of these orbitals (3d or π*) is the subject of discussion[21].

The X-ray structure of **2a** represents the first example of a thiomalonamic ester metal complex. The structure resembles that of lithium acetylacetonate (Li[acac]) and lithium ethyl acetylacetate. The Li-O distance of 1.896(6) Å in **2a** is short (comparable with CH_3COOLi: 1.895 Å[22]); in Li(acac)[23], the Li-O distances are in the range of 1.923(6) to 1.967(6) Å. The O(1)-C(15) distance of 1.249(4) Å is close to the value found for the isolated C=O double bond in a lithium aldolate[24] (1.22 Å), in which the oxygen atom is coordinating to lithium. On the other hand, the C-O single bond lengths in lithium ester enolates[25] (1.30-1.32 Å) are much longer. The C(7)-C(8) and C(8)-C(15) bonds in **2a** (1.424(3) and 1.416(4) Å) are somewhat longer than in Li(acac) (1.398(9) and 1.400(9) Å), whereas the O(1)-C(15) distance of 1.249(4) Å in **2a** is slightly smaller than the corresponding values of Li(acac)[23] (1.256(8) and 1.269(8) Å). Therefore, the C=O bond of **2a** has a higher bond order than the C=O bonds of Li(acac), and O(1) carries less negative charge. However, as both in **2a** and in Li(acac) these bonds are significantly longer than the corresponding distances in the ionic 15-crown-5 complexed sodium ethylacetylacetonate[26] (1.20 Å for the ester carboxyl bond, 1.35 and 1.39 Å for the C-C bonds), they possess a significant amount of covalent character.

The Li-S distance of 2.413(6) Å is in the typical range for lithium thiolates.[27] The C-S bond length of 1.708(3) Å is however relatively short, as the corresponding value in lithium thiolates ranges from 1.751(3) Å for arylthiolates[27a-d] to 1.890 Å for sterically hindered alkylthiolates.[27e,f] It is similar to the 1.703 Å for the C-S bond in Li-S-C(O)-Ph[27g]. Presumably, the major part of the negative charge in **2a** is located at the sulphur atom, which has a higher polarizability than oxygen. We therefore describe **2a** as a lithium thiolate. However, because the dimer is bridged by O(1), the highest charge density is located at this atom, the hardest Lewis base of the two.

Structure in Solution. The solution behaviour of the lithium thiolates **2a** and **2c** and the aluminum thiolate **2e** was studied by cryoscopy in benzene, with naphthalene as an internal reference, and by low-temperature NMR. By cryoscopy, no concentration dependence was observed over a concentration range of 0.008 to 0.1 M. The observed molecular weights of 440 ± 50 for **2a** (calculated value: 460), 380 ± 40 for **2c** (375) and 390 ± 40 for **2e** (436) seem to correlate well with a monomeric species in solution for both lithium thiolates. For the aluminum compound **2e**, a monomeric structure is expected.[28] However, it is highly unlikely that the lithium compounds are monomeric with 1 equivalent of Et_2O coordinating.

The observed molecular weights can also be rationalized by higher aggregates $[LiR]_n$ (*e.g.* hexamers) and n equivalents of free Et_2O. In fact, this interpretation is in accord with NMR measurements. The Et_2O signals are almost exactly at the position of free Et_2O over a temperature range of 190-298 K in toluene-d_8, indicating the

absence of any significant interaction between Et_2O and the lithium thiolate. Moreover, the coordinated Et_2O of **2a** can be almost completely removed by repeatedly dissolving the compound in benzene and evaporating *in vacuo*. The Et_2O compound that is obtained is very soluble in common organic solvents, even in pentane. The NMR signals of this compound are almost identical to those of **2a**, over the temperature range of 190-298 K. We did not succeed in purifying the Et_2O-free compound to such an extent that a cryoscopic determination of the aggregation state of this compound would be meaningful.

Table 2: Relevant ^1H and ^{13}C NMR Data for Compounds **2a-2e**

^1H NMR (C_6D_6, ppm[b])	**2a**	**2b**	**2c**	**2d**	**2e**
N-H	9.05	7.36	8.51	8.31	8.78
O-CH_2CH_3	4.15	4.23	4.23	3.88	3.75
Si(CH_3)$_2$	0.21	0.21	-	0.19	0.01
		0.05			
^{13}C NMR (C_6D_6, ppm[b])	**2a**	**2b**	**2c**	**2d**	**2e**
C=S	178.6	181.5	182.9	n.d.[a]	174.2
C=O	172.1	171.2	171.2	n.d.[a]	171.3
S=C-C-C=O	100.1	97.5	107.3	n.d.[a]	99.9
O-CH_2CH_3	60.1	59.8	59.7	61.9	62.3

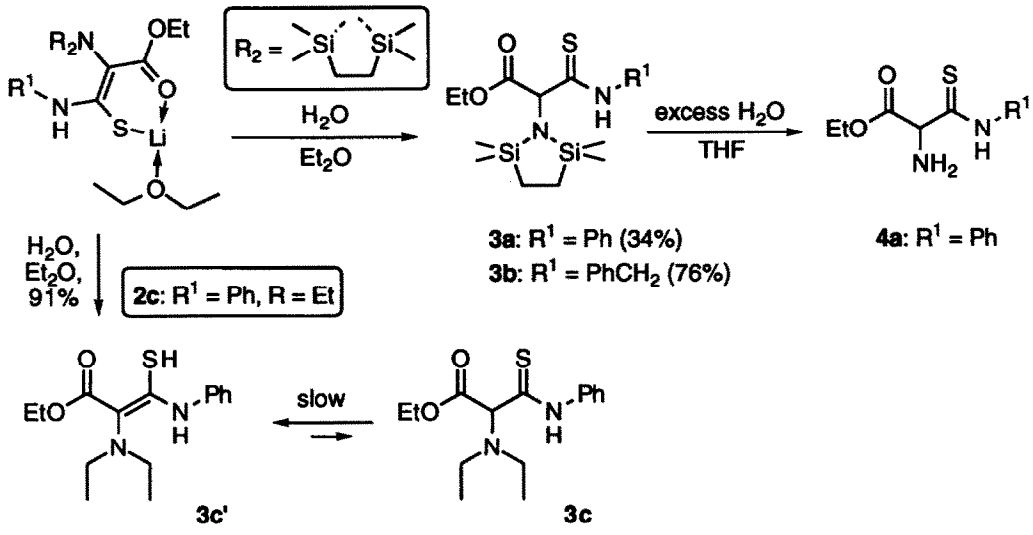
[a]: not determined, because of the limited solubility of **2d** in C_6D_6; [b]: relative to TMS

NMR spectroscopy: The lithium thiolates **2a-c** display similar ^1H and ^{13}C NMR patterns. Hence, we assume that the solution structure of **2b** and **2c** is similar to that of **2a**. The multiplicity of the signals in ^1H and ^{13}C NMR for the STABASE group of **2a** and **2b** and the N-ethyl groups of **2c** shows, that in all three compounds rotation around the C(8)-N(2) bond is fast on the NMR time scale.

The ^1H and ^{13}C NMR spectral data (table 2) of **2d** and **2e** differ only slightly from those of **2a**. Noteworthy, the ester CH_2 protons in both **2d** and **2e** are shifted 0.4 ppm to higher field, suggesting that in **2d** and **2e** coordination of the alkoxy oxygen atom to the metal plays a role. Precedent exists for the coordination of the alkoxy rather than the carbonyl oxygen atom to the metal in ester complexes of zinc and aluminum[29].

Reactions of Lithium Thiolates 2a-c

Hydrolysis: The lithium thiolates **2a-c** were hydrolysed, affording thiomalonamic esters **3a-c**. (scheme 3). The products were characterized by ^1H and ^{13}C NMR, IR, and GCMS. Hydrolysis of lithium thiolates **2a** and **2b** is a rather slow reaction. Deprotection of the STABASE moiety occurs readily, necessitating the use of exactly one equivalent of water. In this way the STABASE-protected[17] thiomalonamic esters **3a** and **3b** were obtained. When an excess of water was used, **3a** was deprotected to **4a**.

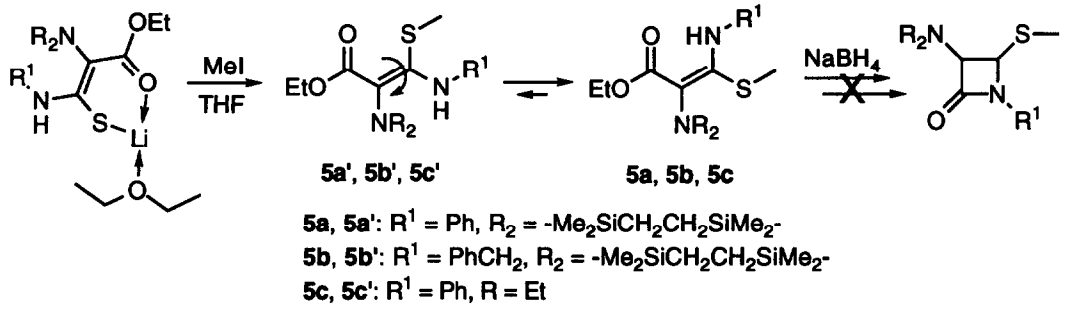


scheme 3

Although **2c** does not contain sensitive protecting groups, the hydrolysis of this compound with more than one equivalent of water leads to unidentified side-products. Hydrolysis of **2c** (scheme 3) with one equivalent of water affords both the C-protonated product (thiomalonamic ester **3c**) and the S-protonated tautomer (β-enamino ester **3c'**, possessing an enethiol function[30]) in a 8:92 ratio. The selectivity of the protonation cannot be determined precisely, because the product slowly equilibrates to a 38:62 ratio of **3c** and **3c'** ($t_{1/2} \approx 3$ h. at 20 °C in C_6D_6). The initially observed 8:92 ratio is considered the minimum value for the regioselectivity of the protonation. The unexpected reaction of lithium thiolate **2c** suggests, that the β-enamino ester **3c'** is stabilized by overlap of the p_z orbital of the Et_2N nitrogen atom with the C=C-C=O delocalized system. The STABASE protected amino substituent of **3a** and **3b** lacks the possibility for this stabilisation, because the p_z orbital of the nitrogen atom is delocalized into low-lying orbitals of the two attached silicon atoms. Consequently, hydrolysis of **2a** and **2b** affords no S-protonated product.

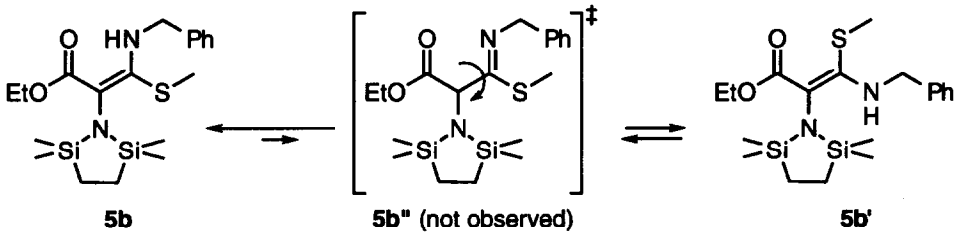
By deprotonating an equilibrated mixture of **3c** and **3c'** with LiHMDS, the starting lithium thiolate **2c** was obtained quantitatively, proving that **3c** and **3c'** are tautomers. The assignment of **3c** and **3c'** is further substantiated by IR, ^1H and ^{13}C NMR spectral data. The IR spectrum of the mixture, dissolved in benzene, showed absorptions at 1743 (isolated ester C=O) as well as 1632 and 1592 cm^{-1} (N-C=C-C=O[31]). The major isomer **3c'** crystallized readily from pentane/Et_2O (2:1) as colorless needles. This compound shows only the IR-absorptions expected for the β-enamino ester[31] (KBr, 1613 and 1596 cm^{-1}). Compounds **3c** and **3a** display similar NMR spectra but, **3c'** is different. The proposed conjugation of the Et_2N p_z orbital with the enaminone π-system is supported by the presence of two discrete, broad signals for the CH_2 protons of the N-ethyl groups in the ^1H NMR spectrum, showing that the pyramidal inversion is slow on the NMR time scale up to 335 K in

toluene-d_8. The tautomers are not exchanging on the NMR time scale at this temperature, since discrete sets of signals for the two species are observed. Noteworthy, the SH and NH protons do not exchange either at 335 K in toluene-d_8.



scheme 4

Reactions with electrophiles. The lithium thiolates **2** possess several nucleophilic sites. Both the sulphur and the carbon atom C(8) are soft Lewis bases, whereas the carboxyl oxygen atom is a hard Lewis base. Weak electrophiles will react at the sulphur atom for steric reasons. Thus, compounds **2a-c** were converted into highly functionalized β-enamino esters by reacting them with weak carbon electrophiles. The reaction of **2a** with iodomethane in refluxing THF afforded the sulphur alkylated product **5a** in almost quantitative yield (scheme 4). Initially, a tautomeric compound **5a'** is formed, observed as the major product after refluxing for 10 minutes. This kinetic product probably has the (*E*)-configuration, resulting from the configuration of the starting lithium thiolate. By refluxing the reaction mixture for 4 hours, it is completely converted into the thermodynamically more stable product **5a**, which probably is the (*Z*)-isomer, having a stabilizing hydrogen bridge[31].



scheme 5

The N-benzyl substituted lithium thiolate **2b** is alkylated much more easily. Probably the absence of a stabilizing conjugation with the phenyl group is the basis for this enhanced reactivity. The reaction of **2b** with

iodomethane is complete within minutes at room temperature, affording a 92:8 mixture of the (*Z*)- and (*E*)-isomers (^{1}H NMR, C_6D_6, 20 °C) of **5b** and **5b'** as a yellow oil. Another possible explanation[32] for the presence of two isomers is an equilibrium between S,N-acetal **5b** and thioimidomalonic ester **5b"** (scheme 5). However, the presence of an imine functionality may be excluded by the multiplicity of the NH proton (triplet), due to coupling with the adjacent CH_2 protons, in the ^{1}H NMR spectrum of both isomers. Probably, **5b"** is a transition state structure in the equilibration of **5b** and **5b'**.

A 94:6 mixture of the two tautomeric products **5c** and **5c'** was obtained by refluxing **2c** with iodomethane in THF (scheme 4). Again, the major product probably is the (*Z*)-isomer, stabilized by the intramolecular hydrogen bridge. The enaminone system of **5c** is stable to acid hydrolysis; after work-up, **5c** is almost completely recovered (> 95 %). Like **5a** and **5b**, **5c** is an oil, which makes purification difficult. In the presence of lithium iodide, both **5b** and **5c** crystallize from Et_2O as yellow needles. The elemental analysis correlates well with 2 molecules of **5** complexed to 1 molecule of LiI (**5b•0.5LiI**). In both cases, the presence of lithium in the sample was established by a flame test, and iodide was confirmed by the formation of a precipitate upon addition of alcoholic $AgNO_3$. In the ^{1}H NMR spectra of the crystallized LiI adducts, the original ratios for the (*Z*)- and (*E*)-isomers of **5b** (92:8) and **5c** (94:6) are still present. We therefore believe, that these are the equilibrium ratios. The organic products can be easily obtained quantitatively by dissolving the crystalline compounds in CH_2Cl_2, from which LiI precipitates.

Attempted reduction. To convert the β-enamino esters into β-lactams, selective reduction of the C=C double bond and ring closure of the resulting β-S,N-acetal ester was attempted. The 1,4-reduction of simple enaminones and enamino esters has been performed using $NaBH_4$ in alcohols[31]. However, enamino ester **5c** did not react with $NaBH_4$ in 2-propanol at room temperature, whereas refluxing resulted in an unidentified mixture of products, containing (among others) desulphurized compounds[33], as was evidenced by the disappearance of the S-methyl signals in ^{1}H and ^{13}C NMR.

Attempted ring closure to β-lactams. Cyclisation of the thiomalonamic esters **3** was attempted with alkylaluminum reagents, according to literature procedures[34]. However, no β-lactams were formed, due to the stability of the intermediate aluminium thiolates. Instead, the starting materials were recovered in 90 % yield after careful hydrolysis. The same result was obtained when the recrystallized aluminum thiolate **2e** was refluxed in toluene.

We have previously reported, that in the reaction of chlorozinc enolates with imines[16] the intermediate chlorozinc amide is readily cyclized to the corresponding β-lactam. Lithium thiolate **2b** was transmetallated *in situ* with $ZnCl_2$ to give the corresponding chlorozinc thiolate. Also in this case no β-lactam formation was observed after refluxing in toluene for 16 hours. Careful hydrolysis afforded again thiomalonic ester **3b**.

CONCLUDING REMARKS

The reaction of isothiocyanates with nucleophiles constitutes an easy route to thioamides[35]. Thiomalonamic esters and diesters have been prepared via the reaction of isothiocyanates with sodium acetylacetonates and malonates[32,36]. These compounds have been employed as ligands in organometallic chemistry; *e.g.* they form very stable, chelated nickel(II) complexes[32]. The C-C coupling reactions of lithium enolates of protected glycine esters with isothiocyanates afford, in good yields, the corresponding thiomalonamic esters, which are easily purified via crystallisation. However, these thiomalonamic esters **3** have unexpected high stability, to the effect that cyclisation to β-lactams via standard methodology could not be achieved.

Sulphur alkylation of the lithiated thiomalonamic esters offers a straightforward route to functionalized β-enamino esters **5**. Enaminones and enamino esters are versatile intermediates for the synthesis of heterocyclic products[37], such as alkaloids and antibiotics. Enaminones similar to compounds **5a-c**, possessing the S,N-acetal function, have recently been employed in a one-pot synthesis of pyranones[38], via 1,4-addition of a Reformatsky reagent. Although $NaBH_4$-reduction of β-enamino ester **5c** to the corresponding β-amino ester was unsuccessful, the observed desulphurisation in itself is promising. Selective desulphurisation offers an entry to 4-unsubstituted β-lactams, via cyclisation of the intermediate β-amino ester.

EXPERIMENTAL SECTION

General Data. All synthetic manipulations with air-sensitive reagents were carried out under a dry, inert nitrogen atmosphere using standard Schlenk techniques. Solvents were dried and distilled from sodium / benzophenone prior to use. Diisopropylamine and hexamethyldisilazane were distilled at atmospheric pressure and stored over molsieves (3Å). Ethyl [(2,2,5,5-tetramethyl-1-aza-2,5-disila)cyclopentyl]acetate (**1a**)[17], ethyl-(diethylamino)acetate (**1b**)[16e], and dry zinc chloride[39] were prepared according to literature procedures. ^1H and ^{13}C NMR spectra were recorded on a Bruker AC 200 and a Bruker AC 300 spectrometer in chloroform-*d* or benzene-d_6. Chemical shifts are in ppm relative to TMS; coupling constants are presented in hertz (Hz). IR spectra were recorded on a Mattson Galaxy FTIR 5000 Spectrometer. Mass spectra (EI, 70 eV) of pure compounds were recorded on a Unicam 610 Automass GCMS System using a direct inlet probe. Melting points and boiling points are uncorrected. Elemental analyses were performed by the Institute of Applied Chemistry TNO, Zeist, The Netherlands, and Dornis und Kolbe Mikroanalytisches Laboratorium, Mülheim a/d Ruhr, Germany.

Lithium {ethyl 3-(N-phenyl)amino-3-sulfido-2-([2,2,5,5-tetramethyl-1-aza-2,5-disila]-cyclopentyl)propenoate-κS,O} · OEt_2 (2a): To a cooled (-78 °C) solution of 6.12 g (60.5 mmol) of diisopropylamine in 100 ml of Et_2O 60.5 mmol of *n*-butyllithium (40.3 ml of a 1.5 M solution in hexanes) was

added. After stirring for 15 min a precooled solution of 14.80 g (60.3 mmol) of ethyl-[(2,2,5,5-tetramethyl-1-aza-2,5-disila)cyclopentyl]acetate in 60 ml of Et_2O was added over a 5 min period via a dropping funnel. Stirring was continued for 30 min at -78 °C, followed by the addition of 8.15 g (60.3 mmol) of phenylisothiocyanate. The solution was warmed to -30 °C in 3 h and was kept at this temperature overnight, resulting in the formation of an off-white precipitate, that redissolved upon warming to room temperature to give a clear, yellow solution. All volatiles were completely removed *in vacuo*. Recrystallisation from a 1:3 Et_2O/pentane solution afforded 22.16 g. (48.2 mmol, 80%) of yellow disk-shaped crystals in 2 crystallisations. ^1H NMR (C_6D_6): δ 9.05 (s, 1H, NH); 7.84 (d, J = 7.6, 2H, *o*-Ph-H); 7.17 (dd, J = 7.6, 8.0, 2H, *m*-Ph-H); 6.95 (t, J = 8.0, 1H, *p*-Ph-H); 4.15 (q, J = 7.1, 2H, OCH_2CH_3); 3.30 (q, J = 7.0., 4H, CH_2 of Et_2O); 1.16 (t, J = 7.1, 3H, OCH_2CH_3); 1.08 (t, J = 7.0, 6H, CH_3 of Et_2O); 0.91 (m, 4H, $SiCH_2CH_2Si$); 0.21 (s, 12H, $Si[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 178.6 (C=S); 172.1 (C=O); 141.4, 128.5, 124.7, 124.2 (aryl C); 100.1 (C[=S]-*C*-C[=O]-); 65.8 (CH_2 of Et_2O); 60.1 (OCH_2CH_3); 15.3 (CH_3 of Et_2O); 14.6 (OCH_2CH_3); 9.0 ($SiCH_2CH_2Si$); 1.0, 0.1 ($Si[CH_3]_2$). Anal. Calcd for $C_{21}H_{37}LiN_2O_3SSi_2$: C 54.75; H 8.09; N 6.08. Found: C 54.38; H 7.83; N 6.04.

Lithium {ethyl 3-(N-benzyl)amino-3-sulfido-2-([2,2,5,5-tetramethyl-1-aza-2,5-disila]-cyclopentyl)propenoate-κS,O} · OEt_2 (2b): Via the same procedure, starting from 1.05 g (7.2 mmol) benzylisothiocyanate, **2b** was obtained as a colorless crystalline compound. Yield (1 crystallisation from Et_2O/pentane): 1.80 g (3.7 mmol, 51%). ^1H NMR (C_6D_6): δ 7.3 (m, 3H, NH & *o*-Ph-H); 7.1 (m, 3H, Ph-H); 5.02 (d, J = 5.1, 2H, NCH_2Ph); 4.23 (q, J = 7.0, 2H, OCH_2CH_3); 3.36 (q, J = 7.0, 4H, CH_2 of Et_2O); 1.25 (t, J = 7.0, 3H, OCH_2CH_3); 1.13 (t, J = 7.0, 6H, CH_3 of Et_2O); 0.73-0.91 (m, 4H, $SiCH_2CH_2Si$); 0.21, 0.05 (s, 12H, $Si[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 181.5 (C=S); 171.2 (C=O); 139.6, 129.1, 128.6, 127.5 (aryl C); 97.5 (C[=S]-*C*-C[=O]-); 65.8 (CH_2 of Et_2O); 59.8 (OCH_2CH_3); 48.7 (NCH_2Ph); 15.3 (CH_3 of Et_2O); 14.6 (OCH_2CH_3); 9.0 ($SiCH_2CH_2Si$); 0.9, 0.1 ($Si[CH_3]_2$). Anal. Calcd for $C_{22}H_{39}LiN_2O_3SSi_2$: C 55.66; H 8.28; N 5.90; S 6.75. Found C 55.53; H 8.35; N 5.94; S 6.84.

Lithium {ethyl 2-(N,N-diethyl)amino-3-(N-phenyl)amino-3-sulfidopropenoate-κS,O} · Et_2O (2c): A solution of 4.62 g (28.7 mmol) of HMDS in 100 ml of THF was cooled to 0 °C. After addition of 28.7 mmol of BuLi (18.0 ml of a 1.6 M solution in hexane), 4.57 g of ester **1b** and 3.88 g of phenylisothiocyanate (both 28.7 mmol) with 10 min intervals, the reaction mixture was refluxed for 45 min. After cooling to room temperature, all volatiles were removed *in vacuo*, leaving a yellow solid. Yellow disk-shaped crystals of **2c** were obtained by crystallisation from Et_2O. Yield: 8.16 g (21.8 mmol, 76%). ^1H NMR (C_6D_6): δ 8.51 (s, 1H, NH); 7.89 (d, J = 7.6, 2H, *o*-Ph-H); 7.16 (dd, J = 7.6, 7.4, 2H, *m*-Ph-H); 6.91 (t, J = 7.4, 1H, *p*-Ph-H); 4.23 (q, J = 7.1, 2H, OCH_2CH_3); 3.32 (q, J = 7.0, 4H, CH_2 of Et_2O); 2.95 (m, 4H, $N[CH_2CH_3]_2$); 1.17 (t, J = 7.1, 3H, OCH_2CH_3); 1.08, 1.05 (t, J = 7.0, 12H, CH_3 of Et_2O and $N[CH_2CH_3]_2$). ^{13}C-NMR (C_6D_6): δ 182.9 (C=S); 171.2 (C=O); 141.7, 128.4, 124.0, 123.7 (Ph-C); 107.3 (Et_2N-C); 65.7 (CH_2 of Et_2O); 59.7 (OCH_2CH_3); 48.8

($N[CH_2CH_3]_2$); 15.1 (CH_3 of Et_2O); 14.8 (OCH_2CH_3); 14.5 ($N[CH_2CH_3]_2$). Anal. Calcd for $C_{19}H_{31}LiN_2O_3S$ (MW = 374.47): C 60.94; H 8.34; N 7.48. Found: C 61.06; H 8.39; N 7.42.

X-Ray data Collection, Structure Determination, and Refinement of Lithium thiolate 2a: A yellowish, plate-shaped crystal was glued to the tip of a glass fiber and transferred into the cold nitrogen stream on an Enraf-Nonius CAD4-F diffractometer. Accurate unit-cell parameters and an orientation matrix were determined by least squares refinement of 25 well-centered reflections (SET4) in the range $10.6° < \Theta < 19.5°$. Reduced-cell calculations did not indicate higher lattice symmetry.[40] Crystal data are presented in table 3. Intensity data of 7604 reflections were collected in the range $1.16° < \Theta < 27.5°$, 5867 of which are independent. 3746 reflections with intensities above the $2.5\sigma(I)$ level were used in the structure analysis. Data were corrected for *Lp* effects and for observed linear decay, but not for absorption. The structure was solved by automated direct methods (SHELXS86[41]). Refinement on *F* was carried out by full-matrix least-squares techniques (SHELX76[42]). Hydrogen atoms were included in the refinement on calculated positions (C-H = 0.98 Å) riding on their carrier atoms, except for the amine hydrogen atom, which was located on a difference Fourier map and subsequently included in the refinement. All non-hydrogen atoms were refined with anisotropic thermal parameters; the hydrogen atoms were refined with two overall isotropic thermal parameters. A final difference Fourier map showed no residual density outside -0.42 and 0.69 e $Å^{-3}$. Neutral atom scattering factors were taken from Cromer and Mann[43], anomalous dispersions from Cromer and Liberman.[44] Geometrical calculations and illustrations were performed with PLATON.[45] All calculations were performed on a MicroVAX-II.

Table 3. Crystallographic Data for **2a**

formula	$[C_{17}H_{27}LiN_2O_2SSi_2.C_4H_{10}O]_2$	D_{calc}, g cm^{-3}	1.194
space group	$P2_1/c$	μ_{calc}, cm^{-1}	2.3
cryst. system	monoclinic	radiation (Mo Kα), Å	0.71073 (Zr-filtered)
Z	2	T, K	100
a, Å	14.238(2)	R_F[a]	0.048
b, Å	10.217(1)	R_{wF}[b]	0.071
c, Å	17.810(2)		
β, deg.	98.573(9)		
V, $Å^3$	2561.8(5)		

[a] $R_F = \Sigma \left| |F_o| - |F_c| \right| / \Sigma |F_o|$; [b] $R_{wF} = [\Sigma[w(|F_o| - |F_c|)^2] / \Sigma[w(F_o^2)]]^{1/2}$

Transmetallations of 2a:

Chlorozinc {ethyl 3-(N-phenyl)amino-3-sulfido-2-([2,2,5,5-tetramethyl-1-aza-2,5-disila]-cyclopentyl)propenoate-κS,O} (2d): At room temperature 3.88 g (8.4 mmol) of **2a** was dissolved in 30 ml. Et_2O. Addition of 8.5 mmol of zinc chloride (7.0 ml of a 1.22 M solution in ether) caused the formation of a white

precipitate. After stirring for 90 min the lithium chloride was filtered off. An orange foam was obtained by concentrating the filtrate *in vacuo*. Stirring with hexane yielded **2d** as a yellow powder. Yield: 3.78 g (7.6 mmol, 90%). ^{1}H NMR: (C_6D_6): δ 8.31 (s, 1H, NH); 7.41 (d, J = 7.7, 2H, *o*-Ph-H); 7.08 (dd, J= 7.7, 7.3, 2H, *m*-Ph-H); 6.96 (t, J = 7.3, 1H, *p*-Ph-H); 3.88 (br.q, J = 6.9, 2H, OCH_2CH_3); 0.98 (t, J = 7.1, 3H, OCH_2CH_3); 0.79 (m, 4H, $SiCH_2CH_2Si$); 0.19 (s, 12H, $Si[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 61.9 (OCH_2CH_3); 14.3 (OCH_2CH_3); 8.8 ($SiCH_2CH_2Si$); 1.2, -0.3 ($Si[CH_3]_2$).

Dimethylaluminium {ethyl 3-(N-phenyl)amino-3-sulfido-2-([2,2,5,5-tetramethyl-1-aza-2,5-disila]cyclopentyl)propenoate-κS,O} (2e): At -50 °C 1.30 g (2.8 mmol) of **2a** was dissolved in 20 ml of Et_2O. To this solution was added 2.8 mmol of dimethylaluminum chloride (2.8 ml of a 1.0 M solution in Et_2O). After slowly warming the yellow reaction mixture to ambient temperature, the solvent was removed *in vacuo*, affording a microcrystalline solid. The product was stirred in hexane and again dried *in vacuo*, yielding a yellow powder. Yield: 1.27 g (2.7 mmol, 97%). Recrystallisation from Et_2O gave yellow disk-shaped crystals. ^{1}H NMR (C_6D_6): δ 8.78 (s, 1H, NH); 7.32 (d, 2H, *o*-Ph-H); 7.10 (dd, 2H, *m*-Ph-H); 6.96 (t, 1H, *p*-Ph-H); 3.75 (q, J = 7.1, 2H, OCH_2CH_3); 0.92 (t, J = 7.1, 3H, OCH_2CH_3); 0.76 (m, 4H, $SiCH_2CH_2Si$); 0.01 (s, 12H, $Si[CH_3]_2$); -0.21 (s, 6H, $Al[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 174.2 (C=S); 171.3 (C=O); 138.7, 129.3, 126.7, 126.0 (Ph-C); 99.9 (C[=S]-*C*-C[=O]-); 62.3 (OCH_2CH_3); 14.3 (OCH_2CH_3); 8.6 ($SiCH_2CH_2Si$); 0.6, -0.5 ($Si[CH_3]_2$); -8.6 (br, $Al[CH_3]_2$).

General procedure for the hydrolysis of 2: To a solution of 0.5 mmol of **2** in 10 ml of Et_2O was added 0.55 mmol of H_2O (0.20 ml of a 2.75 M solution in THF), 0.1 g of solid NH_4Cl and 2 g of $MgSO_4$. After stirring for 30 min, the mixture was filtrated and the residu was washed with Et_2O (two times 10 ml). Evaporation of the combined organic layers yielded the hydrolysed product.

Ethyl 3-(N-phenylamino)-2-([2,2,5,5-tetramethyl-1-aza-2,5-disila]cyclopentyl)-3-thioxo-propanoate (3a): Off-white solid, that was shown by ^{1}H NMR to consist of the hydrolysis product **3a** and the deprotected product **4a** in a 5:1 ratio. Extraction with pentane and crystallisation from pentane afforded yellow crystals of **3a**. Yield: 34 %. Mp: 79 °C. ^{1}H-NMR (C_6D_6): δ 10.21 (s, 1H, NH); 8.09 (d, J = 8.0, 2H, *o*-Ph-H); 7.08 (dd, J = 8.0, 7.3, 2H, *m*-Ph-H); 6.91 (t, J = 7.3, 1H, *p*-Ph-H); 4.99 (s, 1H, C[=S]-CH-C=O); 4.03 (q, J = 7.1 Hz., 2H, OCH_2CH_3); 1.00 (t, J = 7.1, 3H, OCH_2CH_3); 0.70 (m, 4H, $SiCH_2CH_2Si$); 0.23, 0.00 (s, 12H, $Si[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 196.3 (C=S); 170.6 (C=O); 138.8, 129.3, 126.7, 121.8 (Ph-C); 70.7 (C[=S]-*C*-C[=O]); 61.8 (OCH_2CH_3); 13.9 (OCH_2CH_3); 8.7 ($SiCH_2CH_2Si$); 0.0, -0.3 ($Si[CH_3]_2$). IR (KBr, cm^{-1}): 3240 (NH), 1731 (C=O), 1528 (N-C=S). Anal. Calcd for $C_{17}H_{28}N_2O_2SSi_2$: C 53.64; H 7.41; N 7.36. Found: C 53.75; H 7.55; N 7.32.

Ethyl 3-(N-benzylamino)-2-([2,2,5,5-tetramethyl-1-aza-2,5-disila]cyclopentyl)-3-thioxopropanoate (3b): White solid. The product was recrystallized from hexane, affording **3b** as white needles. Yield: 76 %. Mp: 87 °C. ^{1}H NMR (C_6D_6): δ 8.49 (br s, 1H, NH); 7.0-7.1 (m, 5H, Ph-H); 4.99 (s, 1H, C[=S]-CH-C=O); 4.75 (d, *J* = 5.2, 2H, NCH_2Ph); 4.03 (ABX_3, 2H, OCH_2CH_3); 1.01 (t, *J* = 7.1, 3H, OCH_2CH_3); 0.5-0.7 (m, 4H, $SiCH_2CH_2Si$); 0.14, -0.06 (s, 12H, $Si[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 198.7 (C[=S]); 170.8 (-C[=O]); 136.4, 129.0, 128.8, 128.2 (Ph-C); 69.1 (C[=S]-*C*-C[=O]); 61.7 (OCH_2CH_3); 49.5 (NCH_2Ph); 13.9 (OCH_2CH_3); 8.5 ($SiCH_2CH_2Si$); 0.1, -0.2 ($Si[CH_3]_2$). IR (KBr, cm^{-1}): 3314 (NH), 1727 (C=O), 1532 (N-C=S). Anal. Calcd for $C_{18}H_{30}N_2O_2SSi_2$: C 54.78; H 7.66; N 7.10. Found: C 54.66; H 7.65; N 7.13.

Ethyl 2-(N,N-diethyl)amino-3-(N-phenyl)amino-3-thioxopropanoate (3c) and ethyl 2-(N,N-diethyl)amino-3-mercapto-3-(N-phenyl)aminopropenoate (3c'): Yellow oil, that solidified upon standing. Yield: 91 %. The product was shown to be a mixture of two isomeric compounds. Crystallisation from pentane/Et_2O (2:1) yielded the major isomer (enamino ester) as white needles. Yield: 36 %. β-enamino ester **3c'**: Mp: 54-55 °C. ^{1}H NMR (C_6D_6): δ 12.57 (s, 1H, OH); 12.03 (s, 1H, NH); 8.03 (d, *J* = 7.6, 2H, *o*-Ph-H); 7.12 (dd, *J* = 7.6, 7.4, 2H, *m*-Ph-H); 6.88 (t, *J* = 7.4, 1H, *p*-Ph-H); 4.09 (q, *J* = 7.1, 2H, OCH_2CH_3); 2.90, 2.54 (br m, 4H, $N[CH_2CH_3]_2$); 0.99 (t, *J* = 7.1, 3H, OCH_2CH_3); 0.92 (t, *J* = 7.1, 6H, $N[CH_2CH_3]_2$). ^{13}C NMR (C_6D_6): δ 181.8 (C=S); 162.9 (C=O); 142.1, 128.6, 123.9, 123.1 (Ph-C); 97.2 (Et_2N-C); 58.6 (OCH_2CH_3); 50.5 ($N[CH_2CH_3]_2$); 14.9 (OCH_2CH_3); 10.4 ($N[CH_2CH_3]_2$). IR (C_6H_6, cm^{-1}): 1632, 1592 (N-C=C-C=O). IR (KBr, cm^{-1}): 1613, 1596 (N-C=C-C=O). MS: m/z = 294. Anal. Calcd for $C_{15}H_{22}N_2O_2S$: C 61.19; H 7.53; N 9.52. Found: C 61.25; H 7.44; N 9.54. Thiomalonamic ester **3c**: ^{1}H NMR (C_6D_6): δ 10.91 (s, 1H, NH); 7.97 (d, *J* = 7.6, 2H, *o*-Ph-H); 7.09 (dd, *J* = 7.6, 7.4, 2H, *m*-Ph-H); 6.93 (t, *J* = 7.4, 1H, *p*-Ph-H); 4.52 (s, 1H, N-CH-COO); 4.05 (q, *J* = 7.1, 2H, OCH_2CH_3); 2.57 (m, 4H, $N[CH_2CH_3]_2$); 1.01 (t, *J* = 7.1, 3H, OCH_2CH_3); 0.79 (t, *J* = 7.1, 6H, $N[CH_2CH_3]_2$). ^{13}C-NMR (C_6D_6): δ 193.71 (C=S); 168.28 (C=O); 139.10, 129.08, 126.33, 121.92 (Ph-C); 78.74 (Et_2N-C); 61.21 (OCH_2CH_3); 44.55 ($N[CH_2CH_3]_2$); 14.23 (OCH_2CH_3); 12.45 ($N[CH_2CH_3]_2$). IR (C_6H_6, cm^{-1}): 1743 (C=O).

Ethyl 2-amino-3-(N-phenyl)amino-3-thioxopropanoate (4a): A solution of 0.82 g (1.75 mmol) of **2a** in 20 ml of THF was stirred overnight with 10 ml of H_2O. After addition of 30 ml of Et_2O, the organic layer was separated, dried on magnesium sulfate and filtrated. A beige solid was obtained by *in vacuo* removal of the solvent. Washing with hexane and recrystallisation of the residue from Et_2O afforded **4a** as a yellow crystalline product. Yield: 0.36 g (1.5 mmol, 86 %). Mp: 76 °C. ^{1}H NMR (C_6D_6): δ 11.1 (br, 1H, Ph-NH); 7.92 (d, *J* = 7.6, 2H, *o*-Ph-H); 7.05 (dd, *J* = 7.6, 7.3, 2H, *m*-Ph-H); 6.90 (t, *J* = 7.3, 1H, *p*-Ph-H); 4.10 (s, 1H, N-CH-COOEt); 4.03 (ABX_3, 2H, $OCH_aH_bCH_3$); 1.28 (br, 2H, NH_2); 1.02 (t, *J* = 7.1, 3H, OCH_2CH_3). ^{13}C NMR (C_6D_6): δ 194.2 (C=S); 171.1 (COOEt); 138.4, 128.9, 126.4, 122.1 (aryl C); 66.4 (N-*C*H-COOEt); 61.8 (OCH_2CH_3); 14.0 (OCH_2CH_3). IR (KBr, cm^{-1}): 3339, 3254 (NH_2); 1745 (C=O); 1496 (N-C=S). MS: m/z = 238 Anal. Calcd for

$C_{11}H_{14}N_2O_2S$: C 55.44; H 5.92; N 11.76. Found: C 55.34; H 5.89; N 11.64.

Ethyl 3-methylthio-3-(N-phenyl)amino-2-([2,2,5,5-tetramethyl-1-aza-2,5-disila]cyclopentyl)-propenoate (5a): To a solution of 0.83 g (1.8 mmol) of **2a** in 10 ml THF 0.29 g (2.0 mmol) of iodomethane was added. The clear yellow reaction mixture was refluxed for 4 h. *In vacuo* evaporation of the solvent resulted in a yellow foam. This was dissolved in pentane and the solid material was filtered off. From the pentane solution the S-methylated product was obtained by evaporating to dryness. Yield: 0.72 g (1.8 mmol, 99%). ^{1}H NMR (C_6D_6): δ 9.57 (s, 1H, NH); 7.46 (d, J = 7.8, 2H, *o*-Ph-H); 7.08 (dd, J = 7.8, 7.3, 2H, *m*-Ph-H); 6.79 (t, J = 7.3, 1H, *p*-Ph-H); 4.28 (q, J = 7.1, 2H, OCH_2CH_3); 1.63 (s, 3H, SCH_3); 1.07 (t, J = 7.2, 3H, OCH_2CH_3); 0.97 (s, 4H, $SiCH_2CH_2Si$); 0.25 (s, 12H, $Si[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 169.7 (C=O); 157.7 (C=*C*-SMe); 1429, 129.2, 122.6, 120.9 (aryl C); 112.2 (C=*C*-COOEt); 62.8 (OCH_2CH_3); 15.1 (SCH_3); 14.1 (OCH_2CH_3); 8.8 ($SiCH_2CH_2Si$); 0.8 ($Si[CH_3]_2$).

Ethyl 3-methylthio-3-(N-benzyl)amino-2-([2,2,5,5-tetramethyl-1-aza-2,5-disila]cyclopentyl)-propenoate (5b): To a solution of 0.30 g (0.75 mmol) of **2b** in 10 ml of THF, 0.12 g (0.8 mmol) of iodomethane was added. The clear yellow reaction mixture was stirred for 15 min. After concentration, the sticky yellow residue was triturated with benzene. The precipitate was removed by centrifugation, and the solution was concentrated to afford **5b** as an orange-yellow foam. By ^{1}H NMR it was shown that the product consisted of two isomers in a 92:8 ratio. Recrystallisation from Et_2O/pentane (1:1) afforded **5b•0.5 LiI** as off-white block-shaped crystals. Yield: 0.22 g (0.46 mmol, 62 %). Major isomer **5b**: ^{1}H NMR (C_6D_6): δ 8.75 (t, J = 6.8, 1H, NH); 7.40 (d, J = 7.4, 2H, *o*-Ph-H); 7.19 (dd, J = 7.4, 7.1, 2H, *m*-Ph-H); 7.04 (t, J = 7.1, 1H, *p*-Ph-H); 4.40 (d, J = 6.8, 2H, $PhCH_2N$); 4.24 (q, J = 7.1, 2H, OCH_2CH_3); 1.93 (s, 3H, SCH_3); 1.09 (t, J = 7.2, 3H, OCH_2CH_3); 0.94 (m, 4H, $SiCH_2CH_2Si$); 0.04-0.20 (br, 12H, $Si[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 170.2 (C=O); 162.9 (C=*C*-SMe); 139.9, 128.6, 128.4, 127.2 (aryl C); 109.3 (C=*C*-COOEt); 61.3 (OCH_2CH_3); 51.3 ($PhCH_2N$); 16.5 (SCH_3); 14.2 (OCH_2CH_3); 8.7 ($SiCH_2CH_2Si$); 0.3 (br, $Si[CH_3]_2$). IR (KBr, cm^{-1}): 1655, 1562 (N-C=C-C=O). Anal. Calcd for $C_{19}H_{32}I_{0.5}Li_{0.5}N_2O_2SSi_2$ (**5b.0.5LiI**): C 47.98; H 6.78; N 5.89; Si 11.81. Found: C 47.86; H 6.71; N 5.93; Si 11.97. Minor isomer **5b'**: ^{1}H NMR (C_6D_6): δ 5.63 (t, J = 5.9, 1H, NH); 4.28 (d, J = 5.9, 2H, $PhCH_2N$); 4.18 (q, J = 7.1, 2H, OCH_2CH_3); 2.32 (s, 3H, SCH_3); 1.11 (t, J = 7.2, 3H, OCH_2CH_3); 0.69 (s, 4H, $SiCH_2CH_2Si$); 0.28, 0.01 (s, 12H, $Si[CH_3]_2$). ^{13}C NMR (C_6D_6): δ 169.9 (C=O); 155.3 (C=C[SMe]); 138.7, 129.0, 127.8 (Ph-C); 107.2 (C=C-COOEt); 61.6 (OCH_2CH_3); 48.8 ($PhCH_2N$); 20.1 (SCH_3); 14.4 (OCH_2CH_3); 8.6 ($Si\text{-}CH_2CH_2Si$); 1.4, 0.8 ($Si[CH_3]_2$).

Ethyl 2-(N,N-diethyl)amino-3-methylthio-3-(N-phenyl)aminopropenoate (5c): A solution of 0.87 g (2.35 mmol) of **2c** and 0.35 g (2.5 mmol) of iodomethane in 25 ml of THF was refluxed for 1 h. By concentration of the resulting solution a yellow foam was obtained, which was dissolved in pentane, filtrated and concentrated to

give a viscous yellow oil. This was shown to be **5c**, together with 6% of an isomeric compound. In the presence of LiI the oil solidified. Recrystallisation from Et_2O/pentane (1:2) afforded **5c•0.5 LiI** as yellow crystals. Yield: 0.51 g (1.3 mmol, 55%). Mp: 82 °C. Major isomer **5c**: ^{1}H NMR (C_6D_6): δ 9.53 (s, 1H, NH); 7.44 (d, J = 7.9, 2H, *o*-Ph-H); 7.05 (dd, J = 7.3, 7.9, 2H, *m*-Ph-H); 6.79 (t, J = 7.3 , 1H, *p*-Ph-H); 4.34 (q, J = 7.1, 2H, OCH_2CH_3); 2.98 (q, J = 7.2, 4H, $N[CH_2CH_3]_2$); 1.62 (s, 3H, SCH_3); 1.24 (t, J = 7.2, 6H, $N[CH_2CH_3]_2$); 1.03 (t, J = 7.2, 3H, OCH_2CH_3). ^{13}C NMR (C_6D_6) : δ 168.6 (C=O); 164.6 (C=*C*-SMe); 142.8, 129.3, 123.0, 121.2 (Ph-C); 116.4 (MeS-C=*C*-); 61.9 (OCH_2CH_3); 48.6 ($N[CH_2CH_3]_2$); 15.5 (OCH_2CH_3); 14.3 (SCH_3); 14.2 ($N[CH_2CH_3]_2$). IR (KBr, cm^{-1}): 1647, 1599 (N-C=C-C=O). Anal. Calcd for $C_{16}H_{24}I_{0.5}Li_{0.5}N_2O_2S$ (MW: 375.37): C 51.20; H 6.44; I 16.90; N 7.46. Found: C 51.62; H 6.23; I 17.16; N 7.50. Minor isomer **5c'**: ^{1}H NMR (C_6D_6): δ 8.38 (s, 1H, NH); 4.30 (q, J = 7.1, 2H, OCH_2CH_3); 2.79 (q, J = 7.2, 4H, $N[CH_2CH_3]_2$); 1.93 (s, 3H, SCH_3); 0.91 (t, J = 7.2, 3H, OCH_2CH_3). ^{13}C NMR (C_6D_6) : δ 164.6 (C=*C*-SMe); 142.0, 129.5, 124.1, 122.4 (Ph-C); 61.9 (OCH_2CH_3); 48.5 ($N[CH_2CH_3]_2$); 16.9 (OCH_2CH_3); 14.6 (SCH_3); 14.2 ($N[CH_2CH_3]_2$).

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