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Reaction and Characterization of Thioamide Dianions Derived from *N*-Benzyl Thioamides

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Thioamide dianions were generated by the highly efficient reaction of *N*-benzyl thioamides with 2 equiv of BuLi. Alkylation, allylation, and silylation took place selectively at the carbon atom adjacent to the nitrogen atom of the thioamide dianions. Oxiranes and an aldehyde were also used as electrophiles in the reaction of thioamide dianions to form *N*-thioacyl 1,3- or 1,2-amino alcohols. The insertion reaction of elemental sulfur to a thioamide dianion and subsequent ethylation afforded a *N*-thioacyl hemithioaminal. NMR studies on the thioamide mono- and dianions derived from *N*-benzyl 2-methoxythiobenzamide showed a linear relationship between the chemical shifts of all carbon atoms of thioamide mono- and dianions. The results also suggested that the negative charge at the benzylic carbon atom of the dianion is not fully delocalized. The charge distribution patterns of the dianion are consistent with those of π polarization.

Introduction

Synthetic applications of carbanions generated from thioamides are well documented. For tertiary thioamides bearing α-hydrogens, deprotonation proceeds smoothly at a carbon atom α to a thiocarbonyl group to form sulfur isologues of amide enolates **I** (Figure 1), and their chemistry is well documented.[1]

Deprotonation of *N*,*N*-dimethyl thiopivalamide with *sec*-BuLi takes place efficiently at the methyl group attached to a nitrogen atom, and the carbanion **II** generated reacts with a variety of electrophiles.[2] The treatment of *N*,*N*-dimethyl thioformamide with LDA at −100 °C gives a thioformyl anion **III**.[3] The deprotonation of secondary thioamides also shows several reaction modes. The reaction of *N*-methyl or *N*-phenyl α-monosubstituted thioamides with BuLi forms Y-shaped dianions **IV** efficiently, and they react as thioenolates.[4] In the deprotonation of *N*-methyl thiobenzamides, ortho lithiation takes place to form dianions **V**.[5] The treatment of *N*-(benzotriazol-1-ylmethyl) thiobenzamide with BuLi leads to a thioamide dianion **VI**, which is used as a carbanion adjacent to a nitrogen atom.[6] Very recently, the deprotonation of *N*-alkyl 2-methylthiobenzamide derivatives with BuLi was reported to proceed smoothly to give a thioamide dianion **VII**, and subsequent alkylation formed ortho-substituted secondary thiobenzamides.[7] During the course of our studies on the generation of carbanions from selenoamides,[8] we found that the deprotonation of *N*-benzyl selenobenzamide with BuLi occurred not only from the nitrogen atom but also from a carbon atom adjacent to the nitrogen atom to form a selenoamide dianion **VIII** (E = Se).[9] A similar reaction was observed for the deprotonation of *N*-benzyl thiobenzamide. The dianions obtained can be regarded as α-amino benzylic carbanions, which are important carbanions in synthetic reactions.[10] We report here the details of the reaction of thioamide dianions **VIII** (E = S) generated from *N*-benzyl thioamides and their electronic properties.

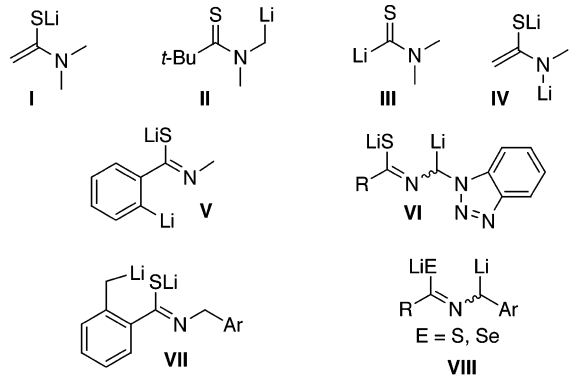

FIGURE 1. Examples of carbanions generated from thioamides.

(1) For a review: Metzner, P.; Thuillier, A. *Sulfur Reagents in Organic Synthesis*; Academic Press: London, 1994.
(2) (a) Lubosch, W.; Seebach, D. *Helv. Chim. Acta* **1980**, *63*, 102. (b) Creary, X.; Zhu, C. *J. Am. Chem. Soc.* **1995**, *117*, 5859.
(3) Seebach, D.; Lubosch, W.; Enders, D. *Chem. Ber.* **1976**, *109*, 1309.
(4) Tamaru, Y.; Kagotani, M.; Furukawa, Y.; Amino, Y.; Yoshida, Z. *Tetrahedron Lett.* **1981**, *22*, 3413.
(5) Fitt, J. J.; Gschwend, H. W. *J. Org. Chem.* **1976**, *41*, 4029.
(6) Katritzky, A. R.; Denisko, O.; Lang, H. *Tetrahedron* **1995**, *51*, 8703.
(7) Ach, D.; Reboul, V.; Metzner, P. *Eur. J. Org. Chem.* **2002**, 2573.
(8) (a) Murai, T.; Ezaka, T.; Ichimiya, T.; Kato, S. *Synlett* **1997**, 775. (b) Murai, T.; Suzuki, A.; Ezaka, T.; Kato, S. *Org. Lett.* **2000**, *2*, 311. (c) Murai, T.; Ishizuka, M.; Suzuki, A.; Kato, S. *Tetrahedron Lett.* **2003**, *44*, 1343.
(9) Murai, T.; Aso, H.; Kato, S. *Org. Lett.* **2002**, *4*, 1407.

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SCHEME 1. Generation and Ethylation of Thioamide Dianions 2

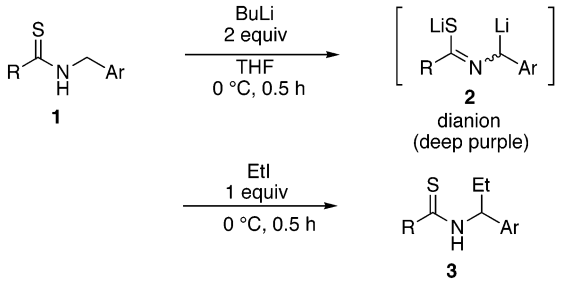


TABLE 1. Reaction of Thioamides 1 with Butyllithium and Ethyl Iodide[a]

entry		thioamide R	Ar	product	yield %[b]
1	**1a**	Ph	Ph	**3a**	92
2	**1b**	4-MeC_6H_4	4-MeC_6H_4	**3b**	78
3	**1c**	2-MeOC_6H_4	Ph	**3c**	78
4	**1d**	2-MeOC_6H_4	1-naphthyl	**3d**	93
5	**1e**	*i*-Pr	Ph	**3e**	91
6	**1f**	*t*-Bu	Ph	**3f**	88
7	**1g**	*t*-Bu	4-MeC_6H_4	**3g**	70

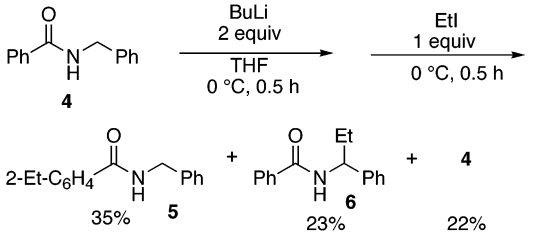
[a] The thioamide **1** was treated with BuLi (2 equiv) at 0 °C for 0.5 h, and then to the reaction mixture was added ethyl iodide at 0 °C. [b] Isolated yield.

Results and Discussion

Initially, *N*-benzyl thiobenzamide (**1a**) was reacted with 2 equiv of BuLi, and 1 equiv of ethyl iodide was then added (Scheme 1, Table 1). When BuLi was added to a THF solution of **1a**, the reaction mixture turned deep purple within a few minutes. The addition of ethyl iodide gave *N*-(1-phenylpropyl) thiobenzamide (**3a**) in 92% yield. Despite the fact that thioamide **1a** possesses aromatic protons, which may be deprotonated, products in which an ethyl group was introduced to an aromatic ring were not observed. The results indicated that the thioamide dianion **2** was formed with high efficiency, and ethylation took place selectively at the benzylic carbon atom adjacent to the nitrogen atom.

To clarify the difference in the reaction mode between ordinary amides[11,12] and thioamides, *N*-benzyl benzamide (**4**) was reacted with BuLi and ethyl iodide (Scheme 2). As in the reaction of **1a**, the reaction mixture of **4** and BuLi turned deep blue.[13] However, two types of products **5** and **6**, in which an ethyl group was introduced to the aromatic ring or to the carbon atom adjacent to the nitrogen atom, were formed.

SCHEME 2. Generation and Ethylation of Amide Dianion



Next, a variety of *N*-benzyl thiobenzamides[15] were synthesized and reacted with 2 equiv of BuLi and 1 equiv of ethyl iodide. The results are shown in Table 1. The reaction of *N*-benzyl aromatic thioamides **1b**−**1d** proceeded smoothly to form the corresponding products in good to high yields (entries 2−4). The methoxy group at the ortho position of the benzene ring did not affect the reaction course (entries 3 and 4).[16] The thioamide dianions from *N*-benzyl aliphatic thioamides **1e** and **1g** were also successfully generated, and the ethyl group was selectively introduced to the benzylic carbon atom adjacent to the nitrogen atom (entries 5−7). The products derived from lithiation at the aromatic ring or at the carbon atom α to a thiocarbonyl group were not observed.

Thioamide dianions **2** were then reacted with a variety of electrophiles. The results are summarized in Table 2. As alkylating agents for thioamides **1**, bromocyclohexane (**7**), allylic bromides **8**−**11**, and **14**, and allylic chlorides **12**, and **13** were used, and the corresponding products were obtained in good to high yields (entries 1−10). In the reaction with 1-bromo-2-butene (**9**) and 2-chloro-3-butene (**13**), the reaction took place at the carbon atom bearing the bromine or chlorine atom, respectively, with high selectivity, and the formation of regioisomers was not observed (entries 3 and 7).

Highly diastereoselective allylation was achieved in the reaction with **13** (entry 7). For the reaction with 1-bromo-2-cyclohexene (**14**), one of the diastereomers was predominantly formed (entries 8−10). A trimethylsilyl group was also selectively introduced to the carbon atom next to the nitrogen atom in the reaction of **1c** with BuLi and silyl chloride **15** (entry 11). The thioamide dianions underwent regioselective ring-opening of propylene oxide (**16**) to form the corresponding thioamide **30**, although the diastereoselectivity of the reaction was low (entry 12). In the ring opening of cyclohexene oxide, two of four possible diastereomers were obtained in good yields (entry 13). In this case, the ring opening of the oxirane ring proceeded in a trans fashion.[17] Finally, the addition of thioamide dianions to carbonyl compounds was examined. Two diastereomers were formed in a ratio of 66:34 in the reaction with 1-naphthaldehyde (entry 14).

(10) For a review: (a) Hoppe, D.; Hense, T. *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 2282. For recent examples: (b) Park, Y. S.; Boys, M. L.; Beak, P. *J. Am. Chem. Soc.* **1996**, *118*, 3757. (c) Voyer, N.; Roby, J.; Chénard, S.; Barberis, C. *Tetrahedron Lett.* **1997**, *38*, 6505. (d) Curtis, M. D.; Beak, P. *J. Org. Chem.* **1999**, *64*, 2996. (e) Hammerschmidt, F.; Hanbauer, M. *J. Org. Chem.* **2000**, *65*, 6121. (f) Dieter, R. K.; Yu, H. *Org. Lett.* **2000**, *2*, 2283. (g) Azzena, U.; Pilo, L.; Piras, E. *Tetrahedron* **2000**, *56*, 3775. (h) Azzena, U.; Pilo, L.; Piras, E. *Tetrahedron Lett.* **2000**, *42*, 129.

(11) Generation of an amide dianion similar to **2a** was achieved by adding BuLi to a mixture of **4**, diisopropylamine, and diglyme over 2 min at −78 °C, but no further details have been reported: Tishler, N. A.; Tishler, M. H. *Tetrahedron Lett.* **1978**, 3.

(12) In the reaction of *N*-benzyl pivalamide with BuLi, there is competition between ortho metalation and deprotonation from the benzylic carbon atom: Simig, G.; Schlosser, M. *Tetrahedron Lett.* **1988**, *29*, 4277.

(13) The indication of a deep-blue color for the mixture of **4** and BuLi has been known to be useful in the titration of organolithium reagents,[14] although selective deprotonation does not proceed.

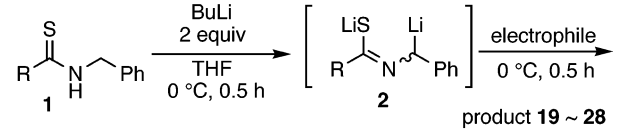
(14) Burchat, A. F.; Chong, J. M.; Nielsen, N. *J. Organomet. Chem.* **1997**, *542*, 281.

(15) *N*-Benzyl aromatic thioamides were prepared by the Willgerodt−Kindeler reaction: Kanyonyo, M. R.: Gozzo, A.; Lambert, D. M.; Lesieur, D.; Poupaert, J. H. *Bull. Soc. Chim. Belg.* **1997**, *106*, 39.

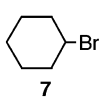
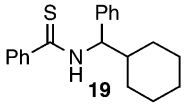
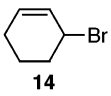
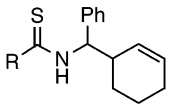
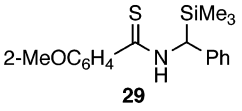
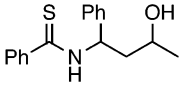
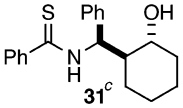
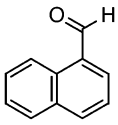
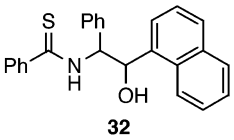
(16) On the contrary, in the reaction of *N*-benzyl 2-methylthiobenzamide, the deprotonation from a methyl group attached to the benzene ring became competitive, as has been reported,[7] and the yield of the product **3** was moderate.

(17) The stereochemistry of the product **31** was determined by comparing its NMR spectra with those of known selenoamides with exactly the same carbon skeletons.[9]

TABLE 2. Reaction of Thioamide Dianions 2 with Electrophiles[a]



1a R = Ph, **1c** R = 2-MeOC$_6$H$_4$, **1e** R = *i*-Pr, **1f** R = *t*-Bu

entry	thioamide 1	electrophile	product	yield (%)[b]
1	**1a**	 **7**	 **19**	85%
2	**1a**	**8** $R^1 = R^2 = R^3 = H$	**20**	63%
3		**9** R^1 = Me, $R^2 = R^3 = H$	**21**	77%
4		**10** $R^1 = R^2$ = Me, $R^3 = H$	**22**	64%
5		**11** $R^1 = R^2 = H$, R^3 = Br	**23**	58%
6	**1c**	**12** R' = H	**24** R = C_6H_4-MeO-2	93%
7	**1f**	**13** R' = Me[c]	**25** R = Bu-t	62%[d] (93 : 7)[e]
8	**1a**	 **14**	 **26** R = Ph	67% (67: 33)[e]
9	**1e**		**27** R = Pr-i	93% (75 : 25)[e]
10	**1f**		**28** R = Bu-t	82% (75 : 25)[e]
11	**1c**	Me_3SiCl **15**	 **29**	63%
12	**1a**	 **16**	 **30**	74% (53 : 47)
13	**1a**	 **17**	 **31**[c]	59% (75 : 25)
14	**1a**	 **18**	 **32**	88% (66 : 34)

[a] The thioamide **1** was treated with BuLi (2 equiv) at 0 °C for 0.5 h, and the electrophile was added to the reaction mixture at 0 °C. [b] Isolated yield. [c] Chloride 13 involved 20% of 1-chloro-2-butene. [d] 5% regioisomer formed. [e] The dr is shown in parentheses. [f] The structure of the major isomer is shown.

Thioamide dianion was also reacted with a sulfur atom as an electrophile (Scheme 3). To a solution of the dianion

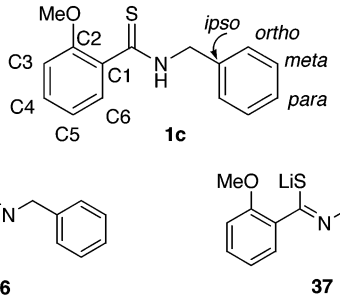
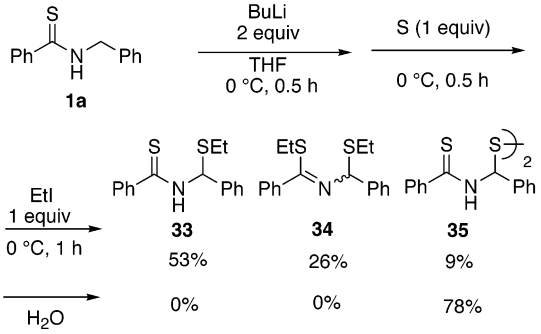


FIGURE 2. Structures of **1c**, **36**, and **37**.

SCHEME 3. Reaction of Thioamide Dianion with Sulfur



generated from thioamide **1a** was added 1 equiv of elemental sulfur and 1 equiv of ethyl iodide. As a result, the expected *N*-thioacyl hemithioaminal[18] **33** was formed in 53% yield, along with a small amount of imide **34**, in which two ethyl groups were introduced, and disulfide **35**. The reaction of the dianion with elemental sulfur without ethyl iodide selectively gave the dimerized product **35** in 78% yield.

To elucidate electronic properties of thioamide dianions **2**, NMR measurements of the in-situ-generated thioamide dianions **2** were carried out in THF-d_8. The dianions **2** were stable unless they were exposed to air and moisture, but complex signals were observed in some cases because some of the dianions were present as stereoisomeric mixtures. Nevertheless, *N*-benzyl 2-methoxythiobenzamide **1c** gave a single isomer of dianion **37** (Figure 2). The NMR results for the dianion **37** are shown in Table 3 along with those for thioamide **1c** and monoanion **36**. The chemical shift differences of these three compounds are also shown.

An X-ray molecular structure analysis of lithium thioacetamidates has been performed, and they were found to be present in dimer form and to form polymers by solvation with THF.[21] On the other hand, α-aminobenzyllithiums are known to be monomeric.[22] As for **36** and **37**, the states of aggregates cannot be estimated,

(18) In contrast to the many examples of *N*-acyl hemithioaminals,[19] only a limited number of *N*-thioacyl hemithioaminals have been reported.[6,20]

(19) Gabbutt, C. D.; Hepworth, J. D. In *Comprehensive Organic Functional Group Transformations*; Katritzky, A. R., Meth-Cohn, O., Rees, C. W., Eds.; Pergamon: Oxford, 1995; Vol. 4, p 315.

(20) (a) Vinogradova, T. K.; Turov, V. V.; Drach, B. S. *Z. Organich. Khim.* **1990**, *26*, 1302. (b) Shimada, K.; Aikawa, K.; Fujita, T.; Sato, M.; Goto, K.; Aoyagi, S.; Takikawa, Y.; Kabuto, C. *Bull. Chem. Soc. Jpn.* **2001**, *74*, 511.

(21) Chivers, T.; Downard, A.; Parvez, M. *Inorg. Chem.* **1999**, *38*, 5565.

TABLE 3. ^{13}C NMR Chemical Shifts of 1c, 36, and 37[a]

	C1	C2	C3	C4	C5	C6	C=S	benzyl	ipso	ortho	meta	para
1c	132.08	155.83	112.16	131.47	121.08	133.36	197.15	50.79	138.75	128.76	129.15	127.95
36	138.98	153.49	114.23	128.52	122.01	134.56	190.69	57.94	143.65	128.91	128.51	126.40
b	Δδ +6.90	Δδ +2.34	Δδ +2.07	Δδ −2.95	Δδ +0.93	Δδ +1.20	Δδ −6.46	Δδ +7.15	Δδ +4.90	Δδ +0.15	Δδ −0.63	Δδ −1.55
37	140.51	153.05	114.64	127.85	122.23	134.85	189.36	59.48	144.72	128.97	128.39	126.08
c	Δδ +8.43	Δδ −2.78	Δδ +2.48	Δδ −3.62	Δδ +1.15	Δδ +1.49	Δδ −7.79	Δδ +8.69	Δδ +5.79	Δδ +0.21	Δδ −0.76	Δδ −1.87
d	Δδ +1.53	Δδ −0.44	Δδ +0.41	Δδ −0.67	Δδ +0.21	Δδ +0.29	Δδ −1.33	Δδ +1.54	Δδ +1.07	Δδ +0.06	Δδ −0.12	Δδ −0.32

[a] The spectra were measured in THF-d_8. [b] Chemical-shift differences between thioamide **1c** and monoanion **36** are shown. Positive signs denote downfield shifts. [c] Chemical-shift differences between thioamide **1c** and dianion **37** are shown. [d] Chemical-shift differences between monoanion **36** and dianion **37** are shown.

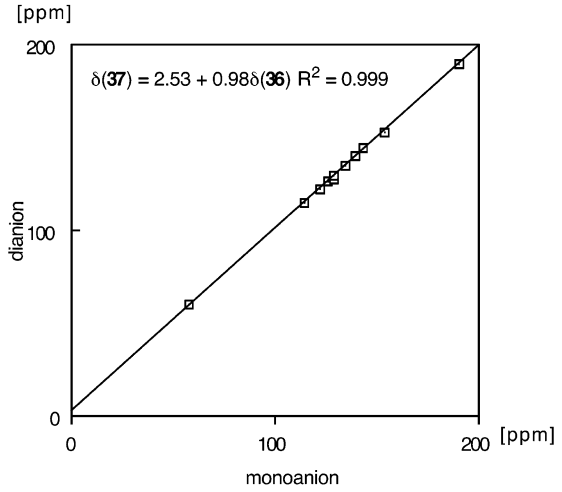


FIGURE 3. Correlation in ^{13}C NMR spectra between monoanion **36** and dianion **37**.

but both appear to adopt similar states of aggregates based on their ^{13}C chemical shifts. A change in chemical shifts was observed to some extent when those of **1c** were compared to those of **36** and **37**.

In contrast, little difference was observed between the chemical shifts of **36** and **37**. In these cases, no strong delocalization of the negative charge to the aromatic ring was observed. This indicates that the lithiation on the aromatic ring does not occur. The signals due to monoanion **36** and dianion **37** showed a similar tendency with regard to the changes in the chemical shifts compared to those of thioamide **1c**. This is supported by the linear correlation between the signals of monoanion **36** and those of dianion **37** (Figure 3).

In fact, the signals due to the ipso and ortho carbon atoms of the benzyl groups of both **36** and **37** were shifted to lower fields, whereas those of the meta and para carbon atoms were observed at higher fields. The degree of the change in the chemical shifts of ipso and para carbon atoms was greater than that of ortho and meta carbon atoms (Figure 4). In previous studies on ^{13}C NMR spectra of α-aminobenzyllithiums,[22] the signals due to para carbon atoms are shifted to higher fields by more than 20 ppm. This has been understood to be due to a resonance effect.[22b] On the contrary, in the case of dianion **37**, the signal of the para carbon atom was shifted by only 1.55 ppm. Thus, the negative charge of the benzylic

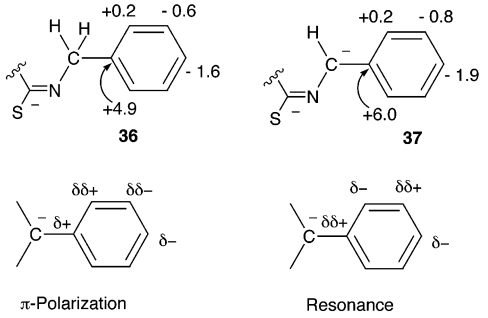


FIGURE 4. Changes of ^{13}C chemical shifts Δδ from **1c** to **36** and **37**. The charge distribution patterns on the benzene ring of the dianion due to the π polarization and resonance are also schematically represented.

carbon atom of **37** is not delocalized to either the C=N group[24] or the aromatic ring via a resonance effect. The charge distribution patterns of the benzene ring attached to the carbanionic center of **37** are consistent with those of π-polarization.[24]

In summary, we have demonstrated that thioamide dianions **2** were efficiently generated from *N*-benzyl thioamides **1** and could be used as α-amino benzylic carbanions. The electronic properties of thioamide dianions were also disclosed on the basis of ^{13}C NMR spectra. Further synthetic applications of thioamide dianions are currently under investigation.

Experimental Section

***N*-(1-Phenylpropyl) Benzenecarbothioamide (3a).** To a THF solution (2 mL) of *N*-benzyl benzenecarbothioamide (**1a**) (0.113 g, 0.50 mmol) was added *n*-BuLi (0.63 mL, 1.00 mmol) at 0 °C. It was stirred at 0 °C for 0.5 h. Then, ethyl iodide (0.040 mL, 0.50 mmol) was added to the reaction mixture at 0 °C and it was stirred at that temperature for 0.5 h. The reaction mixture was poured onto water and extracted with Et_2O (20 mL). The organic layer was dried over $MgSO_4$ and concentrated in vacuo. The residue was purified by column chromatography on silica gel using hexane−CH_2Cl_2 as eluent to give 0.122 g (92%) of **3a** as a yellow oil. ^{1}H NMR: δ 0.96 (t, J = 7.3 Hz, 3H), 1.92−2.03 (m, 1H), 2.08−2.19 (m, 1H), 5.67 (q, J = 7.6 Hz, 1H), 7.28−7.41 (m, 8H), 7.68 (d, J = 6.8 Hz, 2H), 7.79 (br, 1H). ^{13}C NMR: δ 10.6, 28.2, 61.2, 126.6, 127.0, 127.7, 128.4, 128.8, 130.9, 140.2, 142.2, 198.4. MS(EI) *m*/*z*: 255

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(23) This is also in marked contrast to the ab initio structures of 1,3-diphenyl-2-azaallyl anions, which show delocalization of the electrons in 2-azaallyl groups: Andrews, P. C.; Armstrong, D. R.; Baker, D. R.; Mulvey, R. E.; Clegg, W.; Horsburgh, L.; O'Neil, P. A.; Reed, D. *Organometallics* **1995**, *14*, 427.

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(M^+). Anal. Calcd for $C_{16}H_{17}NS$: C, 75.25; H, 6.71. Found: C, 74.97; H, 6.70.

***N*-(1-Phenylpropyl) 2-Methoxybenzenecarbothioamide (3c).** A yellow oil. ^{1}H NMR: δ 0.98 (t, J = 7.6 Hz, 3H), 1.92−2.04 (m, 1H), 2.05−2.16 (m, 1H), 3.86 (s, 3H), 5.74 (q, J = 7.3 Hz, 1H), 6.90 (d, J = 8.3 Hz, 1H), 7.00 (td, J = 7.6, 1.0 Hz, 1H), 7.23−7.29 (m, 1H), 7.32−7.38 (m, 5H), 8.38 (dd, J = 8.0, 2.0 Hz, 1H), 9.43 (br, J = 5.9 Hz, 1H). ^{13}C NMR: δ 10.4, 28.6, 56.0, 61.3, 111.4, 121.2, 126.9, 127.3, 127.9, 128.5, 132.0, 134.6, 140.7, 154.9, 194.6. HRMS cacld for $C_{17}H_{19}NOS$, 285.1187; found, 285.1180.

***N*-(1-Naphthylpropyl) 2-Methoxybenzenecarbothioamide (3d).** A yellow oil. ^{1}H NMR: δ 1.06 (t, J = 7.3 Hz, 3H), 2.19 (sept, J = 7.2 Hz, 1H), 2.29 (sept, J = 7.2 Hz, 1H), 3.66 (s, 3H), 6.51 (q, J = 7.2 Hz, 1H), 6.82 (d, J = 7.3 Hz, 1H), 6.98 (td, J = 7.8, 1.0 Hz, 1H), 7.31 (td, J = 8.3, 2.0 Hz, 1H), 7.41−7.54 (m, 4H), 7.78 (d, J = 7.8 Hz, 1H), 7.85 (d, J = 8.3 Hz, 1H), 8.25 (d, J = 8.8 Hz, 1H), 8.38 (dd, J = 7.8, 2.0 Hz, 1H), 9.42 (br, J = 6.8 Hz, 1H). ^{13}C NMR: δ 10.8, 27.4, 55.9, 57.7, 111.5, 121.2, 123.2, 123.6, 125.2, 125.7, 126.4, 128.0, 128.2, 128.7, 131.6, 132.0, 134.0, 134.5, 136.3, 154.9, 194.4. HRMS calcd for $C_{21}H_{21}NOS$, 335.1344; found, 335.1335.

***N*-(1-Phenylpropyl) 2-Methylpropanethioamide (3e).** A yellowish-orange oil. ^{1}H NMR: δ 0.92 (t, J = 7.3 Hz, 3H), 1.22 (d, J = 6.8 Hz, 3H), 1.26 (d, J = 6.8 Hz, 3H), 1.85−1.96 (m, 1H), 1.99−2.10 (m, 1H), 2.81 (sept, J = 6.7 Hz, 1H), 5.58 (q, J = 7.5 Hz, 1H), 7.27−7.34 (m, 5H, Ar), 7.49 (br, 1H). ^{13}C NMR: δ 10.5, 22.5, 22.6, 27.9, 44.7, 59.9, 126.9, 127.6, 128.7, 140.3, 210.6. MS (EI) m/z: 221 (M^+). Anal. Calcd for $C_{13}H_{19}NS$: C, 70.54; H, 8.65. Found: C, 70.63; H, 8.80.

***N*-(1-Phenylpropyl) 2,2-Dimethylpropanethioamide (3f).** A pale-yellow solid. Mp: 85.5−88.0 °C. ^{1}H NMR: δ 0.92 (t, J = 7.6 Hz, 3H), 1.35 (s, 9H), 1.91 (sept, J = 7.3 Hz, 1H), 2.03 (sept, J = 7.3 Hz, 1H), 5.59 (q, J = 7.5 Hz, 1H), 7.22−7.40 (m, 5H), 7.52 (br, 1H). ^{13}C NMR: δ 10.4, 28.1, 30.1, 44.5, 60.2, 126.7, 127.5, 128.7, 140.4, 212.2. MS(EI) m/z: 235 (M^+). Anal. Calcd for $C_{14}H_{21}NS$: C, 71.44; H, 8.99. Found: C, 71.64; H, 8.86.

***N*-(Cyclohexylphenylmethyl) Benzenecarbothioamide (19).** A pale-yellow solid. Mp: 188.5−190.0 °C. ^{1}H NMR: δ 0.95−1.19 (m, 5H), 1.43−1.87 (m, 6H), 5.54 (t, J = 8.8 Hz, 1H), 7.17−7.31 (m, 7H), 7.36 (t, J = 7.3 Hz, 1H), 7.62 (d, J = 7.8 Hz, 2H), 7.77 (br, J = 8.3 Hz, 1H). ^{13}C NMR: δ 25.9, 26.0, 26.2, 29.7, 30.0, 43.1, 64.7, 126.6, 127.5, 127.6, 128.5, 128.6, 130.9, 139.6, 142.5, 198.6. MS(EI) m/z: 309 (M^+). HRMS calcd for $C_{20}H_{23}NS$, 309.15500; found, 309.15262.

***N*-(1-Phenyl-3-butenyl) Benzenecarbothioamide (20).** A pale-yellow solid. Mp: 71−74 °C. ^{1}H NMR: δ 2.77 (dt, J = 14.1, 6.4 Hz, 1H), 2.85 (dt, J = 14.1, 6.4 Hz, 1H), 5.19 (dd, J = 10.2, 1.0 Hz, 1H), 5.24 (dq, J = 17.1, 2.1 Hz, 1H), 5.79 (ddt, J = 17.2, 10.2, 6.9 Hz, 1H), 5.85 (q, J = 7.1 Hz, 1H), 7.24−7.47 (m, 8H), 7.72 (d, J = 6.8 Hz, 2H), 7.82 (br, 1H). ^{13}C NMR: δ 39.6, 58.4, 118.9, 126.6, 126.7, 127.7, 128.5, 128.7, 131.1, 133.4, 139.8, 142.0, 198.4. Mass (m/z): 267 (M^+). HRMS calcd for $C_{17}H_{17}NS$, 267.1082; found, 267.1099.

***N*-(1-Phenyl-3-pentenyl) Benzenecarbothioamide (21).** A pale-yellow solid. Mp: 69−73 °C. *E*-isomer ^{1}H NMR: δ 1.67 (d, J = 6.3 Hz, 3H), 2.66−2.79 (m, 2H), 5.36−5.43 (m, 1H), 5.64 (ddd, J = 21.0, 14.6, 8.3 Hz, 1H), 5.76 (q, J = 6.8 Hz, 1H), 7.24−7.46 (m, 8H), 7.72 (d, J = 7.4 Hz, 2H), 7.83 (br, 1H). ^{13}C NMR: δ 18.1, 38.6, 58.8, 125.7, 126.6, 126.7, 127.5, 128.5, 128.7, 129.7, 131.0, 140.0, 142.1, 198.3. Mass (m/z): 281 (M^+). Anal. Calcd for $C_{18}H_{19}NS$: C, 76.82; H, 6.81; N, 4.98. Found: C, 76.70; H, 6.75; N, 4.92.

***N*-(4-Methyl-1-phenyl-3-pentenyl) Benzenecarbothioamide (22).** A pale-yellow solid. Mp: 93−96 °C. ^{1}H NMR: δ 1.63 (s, 3H), 1.69 (s, 3H), 2.75 (m, 2H), 5.10 (t, J = 7.3 Hz, 1H), 5.75 (q, J = 7.0 Hz, 1H), 7.24−7.46 (m, 8H), 7.71 (d, J = 8.3 Hz, 2H), 7.80 (br, 1H). ^{13}C NMR: δ 18.1, 25.8, 33.7, 59.4, 118.6, 126.5, 126.7, 127.5, 128.5, 128.7, 131.0, 135.9, 140.1, 142.1, 198.3. Mass (m/z): 295 (M^+). HRMS calcd for $C_{19}H_{21}NS$, 295.1395; found, 295.1404. Anal. Calcd for $C_{19}H_{21}NS$: C, 77.24; H, 7.16; N, 4.74. Found: C, 76.56; H, 7.12; N, 4.66.

***N*-(3-Bromo-1-phenyl-3-butenyl) Benzenecarbothioamide (23).** A pale-yellow solid. Mp: 169−173 °C. ^{1}H NMR: δ 3.07 (dd, J = 14.9, 6.9 Hz, 1H), 3.27 (dd, J = 14.9, 7.3 Hz, 1H), 5.52 (d, J = 2.0 Hz, 1H), 5.64 (d, J = 2.0 Hz, 1H), 6.06 (dt, J = 7.3, 6.9 Hz, 1H), 7.25−7.47 (m, 8H), 7.72 (d, J = 8.3 Hz, 2H), 7.86 (br, 1H). ^{13}C NMR: δ 46.7, 58.2, 120.1, 126.7, 126.9, 128.1, 128.5, 128.6, 128.9, 131.1, 139.0, 142.0, 198.8. Mass (m/z): 345 (M^+). HRMS calcd for $C_{17}H_{16}NBrS$, 345.0187; found, 345.0187.

***N*-(2-Methyl-1-phenyl-3-butenyl) (2-Methoxybenzene)-carbothioamide (24).** A yellow liquid. ^{1}H NMR: δ 2.70−2.87 (m, 2H), 3.89 (s, 3H), 5.14 (dd, J = 16.6, 1.5 Hz, 1H), 5.17 (dd, J = 22.9, 1.5 Hz, 1H), 5.77 (ddt, J = 27.3, 17.1, 6.8 Hz, 1H), 5.93 (q, J = 7.3 Hz, 1H), 6.93 (q, J = 8.3 Hz, 1H), 7.02 (t, J = 7.8 Hz, 1H), 7.23−7.40 (m, 6H), 8.38 (dd, J = 7.8, 2.0 Hz, 1H), 9.60 (brd, J = 5.7 Hz, 1H). ^{13}C NMR: δ 40.0, 55.9, 59.1, 118.5, 133.6, 111.4, 121.2, 126.7, 127.3, 127.5, 128.6, 132.2, 135.0, 140.3, 155.2, 194.7. MS(EI) m/z: 297 (M^+). HRMS calcd for $C_{18}H_{19}NOS$, 297.1186; found, 297.1187.

***N*-(2-Methyl-1-phenyl-3-butenyl) 2,2-Dimethylpropanethioamide (25).** A yellow liquid. ^{1}H NMR: δ 1.06 (d, J = 6.8 Hz, 3H) 1.35 (s, 9H), 2.76 (m, 1H), 5.18 (m, 2H), 5.51 (m, 1H), 5.80 (m, 1H), 7.22−7.33 (m, 5H). ^{13}C NMR: δ 16.8, 30.2, 30.9, 43.4, 62.2, 116.5, 127.7, 126.9, 127.3, 128.5, 139.5, 212,6. Mass (m/z): 261 (M^+). Anal. Calcd for $C_{16}H_{23}NS$: C, 73.51; H, 8.87. Found: C, 73.26; H, 8.99.

***N*-[1-(2-Cyclohexenyl)phenylmethyl] Benzenecarbothioamide (26).** Major isomer. A yellow solid. Mp: 146−150 °C. ^{1}H NMR: δ 1.42−2.07 (m, 6H), 2.82−2.91 (m, 1H), 5.62−6.01 (m, 3H), 7.26−7.49 (m, 8H), 7.75−7.81 (m, 2H), 7.91 (br, 1H). ^{13}C NMR: δ 21.5, 25.2, 27.5, 41.4, 62.7 124.9, 127.2 126.5, 127.3, 127.5, 128.5, 128.6, 131.1, 139.4, 142.0, 199.0. Mass (m/z): 307 (M^+). Anal. Calcd for $C_{20}H_{21}NS$: C, 78.13; H, 6.88; N, 4.56. Found: C, 78.21; H, 6.85; N, 4.53.

***N*-[1-(2-Cyclohexenyl)phenylmethyl] 2-Methylpropanethioamide (27).** A yellow liquid. ^{1}H NMR: δ 1.22−1.31 (m, 6H), 1.30 (d, J = 6.8 Hz, 3H), 1.33 (d, J = 6.8 Hz, 3H), 2.92−2.96 (m, 1H), 5.37−5.95 (m, 3H), 7.22−7.32 (m, 5H), 7.57 (s, 1H). ^{13}C NMR: δ 22.5, 22.6, 21.5, 25.2, 27.4, 44.9, 61.3, 124.9, 132.6, 126.5, 127.2, 128.5, 139.5, 211.2. Mass (m/z): 273 (M^+). Anal. Calcd for $C_{17}H_{23}NS$: C, 74.73; H, 8.42. Found: C, 74.47; H, 8.52.

***N*-[1-(2-Cyclohexenyl)-phenylmethyl] 2,2-Dimethylpropanethioamide (28).** A yellow liquid. ^{1}H NMR: δ 1.36 (s, 9H), 1.4−2.1 (m, 6H), 2.79 (m, 1H), 5.4−6.1 (m, 3H) 7.17−7.35 (m, 5H), 7.78 (s, 1H). ^{13}C NMR: δ 21.6, 25.2, 27.6, 30.2, 44.8, 61.6, 124.8, 127.0, 126.3, 127.1, 133.0, 139.7, 213.1. Mass (m/z): 286 (M^+). Anal. Calcd for $C_{18}H_{25}NS$: C, 75.47; H, 8.44. Found: C, 75.20; H, 8.73.

***N*-[1-(Trimethylsilyl)phenylmethyl] (2-Methoxybenzene)carbothioamide (29).** A yellow solid. Mp: 99−102 °C (dec). ^{1}H NMR: δ 0.00 (s, 9H), 3.88 (s, 3H), 5.73 (d, J = 9.3 Hz, 1H), 6.86 (d, J = 8.3 Hz, 1H), 6.93 (t, J = 7.6 Hz, 1H), 7.02−7.07 (m, 3H), 7.18 (t, J = 7.6 Hz, 2H), 7.29 (dd, J = 7.8, 1.5 Hz, 1H), 8.36 (dd, J = 7.8, 2.0 Hz, 1H), 9.70 (brd, J = 7.8 Hz, 1H, NH). ^{13}C NMR: δ −3.2, 54.1, 56.1, 111.4, 121.4, 125.8, 126.2, 127.7, 128.4, 132.0, 135.3, 139.8, 154.9, 194.5. MS (EI) m/z: 329 (M^+). HRMS calcd for $C_{18}H_{23}NOSSi$, 329.1270; found, 329.1279.

***N*-(3-Hydroxy-1-phenylbutyl) Benzenecarbothioamide (30).** Major/minor = 53:47. A yellow oil. Major isomer. ^{1}H NMR: δ 1.18 (d, J = 6.3 Hz, 3H), 1.99−2.11 (m, 2H), 3.00 (br, 1H), 3.87−3.94 (m, 1H), 6.03 (dt, J = 11.7, 3.7 Hz, 1H), 7.26−7.36 (m, 7H), 7.43 (t, J = 7.3 Hz, 1H), 7.78 (d, J = 8.3 Hz, 2H), 9.22 (br, 1H). ^{13}C NMR: δ 23.7, 43.2, 57.9, 64.7, 126.5, 126.8, 127.5, 128.4, 128.8, 131.2, 139.8, 141.3, 198.1. Minor isomer. ^{1}H NMR: δ 1.23 (d, J = 6.3 Hz, 3H), 2.00−2.06 (m, 1H), 2.19 (br, 1H), 2.21 (dt, J = 14.2, 8.8 Hz, 1H), 3.90−3.98 (m, 1H), 5.78 (dt, J = 8.8, 6.8 Hz, 1H), 7.25−7.48 (m, 8H), 7.76 (d, J = 6.8 Hz, 2H), 8.53 (br, 1H). ^{13}C NMR: δ 24.7, 44.7, 59.2,

66.7, 126.8, 127.7, 128.4, 128.7, 128.9, 131.0, 140.9, 141.8, 198.0. MS(EI) *m*/*z*: 285 (M^+). HRMS calcd for $C_{17}H_{19}NOS$, 285.1187; found, 285.1178.

***N*-[(2-Hydroxycyclohexyl)phenylmethyl] Benzenecarbothioamide (31).** Major/minor = 75:25. A yellow solid. Mp: 149.5−153.0 °C. Major isomer. ^{1}H NMR: δ 1.01−2.02 (m, 9H), 2.33 (br, 1H), 3.54 (td, J = 10.2, 4.4 Hz, 1H), 5.55 (t, J = 7.3 Hz, 1H), 7.23−7.42 (m, 8H), 7.80 (d, J = 6.8 Hz, 2H), 9.47 (br, 1H). ^{13}C NMR: δ 24.4, 25.0, 28.4, 36.5, 48.8, 64.6, 73.2, 126.8, 127.3, 128.2, 128.2, 128.3, 130.8, 140.2, 142.0, 197.2. Minor isomer. ^{1}H NMR: δ 0.88−2.02 (m, 9H), 2.43 (br, 1H), 3.48 (tt, J = 10.0, 3.4 Hz, 1H), 5.84 (dd, J = 8.5, 2.7 Hz, 1H), 7.28−7.52 (m, 8H), 7.84 (d, J = 7.3 Hz, 2H), 9.90 (br, 1H). ^{13}C NMR: δ 24.3, 25.3, 28.2, 36.0, 48.3, 63.7, 72.0, 126.9, 127.4, 128.2, 128.3, 128.5, 131.0, 137.8, 141.8, 197.0. MS (EI) *m*/*z*: 325 (M^+). HRMS calcd for $C_{20}H_{23}NOS$, 325.1500; found, 325.1492.

***N*-(2-Hydroxy-2-naphthyl-1-phenylethyl) Benzenecarbothioamide (32).** Major/minor = 66:34. A yellow oil. Major isomer. ^{1}H NMR: δ 2.65 (br, 1H), 5.88 (s, 1H), 6.09 (dd, J = 7.8, 2.0 Hz, 1H), 7.28−7.58 (m, 11H), 7.62 (d, J = 7.3 Hz, 2H), 7.70 (d, J = 7.3 Hz, 1H), 7.80 (d, J = 7.8 Hz, 1H), 7.87 (d, J = 7.8 Hz, 1H), 8.04 (d, J = 8.3 Hz, 1H), 8.59 (br, J = 7.3 Hz, 1H). ^{13}C NMR: δ 63.3, 73.1, 122.3, 123.2, 125.1, 125.9, 126.7, 126.7, 127.0, 127.9, 128.4, 128.9, 129.0, 129.3, 130.0, 131.0, 133.8, 135.7, 138.9, 141.9, 199.0. Minor isomer. ^{1}H NMR: δ 2.34 (br, 1H), 6.16 (d, J = 3.9 Hz, 1H), 6.21 (dd, J = 8.3, 3.4 Hz, 1H), 6.93 (d, J = 6.8 Hz, 2H), 7.01 (d, J = 7.3 Hz, 1H), 7.10 (t, J = 7.3 Hz, 2H), 7.17 (t, J = 7.8 Hz, 2H), 7.36 (t, J = 7.3 Hz, 2H), 7.44 (t, J = 7.3 Hz, 1H), 7.52 (t, J = 7.3 Hz, 1H), 7.60 (t, J = 7.4 Hz, 1H), 7.69 (d, J = 8.3 Hz, 1H), 7.76 (d, J = 6.8 Hz, 2H), 7.85 (d, J = 8.3 Hz, 1H), 8.37 (d, J = 8.8 Hz, 1H), 8.63 (br, J = 8.3 Hz, 1H). ^{13}C NMR: δ 63.7, 71.6, 122.9, 124.0, 124.9, 125.8, 126.7, 126.8, 127.9, 127.9, 128.3, 128.4, 128.6, 128.9, 130.1, 131.2, 133.3, 135.4, 141.9, 198.4. MS(EI) *m*/*z*: 383 (M^+). HRMS calcd for $C_{25}H_{21}NOS$, 383.13428; found, 383.13360.

***N*-(1-Ethylthiophenylmethyl) Benzenecarbothioamide (33).** A pale-orange solid. Mp: 91.0−92.5 °C. ^{1}H NMR: δ 1.37 (t, J = 7.3 Hz, 3H), 2.65−2.73 (m, 1H), 2.80−2.86 (m, 1H), 7.14 (d, J = 8.8 Hz, 1H), 7.24−7.52 (m, 8H), 7.76 (d, J = 7.3 Hz, 2H), 8.07 (br, J = 8.3 Hz, 1H). ^{13}C NMR: δ 15.1, 26.0, 62.0, 126.7, 126.7, 128.5, 128.6, 128.8, 131.4, 137.7, 141.3, 198.3. MS (EI) *m*/*z*: 287 (M^+). Anal. Calcd for $C_{16}H_{17}NS_2$: C, 66.86; H, 5.96. Found: C, 66.81; H, 5.90.

***N*-[1-Ethylthiophenylmethyl] Benzenecarboximidothioic Acid Ethyl Ester (34).** *E*/*Z* = 38:62. A yellow liquid. ^{1}H NMR: δ 1.07 (t, J = 7.3 Hz, 3H, *E*), 1.08 (t, J = 7.3 Hz, 3H, *Z*), 1.26 (t, J = 7.6 Hz, 3H, *E*), 1.41 (t, J = 7.3 Hz, 3H, *Z*), 2.34−2.71 (m, 2H), 3.13−3.26 (m, 2H), 5.65 (s, 1H, *Z*), 6.33 (s, 1, *E*), 7.22−7.48 (m, 8H), 7.58−7.66 (m, 2H). ^{13}C NMR: δ 14.3, 14.6, 14.9, 15.6, 24.1, 24.5, 25.0, 28.2, 67.8, 69.0, 127.1, 127.3, 127.5, 127.6, 127.6, 128.4, 128.4, 128.4, 128.5, 128.6, 129.6, 129.9, 135.8, 138.3, 140.8, 141.5 (Ar), 166.8. MS (EI) *m*/*z*: 254 ($M^+ - SCH_2CH_3$).

Bis(1-*N*-thiobenzoylaminophenylmethane) Disulfide (35). Major/minor = 60:40. A yellow solid. Mp: 66.5−68.0 °C. Major isomer. ^{1}H NMR: δ 7.12 (d, J = 8.8 Hz, 2H), 7.26−7.51 (m, 16H), 7.60 (d, J = 7.3 Hz, 4H), 8.67 (br, J = 8.8 Hz, 2H). ^{13}C NMR: δ 62.2, 126.7, 127.0, 128.4, 128.5, 129.0, 131.5, 137.4, 140.8, 197.5. Minor isomer. ^{1}H NMR: δ 7.01 (d, J = 8.3 Hz, 2H), 7.26−7.51 (m, 16H), 7.74 (d, J = 7.3 Hz, 4H), 8.56 (br, J = 8.3 Hz, 2H). ^{13}C NMR: δ 62.1, 127.0, 127.0, 128.4, 128.8, 129.0, 131.6, 137.2, 140.6, 198.3. MS (EI) *m*/*z*: 516 (M^+). Anal. Calcd for $C_{28}H_{24}N_2S_4$: C, 65.08; H, 4.68. Found: C, 64.92; H, 4.75.

Lithium *N*-Benzyl 2-Methoxybenzenecarbothioimidate (36). In a 20-mL two-necked flask, butyllithium (0.19 mL, 0.30 mmol) was added to a THF solution (1.4 mL) of *N*-benzyl 2-methoxybenzenecarbothioamide (**1c**) (0.074 g, 0.29 mmol) at 0 °C. It was stirred at 0 °C for 0.5 h. The reaction mixture was concentrated in vacuo to give **36** as a pale-red solid. ^{1}H NMR (THF-d_8): δ 3.67 (s, 3H), 4.98 (s, 2H), 6.92 (t, J = 7.8 Hz, 2H), 7.12 (q, J = 7.5 Hz, 2H), 7.21 (t, J = 7.6 Hz, 2H), 7.37 (d, J = 7.3 Hz, 2H), 8.17 (d, J = 7.8 Hz, 1H). ^{13}C NMR (THF-d_8): δ 57.9, 114.2, 122.0, 126.4, 128.5, 128.5, 128.9, 134.6, 139.0, 143.7, 153.5, 190.7.

***N*-Benzyl 2-Methoxybenzenecarbothioimidate Dilithium (37).** In a 20-mL two-necked flask, butyllithium (0.38 mL, 0.60 mmol) was added to a THF solution (1.5 mL) of *N*-benzyl 2-methoxybenzenecarbothioamide (**1c**) (0.082 g, 0.32 mmol) at 0 °C. It was stirred at 0 °C for 0.5 h. The reaction mixture was concentrated in vacuo to give **37** as a deep-purple solid. ^{1}H NMR (THF-d_8): δ 3.62 (s, 3H), 4.94 (s, 1H), 6.81−7.17 (m, 7H), 7.33 (d, J = 7.3 Hz, 1H), 8.19 (d, J = 7.3 Hz, 1H). ^{13}C NMR (THF-d_8): δ 58.3, 59.5, 114.6, 122.2, 126.1, 127.9, 128.4, 129.0, 134.9, 140.5, 144.7, 153.0, 189.4.

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Supporting Information Available: Copies of ^{13}C NMR spectra for compounds **3c**, **3d**, **19**, **20**, **22**−**24**, **29**−**32**, **34**, **36**, and **37**. This material is available free of charge via the Internet at http://pubs.acs.org.

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