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Synthesis and Properties of a Novel Cyclic Sulfilimine, 2-Methyl-2,4,1-benzodithiazin-2-ium-1-ide

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ABSTRACT

*A novel cyclic sulfilimine, 2-methyl-2,4,1-benzodithiazin-2-ium-1-ide (**4**) was synthesized by deprotonation of the corresponding azasulfonium salt (**3**) with base. The compound **4** was oxidized with potassium permanganate to afford the sulfoximine **5**, exclusively. On refluxing in several solvents, compound **4** underwent a ring contraction to afford benzothiazole (**8**) via the 1,2-imino shift. The reaction of **4** with a variety of electrophiles, such as dialkyl acetylenedicarboxylate, acylating agents, diphenylcyclopropenone, and phenyl isocyanate, afforded ring-opened adducts. Synthetic approaches to cyclic disulfonium ylides are also described.*

INTRODUCTION

In connection with our interest in the properties of conjugated six-membered cyclic sulfonium ylides, we have extensively investigated the chemistry of azathiabenzenes, in which a sulfur–nitrogen bond forms part of a cyclic conjugated ring system containing six π-electrons [1]. In continuing our study of the chemistry of cyclic sulfilimines, we have next investigated the synthesis of novel cyclic sulfilimines containing another heteroatom in the ring, because studies on the chemistry of these types of sulfilimines are almost unknown [2]. In this article, we report the synthesis and chemical properties of a novel cyclic sulfilimine, 2-methyl-2,4,1-benzodithiazin-2-ium-1-ide (**4**), which contains a sulfur atom at the 4-position as another heteroatom in the ring.

RESULTS AND DISCUSSION

Preparation of 2-Methyl-2,4,1-benzodithiazin-2-ium-1-ide (**4**)

The benzodithiazinium-1-ide **4** was synthesized by the procedure depicted in Scheme 1. Treatment of the sodium salt of 2-aminobenzenethiol (**1**) with chloromethyl methyl sulfide afforded, in 67% yield, 2-methylthiomethylthioaniline (**2**) as a yellow oil. Cyclization of the amino sulfide **2** with *N*-chlorosuccinimide (NCS) in dichloromethane at −50°C, followed by treatment with silver perchlorate, gave 2-methyl-2,4,1-benzodithiazinium perchlorate (**3a**) in 69% yield. Deprotonation of salt **3a** with sodium hydride in THF at 0°C yielded 2-methyl-2,4,1-benzodithiazin-2-ium-1-ide (**4**) as yellow prisms, mp 82–84°C (dec) in 68% yield. Deprotonation of the salt **3a** with *n*-butyllithium or lithium diisopropylamide (LDA) also afforded benzodithiazinium-1-ide **4** in 59% and 65% yields, respectively, while using triethyamine or potassium hydroxide as a base resulted in the formation of undetermined complex mixtures. The IR spectrum of compound **4** showed strong bands at 950 and 920 cm^{-1}, characteristic of the S–N stretching frequency of a sulfilimine. Compound **4** gradually decomposed on standing at room temperature.

Dedicated to Professor Shigeru Oae on the occasion of his seventy-fifth birthday.

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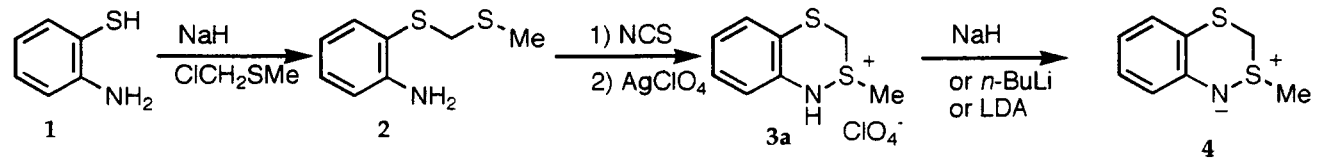
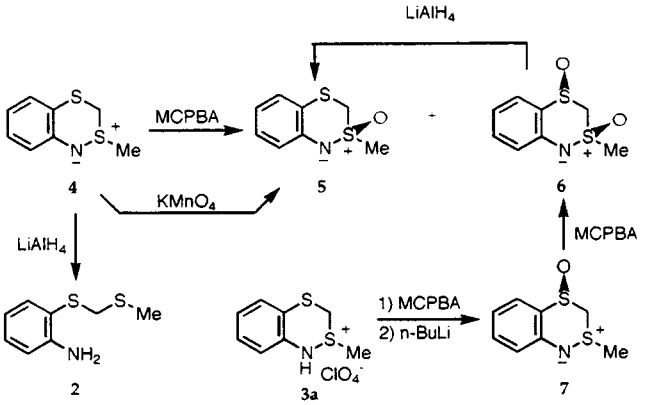


SCHEME 1



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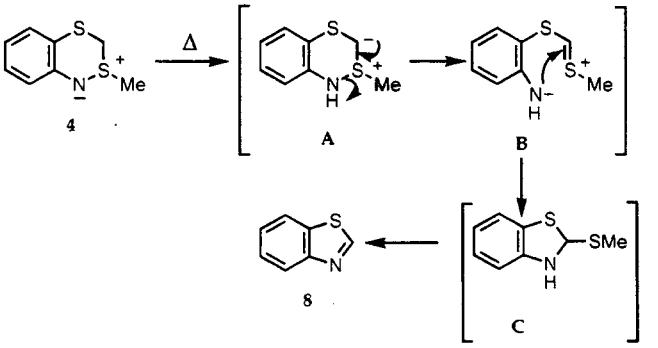


SCHEME 3

Oxidation and Reduction of the Benzodithiazinium-1-ide 4

It is well documented that sulfilimines can be oxidized with potassium permanganate [3] or *m*-chloroperbenzoic acid (MCPBA) [4] to give the corresponding sulfoximines. Compound **4** has two different types of sulfur atoms. It was, therefore, of interest to examine which sulfur atom would be more reactive to oxidizing agents. When compound **4** was treated with an equivalent amount of MCPBA in dichloromethane at 0°C, monosulfoxide **5** and disulfoxide **6** were obtained in 12 and 16% yields, respectively (Scheme 2).

On the contrary, oxidation with potassium permanganate in dioxane afforded only monosulfoxide **5** in 33% yield. These results indicate that the sulfur atom of the S–N bond is more easily oxidized than that of the sulfide bond despite the presence of a sulfur atom having a formal positive charge. Next, we have attempted to prepare another type of monosulfoxide **7** to compare its structure with that of the monosulfoxide **5**, as shown in Scheme 2. We expected the aza sulfonium salt **3a** to be selectively oxidized on the sulfur atom at the 4-position, because the sulfur at the 2-position is very electron deficient due to its sulfonium structure. Thus, oxidation of the salt **3a** with an equivalent amount of MCPBA, followed by treatment with *n*-butyllithium, afforded only monosulfoxide **7** in 33% yield, as expected. The monosulfoxide **7** was easily converted to the disulfoxide **6** in 46% yield by further oxidation with MCPBA. When the disulfoxide **6** was subjected to reduction with $LiAlH_4$, only sulfoximine **5** was obtained in 53% yield and no mono sulfoxide **7** was detected. On the other hand, reduction of compound **4** with $LiAlH_4$ in THF afforded amino sulfide **2** in 72% yield.

Thermolysis of the Benzodithiazinium-1-ide 4

Thermal 1,2-imino shifts from the sulfur atom to the α-methylene carbon atom of sulfilimines are well known [5]. However, thermal 1,2-alkyl shifts from sulfur to nitrogen have rarely been observed in sulfilimines [6]. We recently reported on 1,2-alkyl shifts of 9-alkylazathiaphenanthrenes [7]. It is therefore of interest to examine whether compound **4** undergoes a 1,2-imino shift or a 1,2-alkyl shift.

When refluxed in dichloromethane for 48 hours, compound **4** underwent a thermal ring contraction to give benzothiazole **8** in 39% yield. Similar ring contraction was observed with the use of refluxing acetonitrile, toluene or *N,N*-dimethylformamide as the solvent to give benzothiazole **8** in 44, 44, or 52% yield, respectively. On the contrary, thermolysis of **4** in ethanol, a protic solvent afforded a much higher yield (73%) of benzothiazole **8**, together with 2-methylsulfinylmethylthioaniline (14%). The latter compound might have been formed via hydrolysis of compound **4** with a small amount of water contaminant in the ethanol. The well-known 1,2-imino shifts are believed to occur after proton transfer from the α-carbon atom to the nitrogen atom, generating a sulfonium ylide intermediate [5]. The ring contraction of the sulfilimine **4** to benzothiazole **8**

is understandable in terms of this 1,2-imino shift, as shown in Scheme 3, namely, by the sequential formation of intermediates A, B, and C.

Reactions of the Benzodithiazinium-1-ide **4** *with Electrophiles*

Treatment of cyclic sulfilimine **4** with dimethyl acetylenedicarboxylate (DMAD) in dry dichloromethane at room temperature gave the crystalline adduct **9a** as yellow prisms in 24% yield (Scheme 4).

Similarly, the reaction of **4** with diethyl acetylenedicarboxylate (DEAD) also afforded the corresponding adduct **9b** in 41% yield. The structures of the compounds **9a** and **9b** were determined on the basis of their spectroscopic data (see the Experimental section), and especially, the structure of compound **9a** was confirmed by an alternative synthesis of an authentic sample, as shown in Scheme 4. Treatment of 2-methylthiomethylthioaniline (**2**) with DMAD in dichloromethane, followed by oxidation of the adduct **10** with MCPBA, afforded the compound **9a** in 63% yield.

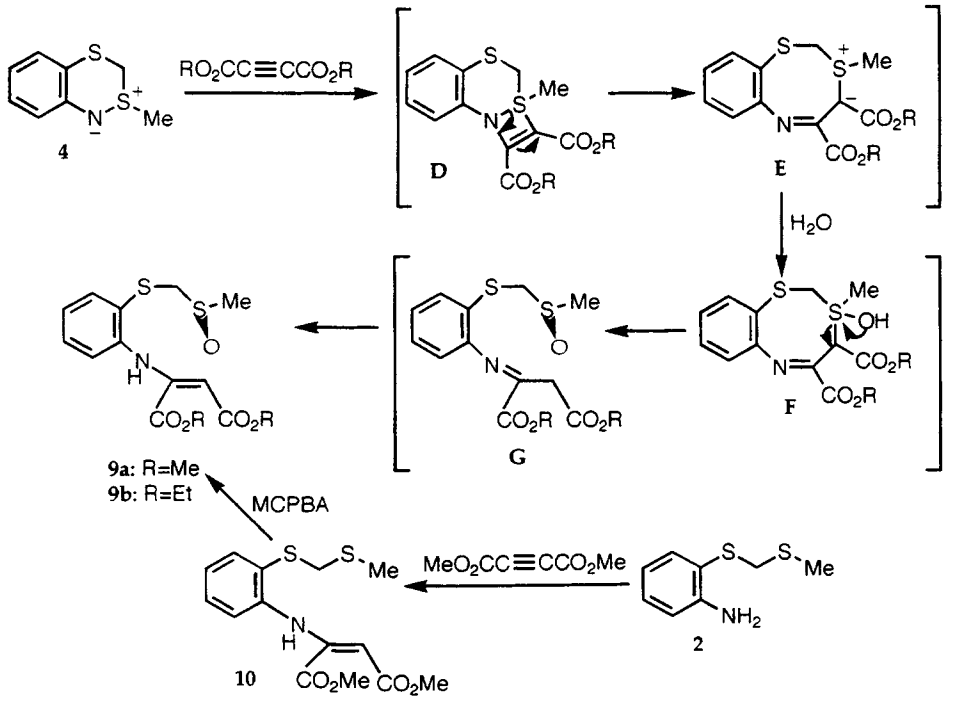
A plausible mechanism for the formation of **9** from **4** is depicted in Scheme 4. Nucleophilic attack of the anionic center of **4** on the electron-deficient acetylene (DMAD or DEAD) forms a zwitterionic intermediate, which gives rise to the four-center sulfurane intermediate D by ring closure. The intermediate D collapses to the intermediate E by heterolytic cleavage of the N–S bond, and then the intermediate E is easily hydrolyzed and isomerized via the sequential formation of intermediates F and G to give the ring-opened sulfoxide **9**.

Next, we investigated the acylation of compound **4** with an acid chloride or acid anhydride (Scheme 5).

Treatment of **4** with benzoyl chloride in dry dichloromethane resulted in the formation of the *N*-benzoylated ring-opened sulfoxide **11a** in 23% yield. Similarly, the reaction of **4** with acetic anhydride afforded the *N*-acetylated ring-opened sulfoxide **11b** in 35% yield. The formation of products **11** might be explained in terms of the hydrolysis of unstable *N*-acylated compounds H during workup. On treatment with trifluoroacetic anhydride in dichloromethane, the compounds **11a** and **11b** were easily transformed into the corresponding 2-substituted benzothiazoles **12a** and **12b** in 80 and 67% yields, respectively (Scheme 5). The transformation might be rationalized by a mechanism involving a Pummerer rearrangement intermediate I, as shown in Scheme 5.

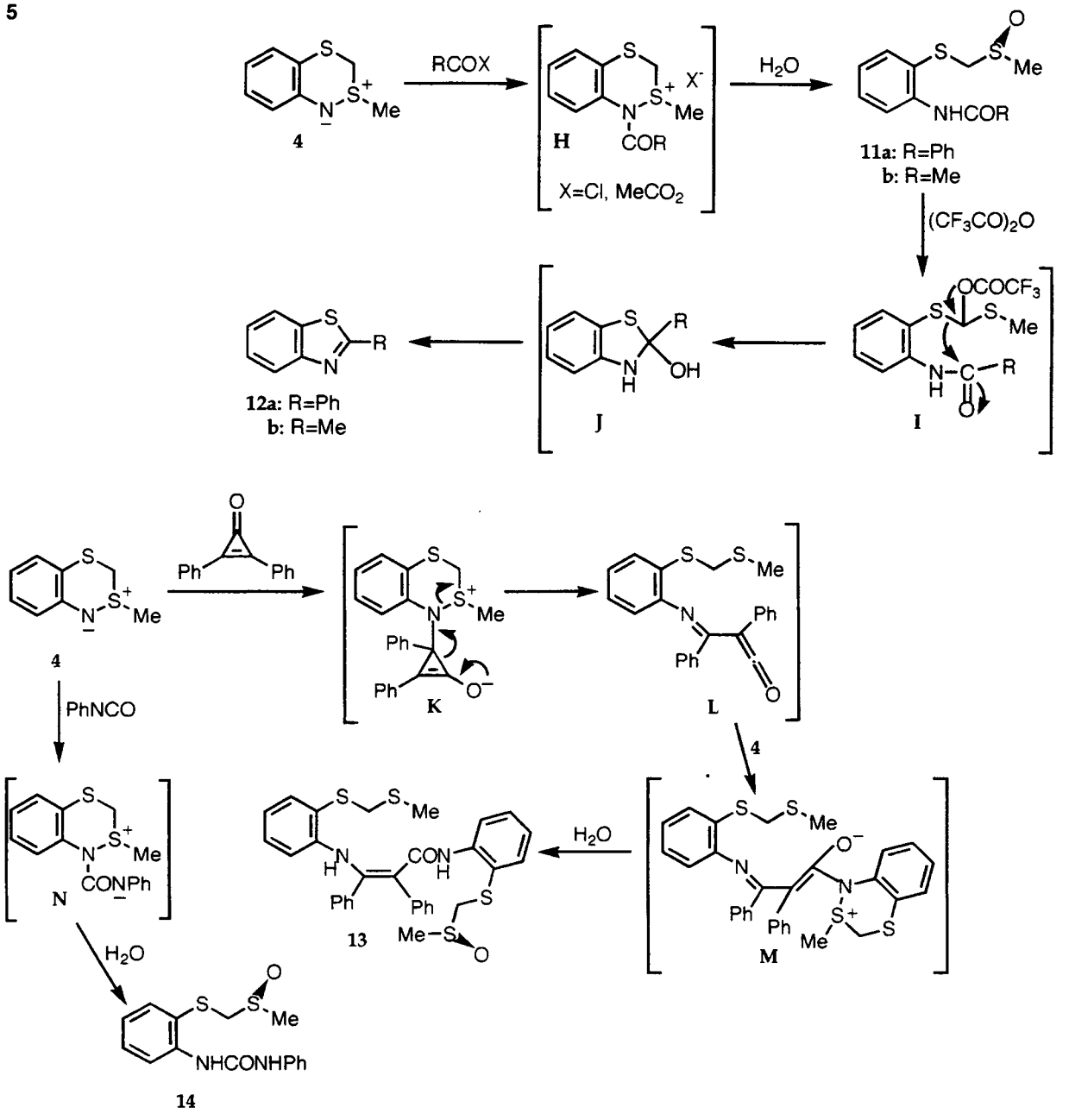
Compound **4** reacted with diphenylcyclopropenone in dichloromethane to afford product **13** in 11% yield (Scheme 6).

The structure of product **13** was established mainly on the basis of spectral evidence. Elemental analyses and mass spectral data (*m/z*, 590 (M^+)) indicated a molecular formula of $C_{31}H_{30}N_2O_2S_4$ for this compound. The IR spectrum showed characteristic absorption bands at 3320 cm^{-1} for the secondary amino group and at 1640 cm^{-1} for the amide-carbonyl group. The ^1H NMR spectrum



SCHEME 4

SCHEME 5

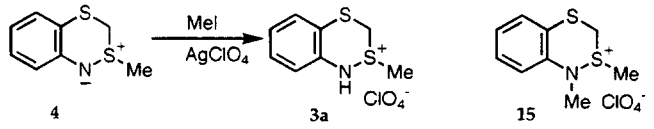


SCHEME 6

showed two methyl signals at δ 2.36 and 2.44 with two methylene signals at δ 3.34 and 4.12, the former being an ABq (J = 13.0 Hz), attributable to the methylene group attached to the sulfinyl moiety. The stereostructure of the stilbene moiety is not clear at present. A possible mechanism for the formation of compound **13** is presented in Scheme 6. Nucleophilic attack of **4** on cyclopropenone forms the zwitterionic intermediate K, which is transformed into the ketene intermediate L with cleavage of the N–S bond. The ketene intermediate L undergoes nucleophilic attack by sulfilimine **4** to give the intermediate M, which is protonated and hydrolyzed during workup to give the final product **13**.

When compound **4** was treated with phenyl isocyanate as an electrophile, the ring-opened adduct **14** was obtained in 27% yield via the *N*-acylated intermediate N, as shown in Scheme 6.

Treatment of compound **4** with methyl iodide in the presence of silver perchlorate did not give



4 3a 15

SCHEME 7

the expected *N*-methylated product **15** but instead the protonated product **3a** in 82% yield (Scheme 7).

This result is similar to that of the attempted alkylation of azathiaphenanthrenes with the same reagents as reported previously [8].

Attempts to Prepare Cyclic Disulfonium Ylides

Although there are a few reported examples of the preparation of acyclic diylides containing two ylide structures in a given molecule [9], there is no report of cyclic diylides. Therefore, we planned to prepare cyclic disulfonium ylides having the benzodithiazine skeleton. Refluxing of azasulfonium salt **3b** with methyl iodide in the presence of silver tetrafluoroborate in dry dichloromethane afforded disulfonium salt **16** as a single isomer in 66% yield. The stereostructure of the salt **16** has not been elucidated at present. Deprotonation of the salt **16** with two equivalents of LDA afforded no corresponding disulfonium ylide **17**, but only the sulfilimine **4** in 72% yield.

We next turned our attention to the generation of another type of cyclic disulfonium ylide. Treatment of sulfoximine **6** with *n*-butyllithium, followed by addition of benzyl bromide, yielded the 3-benzylated sulfoximine **18** in 70% yield. This result indicates the generation of diylide O as an intermediate. The diylide O was also intercepted with other electrophiles. It is of interest that the addition of methyl iodide to the solution of diylide O afforded the dimethylated sulfoximine **19** exclusively, while the addition of trimethylsilyl chloride, surprisingly, gave the 3-chlorinated sulfoximine **21** in 55% yield. Similarly, benzenesulfonyl chloride or phenyl chloroformate also reacted with the ylide O to give **21** in 65 and 49% yields, respectively. On the other hand, treatment of sulfilimine **7** with *n*-butyllithium or LDA, followed by addition of methyl iodide, afforded the 3,3-dimethylated sulfilimine **22** via the diylide P as in the case of sulfoximine **6**.

EXPERIMENTAL

General

Proton NMR spectra were obtained on Hitachi R-20B and JEOL FX-100 spectrometers and are referenced to tetramethysilane as an internal standard. Infrared (IR) spectra were determined on a JASCO IR A-1 infrared spectrometer and are expressed in reciprocal centimeters. Mass spectra (MS) were obtained on a JEOL JMS-D 300 spectrometer with a direct-insertion probe at an ionization voltage of 70 eV. Exact mass determination was conducted on the JMA 2000 on-line system. Melting points were taken on a Yanagimoto micromelting point apparatus and are uncorrected. Elemental analyses were performed by the Microanalytical Laboratory of Gifu Pharmaceutical University. Analytical and preparative thin-layer chromatography (preparative TLC) were performed by using E. M. Merck silica gel 60PF-254.

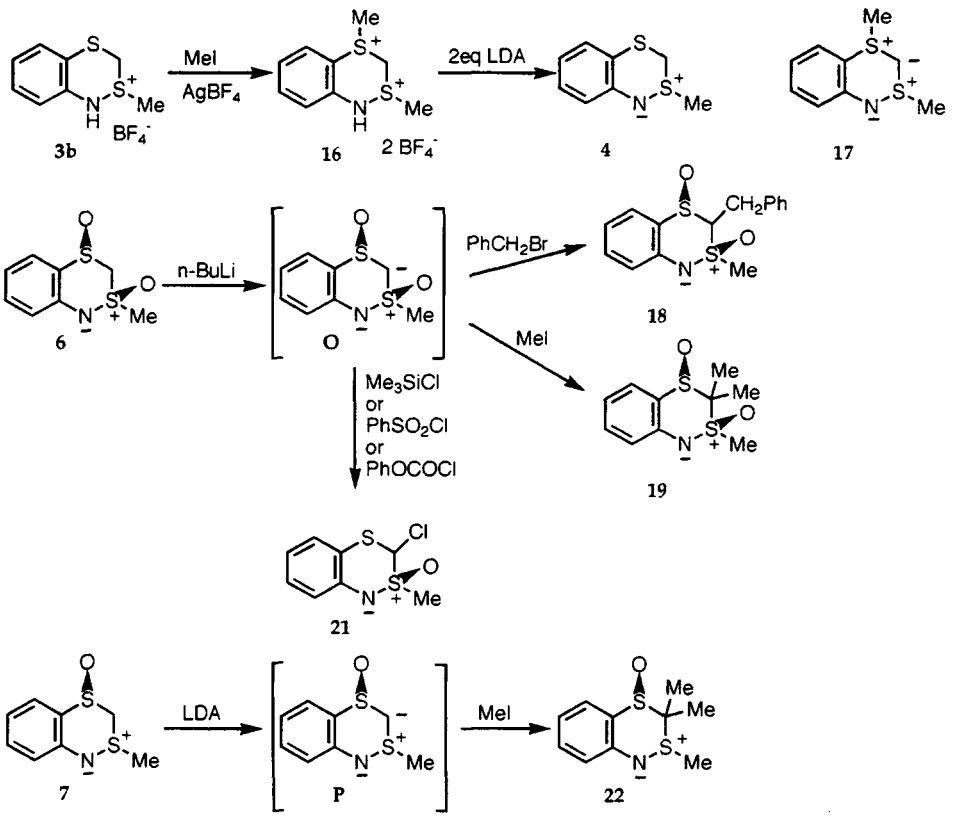
2-Methylthiomethylthioaniline (**2**)

To a stirred solution of 2-aminobenzenethiol (**1**) (5 g, 39.9 mmol) in dry acetonitrile (30 mL) was added portionwise sodium hydride (60%, 2.04 g, 41.9 mmol) at room temperature. After having been stirred for 1 hour, the reaction mixture was cooled to 0°C with an ice-bath. To this was added dropwise chloromethyl methyl sulfide (3.99 g, 41.3 mmol), and the new mixture was stirred at room temperature for 6 hours. The reaction mixture was poured into ice-water and extracted with ether. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated to dryness. The residual oil was purified by column chromatography on silica gel using hexane-ethyl acetate (3:1) as eluent to afford 4.9 g (67.4%) of **2** as a yellow oil; IR (neat), 3460, 3350 cm^{-1} (NH_2); ^1H NMR ($CDCl_3$), δ 2.13 (3H, s, SCH_3), 3.75 (2H, s, CH_2), 4.38 (2H, brs, NH_2), 6.50–7.50 (4H, m, ArH); MS, *m/z*, 185 (M^+), 138 (base); exact mass calcd for $C_8H_{11}NS_2$: 185.0303. found, 185.0316.

2-Methyl-2,4,1-benzodithiazinium Perchlorate (**3a**)

Compound **2** (5 g, 27 mmol) was dissolved in dry dichloromethane (150 mL). The solution was cooled to −50°C and stirred while a solution of NCS (3.76 g, 28.2 mmol) in dry dichloromethane (150 mL) was added dropwise. Stirring was continued for a further 5 hours. Sufficient dry ether was added to the reaction mixture to precipitate a brown oil. The supernatant liquid was discarded, and the residual oil was dissolved in dichloromethane (100 mL). Silver perchlorate (5.6 g, 27 mmol) was added to the dichloromethane solution, and the mixture was stirred for 12 hours at room temperature. The precipitated silver chloride was filtered off and washed several times with acetone. The filtrates and washings were combined and evaporated under reduced pressure to give 5.14 g (67.1%) of **3a** as colorless prisms after recrystallization from acetone-ether; mp 125–126°C (dec); IR (KBr), 3200 (NH), 1100 cm^{-1} (ClO_4^-); ^1H NMR (CF_3CO_2H), δ 3.15 (3H, s, SCH_3), 4.67 (2H, s, CH_2), 6.95 (1H, brs, NH), 7.10–

SCHEME 8



7.45 (4H, m, ArH); MS *m/z*, 135 (base). Anal. calcd for $C_8H_{10}ClNO_4S_2$: C, 33.86; H, 3.55; N, 4.94. Found, C, 33.67; H, 3.48; N, 4.95.

2-Methyl-2,4,1-benzodithiazin-2-ium-1-ide (4)

Sodium hydride (60%, 81.2 mg, 2.03 mmol) was added to an ice-cooled suspension of compound **3a** (522 mg, 1.84 mmol) in dry THF (20 mL) with stirring, and the mixture was stirred for a further 2 hours. The reaction mixture was poured into ice-water and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated to dryness under reduced pressure. The residual solid was recrystallized from dichloromethane-hexane to give 230 mg (68.1%) of **4** as yellow prisms; mp 82–84°C (dec); IR (KBr), 950, 920 cm^{-1}; ^1H NMR ($CDCl_3$), δ 2.62 (3H, s, SCH_3), 3.69 (2H, s, CH_2), 6.60–7.20 (4H, m, ArH); MS *m/z*, 183 (M^+), 136 (base). Anal. calcd for $C_8H_9NS_2$: C, 52.42; H, 4.95; N, 7.64. Found, C, 52.32; H, 5.00; N, 7.67. The preceding reaction was performed with LDA or *n*-butyllithium as a base instead of sodium hydride to afford compound **4** in 64.5 and 58.6% yields, respectively.

Oxidation of Compound 4 *with MCPBA*

To a stirred, ice-cooled solution of compound **4**(300 mg, 1.64 mmol) in dichloromethane (30 mL) was added portionwise MCPBA (404 mg, 1.64 mmol), and the mixture was stirred for 51 hours. The reaction mixture was washed with an aqueous $NaHCO_3$ solution, dried over anhydrous $MgSO_4$, and evaporated to dryness. The residue was submitted to preparative TLC on silica gel using ethyl acetate as eluent to afford the following two compounds. 2-Methyl-2,4,1-benzodithiazin-2-ium-1-ide 2-oxide (**5**) (38.5 mg, 11.8%) as yellow prisms (dichloromethane-hexane); mp 148–149°C; IR (KBr), 1210 cm^{-1}; ^1H NMR ($CDCl_3$), δ 3.30 (3H, s, SCH_3), 3.95 (2H, ABq, J = 12.0 Hz, $\Delta\nu$ = 19.0 Hz, CH_2), 6.60–7.40 (4H, m, ArH); MS *m/z*, 199 (M^+), 136 (base). Anal. calcd for $C_8H_9NOS_2$: C, 48.22; H, 4.55; N, 7.03. Found; C, 48.14; H, 4.88; N, 7.14. 2-Methyl-2,4,1-benzodithiazin-2-ium-1-ide 2,4-dioxide (**6**) (57.5 mg, 16.3%) as yellow prisms (dichloromethane-hexane); mp 133–134°C; IR (KBr), 1210, 1030 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 3.45 (3H, s, SCH_3), 4.35 (2H, ABq, J = 15.0 Hz, $\Delta\nu$ = 54.9 Hz, CH_2), 6.90–7.70 (4H, m, ArH); MS *m/z*, 215 (M^+). Anal. cacld for $C_8H_9NO_2S_2$: C, 44.63; H, 4.21; N, 6.51. Found: C, 44.47; H, 4.11; N, 6.47.

Oxidation of Compound 4 *with Potassium Permanganate*

To a stirred solution of compound **4** (124 mg, 0.68 mmol) in dioxane (20 mL) was added slowly potassium permanganate (107.5 mg, 0.68 mmol), and

the mixture was stirred at room temperature for a further 24 hours. The reaction mixture was poured into water and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated to dryness. The residue was purified by preparative TLC on silica gel using ethyl acetate as eluent to give 44 mg (32.7%) of compound **5**.

2-Methyl-2,4,1-benzodithiazin-2-ium-1-ide 4-Oxide (**7**)

MCPBA (364 mg, 1.48 mmol) was added portionwise to a stirred, ice-cooled suspension of compound **3a** (420 mg, 1.48 mmol) in dry dichloromethane (30 mL), and the mixture was stirred for an additional 24 hours at 0°C, and then for a further 24 hours at room temperature. The solvent was evaporated under reduced pressure, and the residue was dissolved in dry THF (30 mL). To this solution was added an ether solution of *n*-butyllithium (2.96 mmol) at −20°C, and the mixture was stirred for 2 hours. The reaction mixture was poured into ice-water and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated. The residue was submitted to preparative TLC on silica gel using ethyl acetate as eluent to afford 98 mg (33.3%) of compound **7** as yellow prisms after recrystallization from dichloromethane-hexane; mp 111–112°C; IR (KBr), 1030 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 2.29 (3H, s, SCH_3), 5.05 (2H, s, CH_2), 6.70–7.60 (4H, m, ArH); MS *m/z*, 199 (M^+), 136 (base). Anal. calcd for $C_8H_9NOS_2$: C, 48.22; H, 4.55; N, 7.03. Found: C, 48.03; H, 4.56; N, 6.83.

Oxidation of Compound **7** *with MCPBA*

MCPBA (227 mg, 0.92 mmol) was added portionwise to an ice-cooled solution of compound **7** (183 mg, 0.92 mmol) in dry dichloromethane (30 mL) with stirring. After having been stirred for 48 hours at 0°C, the mixture was poured into water, made basic with $NaHCO_3$, and extracted with dichloromethane. The extract was washed with water, dried over $MgSO_4$, and evaporated. The residue was purified by preparative TLC on silica gel using ethyl acetate as eluent to afford 90 mg (45.6%) of compound **6**.

Reduction of Compound **6** *with* $LiAlH_4$

$LiAlH_4$ (13 mg, 1.39 mmol) was added to an ice-cooled solution of compound **6** (300 mg, 1.39 mmol) in dry THF (30 mL) with stirring. After having been stirred for 29 hours at room temperature, the reaction mixture was poured onto ice and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated. The residue was subjected to preparative TLC on silica gel using ethyl acetate as eluent to give 46 mg (7.9%) of compound **2** and 146 mg (52.7%) of sulfoximine **5**.

Reduction of Compound **4** *with* $LiAlH_4$

To an ice-cooled solution of compound **4** (121 mg, 0.66 mmol) in dry THF (20 mL) was slowly added $LiAlH_4$ (65 mg, 0.68 mmol) with stirring, and the mixture was stirred at 0°C for an additional 5 hours and then at room temperature for 18 hours. The reaction mixture was poured into ice-water and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated to dryness. The residue was purified by preparative TLC on silica gel using ethyl acetate-hexane (1:5) as eluent to afford 87.8 mg (71.9%) of compound **2**.

Thermolysis of Compound **4**

A solution of compound **4** (298 mg, 1.63 mmol) in dry toluene (30 mL) was refluxed for 20 hours under a nitrogen atmosphere. The reaction mixture was concentrated to dryness, and the residual oil was purified by preparative TLC on silica gel using hexane-ethyl acetate (5:1) as eluent to afford 97.6 mg (44.3%) of benzothiazole **8**, which was identified by the comparison of its spectral data with those of a commercially available sample. Similarly, the preceding thermolysis of compound **4** in refluxing dry ethanol afforded compound **8** in 72.6% yield, together with 31 mg (14.2%) of 2-methylsulfinylmethylthioaniline, mp 66–67.5°C; IR (KBr), 3400, 3300 (NH_2), 1020 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 2.58 (3H, s, SCH_3), 3.89 (2H, s, CH_2), 4.31 (2H, brs, NH_2), 6.50–7.60 (4H, m, ArH); MS *m/z*, 201 (M^+), 138 (base). Anal. calcd for $C_8H_{11}NOS_2$: C, 47.73; H, 5.51; N, 6.96. Found, C, 47.64; H, 5.49; N, 6.98.

Reaction of Compound **4** *with DMAD*

A solution of DMAD (204 mg, 1.4 mmol) in dry dichloromethane (5 mL) was added dropwise to a stirred solution of compound **4** (239 mg, 1.3 mmol) in dry dichloromethane (20 mL) at −20°C, and the mixture was stirred for 24 hours at 0°C, and then for a further 24 hours at room temperature. The solvent was evaporated under reduced pressure, and the residue was subjected to preparative TLC on silica gel using hexane-ethyl acetate (1:1) as eluent to afford 105 mg (23.5%) of dimethyl 2-(2-methylsulfinylmethylthiophenylamino)maleate **9a** as yellow prisms after recrystallization from dichloromethane-hexane, mp 96–98°C (dec); IR (KBr), 3240 (NH), 1740 and 1680 (ester), 1050 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 2.66 (3H, s, SCH_3), 3.72 (3H, s, OCH_3), 3.77 (3H, s, OCH_3), 4.03 (2H, ABq, J = 13.2 Hz, CH_2), 5.58 (1H, s, =CH), 6.71–7.64 (4H, m, ArH), 9.88 (1H, brs, NH); ^{13}C NMR ($CDCl_3$), δ 37.99 (q),

51.46 (q), 52.93 (q), 56.13 (t), 96.55 (d), 120.88 (d), 123.53 (s), 124.61 (d), 130.07 (d), 135.39 (d), 142.11 (s), 146.51 (s), 164.39 (s), 169.41 (s); MS *m/z*, 343 (M^+), 248 (base). Anal. calcd for $C_{14}H_{17}NO_5S_2$: C, 48.97; H, 4.99; N, 4.08. Found: C, 49.10; H, 5.05; N, 4.14.

Reaction of Compound **4** *with DEAD*

A mixture of compound **4** (130 mg, 0.71 mmol) and DEAD (133 mg, 0.78 mmol) in dry dichloromethane (20 mL) was stirred for 2 days and worked up as previously discussed to afford 108 mg (40.9%) of diethyl 2-(2-methylsulfinylmethylthiophenylamino)maleate (**9b**) as a yellow oil, IR (neat), 3240 (NH), 1740 and 1660 (ester), 1030 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 1.10 (3H, t, J = 7.2 Hz, $CH_2\underline{CH_3}$), 1.28 (3H, t, J = 7.2 Hz, $CH_2\underline{CH_3}$), 2.61 (3H, s, SCH_3), 4.00 (2H, ABq, J = 13.2 Hz, CH_2), 4.15 (2H, q, J = 7.2 Hz, $C\underline{H_2}CH_3$), 4.20 (2H, q, J = 7.2 Hz, $C\underline{H_2}CH_3$), 5.52 (1H, s, C=CH), 6.60–7.70 (4H, m, ArH), 9.82 (1H, brs, NH); MS *m/z*, 371 (M^+), 234 (base).

Dimethyl 2-(2-Methylthiomethylthiophenylamino)maleate (**10**)

To a stirred solution of 2-methylthiomethylthioaniline (**2**) (1 g, 5.4 mmol) in dry dichloromethane (50 mL) was added a solution of DMAD (767 mg, 5.4 mmol) in dry dichloromethane (5 mL), and the mixture was stirred for 24 hours at room temperature. The solvent was evaporated under reduced pressure to leave crystals, which were recrystallized from dichloromethane-hexane to give 1.7 g (96.7%) of compound **10** as yellow prisms, mp 80–82°C, IR (KBr), 3260 (NH), 1740 and 1680 cm^{-1} (ester); ^1H NMR ($CDCl_3$), δ 2.19 (3H, s, SCH_3), 3.61 (3H, s, OCH_3), 3.68 (3H, s, OCH_3), 3.88 (2H, s, CH_2), 5.41 (1H, s, C=CH), 6.50–7.55 (4H, m, ArH), 9.80 (1H, brs, NH); MS *m/z*, 327 (M^+), 266 (base). Anal. calcd for $C_{14}H_{17}NO_4S_2$: C, 51.36; H, 5.23; N, 4.28. Found, C, 51.21; H, 5.19; N, 4.16.

Dimethyl 2-(2-Methylsulfinylmethylthiophenylamino)maleate (**9a**)

MCPBA (377 mg, 1.53 mmol) was added portionwise to a stirred solution of compound **10** (500 mg, 1.53 mmol) in dry dichloromethane (50 mL) at 0°C, and the mixture was stirred for 24 hours at the same temperature. The reaction mixture was washed twice with an aqueous $NaHCO_3$ solution, dried over anhydrous $MgSO_4$, and evaporated to dryness. The residue was purified by preparative TLC on silica gel with hexane-ethyl acetate (1:1) as eluent to afford 328 mg (62.5%) of compound **9a**.

Reaction of Compound **4** *with Benzoyl Chloride*

A solution of benzoyl chloride (285 mg, 2.02 mmol) in dry dichloromethane (5 mL) was added dropwise to a stirred solution of compound **4** (338 mg, 2.02 mmol) in dry dichloromethane (30 mL) at −50°C, and the mixture was stirred for 3 hours at −50°C, and then for a further 10 hours at room temperature. After the solvent had been evaporated, the residue was submitted to preparative TLC on silica gel using hexane-ethyl acetate (1:1) as eluent to give colorless crystals, which were recrystallized from dichloromethane-hexane to afford 128 mg (22.8%) of *N*-(2-methylsulfinylmethylthiophenyl)benzamide (**11a**) as colorless prisms, mp 73–74°C, IR (KBr), 3180 (NH), 1660 (CO), 1030 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 2.53 (3H, s, SCH_3), 4.00 (2H, ABq, J = 13.5 Hz, CH_2), 7.00–8.40 (9H, m, ArH), 10.02 (1H, brs, NH); MS *m/z*, 306 (M^+), 242 (base). Anal. calcd for $C_{15}H_{15}NO_2S_2$: C, 58.99; H, 4.95; N, 4.59. Found: C, 58.77; H, 4.91; N, 4.52.

Reaction of Compound **4** *with Acetic Anhydride*

A solution of compound **4** (138 mg, 0.75 mmol) in acetic anhydride (5 mL) was stirred for 3 hours at 30°C. The reaction mixture was poured into water, made basic with $NaHCO_3$, and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated under reduced pressure. The residual oil was purified by preparative TLC on silica gel with hexane-ethyl acetate (1:1) as eluent to give 75 mg (34.5%) of *N*-(2-methylsulfinylmethylthiophenyl)acetamide (**11b**) as colorless prisms after recrystallization from dichloromethane-hexane, mp 94–95°C; IR (KBr), 3200 (NH), 1680 (CO), 1030 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 2.21 (3H, s, SCH_3), 2.54 (3H, s, $COCH_3$), 3.92 (2H, s, CH_2), 6.85–8.30 (4H, m, ArH), 9.60 (1H, brs, NH); MS *m/z*, 244 (M^+), 180 (base). Anal. calcd for $C_{10}H_{13}NO_2S_2$: C, 49.36; H, 5.39; N, 5.76. Found: C, 49.28; H, 5.33; N, 5.60.

Reaction of Compound **11** *with Trifluoroacetic Anhydride*

A solution of trifluoroacetic anhydride (114 mg, 0.54 mmol) in dry dichloromethane (5 mL) was added dropwise to a solution of compound **11a** (150 mg, 0.49 mmol) in dry dichloromethane (15 mL) at 0°C, and the mixture was stirred for 18 hours at room temperature. The reaction mixture was poured into water, made basic with $NaHCO_3$, and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated. The residue was purified by preparative TLC on silica gel using hexane-ethyl acetate (3:1) as eluent to give 83 mg (80%) of 2-phenylbenzothiazole (**12a**). Similarly, treatment of compound **11b** (100 mg, 0.41 mmol) with trifluoroacetic anhydride (95 mg, 0.45 mmol) in dry dichloromethane (13 mL), followed by workup as above afforded 41 mg (67.1%) of 2-methylbenzothiazole (**12b**). The

previously discussed, two benzothiazoles **12a** and **12b** were identical in all respects preceding with commercially available samples.

Reaction of Compound **4** *with Diphenylcyclopropenone*

A mixture of compound **4** (391 mg, 2.13 mmol) and diphenylcyclopropenone (483 mg, 2.34 mmol) in dry dichloromethane (30 mL) was stirred for 24 hours at room temperature. The reaction mixture was evaporated to leave an oil, which was separated by preparative TLC on silica gel using hexane-ethyl acetate (1:1) as eluent to afford 156 mg (11.2%) of 1-[2-(methylthiomethylthiophenylamino)]-2-(2-methylsulfinylmethylthiophenylcarbamoyl) - 1, 2-diphenylethylene (**13**) as yellow prisms, mp 89–90°C; IR (KBr), 3320 (NH), 1640 (CO), 1050 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 2.36 (3H, s, SCH_3), 2.44 (3H, s, SCH_3), 3.34 (2H, ABq, J = 13.0 Hz, CH_2), 4.12 (2H, s, CH_2), 6.25–7.50 (8H, m, ArH), 8.23 (1H, brs, NH), 8.48 (1H, brs, NH); MS m/z, 590 (M^+), 302 (base). Anal. calcd for $C_{31}H_{30}N_2O_2S_4$: C, 61.16; H, 5.29; N, 4.60. Found: C, 61.40; H, 4.98; N, 4.58.

Reaction of Compound **4** *with Phenyl Isocyanate*

A mixture of compound **4** (500 mg, 2.73 mmol) and phenyl isocyanate (326 mg, 2.73 mmol) in dry dichloromethane (50 mL) was stirred for 24 hours at 10°C. The reaction mixture was concentrated to dryness and the residue was submitted to preparative TLC on silica gel using hexane-ethyl acetate (1:1) as eluent to give 231 mg (26.4%) of *N*-(2-methylsulfinylmethylthiophenyl)-*N'*-phenylurea (**14**) as a yellow oil, IR (neat), 3320 (NH), 1710 (CO), 1030 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 2.53 (3H, s, SCH_3), 3.88 (2H, s, CH_2), 6.75–8.00 (4H, m, ArH), 8.20 (1H, brs, NH), 9.08 (1H, brs, NH); MS m/z, 320 (M^+), 138 (base).

Reaction of Compound **4** *with Methyl Iodide in the Presence of Silver Perchlorate*

Silver perchlorate (370 mg, 1.79 mmol) was added to a stirred mixture of compound **4** (297 mg, 1.62 mmol) and methyl iodide (1.3 g, 9.16 mmol) in dry dichloromethane (30 mL), and the mixture was stirred for 24 hours at room temperature. A precipitate was filtered off and washed with acetonitrile. The filtrate and washings were combined and evaporated under reduced pressure to afford 375 mg (81.6%) of 2-methyl-2,4,1-benzodithiazinium perchlorate (**3a**).

2,4-Dimethyl-2,4,1-benzodithiazin-2,4-diium Bis-tetrafluoroborate (**16**)

To a stirred solution of 2-methyl-2,4,1-benzodithiazinium tetrafluoroborate (**3b**) (1.5 g, 5.53 mmol) and methyl iodide (15.7 g, 0.11 mol) in dry dichloromethane (50 mL) was added silver tetrafluoroborate (1.08 g, 5.54 mmol), and the mixture was refluxed for 48 hours. The reaction mixture was filtered and solids were washed twice with acetonitrile. The filtrate and washings were combined and evaporated to give crystals, which were recrystallized from acetonitrile-hexane to afford 1.37 g (66.4%) of compound **16** as colorless prisms, mp 144–146°C; IR (KBr), 1100 cm^{-1} (BF_4^-); ^1H NMR (CF_3CO_2H), δ 3.20 (3H, s, CH_3), 3.68 (3H, s, CH_3), 5.95 (2H, ABq, J = 15.0 Hz, $\Delta\nu$ = 30.2 Hz, CH_2), 7.70–8.40 (5H, m, ArH and NH); MS m/z, 135 (base). Anal. calcd for $C_9H_{13}B_2F_8NS_2$: C, 28.99; H, 3.51; N, 3.76. Found, C, 29.05; H, 3.52; N, 3.78.

Treatment of Compound **16** *with LDA*

A THF solution of LDA (1.186 mmol) was added at −50°C to a stirred suspension of compound **16** (200 mg, 0.536 mmol) in dry THF (20 mL) under a nitrogen atmosphere, and the mixture was stirred for 1 hour at the same temperature. The reaction mixture was poured into water and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated to give 71.1 mg (72.3%) of compound **4** after preparative TLC purification.

Reaction of the Carbanion Derived from Compound **6** *with Electrophiles*

With Benzyl Bromide. An ethereal solution of *n*-butyllithium (2.49 mmol) was added to a stirred solution of compound **6** (500 mg, 2.32 mmol) in dry THF (30 mL) at −30°C under a nitrogen atmosphere, and the mixture was stirred for 2 hours at −30°C. To this solution was added dropwise a solution of benzyl bromide (420 mg, 2.46 mmol) in dry THF (5 mL), and the mixture was stirred for 19 hours. The reaction mixture was poured into water and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$, and evaporated to dryness. The residue was subjected to preparative TLC on silica gel using ethyl acetate as eluent to afford 498 mg (70.3%) of 3-benzyl-2-methyl-2,4,1-benzodithiazin-2-ium-1-ide 2,4-dioxide (**18**) as colorless needles, after recrystallization from dichloromethane-hexane, mp 165.5–166.5°C; IR (KBr), 1220, 1020 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 3.40 (3H, s, CH_3), 3.50–4.13 (3H, m, CH_2 and CH), 6.75–7.75 (9H, m, ArH); MS m/z, 305 (M^+, base). Anal. calcd for $C_{15}H_{15}NO_2S$: C, 58.99; H, 4.95; N, 4.59. Found: C, 58.72; H, 4.95; N, 4.57.

With Methyl Iodide. The reaction was performed using methyl iodide instead of benzyl bromide and worked up as above to give 45.2% of 2,3,3-trimethyl-2,4,1-benzodithiazin-2-ium-1-ide 2,4-di-

oxide (**19**) as a yellow oil; IR (neat), 1220, 1030, 1025 cm^{-1} (SO); ^1H NMR ($CDCl_3$), δ 1.42 (3H, s, CH_3), 1.97 (3H, s, CH_3), 3.34 (3H, s, SCH_3), 6.91–7.64 (4H, m, ArH); ^{13}C NMR ($CDCl_3$), δ 15.56 (q), 17.08 (q), 40.71 (q), 65.29 (s), 120.88 (s), 120.89 (d), 125.05 (d), 132.22 (d), 134.45 (d), 143.61 (s); MS *m/z*, 243 (M^+), 163 (base). High resolution MS, calcd for $C_{10}H_{13}NO_2S_2$: 243.339. Found, 243.036.

With Trimethylsilyl Chloride. The reaction was performed by using trimethylsilyl chloride instead of methyl iodide and worked up as previously discussed to afford 54.8% of 3-chloro-2-methyl-2,4,1-benzodithiazin-2-ium-1-ide 2-oxide (**21**) as pale yellow prisms, mp 142–143°C; IR (KBr) 1215 cm^{-1}; ^1H NMR ($CDCl_3$), δ 3.40 (3H, s, CH_3), 5.93 (1H, s, CH), 6.75–7.50 (4H, m, ArH); MS *m/z*, 233 (M^+), 135 (base). Anal. calcd for $C_8H_8ClNOS_2$: C, 41.11; H, 3.45; N, 5.99. Found: C, 40.90; H, 3.36; N, 5.99. Similarly, benzenesulfonyl chloride or phenyl chloroformate also reacted with the anion of compound **6** to give compound **21** in 64.5 and 49.2% yields, respectively.

Reaction of the Carbanion Derived from Compound **7** *with Methyl Iodide*

A THF solution of LDA (0.72 mmol) was added at −50°C to a stirred solution of compound **7** (143 mg, 0.72 mmol) in dry THF (15 mL) under a nitrogen atmosphere, and the mixture was stirred for 1 hour. To this solution was added a solution of methyl iodide (102 mg, 0.72 mmol) in THF (3 mL), and the mixture was stirred for 24 hours. The reaction mixture was poured into water and extracted with dichloromethane. The extract was washed with water, dried over anhydrous $MgSO_4$ and evaporated. The residue was separated by preparative TLC on silica gel using ethyl acetate as eluent to afford 42 mg (25.7%) of 2,3,3-trimethyl-2,4,1-benzodithiazin-2-ium-1-ide 4-oxide (**22**) and 30 mg of starting material. Compound **22**: a yellow oil; IR (neat), 1125, 1110 cm^{-1}; ^1H NMR ($CDCl_3$), δ 1.60 (3H, s, CH_3), 2.13 (3H, s, CH_3), 3.28 (3H, s, CH_3), 6.63–7.50 (4H, m, ArH); MS *m/z*, 227 (M^+, very weak), 164 (base).

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