Supporting Information

for

Bromomethyllithium-Mediated Chemoselective Homologation of Disulfides to Dithioacetals

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**Instrumentation and General Analytical Methods**

Melting points were determined on a Reichert–Kofler hot-stage microscope and are uncorrected. Mass spectra were obtained on a Shimadzu QP 1000 instrument (EI, 70 eV) and on a Bruker maXis 4G instrument (ESI-TOF, HRMS). IR spectra were recorded on a Perkin-Elmer FTIR 1605 spectrophotometer. $^1$H, $^{13}$C, $^{15}$N and $^{19}$F NMR spectra were recorded with a Bruker Avance III 400 spectrometer (400 MHz for $^1$H, 100 MHz for $^{13}$C, 40 MHz for $^{15}$N, 376 MHz for $^{19}$F) at 297 K using a “directly” detecting broadband observe (BBFO) probe. The center of the solvent signal was used as an internal standard which was related to TMS with $\delta$ 7.26 ppm ($^1$H in CDCl$_3$), $\delta$ 77.0 ppm ($^{13}$C in CDCl$_3$). $^{15}$N NMR spectra (gs-HMBC) were referenced against neat, external nitromethane, $^{19}$F NMR spectra by absolute referencing via $\varepsilon$ ratio. Spin-spin coupling constants ($J$) are given in Hz. In nearly all cases, full and unambiguous assignment of all resonances was performed by combined application of standard NMR techniques, such as APT, HSQC, HMBC, COSY and NOESY experiments.

THF and 2-MeTHF were distilled over Na / benzophenone. Chemicals were purchased from Sigma-Aldrich, Acros, Alfa Aesar and TCI Europe, otherwise specified. Solutions were evaporated under reduced pressure with a rotary evaporator. TLC was carried out on aluminium sheets precoated with silica gel 60F254 (Macherey-Nagel, Merk); the spots were visualised under UV light ($\lambda$ = 254 nm) and/or KMnO$_4$ (aq.) was used as revealing system.
General Procedure for the preparation of dithioacetals or diselenoacetals

To a cooled (-78 °C) solution of disulfide or diselenide (1.0 equiv) in dry THF was added trimethylsilyl chloride (2.0 equiv) and bromoiodomethane (3.0 equiv). After 2 min, an ethereal solution of MeLi-LiBr (2.5 equiv, 1.5 M) was added dropwise over 5 min. The resulting solution was stirred for 2 h at that temperature and, after removing the cooling bath the mixture was stirred for 1 additional hour at rt. Saturated aq. NH₄Cl was added (2 mL/mmol substrate) and then, the organic phase was extracted with Et₂O (2 x 5 mL), washed with water (5 mL) and brine (10 mL). The organic phase was dried (anhydrous Na₂SO₄), filtered and, after removal of the solvent under reduced pressure, the so-obtained crude mixture was subjected to chromatography (silica gel) to afford pure compounds.

[(chloromethyl)sulfanyl]benzene (2a)

\[
\text{S-Cl} \quad \text{Ph}
\]

By following the General Procedure 1, starting from diphenyl disulfide (0.20 g, 0.92 mmol, 1.0 equiv), TMSCl (0.20 g, 0.23 mL, 1.84 mmol, 2.0 equiv), ICH₂Cl (0.41 g, 0.17 mL, 2.30 mmol, 2.5 equiv), and MeLi-LiBr (1.53 mL, 2.30 mmol) in THF, compound 2a was obtained in 68% (99 mg) as a colorless oil after chromatography on silica gel (n-hexane-DCM, 95:5).

\(^1\text{H NMR}\) (400 MHz, CDCl₃) δ: 7.50 (m, 2H, Ph H-2,6), 7.38 (m, 2H, Ph H-3,5), 7.30 (m, 1H, Ph H-4), 5.38 (s, 2H, SCH₂Cl).

\(^{13}\text{C NMR}\) (100 MHz, CDCl₃) δ: 133.9 (Ph C-1), 129.2 (Ph C-2,3,5,6), 127.3 (Ph C-4), 50.2 (SCH₂Cl).

HRMS (APCI), m/z: calcd. for C₇H₈ClH⁺ 159.0029 [M+H]⁺; found 159.0027.
1,1’-(methylenedisulfanediyl)dibenzene (3a)

By following the General Procedure 1, starting from diphenyl disulfide (0.20 g, 0.92 mmol, 1.0 equiv), TMSCl (0.20 g, 0.23 mL, 1.84 mmol, 2.0 equiv), ICH2Br (0.61 g, 0.21 mL, 2.76 mmol, 3.0 equiv), and MeLi-LiBr (1.53 mL, 2.30 mmol) in THF, compound 3a was obtained in 95% (203 mg) as a white solid after chromatography on silica gel (n-hexane-DCM, 95:5). mp 34 °C (lit.1 30-34 °C).

1H NMR (400 MHz, CDCl3) δ: 7.43 (m, 4H, Ph H-2,6), 7.32 (m, 4H, Ph H-3,5), 7.25 (m, 2H, Ph H-4), 4.35 (s, 2H, SCH2S).
13C NMR (100 MHz, CDCl3) δ: 135.0 (Ph C-1), 130.7 (Ph C-2,6), 129.0 (Ph C-3,5), 127.1 (Ph C-4), 40.6 (SCH2S).
HRMS (APCI), m/z: calcd. for C13H12S2 232.0380 M+; found 232.0372.

1,1’-(methylenedisulfanediyl)bis(4-methylbenzene) (3b)

By following the General Procedure 1, starting from p-tolyl disulfide (0.20 g, 0.81 mmol, 1.0 equiv), TMSCl (0.18 g, 0.21 mL, 1.62 mmol, 2.0 equiv), ICH2Br (0.54 g, 0.20 mL, 2.43 mmol, 3.0 equiv), and MeLi-LiBr (1.35 mL, 2.03 mmol) in THF, compound 3b was obtained in 90% (190 mg) as a colorless oil after chromatography on silica gel (n-hexane-DCM, 95:5).

1H NMR (400 MHz, CDCl3) δ: 7.36 (m, 4H, Ph H-2,6), 7.15 (m, 4H, Ph H-3,5), 4.29 (s, 2H, SCH2S), 2.36 (s, 6H, Ph-4-CH3).
13C NMR (100 MHz, CDCl3) δ: 137.3 (Ph C-4), 131.4 (Ph C-2,6), 131.2 (Ph C-1), 129.7 (Ph C-3,5), 41.9 (SCH2S), 21.1 (Ph-4-CH3).
HRMS (APCI), m/z: calcd. for C15H16S2H+ 261.0766 [M+H]+; found 261.0773.
1,1’-(methylenebisulfanediyl)bis(4-methoxybenzene) (3c)

By following the General Procedure 1, starting from bis(4-methoxyphenyl)disulfide (0.20 g, 0.72 mmol, 1.0 equiv), TMSCl (0.16 g, 0.18 mL, 1.44 mmol, 2.0 equiv), ICH₂Br (0.48 g, 0.16 mL, 2.16 mmol, 3.0 equiv), and MeLi-LiBr (1.91 mL, 2.87 mmol) in THF, compound 3c was obtained in 81% (171 mg) as a white solid after chromatography on silica gel (n-hexane-EtOAc, 95:5). mp 67 °C (lit.¹ 66-67 °C).

¹H NMR (400 MHz, CDCl₃) δ: 7.40 (m, 4H, Ph H-2,6), 6.86 (m, 4H, Ph H-3,5), 4.15 (s, 2H, SCH₂S), 3.81 (s, 6H, Ph-4-OCH₃).

¹³C NMR (100 MHz, CDCl₃) δ: 159.6 (Ph C-4), 134.4 (Ph C-2,6), 125.2 (Ph C-1), 114.6 (Ph C-3,5), 55.3 (Ph-4-OCH₃), 44.5 (SCH₂S).

HRMS (APCI), m/z: calcd. for C₁₅H₁₆O₂S₂H⁺ 293.4190 [M+H⁺]; found 293.4188.

1,1’-(methylenebisulfanediyl)bis(4-chlorobenzene) (3d)

By following the General Procedure 1, starting from 4,4’-dichlorodiphenyl disulfide (0.20 g, 0.70 mmol, 1.0 equiv), TMSCl (0.15 g, 0.18 mL, 1.40 mmol, 2.0 equiv), ICH₂Br (0.46 g, 0.16 mL, 2.10 mmol, 3.0 equiv), and MeLi-LiBr (1.17 mL, 1.75 mmol) in THF, compound 3d was obtained in 90% (190 mg) as a white solid after chromatography on silica gel (n-hexane-DCM, 95:5). mp 43 °C (lit.¹ 42-43 °C)

¹H NMR (400 MHz, CDCl₃) δ: 7.34 (m, 4H, Ph H-2,6), 7.29 (m, 4H, Ph H-3,5), 4.28 (s, 2H, SCH₂S).

¹³C NMR (100 MHz, CDCl₃) δ: 133.5 (Ph C-4), 132.9 (Ph C-1), 132.4 (Ph C-2,6), 129.2 (Ph C-3,5), 41.2 (SCH₂S).

HRMS (APCI), m/z: calcd. for C₁₃H₁₀Cl₂S₂ 299.9595 [M+H⁺]; found 299.9601.
1,1’-(methylenedisulfanediyl)bis(2,4,5-trichlorobenzene) (3e)

By following the General Procedure 1, starting from the 1,2,4-trichloro-5-[(2,4,5-trichlorophenyl)disulfonyl]benzene (0.20 g, 0.47 mmol, 1.0 equiv), TMSCI (0.10 g, 0.12 mL, 0.94 mmol, 2.0 equiv), ICH\textsubscript{2}Br (0.31 g, 0.11 mL, 1.41 mmol, 3.0 equiv), and MeLi-LiBr (0.78 mL, 1.18 mmol) in THF, compound 3e was obtained in 92% (190 mg) as a white solid after chromatography on silica gel (n-hexane-EtOAc, 95:5). mp 146 °C (lit.\textsuperscript{2} 146-147 °C)

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\): 7.51 (s, 2H, Ph H-6), 7.50 (s, 2H, Ph H-3), 4.37 (s, 2H, SCH\textsubscript{2}S).

\textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\): 134.3 (Ph C-2), 133.0 (Ph C-1), 132.7 (Ph C-6), 132.4 (Ph C-4), 131.5 (Ph C-5), 131.0 (Ph C-3), 37.6 (SCH\textsubscript{2}S).

HRMS (APCI), \(m/z\): calcd. for C\textsubscript{13}H\textsubscript{6}Cl\textsubscript{6}S\textsubscript{2} 435.8037 M\textsuperscript{+}; found 435.8042.

1,1’-(methylenedisulfanediyl)bis(5-bromo-2-chlorobenzene) (3f)

By following the General Procedure 1, starting from di(5-bromo-2-chlorophenyl)disulfide (0.20 g, 0.45 mmol, 1.0 equiv), TMSCI (0.10 g, 0.11 mL, 0.90 mmol, 2.0 equiv), ICH\textsubscript{2}Br (0.30 g, 0.10 mL, 1.35 mmol, 3.0 equiv), and MeLi-LiBr (0.94 mL, 1.13 mmol) in THF, compound 3f was obtained in 87% (180 mg) as a white solid after chromatography on silica gel (n-hexane-DCM, 95:5). mp 88 °C

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\): 7.57 (d, \(^4J = 2.2\) Hz, 2H, Ph H-6), 7.32 (dd, \(^3J = 8.5\) Hz, \(^4J = 2.2\) Hz, 2H, Ph H-4), 7.25 (d, \(^4J = 8.5\) Hz, 2H, Ph H-3), 4.39 (s, 2H, SCH\textsubscript{2}S).

\textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\): 135.4 (Ph C-1), 134.1 (Ph C-2), 133.7 (Ph C-6), 131.3 (Ph C-4), 131.0 (Ph C-3), 120.7 (Ph C-5), 37.1 (SCH\textsubscript{2}S).

HRMS (APCI), \(m/z\): calcd. for C\textsubscript{13}H\textsubscript{8}Br\textsubscript{2}Cl\textsubscript{2}S\textsubscript{2}H\textsuperscript{+} 455.7812 [M+H]\textsuperscript{+}; found 455.7823.
1,1’-(methylenebisulfanediyl)bis(4-bromobenzene) (3g)

By following the General Procedure 1, starting from the 4-bromophenyl disulfide (0.20 g, 0.53 mmol, 1.0 equiv), TMSCl (0.12 g, 0.13 mL, 1.06 mmol, 2.0 equiv), ICH₂Br (0.35 g, 0.12 mL, 1.59 mmol, 3.0 equiv), and MeLi-LiBr (1.42 mL, 2.13 mmol) in THF, compound 3g was obtained in 86% (178 mg) as a white solid after chromatography on silica gel (n-hexane-DCM, 95:5). mp 71 °C (lit.¹ 70.5-72.0 °C)

¹H NMR (400 MHz, CDCl₃) δ: 7.43 (m, 4H, Ph H-3,5), 7.27 (m, 4H, Ph H-2,6), 4.28 (s, 2H, SCH₂S).

¹³C NMR (100 MHz, CDCl₃) δ: 133.6 (Ph C-1), 132.5 (Ph C-2,6), 132.1 (Ph C-3,5), 121.5 (Ph C-4), 40.8 (SCH₂S).

HRMS (APCI), m/z: calcd. for C₁₃H₁₀Br₂S₂H⁺ 388.8663 [M+H]⁺; found 388.8671.

1,1’-(methylenebisulfanediyl)bis(4-fluorobenzene) (3h)

By following the General Procedure 1, starting from bis(4-fluorophenyl)disulfide (0.20 g, 0.79 mmol, 1.0 equiv), TMSCl (0.17 g, 0.20 mL, 1.58 mmol, 2.0 equiv), ICH₂Br (0.52 g, 0.18 mL, 2.37 mmol, 3.0 equiv), and MeLi-LiBr (1.32 mL, 1.97 mmol) in THF, compound 3h was obtained in 83% (194 mg) as a colorless oil after chromatography on silica gel (n-hexane-DCM, 95:5).

¹H NMR (400 MHz, CDCl₃) δ: 7.41 (m, 4H, Ph H-2,6), 7.02 (m, 4H, Ph H-3,5), 4.22 (s, 2H, SCH₂S).

¹³C NMR (100 MHz, CDCl₃) δ: 162.5 (Ph C-4, ¹JC,F = 248.0 Hz), 134.0 (Ph C-2,6, ³JC,F = 8.2 Hz), 129.5 (Ph C-1, ⁴JC,F = 3.4 Hz), 116.2 (Ph C-3,5, ²JC,F = 21.9 Hz), 43.2 (SCH₂S).

¹⁹F NMR (376 MHz, CDCl₃) δ: -113.6 (m, Ph-4-F).

HRMS (APCI), m/z: calcd. for C₁₃H₁₀F₂S₂ 268.0187 M⁺; found 268.0192.
bis(2-methyl-2-propanyl) 2,2’-[methylenebis(sulfanediyl-4,1-phenyleneoxy)]diacetate (3i)

![Chemical structure of 3i]

By following the General Procedure 1, starting from the corresponding disulfide derivative (0.20 g, 0.42 mmol, 1.0 equiv), TMSCl (0.09 g, 0.10 mL, 0.84 mmol, 2.0 equiv), ICH₂Br (0.28 g, 0.09 mL, 1.26 mmol, 3.0 equiv), and MeLi-LiBr (0.70 mL, 1.05 mmol) in THF, compound 3i was obtained in 83% (172 mg) as a colourless oil after chromatography on silica gel (n-hexane-EtOAc, 95:5).

\(^1\)H NMR (400 MHz, CDCl₃) δ: 7.38 (m, 4H, Ph H-3,5), 6.84 (m, 4H, Ph H-2,6), 4.51 (s, 4H, COCH₂O), 4.16 (s, 2H, SCH₂S), 1.49 (s, 18H, C(CH₃)₃).

\(^1\)H NMR (400 MHz, CDCl₃) δ: 9.30 (br s, 1H, NH), 8.65 (m, 2H, Ph’ H-6), 7.97 (m, 4H, Ph H-2,6), 7.67 (m, 2H, Ph’ H-3), 7.58 (m, 2H, Ph H-4), 7.53 (m, 4H, Ph H-3,5), 7.51 (m, 2H, Ph’ H-5), 7.17 (m, 2H, Ph’ H-4), 4.82 (s, 2H, SCH₂S).

\(^1\)H NMR (400 MHz, CDCl₃) δ: -256.1 (NH)

HRMS (ESI), m/z: calcd. for C₂₇H₂₂N₂O₂S₂H⁺ 493.1195 [M+H]⁺; found 471.1193.

N,N’-[methylenebis(sulfanediyl-2,1-phenylene)]dibenzamide (3j)

![Chemical structure of 3j]

By following the General Procedure 1, starting from bis(2-benzamidophenyl) disulfide (0.20 g, 0.44 mmol, 1.0 equiv), TMSCl (0.09 g, 0.11 mL, 0.88 mmol, 2.0 equiv), ICH₂Br (0.29 g, 0.10 mL, 1.32 mmol, 3.0 equiv), and MeLi-LiBr (0.73 mL, 1.10 mmol) in THF, compound 3j was obtained in 84% (174 mg) as a colourless to yellow solid after chromatography on silica gel (silica gel, n-hexane-EtOAc, 95:5), mp 143 °C.

\(^1\)H NMR (400 MHz, CDCl₃) δ: 167.8 (OCOCH₂), 157.9 (Ph C-1), 134.2 (Ph C-3,5), 126.4 (Ph C-4), 115.2 (Ph C-2,6), 82.5 (C(CH₃)₃), 65.7 (COCH₂O), 44.0 (SCH₂S), 28.0 (C(CH₃)₃).

HRMS (APCI), m/z: calcd. for C₂₅H₂₂O₆S₂H⁺ 493.1713 [M+H]⁺; found 493.1707.
1,1’-[methylenebis(sulfanedimethylene)]dibenzene (3k)

By following the General Procedure 1, starting from dibenzyl disulfide (0.20 g, 0.81 mmol, 1.0 equiv), TMSCl (0.18 g, 0.20 mL, 1.62 mmol, 2.0 equiv), ICH2Br (0.54 g, 0.18 mL, 2.43 mmol, 3.0 equiv), and MeLi-LiBr (1.35 mL, 2.02 mmol) in THF, compound 3k was obtained in 80% (169 mg) as a white solid after chromatography on silica gel (n-hexane-DCM, 95:5). mp 54 °C (lit.3 55 °C)

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.31 (m, 8H, Ph H-2,3,5,6), 7.25 (m, 2H, Ph H-4), 3.84 (s, 4H, PhCH\(_2\)S), 3.38 (s, 2H, SCH\(_2\)S).

\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 137.7 (Ph C-1), 129.1 (Ph C-2,6), 128.5 (Ph C-3,5), 127.0 (Ph C-4), 34.4 (PhCH\(_2\)S), 33.4 (SCH\(_2\)S).

HRMS (APCI), m/z: calcd. for C\(_{15}\)H\(_{16}\)S\(_2\)H\(^+\) 261.0766 [M+H]\(^+\); found 261.0764.

\{[(benzylsulfanyl)methyl]sulfanyl\}benzene (3l)

By following the General Procedure 1, starting from the benzyl phenyl disulfide (0.20 g, 0.86 mmol, 1.0 equiv), TMSCl (0.19 g, 0.22 mL, 1.72 mmol, 2.0 equiv), ICH2Br (0.66 g, 0.22 mL, 2.58 mmol, 3.0 equiv), and MeLi-LiBr (1.43 mL, 2.15 mmol) in THF, compound 3l was obtained in 77% (163 mg) as a colorless oil after chromatography on silica gel (n-hexane-DCM, 95:5).

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.41 (m, 2H, SPh H-2,6), 7.32 (m, 6H, SPh H-3,5, CPh H-2,3,5,6), 7.25 (m, 2H, SPh H-4, CPh H-4), 3.88 (s, 2H, CPhCH\(_2\)S), 3.85 (s, 2H, SCH\(_2\)S).

\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 137.4 (CPh C-1), 135.0 (SPh C-1), 130.6 (SPh C-2,6), 129.1 (CPh C-2,6), 129.0 (SPh C-3,5), 128.6 (CPh C-3,5), 127.2 (CPh C-4), 127.0 (SPh C-4), 36.8 (SCH\(_2\)S), 35.0 PhCH\(_2\)S).

HRMS (APCI), m/z: calcd. for C\(_{14}\)H\(_{14}\)S\(_2\)H\(^+\) 247.0610 [M+H]\(^+\); found 247.0617.
2,2’-(methylenebisulfanediyl)dithiophene (3m)

By following the General Procedure 1, starting from 2-thienyl disulfide (0.20 g, 0.87 mmol, 1.0 equiv), TMSCl (0.19 g, 0.22 mL, 1.74 mmol, 2.0 equiv), ICH₂Br (0.58 g, 0.20 mL, 2.61 mmol, 3.0 equiv), and MeLi-LiBr (1.40 mL, 2.10 mmol) in THF, compound 3m was obtained in 84% (179 mg) as a colorless oil after chromatography on silica gel (n-hexane-DCM, 95:5).

\[ ^1H \text{ NMR} (400 \text{ MHz, CDCl}_3) \delta: 7.42 \text{ (dd, } J_{\text{Th H-5, Th H-4}} = 5.4 \text{ Hz, } J_{\text{Th H-5, Th H-3}} = 1.2 \text{ Hz, } 2\text{H, Th H-5}), 7.22 \text{ (dd, } J_{\text{Th H-3, Th H-4}} = 3.6 \text{ Hz, } J_{\text{Th H-3, Th H-5}} = 1.2 \text{ Hz, } 2\text{H, Th H-3}), 7.02 \text{ (dd, } J_{\text{Th H-4, Th H-5}} = 5.4 \text{ Hz, } J_{\text{Th H-4, Th H-3}} = 3.6 \text{ Hz, } 2\text{H, Th H-4}), 4.05 \text{ (s, } 2\text{H, SCH}_2\text{S}). \]

\[ ^13C \text{ NMR} (100 \text{ MHz, CDCl}_3) \delta: 135.1 \text{ (Th C-3), 132.2 (Th C-2), 130.5 (Th C-5), 127.6 (Th C-4), 49.1 (SCH}_2\text{S).} \]

HRMS (APCI), \( m/z: \) calcd. for C₉H₈S₄H⁺ 244.9582 [M+H]⁺; found 244.9581.

2,2’-(methylenebisulfanediyl)bis(1,3-benzothiazole) (3n)

By following the General Procedure 1, starting from 2,2’-dibenzothiazoyl disulfide (0.20 g, 0.60 mmol, 1.0 equiv), TMSCl (0.13 g, 0.15 mL, 1.20 mmol, 2.0 equiv), ICH₂Br (0.40 g, 0.51 mL, 0.14 mmol, 3.0 equiv), and MeLi-LiBr (1.00 mL, 1.50 mmol) in THF, compound 3n was obtained in 79% (164 mg) as a white solid after chromatography on silica gel (n-hexane-DCM, 95:5); mp 93 °C.

\[ ^1H \text{ NMR} (400 \text{ MHz, CDCl}_3) \delta: 7.92 \text{ (m, } 2\text{H, BnTh H-4}), 7.77 \text{ (m, } 2\text{H, BnTh H-7}), 7.44 \text{ (m, } 2\text{H, BnTh H-5}), 7.32 \text{ (m, } 2\text{H, BnTh H-6}), 5.34 \text{ (s, } 2\text{H, SCH}_2\text{S).} \]

\[ ^13C \text{ NMR} (100 \text{ MHz, CDCl}_3) \delta: 164.8 \text{ (BnTh C-2), 152.9 (BnTh C-3a), 135.6 (BnTh C-7a), 126.2 (BnTh C-5), 124.5 (BnTh C-6), 121.9 (BnTh C-4), 121.1 (BnTh C-7), 36.5 (SCH}_2\text{S).} \]

\[ ^15N \text{ NMR} (40 \text{ MHz, CDCl}_3) \delta: -83.1 \text{ (BnTh N-3).} \]

HRMS (ESI), \( m/z: \) calcd. for C₁₅H₁₀N₂S₄H⁺ 346.9800 [M+H]⁺; found 346.9802.
2,2’-(methylenedisulfanediyl)dipyridine (3o)

![Structure of 2,2’-(methylenedisulfanediyl)dipyridine (3o)](image)

By following the General Procedure 1, starting from the 2,2’-dithiodipyridine (0.20 g, 0.91 mmol, 1.0 equiv), TMSCl (0.29 g, 0.34 mL, 1.82 mmol, 2.0 equiv), ICH₂Br (0.20 g, 0.23 mL, 4.08 mmol, 3.0 equiv), and MeLi-LiBr (1.52 mL, 2.27 mmol) in THF, compound 3o was obtained in 78% (166 mg) as a white solid after chromatography on silica gel (n-hexane-EtOAc, 90:10); mp 93 °C (lit.⁵ 92-95 °C).

**¹H NMR** (400 MHz, CDCl₃) δ: 8.49 (ddd, ³Jₚyr H-6, Pyr H-5 = 4.9 Hz, ⁴Jₚyr H-6, Pyr H-4 = 1.9 Hz, ⁵Jₚyr H-6, Pyr H-3 = 1.0 Hz, 2H, Pyr H-6), 7.49 (ddd, ³Jₚyr H-4, Pyr H-3 = 8.0 Hz, ⁴Jₚyr H-4, Pyr H-5 = 7.3 Hz, ⁵Jₚyr H-4, Pyr H-6 = 1.9 Hz, 2H, Pyr H-4), 7.18 (ddd, ³Jₚyr H-3, Pyr H-4 = 8.0 Hz, ⁴Jₚyr H-3, Pyr H-5 = 1.1 Hz, ⁵Jₚyr H-3, Pyr H-6 = 1.0 Hz, 2H, Pyr H-3), 7.01 (ddd, ³Jₚyr H-5, Pyr H-4 = 7.3 Hz, ³Jₚyr H-5, Pyr H-6 = 4.9 Hz, ⁴Jₚyr H-5, Pyr H-3 = 1.1 Hz, 2H, Pyr H-5), 5.06 (s, 2H, SCH₂S).

**¹³C NMR** (100 MHz, CDCl₃) δ: 157.7 (Ph C-2), 149.5 (Ph C-6), 136.0 (Ph C-4), 122.5 (Ph C-3), 119.7 (Ph C-5), 30.7 (SCH₂S).

**¹⁵N NMR** (40 MHz, CDCl₃) δ: -81.1 (N-Pyr)

HRMS (APCI), m/z: calcd. for C₁₁H₁₀N₂S₂H⁺ 235.0358 [M+H]⁺; found 235.0361.
Exploration of the Reactivity of dithioacetalés (Scheme 3)

2,2′-[methylenebis(sulfanediyl-4,1-phenylene)]dithiophene (4)\(^6\)

![Diagram of dithioacetal structure]

In a dry Schlenk flask \(\text{Pd}_2(\text{dba})_3\) (0.014 mmol, 12.91 mg) and \(\text{P}(t\text{-Bu})_3\) (0.042 mmol, 8.56 mg) were dissolved in anhydrous toluene and dithioketal 3g (0.28 mmol, 110 mg) was added and the solution was warmed up to 40 °C. 2-Thienyllithium (0.85 mmol, 1.41 mL) was diluted with toluene to reach the concentration of 0.6 M and TMEDA (0.85 mmol, 0.13 mL) was added to it; this solution was slowly added over 1 h by the use of a syringe pump.\(^6\) After the addition was completed a saturated solution of \(\text{NH}_4\text{Cl}\) was added and the mixture was extracted 3 times with diethyl ether. The organic phases were collected and evaporation under reduced pressure afforded the crude mixture that was then purified by column chromatography on silica gel (\(n\)-hexane-EtOAc, 99:1), giving 4 as a colorless oil (71 mg, 64% yield).

\(\text{^1H NMR}\) (400 MHz, CDCl\(_3\)) \(\delta\): 7.55 (m, 4H, Ph H-2,6), 7.43 (m, 4H, Ph H-3,5), 7.30 (dd, \(^3J_{\text{Th-H}3,\text{Th-H}4}\) = 3.6 Hz, \(^4J_{\text{Th-H}3,\text{Th-H}5}\) = 1.2 Hz, 2H, Th H-3), 7.29 (dd, \(^3J_{\text{Th-H}5,\text{Th-H}4}\) = 5.1 Hz, \(^4J_{\text{Th-H}5,\text{Th-H}3}\) = 1.2 Hz, 2H, Th H-5), 7.08 (dd, \(^3J_{\text{Th-H}4,\text{Th-H}5}\) = 5.1 Hz, \(^3J_{\text{Th-H}4,\text{Th-H}3}\) = 3.6 Hz, 2H, Th H-4), 4.37 (s, 2H, SCH\(_2\)S).

\(\text{^13C NMR}\) (100 MHz, CDCl\(_3\)) \(\delta\): 143.5 (Th C-2), 133.8 (Ph C-4), 133.4 (Ph C-1), 131.3 (Ph C-3,5), 128.1(Th C-4), 126.3 (Ph C-2,6), 125.1(Th C-5), 123.3 (Th C-3), 40.8 (SCH\(_2\)S).

HRMS (APCI), \(m/z\): calcd. for C\(_{21}\)H\(_{16}\)S\(_4\)H\(^+\) 397.0207 [M+H]\(^+\); found 397.0208.

\(N\)-methoxy-\(N\)-methyl-4,4-bis(phenylsulfanyl)butanamide (5)

![Diagram of butanamide structure]

\(\text{To a solution of dithioketal } 3\text{a} \) (0.23 g, 1.0 mmol, 1.0 equiv) in 2-MeTHF (2 mL) cooled at – 78 °C was added under Ar dropwise a solution of \(n\)-BuLi in Et\(_2\)O (1.6 M, 1.1 mmol, 1.1 equiv, 0.69 mL) and the resulting mixture was stirred for 1 h. Subsequently, a solution of \(N\)-methoxy-\(N\)-methylacrylamide (0.11 g, 1.0 mmol, 1.0 equiv) in 2-MeTHF (2 mL) was cannulated into the lithiated dithioketal. After 2 h at -78 °C a saturated solution of \(\text{NH}_4\text{Cl}\) (aq.) was added and after removing the cooling bath it was allowed to reach rt. Additional 2-MeTHF (5 mL) was added to extract the organic phase which was then dried over anhydrous Na\(_2\)SO\(_4\), filtered and concentrated.
After chromatography on silica gel (n-hexane – EtOAc, 1:1) compound 5 was obtained as a colorless oil.

$^1$H NMR (400 MHz, CDCl$_3$) δ: 7.48 (m, 4H, Ph H-2,6), 7.31 (m, 4H, Ph H-3,5), 7.26 (m, 2H, Ph H-4), 4.61 (t, $^3J$ = 6.8 Hz, 1H, COCH$_2$CH$_2$CH), 3.67 (s, 3H, OCH$_3$), 3.16 (s, 3H, NCH$_3$), 2.77 (t, $^3J$ = 7.2 Hz, 2H, COCH$_2$), 2.21 (m, 2H, COCH$_2$CH$_2$CH).

$^{13}$C NMR (100 MHz, CDCl$_3$) δ: 173.3 (CON), 134.0 (Ph C-1), 132.5 (Ph C-2,6), 128.9 (Ph C-3,5), 127.6 (Ph C-4), 61.2 (OC$_3$H$_3$), 57.2 (SC$_3$H$_3$), 32.2 (NC$_3$H$_3$), 30.5 (COCH$_2$CH$_2$CH), 29.1 (COCH$_2$).

HRMS (APCI), m/z: calcd. for C$_{18}$H$_{21}$NO$_2$S$_2$H$^+$ 348.1086 [M+H]$^+$; found 348.1090.

1,1’-[methylenebis(selanylmethylene)]dibenzene (7a)

By following the General Procedure 1, starting from dibenzyl diselenide (0.20 g, 0.59 mmol, 1.0 equiv), TMSCl (0.13 g, 0.15 mL, 1.18 mmol, 2.0 equiv), ICH$_2$Br (0.39 g, 0.13 mL, 1.77 mmol, 3.0 equiv), and MeLi-LiBr (0.98 mL, 1.48 mmol) in THF, compound 7a was obtained in 85% (171 mg) as a yellow solid after chromatography on silica gel (n-hexane-DCM, 95:5). mp 61 °C (lit. 7 60 °C)

$^1$H NMR (400 MHz, CDCl$_3$) δ: 7.27 (m, 8H, Ph H-2,3,5,6), 7.21 (m, 2H, Ph H-4), 3.87 (s, 4H, PhCH$_2$Se), 3.42 (s, 2H, SeCH$_2$Se).

$^{13}$C NMR (100 MHz, CDCl$_3$) δ: 138.7 (Ph C-1), 129.0 (Ph C-2,6), 128.5 (Ph C-3,5), 126.8 (Ph C-4), 28.5 (PhCH$_2$Se), 13.7 (SeCH$_2$Se).

HRMS (APCI), m/z: calcd. for C$_{15}$H$_{16}$Se$_2$H$^+$ 356.9655 [M+H]$^+$; found 356.9657.

1,1’-(methylenediselanyl)dibenzene (7b)

By following the General Procedure 1, starting from diphenyl diselenide (0.20 g, 0.64 mmol, 1.0 equiv), TMSCl (0.14 g, 0.16 mL, 1.28 mmol, 2.0 equiv), ICH$_2$Br (0.42 g, 0.14 mL, 1.92 mmol, 3.0 equiv), and MeLi-LiBr (1.07 mL, 1.60 mmol) in THF, compound 7b was obtained in 88% (184 mg) as a colorless solid after chromatography on silica gel (n-hexane-DCM, 95:5). mp 38 °C (lit. 8 36-38 °C)

$^1$H NMR (400 MHz, CDCl$_3$) δ: 7.54 (m, 4H, Ph H-2,6), 7.29 (m, 6H, Ph H-3,4,5), 4.24 (s, 2H, SeCH$_2$Se).
$^{13}$C NMR (100 MHz, CDCl$_3$) δ: 133.0 (Ph C-2,6), 130.8 (Ph C-1), 129.1 (Ph C-3,5), 127.6 (Ph C-4), 21.0 (SeCH$_2$Se).
HRMS (APCI), m/z: calcd. for C$_{13}$H$_{12}$Se$_2$ 327.9264 M$^+$; found 327.9269.
(3b)
(3d)
(3e)

![Chemical structure and NMR spectrum](image-url)
(3g)
(3i)

Chemical structure and NMR spectra of compound 3i.
(3k)

![Chemical structure image]
(3m)
(3o)
(7b)
References