Controllable Synthesis of Disulfides and Thiosulfonates from Sodium Sulfinates Mediated by Hydroiodic Acid using Ethanol and H$_2$O as Solvent Respectively

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1. General Information

All reactions were performed in sealed tube with magnetic stirring. Unless otherwise stated, all commercially available reagents were used without further purification. $^1$H and $^{13}$C NMR spectra were recorded at ambient temperature on Bruker Advance III HD 600 or UltrasoundTM 300 instruments. All spectra were referenced to CDCl$_3$ ($^1$H $\delta$ 7.26 ppm and $^{13}$C NMR $\delta$ 77.00 ppm). Data were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublets, td = triplet of doublets, qd = quartet of doublets, m = multiplet), coupling constants (Hz) and integration.

2. Experimental Procedure

(1) Synthesis of symmetric disulfide (2a-2o)

A 10 mL sealed tube was charged with substituted sodium sulfinate (0.6 mmol), EtOH (4 mL) and HI (55%-57% aqueous solution, 5 eq). The mixture was allowed to stir at room temperature and monitored by TLC until the reaction was complete. Saturated aqueous Na$_2$SO$_3$ solution was added to the reaction mixture and the aqueous phase was further extracted with DCM (3×10 mL). The combined organic layers were dried over anhydrous Na$_2$SO$_4$ and concentrated under a vacuum to give the crude product. The residue was purified by column chromatography on silica gel using petroleum and n-hexane as eluent to provide the desired product.

(2) Synthesis of asymmetric disulfide (3a-3k)

A 10 mL sealed tube was charged with substituted sodium sulfinate (1, 0.3 mmol) and another sodium sulfinate (2, 0.3 mmol), EtOH (4 mL), HI (55%-57% aqueous solution, 5 eq). The mixture was allowed to stir at room temperature and monitored by TLC until the reaction was complete. Saturated aqueous Na$_2$SO$_3$ solution was added to the reaction mixture and the aqueous phase was further extracted with DCM (3×10 mL). The combined organic layers were dried over anhydrous Na$_2$SO$_4$ and concentrated under a vacuum to give the crude product. The residue was purified by column chromatography on silica gel using petroleum, acetonitrile, and H$_2$O as eluent to provide the desired products.

(3) Synthesis of symmetric thiosulfonate

The general procedure for thiosulfonates (4a, 4d-4i)

A 10 mL sealed tube was charged with substituted sodium sulfinate (0.6 mmol) in H$_2$O (4 mL), HI (55%-57% aqueous solution, 5 eq) was added to the mixture. The reaction mixture was allowed to stir at 50°C and monitored by TLC until the reaction was complete. The solid crude product is filtered, washed with saturated Na$_2$SO$_3$, water, and dried in vacuo to obtain the target compound.

The general procedure for thiosulfonates (4b-4c, 4j-4k)

A 10 mL sealed tube was charged with substituted sodium sulfinate (0.6 mmol) in H$_2$O (4 mL), then HI (55%-57% aqueous solution, 5 eq) was added. The mixture was allowed to stir at 50°C and monitored by TLC until the reaction was complete. Saturated aqueous Na$_2$SO$_3$ solution was
added to the mixture and the aqueous phase was further extracted with DCM (3×10 mL). The combined organic layers was dried over anhydrous Na₂SO₄ and concentrated. The residue was purified by column chromatography on silica gel using petroleum/n-hexane/ethyl acetate as eluent to provide the desired product.

3. Analytical Data for the Products

![1,2-Di-p-tolydisulfide (2a)](image)

1,2-Di-p-tolydisulfide (2a)\(^\text{[1]}\). White solid. 71 mg, yield 95%.
\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.39 (d, \(J = 8.2\) Hz, 4H), 7.11 (d, \(J = 8.0\) Hz, 4H), 2.33 (s, 6H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 137.58, 134.04, 129.92, 128.68, 21.2.

![1,2-Diphenyldisulfide (2b)](image)

1,2-Diphenyldisulfide (2b)\(^\text{[1]}\). Pale yellow solid, 68 mg, yield 92%.
\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.49 (d, \(J = 7.2\) Hz, 4H), 7.29 (t, \(J = 7.7\) Hz, 4H), 7.24 – 7.20 (q, 2H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 137.17, 129.20, 127.65, 127.29.

![1,2-bis(4-isopropylphenyl) disulfide (2c)](image)

1,2-bis(4-isopropylphenyl) disulfide (2c)\(^\text{[1]}\). White solid, 85 mg, yield 94%.
\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.43 (d, \(J = 7.3\) Hz, 4H), 7.17 (d, \(J = 7.6\) Hz, 4H), 2.88 (h, \(J = 6.9\) Hz, 2H), 1.23 (dd, \(J = 6.9, 1.3\) Hz, 12H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 148.45, 134.43, 128.38, 127.36, 33.90, 24.05.

![1,2-Di(1,1'-biphenyl-4-yl) disulfide (2d)](image)

1,2-Di(1,1'-biphenyl-4-yl) disulfide (2d)\(^\text{[1]}\). Pale yellow solid, 58 mg, yield 52%.
\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.60 (d, \(J = 8.4\) Hz, 4H), 7.57 – 7.54 (t, 8H), 7.43 (t, \(J = 7.6\) Hz, 4H), 7.36 – 7.33 (t, 2H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 140.52, 140.35, 136.18, 129.00, 128.36, 127.95, 127.68, 127.13.
1,2-Bis(4-(trifluoromethoxy) phenyl) disulfide (2e)\textsuperscript{[1]}. Colourless oil, 94 mg, yield 81%.
\[ ^1H \text{NMR (600 MHz, CDCl}_3 \delta 7.53 - 7.49 (m, 4H), 7.18 (d, } J = 7.9 \text{ Hz, 4H). } ^{13}C \text{NMR (151 MHz, CDCl}_3 \delta 148.83, 148.82, 135.32, 129.43, 121.87.} \]

1,2-Bis(4-(trifluoromethyl) phenyl) disulfide (2f)\textsuperscript{[1]}. Yellow solid, 91 mg, yield 81%.
\[ ^1H \text{NMR (600 MHz, CDCl}_3 \delta 7.60 - 7.56 (m, 8H). } ^{13}C \text{NMR (151 MHz, CDCl}_3 \delta 140.8, 129.4 (q, } J = 33.0 \text{ Hz), 126.6, 126.1 (q, } J = 3.7 \text{ Hz), 123.9 (q, } J = 273.0 \text{ Hz). } ^{19}F \text{NMR (565 MHz, CDCl}_3 \delta -62.60.} \]

1,2-bis(4-fluorophenyl) disulfide (2g)\textsuperscript{[1]}. Colourless oil, 71 mg, yield 92%.
\[ ^1H \text{NMR (600 MHz, CDCl}_3 \delta 7.47 - 7.43 (m, 4H), 7.03 - 6.99 (m, 4H). } ^{13}C \text{NMR (151 MHz, CDCl}_3 \delta 163.56, 161.92, 132.32, 132.30, 131.44, 131.38, 116.49, 116.34. } ^{19}F \text{NMR (565 MHz, CDCl}_3 \delta -113.43 (ddd, } J = 14.0, 8.7, 5.1 \text{ Hz).} \]

1,2-Bis(4-chlorophenyl) disulfide (2h)\textsuperscript{[1]}. Pale yellow solid, 62 mg, yield 72%.
\[ ^1H \text{NMR (600 MHz, CDCl}_3 \delta 7.39 (d, } J = 8.7 \text{ Hz, 4H), 7.26 (d, } J = 8.7 \text{ Hz, 4H). } ^{13}C \text{NMR (151 MHz, CDCl}_3 \delta 135.26, 133.76, 129.45, 129.42.} \]

1,2-Bis(4-bromophenyl) disulfide (2i)\textsuperscript{[1]}. Pale yellow solid, 91 mg, yield 81%.
\[ ^1H \text{NMR (600 MHz, CDCl}_3 \delta 7.44 - 7.41 (m, 4H), 7.35 - 7.32 (m, 4H). } ^{13}C \text{NMR (151 MHz, CDCl}_3 \delta 135.85, 132.33, 129.50, 121.66.} \]
1,2-Bis (4-nitrophenyl) disulfide (2j)\(^2\). Yellow solid, 77 mg, yield 83%.
1\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta 8.21 – 8.17\) (m, 4H), 7.64 – 7.60 (m, 4H). \(^1\)C NMR (151 MHz, CDCl\(_3\)) \(\delta 147.14, 144.20, 126.54, 124.61, 77.37, 76.95\).

1,2-di-\(m\)-tolyldisulfide (2k)\(^2\). White solid, 65 mg, yield 88%.
1\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta 7.29\) (d, \(J = 7.1\) Hz, 4H), 7.17 (t, \(J = 7.9\) Hz, 2H), 7.03 – 6.99 (m, 2H), 2.30 (s, 6H). \(^1\)C NMR (151 MHz, CDCl\(_3\)) \(\delta 139.02, 137.04, 129.01, 128.13, 128.12, 124.68, 21.50\).

1,2-Bis(3-bromophenyl) disulfide (2l)\(^2\). Colourless oil, 81 mg, yield 72%.
1\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta 7.63\) (t, \(J = 1.8\) Hz, 2H), 7.40 (ddd, \(J = 7.9, 1.9, 0.9\) Hz, 2H), 7.37 (ddd, \(J = 8.0, 1.9, 1.0\) Hz, 2H), 7.18 (t, \(J = 7.9\) Hz, 2H). \(^1\)C NMR (151 MHz, CDCl\(_3\)) \(\delta 138.76, 130.61, 130.05, 126.01, 123.26\).

1,2-Di(naphthalen-2-yl) disulfide (2m)\(^2\). White solid, 78 mg, yield 82%.
1\(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta 7.99\) (d, \(J = 1.6\) Hz, 2H), 7.82 – 7.71 (m, 6H), 7.62 (dd, \(J = 8.7, 1.9\) Hz, 2H), 7.50 – 7.42 (m, 4H). \(^1\)C NMR (75 MHz, CDCl\(_3\)) \(\delta 134.35, 133.57, 132.59, 129.11, 127.90, 127.59, 126.87, 126.60, 126.36, 125.74\).
1,2-Bis(5-chlorothiophen-2-yl) disulfide (2n)\[^2\]. Yellow oil, 67 mg, yield 75%.
\[^1\]H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 6.97 (d, \(J = 3.9\) Hz, 2H), 6.84 (s, 2H). \[^13\]C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 136.02, 135.87, 134.01, 127.28.

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1,2-Di(thiophen-2-yl) disulfide (2o)\[^2\]. Yellow solid, 65 mg, yield 93%.
\[^1\]H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.50 (dd, \(J = 5.3, 1.3\) Hz, 2H), 7.15 (dd, \(J = 3.6, 1.2\) Hz, 2H), 7.01 (q, \(J = 5.3, 3.6\) Hz, 2H). \[^13\]C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 135.73, 135.68, 132.36, 127.80.

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1-cyclopropyl-2-(\(p\)-tolyl) disulfide (2p)\[^3\]. White solid. 34 mg, yield 57%.
\[^1\]H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.47 (d, \(J = 8.2\) Hz, 2H), 7.17 – 7.11 (d, 2H), 2.35 (s, 3H), 2.33 – 2.26 (m, 1H), 0.97 – 0.71 (m, 4H). \[^13\]C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 137.38, 134.44, 129.83, 129.31, 21.21, 19.32, 9.67.

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1-cyclopropyl-2-(4-methoxyphenyl) disulfide (2q)\[^3\]. White solid. 38 mg, yield 60%.
\[^1\]H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.52 (d, \(J = 8.7\) Hz, 2H), 6.86 (d, \(J = 8.8\) Hz, 2H), 3.81 (s, 3H), 2.29 (tt, \(J = 7.6, 4.3\) Hz, 1H), 0.97 – 0.68 (m, 4H). \[^13\]C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 159.82, 132.68, 128.71, 114.71, 55.53, 19.25, 9.55.

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1-(4-chlorophenyl)-2-cyclopropyl disulfide (2r)\[^3\]. White solid. 34 mg, yield 53%.
\[^1\]H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.50 (dd, \(J = 8.4, 1.4\) Hz, 2H), 7.35 – 7.27 dd, 2H), 2.33 – 2.25 (m, 1H), 0.97 – 0.73 (m, 4H). \[^13\]C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 136.54, 133.09, 129.75, 129.19, 19.30, 9.78.

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2-chloro-5-(cyclopropyldisulfaneyl) thiophene (2s)\[^3\]. Colourless oil, 32 mg, yield 47%.
\[^1\]H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.50 (d, \(J = 8.6\) Hz, 2H), 7.29 (d, \(J = 8.5\) Hz, 2H), 2.28 (tt, \(J = 7.4, 4.3\) Hz, 1H), 0.96 – 0.93 (m, 2H), 0.75 – 0.72 (m, 2H). \[^13\]C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 136.52, 133.06, 129.72, 129.17, 19.29, 9.78.
**S-(p-tolyl) 4-methylbenzenesulfonothioate (3a)**\(^4\). White solid, 79 mg, yield 95%.

\(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.45 (d, \(J = 8.3\) Hz, 2H), 7.22 (t, \(J = 7.4\) Hz, 4H), 7.14 (d, \(J = 8.0\) Hz, 2H), 2.42 (s, 3H), 2.38 (s, 3H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 144.70, 142.16, 140.59, 136.61, 130.32, 129.48, 127.72, 124.72 21.79, 21.61.

\[\text{\includegraphics[width=0.5\textwidth]{s-p-tolyl-4-methylbenzenesulfonothioate}}\]

**S-phenyl benzenesulfonothioate (3b)**\(^4\). Colorless oil, 61 mg, yield 81%.

\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.57 (dd, \(J = 11.1, 7.4\) Hz, 3H), 7.47 (t, \(J = 7.0\) Hz, 1H), 7.43 – 7.40 (m, 2H), 7.36 – 7.31 (m, 4H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 143.07, 136.71, 133.76, 131.54, 129.56, 128.93, 127.96, 127.68.

\[\text{\includegraphics[width=0.5\textwidth]{s-phenyl-benzenesulfonothioate}}\]

**S-4-(Isopropyl) phenyl-4-isopropylbenzenesulfonothioate (3c)**\(^4\). Colourless oil. 62 mg, yield 62%.

\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.48 (d, \(J = 8.4\) Hz, 2H), 7.28 – 7.26 (m, 2H), 7.24 (d, \(J = 8.4\) Hz, 2H), 7.18 (d, \(J = 8.2\) Hz, 2H), 2.99 – 2.89 (m, 2H), 1.25 (dd, \(J = 10.1, 6.9\) Hz, 12H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 155.40, 152.91, 140.74, 136.79, 127.90, 127.69, 126.91, 125.0, 34.39, 34.18, 23.91, 23.77.

\[\text{\includegraphics[width=0.5\textwidth]{s-4-isopropyl-phenyl-4-isopropylbenzenesulfonothioate}}\]

**S-(4-methoxyphenyl)4-methoxybenzenesulfonothioate (3d)**\(^4\). White solid, 86 mg, yield 92%.

\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.50 (d, \(J = 5.5\) Hz, 2H), 7.29 – 7.25 (m, 2H), 6.92 – 6.81 (m, 4H), 3.85 (d, \(J = 21.6\) Hz, 6H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 163.66, 162.34, 138.51, 135.12, 130.05, 119.10, 115.05, 113.97, 55.84, 55.61.

\[\text{\includegraphics[width=0.5\textwidth]{s-4-methoxyphenyl-4-methoxybenzenesulfonothioate}}\]
S-((1,1′-biphenyl)-4-yl)-(1,1′-biphenyl)-4-sulphonothioate (3e) [5]. White solid, 97 mg, yield 81%.

$^1$H NMR (300 MHz, CDCl$_3$) δ 7.67 – 7.57 (m, 9H), 7.52 – 7.31 (m, 9H). $^{13}$C NMR (75 MHz, CDCl$_3$) δ 146.60, 144.40, 141.80, 139.51, 139.00, 137.15, 129.24, 129.14, 128.90, 128.45, 128.25, 128.18, 127.49, 127.47, 127.33, 126.62.

S-(4-fluorophenyl) 4-fluorobenzenesulphonothioate(3f) [5]. White solid, 79 mg, yield 92%.

$^1$H NMR (600 MHz, CDCl$_3$) δ 7.59 (dd, $J$ = 8.8, 5.0 Hz, 2H), 7.37 (d, $J$ = 8.7 Hz, 2H), 7.12 (t, $J$ = 8.5 Hz, 2H), 7.06 (t, $J$ = 8.5 Hz, 2H). $^{13}$C NMR (151 MHz, CDCl$_3$) δ 166.61, 165.87, 164.90, 164.19, 139.01, 138.95, 130.63, 130.57, 117.16, 117.02, 116.43, 116.28, 5.19 $^1$F NMR (565 MHz, CDCl$_3$) δ -102.49, -106.82.

S-(4-chlorophenyl) 4-chlorobenzenesulphonothioate (3g) [5]. White solid, 86 mg, yield 90%.

$^1$H NMR (600 MHz, CDCl$_3$) δ 7.52 (d, $J$ = 8.4 Hz, 2H), 7.43 (d, $J$ = 8.1 Hz, 2H), 7.38 – 7.29 (m, 4H). $^{13}$C NMR (151 MHz, CDCl$_3$) δ 141.46, 140.72, 138.72, 137.84, 130.07, 129.42, 129.09, 126.18.

S-(4-bromophenyl) 4-bromobenzenesulphonothioate (3h) [5]. White solid, 107 mg, yield 88%.

$^1$H NMR (600 MHz, CDCl$_3$) δ 7.60 (d, $J$ = 8.6 Hz, 2H), 7.52 (d, $J$ = 8.5 Hz, 2H), 7.44 (d, $J$ = 8.8 Hz, 2H), 7.26 (d, $J$ = 5.3 Hz, 2H). $^{13}$C NMR (151 MHz, CDCl$_3$) δ 142.03, 137.99, 133.08, 132.44, 129.35, 129.10, 127.18, 126.76.
S-(4-(trifluoromethyl) phenyl) 4-(trifluoromethyl) benzenesulfonothioate (3i)\[^5\]. White solid, 106 mg, yield 92%.

\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.73 (s, 4H), 7.65 (d, \(J = 8.0\) Hz, 2H), 7.54 (d, \(J = 7.9\) Hz, 2H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\): 122.9 (q, \(J = 272\) Hz), 123.3 (q, \(J = 272\) Hz), 126.3 (q, \(J = 4\) Hz), 126.5 (q, \(J = 4\) Hz), 127.9, 131.6, 133.6 (q, \(J = 33\) Hz), 135.5 (q, \(J = 33\) Hz), 136.7, 146.1. \(^{19}\)F NMR (565 MHz, CDCl\(_3\)) \(\delta\) -63.11, -63.21.

S-(naphthalen-2-yl) naphthalene-2-sulfonothioate (3j)\[^5\]. White solid, 63 mg, yield 60%.

\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.94 (s, 1H), 7.89 (dd, \(J = 8.4, 5.0\) Hz, 2H), 7.85 – 7.82 (m, 2H), 7.74 (d, \(J = 8.5\) Hz, 1H), 7.69 – 7.62 (m, 4H), 7.59 – 7.52 (m, 2H), 7.50 – 7.47 (m, 1H), 7.35 (dd, \(J = 8.5, 1.8\) Hz, 1H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 139.84, 137.85, 135.27, 134.26, 133.41, 132.00, 131.77, 129.62, 129.51, 129.48, 129.45, 129.26, 128.55, 128.37, 128.02, 127.87, 127.80, 127.04, 125.33, 122.58.

S-(Thiophen-2-yl) thiophene-2-sulfonothioate (3k)\[^5\]. Yellow oil, 61 mg, yield 78%.

\(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.26 (d, \(J = 4.2\) Hz, 2H), 7.10 (d, \(J = 4.0\) Hz, 2H), 6.96 (dd, \(J = 9.1, 4.1\) Hz, 4H). \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 140.75, 140.12, 139.81, 139.70, 134.31, 128.20, 127.00, 123.29.

S-(5-Chlorothiophen-2-yl)5-chlorothiophene-2-sulfonothioatea (3l)\[^5\]. Yellow oil, 71 mg, yield 72%.

\(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.27 (s, 1H), 7.10 (d, \(J = 4.0\) Hz, 1H), 6.97 (d, \(J = 4.0\) Hz, 1H), 6.94 (d, \(J = 4.1\) Hz, 1H). \(^{13}\)C NMR (151 MHz, CDCl\(_3\)) \(\delta\) 140.79, 140.31, 139.82, 139.75, 134.30, 128.21, 127.00, 123.43.
Copies of $^1$H NMR, $^{13}$C NMR and $^{19}$F NMR spectra

$^1$H NMR of 1,2-Di-$p$-tolydisulfane (2a)$^{[1]}$

$^{13}$C NMR of 1,2-Di-$p$-tolydisulfane (2a)$^{[1]}$
$^1$H NMR of 1,2-Diphenyldisulfide (2b)$^{[1]}$

$^{13}$C NMR of 1,2-Diphenyldisulfide (2b)$^{[1]}$
$^1$H NMR of 1,2-Bis(4-isopropylphenyl) disulfide (2c)$^{[1]}$

$^{13}$C NMR of 1,2-Bis(4-isopropylphenyl) disulfide (2c)$^{[1]}$
$^1$H NMR of 1,2-Di([1,1'-biphenyl]-4-yl) disulfide (2d) $^{[1]}$

[Chemical structure image]

$^1$H NMR data:
- f1 (ppm): 2.00, 4.01, 8.01, 4.00
- CDCl$_3$ 7.26, 7.33, 7.35, 7.36, 7.42, 7.43, 7.45, 7.54, 7.56, 7.57, 7.59, 7.61

$^{13}$C NMR of 1,2-Di([1,1'-biphenyl]-4-yl) disulfide (2d) $^{[1]}$

[Chemical structure image]

$^{13}$C NMR data:
- f1 (ppm): 76.95, 77.16, 77.37
- CDCl$_3$ 127.13, 127.68, 127.95, 128.36, 129.00, 136.18, 140.35, 140.52
$^1$H NMR of 1,2-Bis(4-(trifluoromethoxy) phenyl) disulfide (2e) $^1$

$^{13}$C NMR of 1,2-Bis(4-(trifluoromethoxy) phenyl) disulfide (2e) $^1$
$^{1}H$ NMR of 1,2-Bis(4-(trifluoromethyl)phenyl) disulfide (2f)$^{[1]}$

$^{13}C$ NMR of 1,2-Bis(4-(trifluoromethyl)phenyl) disulfide (2f)$^{[1]}$
$^{19}$F NMR of 1,2-Bis(4-(trifluoromethyl) phenyl) disulfide (2f)$^{[1]}$

$^1$H NMR of 1,2-bis(4-fluorophenyl) disulfide (2g)$^{[1]}$
\[ {\text{13C NMR of 1,2-bis(4-fluorophenyl) disulfide (2g)}} \]

\[ {\text{19F NMR of 1,2-bis(4-fluorophenyl) disulfide (2g)}} \]
$^1$H NMR of 1,2-Bis(4-chlorophenyl) disulfide (2h)$^{[1]}$

$^{13}$C NMR of 1,2-Bis(4-chlorophenyl) disulfide (2h)$^{[1]}$
$^1$H NMR of 1,2-Bis(4-bromophenyl) disulfide (2i)

$^{13}$C NMR of 1,2-Bis(4-bromophenyl) disulfide (2i)$^{[1]}$
$^1$H NMR of 1,2-Bis(4-nitrophenyl) disulfide (2j)$^{[2]}$
$^1$H NMR of 1,2-di-m-tolyldisulfide (2k)$^2$

$^{13}$C NMR of 1,2-di-m-tolyldisulfide (2k)$^2$
$^1$H NMR of 1,2-Bis(3-bromophenyl) disulfide (2l) $^{[2]}$

$^{13}$C NMR of 1,2-Bis(3-bromophenyl) disulfide (2l) $^{[2]}$
$^{1}$H NMR of 1,2-Di(naphthalen-2-yl) disulfide (2m)$^{[2]}$

$^{13}$C NMR of 1,2-Di(naphthalen-2-yl) disulfide (2m)$^{[2]}$

$^1$H NMR of 1,2-Bis(5-chlorothiophen-2-yl) disulfide (2n) \[^2\]

$^{13}$C NMR of 1,2-Bis(5-chlorothiophen-2-yl) disulfide (2n) \[^2\]
$^1$H NMR of 1,2-Di(thiophen-2-yl) disulfide (2o)$^{[2]}$

$^{13}$C NMR of 1,2-Di(thiophen-2-yl) disulfide (2o)$^{[2]}$
$^1$H NMR of 1-cyclopropyl-2-(p-tolyl) disulfide (2p) \[^3\]

$^{13}$C NMR of 1-cyclopropyl-2-(p-tolyl) disulfide (2p) \[^3\]
$^1$H NMR of 1-cyclopropyl-2-(4-methoxyphenyl) disulfide (2q)\textsuperscript{[3]}

$^{13}$C NMR of 1-cyclopropyl-2-(4-methoxyphenyl) disulfide (2q)\textsuperscript{[3]}
$^1$H NMR of 1-(4-chlorophenyl)-2-cyclopropyldisulfide (2r)\textsuperscript{[3]}

$^{13}$C NMR of 1-(4-chlorophenyl)-2-cyclopropyldisulfide (2r)\textsuperscript{[3]}
$^1$H NMR of 2-chloro-5-(cyclopropyldisulfaneyl) thiophene (2s)$^3$

$^{13}$C NMR of 2-chloro-5-(cyclopropyldisulfaneyl) thiophene (2s)$^3$
$^1$H NMR of S-(p-tolyl) 4-methylbenzenesulfonothioate (3a)$^{[4]}$

$^{13}$C NMR of S-(p-tolyl) 4-methylbenzenesulfonothioate (3a)$^{[4]}$
$^1$H NMR of S-phenyl benzenesulfonothioate (3b) [4]

$^{13}$C NMR of S-phenyl benzenesulfonothioate (3b) [4]
$^1$H NMR of S-4-(Isopropyl)phenyl-4-isopropylbenzenesulfonothioate (3c)$^{[4]}$
$^1$H NMR of S-(4-methoxyphenyl) 4-methoxybenzenesulfonothioate (3d) $^{[4]}$

$^{13}$C NMR of S-(4-methoxyphenyl) 4-methoxybenzenesulfonothioate (3d) $^{[4]}$
$^1$H NMR of S-([1,1′-biphenyl]-4-yl)-[1,1′-biphenyl]-4-sulfonothioate (3e)$^{[5]}$

$^{13}$C NMR of S-([1,1′-biphenyl]-4-yl)-[1,1′-biphenyl]-4-sulfonothioate (3e)$^{[5]}$
$^1$H NMR of S-(4-fluorophenyl) 4-fluorobenzenesulfonothioate (3f)\textsuperscript{[5]}

$^{13}$C NMR of S-(4-fluorophenyl) 4-fluorobenzenesulfonothioate (3f)\textsuperscript{[5]}
\(^{19}\)F NMR Of S-(4-fluorophenyl) 4-fluorobenzenesulfonothioate (3f)\(^{[5]}\)

\(^{1}\)H NMR of S-(4-chlorophenyl) 4-chlorobenzenesulfonothioate (3g)\(^{[5]}\)
$^{13}$C NMR of S-(4-chlorophenyl) 4-chlorobenzenesulfonothioate (3g) $^5$

$^1$H NMR of S-(4-bromophenyl) 4-bromobenzenesulfonothioate (3h) $^5$
$^{13}$C NMR of S-(4-bromophenyl) 4-bromobenzenesulfonothioate (3h) $^{[5]}$

$^1$H NMR of S-(4(trifluoromethyl)phenyl)4(trifluoromethyl)benzenesulfonothioate (3i) $^{[5]}$
$^{13}$C NMR of S-(4-(trifluoromethyl)phenyl) 4-(trifluoromethyl)benzenesulfonothioate (3i) [5]

$^{19}$F NMR of S-(4-(trifluoromethyl)phenyl) 4-(trifluoromethyl) benzenesulfonothioate (3i) [5]
$^1$H NMR of S-(naphthalen-2-yl) naphthalene-2-sulfonothioate (3j)$^{[5]}$

$^{13}$C NMR of (naphthalen-2-yl) naphthalene-2-sulfonothioate (3j)$^{[5]}$
$^1$H NMR of S-(Thiophen-2-yl)thiophene-2-sulfonothioate ($3k$)$^5$

$^{13}$C NMR of S-(Thiophen-2-yl) thiophene-2-sulfonothioate ($3k$)$^5$
$^1$H NMR of S-(5-Chlorothiophen-2-yl)5-chlorothiophene-2-sulfonothioate (3l) $^5$

$^{13}$C NMR of S-(5-Chlorothiophen-2-yl)5-chlorothiophene-2-sulfonothioate (3l) $^5$
References