Supporting Information

Synthesis of *β*-cyanoalkylsulfonylated vinyl selenides through a four-component reaction

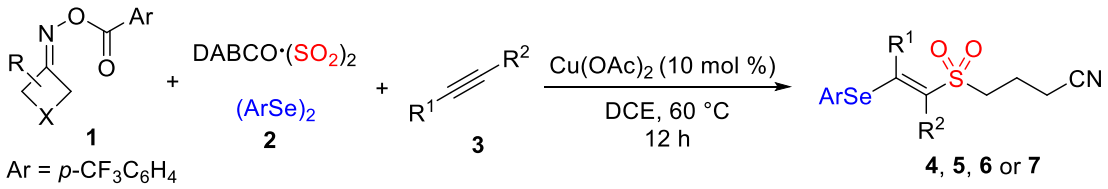
Fu-Sheng He,* Yanfang Yao, Zhimei Tang, Yanjie Qiu, Wenlin Xie, and Jie Wu*

Table of Contents

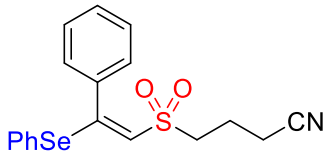
1. General Information

Unless otherwise stated, all commercial reagents were used as received. All solvents were dried and distilled according to standard procedures. Flash column chromatography was performed using silica gel (60-Å pore size, 32-63 μm, standard grade). Analytical thin-layer chromatography was performed using glass plates pre-coated with 0.25 mm 230-400 mesh silica gel impregnated with a fluorescent indicator (254 nm). Thin layer chromatography plates were visualized by exposure to ultraviolet light. X-ray single crystal diffraction data were recorded on Bruker D8 VENTURE. Nuclear magnetic resonance (NMR) spectra are recorded in parts per million from internal tetramethylsilane on the δ scale. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Bruker DRX-400 spectrometer operating at 400 MHz and 100 MHz, respectively. All chemical shift values are quoted in ppm and coupling constants quoted in Hz. High resolution mass spectrometry (HRMS) spectra were obtained on a micrOTOF II Instrument.

2. General Experimental Procedure and Characterization Data

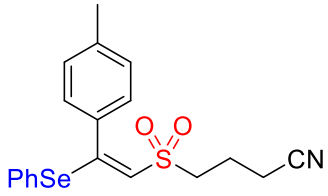


1,2-Dichloroethane (2.0 mL) was added to a sealed tube containing cycloketone oxime esters **1** (0.2 mmol), DABCO·$(SO_2)_2$ (0.2 mmol), diselenides **2** (0.2 mmol), alkynes **3** (0.3 mmol) and $Cu(OAc)_2$ (10 mol%) under a nitrogen atmosphere via a syringe. The resulting mixture was stirred at 60 ℃ in an oil bath for 12 hours. After completion of reaction as monitored by TLC analysis, the mixture was diluted with DCM and washed with saturated aqueous $NaHCO_3$ (10 mL), brine (10 mL), and dried over anhydrous Na_2SO_4. Subsequently, the solvent was concentrated under reduced pressure, and the residue was purified by column chromatography on silica gel (petroleum ether/ethyl acetate = 2:1) to give the corresponding products **4**, **5**, **6** or **7**.



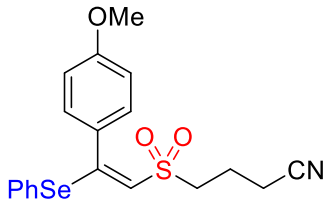
(*E*)-4-((2-Phenyl-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4a)

Yellow solid, 70% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 (dd, *J* = 7.8, 1.6 Hz, 2H), 7.52 – 7.40 (m, 8H), 5.88 (s, 1H), 2.73 (t, *J* = 7.2 Hz, 2H), 2.38 (t, *J* = 7.1 Hz, 2H), 2.17 – 1.84 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.3, 136.8, 134.3, 130.6, 130.5, 130.2, 128.4, 128.3, 126.6, 122.2, 118.2, 53.3, 18.8, 16.1; HRMS (ESI) calcd for $C_{18}H_{17}NO_2NaSSe^+$ ($M+Na^+$): 414.0043, found: 414.0048.



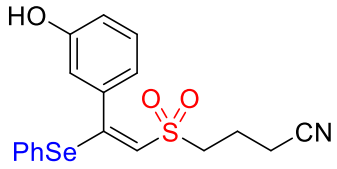
(*E*)-4-((2-(Phenylselanyl)-2-(*p*-tolyl)vinyl)sulfonyl)butanenitrile (4b)

Yellow solid, 74% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 – 7.64 (m, 2H), 7.51 – 7.42 (m, 3H), 7.39 (d, *J* = 8.1 Hz, 2H), 7.23 (d, *J* = 7.9 Hz, 2H), 5.84 (s, 1H), 2.73 (t, *J* = 7.2 Hz, 2H), 2.54 – 2.26 (m, 5H), 2.00 – 1.90 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.5, 140.6, 136.7, 131.4, 130.5, 129.1, 128.3, 126.8, 121.9, 118.2, 53.2, 21.5, 18.8, 16.1; HRMS (ESI) calcd for $C_{19}H_{19}NO_2NaSSe^+$ ($M+Na^+$): 428.0199, found: 428.0207.



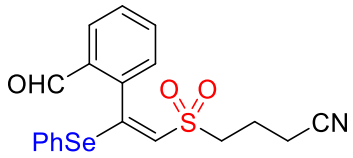
(*E*)-4-((2-(4-Methoxyphenyl)-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4c)

Yellow solid, 68% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.63 (m, 2H), 7.52 – 7.42 (m, 5H), 7.00 – 6.89 (m, 2H), 5.85 (s, 1H), 3.83 (s, 3H), 2.72 (t, *J* = 7.2 Hz, 2H), 2.40 (t, *J* = 7.1 Hz, 2H), 2.01 – 1.89 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.2, 160.1, 136.6, 130.5, 130.4, 130.2, 127.0, 126.3, 121.7, 118.3, 113.9, 55.4, 53.0, 18.9, 16.1; HRMS (ESI) calcd for $C_{19}H_{19}NO_3NaSSe^+$ ($M+Na^+$): 444.0149, found: 444.0157.



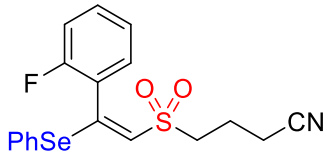
(*E*)-4-((2-(3-Hydroxyphenyl)-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4d)

Yellow solid, 45% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 – 7.61 (m, 2H), 7.52 – 7.41 (m, 3H), 7.29 (d, *J* = 7.9 Hz, 1H), 7.01 (d, *J* = 7.6 Hz, 1H), 6.96 – 6.83 (m, 2H), 6.41 (s, 1H), 5.85 (s, 1H), 2.80 (t, *J* = 7.3 Hz, 2H), 2.42 (t, *J* = 7.0 Hz, 2H), 2.02 – 1.93 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.6, 155.9, 136.7, 135.4, 130.6, 130.5, 129.9, 126.5, 121.7, 120.3, 118.5, 117.7, 115.3, 53.3, 18.8, 16.1; HRMS (ESI) calcd for $C_{18}H_{17}NO_3NaSSe^+$ ($M+Na^+$): 429.9992, found: 429.9991.



(*E*)-4-((2-(2-Formylphenyl)-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4e)

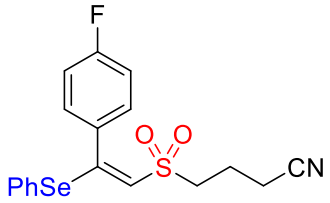
Red brown solid, 50% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.16 (s, 1H), 7.91 (dd, *J* = 7.6, 1.2 Hz, 1H), 7.70 – 7.65 (m, 2H), 7.63 (td, *J* = 7.5, 1.4 Hz, 1H), 7.56 (td, *J* = 7.5, 1.2 Hz, 1H), 7.52 – 7.42 (m, 3H), 7.35 (dd, *J* = 7.5, 0.9 Hz, 1H), 6.08 (s, 1H), 2.90 – 2.78 (m, 2H), 2.45 – 2.38 (m, 2H), 2.05 – 1.93 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.8, 158.4, 136.8, 135.9, 133.4, 132.7, 131.2, 130.7, 130.5, 130.0, 129.5, 126.2, 122.8, 118.2, 53.4, 18.5, 16.1; HRMS (ESI) calcd for $C_{19}H_{17}NO_3NaSSe^+$ ($M+Na^+$): 441.9992, found: 442.0000.



(*E*)-4-((2-(2-Fluorophenyl)-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4f)

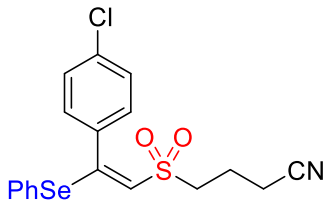
Yellow oil, 80% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.63 (m, 2H), 7.51 – 7.40 (m, 3H), 7.40 – 7.29 (m, 2H), 7.20 – 7.15 (m, 1H), 7.08 (t, *J* = 9.0 Hz, 1H), 6.04 (s, 1H), 2.94 (t, *J* = 7.3 Hz, 2H), 2.45 (t, *J* = 7.1 Hz, 2H), 2.15 – 1.96 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.8 (d, *J* = 248.1 Hz), 154.1, 136.8, 131.7 (d, *J* = 8.2 Hz), 130.6,

130.4, 130.1 (d, J = 1.9 Hz), 126.1, 124.1 (d, J = 3.5 Hz), 123.2, 122.4 (d, J = 15.9 Hz), 118.2, 115.7 (d, J = 21.3 Hz), 53.1, 18.6, 16.2; HRMS (ESI) calcd for $C_{18}H_{16}NO_2FNaSSe^+$ (M+Na^+): 431.9949, found: 431.9958.



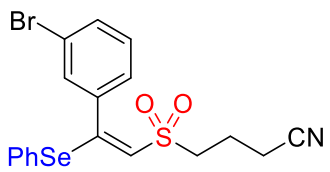
(*E*)-4-((2-(4-Fluorophenyl)-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4g)

Yellow solid, 72% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 – 7.64 (m, 2H), 7.53 – 7.43 (m, 5H), 7.15 – 7.07 (m, 2H), 5.91 (s, 1H), 2.79 (t, J = 7.2 Hz, 2H), 2.43 (t, J = 7.0 Hz, 2H), 2.02 – 1.93 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.6 (d, J = 251.3 Hz), 159.5, 136.7, 130.6 (d, J = 4.3 Hz), 130.5, 130.5, 130.2 (d, J = 3.5 Hz), 126.5, 122.3, 118.1, 115.6 (d, J = 22.0 Hz), 53.3, 18.7, 16.1; HRMS (ESI) calcd for $C_{18}H_{16}NO_2NaSSeF^+$ (M+Na^+): 431.9949, found: 431.9957.



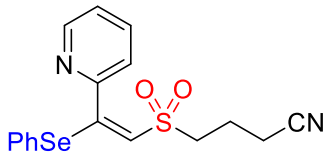
(*E*)-4-((2-(4-Chlorophenyl)-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4h)

Yellow solid, 76% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 – 7.63 (m, 2H), 7.54 – 7.43 (m, 3H), 7.43 – 7.37 (m, 4H), 5.89 (s, 1H), 2.80 (t, J = 7.3 Hz, 2H), 2.42 (t, J = 7.0 Hz, 2H), 2.02 – 1.93 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.3, 136.7, 136.3, 132.8, 130.7, 130.6, 129.7, 128.7, 126.4, 122.3, 118.2, 53.4, 18.7, 16.1; HRMS (ESI) calcd for $C_{18}H_{16}NO_2NaSClSe^+$ (M+Na^+): 447.9653, found: 447.9656.



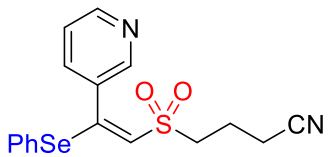
(*E*)-4-((2-(3-Bromophenyl)-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4i)

Yellow solid, 52% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.63 (m, 2H), 7.59 (t, *J* = 1.7 Hz, 1H), 7.56 – 7.44 (m, 4H), 7.38 (d, *J* = 7.8 Hz, 1H), 7.29 (d, *J* = 7.9 Hz, 1H), 5.88 (s, 1H), 2.82 (t, *J* = 7.2 Hz, 2H), 2.43 (t, *J* = 7.0 Hz, 2H), 2.12 – 1.87 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.6, 136.8, 136.3, 133.0, 130.9, 130.7, 130.6, 129.8, 127.0, 126.3, 122.4, 122.2, 118.2, 53.5, 18.7, 16.1; HRMS (ESI) calcd for $C_{18}H_{16}NO_2NaSSeBr^+$ ($M+Na^+$): 491.9148, found: 491.9154.



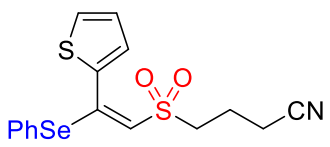
(*E*)-4-((2-(Phenylselanyl)-2-(pyridin-2-yl)vinyl)sulfonyl)butanenitrile (4j)

Brown solid, 54% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.70 – 8.63 (m, 1H), 7.79 – 7.73 (m, 1H), 7.70 – 7.67 (m, 2H), 7.58 (d, *J* = 7.8 Hz, 1H), 7.53 – 7.43 (m, 3H), 7.35 – 7.30 (m, 1H), 5.95 (s, 1H), 3.23 (t, *J* = 7.2 Hz, 2H), 2.49 (t, *J* = 7.1 Hz, 2H), 2.14 – 2.05 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.9, 153.4, 149.4, 136.8, 136.5, 130.6, 130.5, 125.8, 124.5, 124.3, 122.9, 118.3, 54.6, 18.7, 16.2; HRMS (ESI) calcd for $C_{17}H_{16}N_2O_2NaSSe^+$ ($M+Na^+$): 414.9995, found: 415.0002.



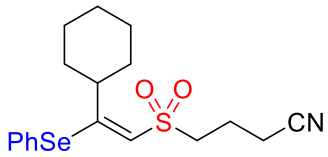
(*E*)-4-((2-(Phenylselanyl)-2-(pyridin-3-yl)vinyl)sulfonyl)butanenitrile (4k)

Yellow solid, 48% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.67 – 8.60 (m, 2H), 7.83 – 7.72 (m, 1H), 7.68 – 7.64 (m, 2H), 7.56 – 7.44 (m, 3H), 7.39 – 7.31 (m, 1H), 6.00 (s, 1H), 2.87 (t, *J* = 7.3 Hz, 2H), 2.45 (t, *J* = 7.0 Hz, 2H), 2.09 – 1.91 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.0, 150.8, 148.1, 136.7, 136.0, 130.8, 130.6, 126.1, 123.1, 122.9, 118.1, 53.7, 18.6, 16.1; HRMS (ESI) calcd for $C_{17}H_{16}N_2O_2NaSSe^+$ ($M+Na^+$): 414.9995, found: 415.0003.



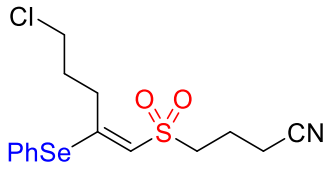
(*E*)-4-((2-(Phenylselanyl)-2-(thiophen-2-yl)vinyl)sulfonyl)butanenitrile (4l)

Yellow solid, 65% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 – 7.65 (m, 2H), 7.61 – 7.54 (m, 2H), 7.52 – 7.43 (m, 3H), 7.14 – 7.10 (m, 1H), 5.92 (s, 1H), 2.82 (t, *J* = 7.2 Hz, 2H), 2.43 (t, *J* = 7.1 Hz, 2H), 2.04 – 1.93 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.6, 136.5, 134.7, 131.5, 130.6, 130.5, 130.2, 128.1, 127.2, 123.0, 118.1, 52.4, 18.9, 16.2; HRMS (ESI) calcd for $C_{16}H_{15}NO_2NaS_2Se^+$ ($M+Na^+$): 419.9607, found: 419.9604.



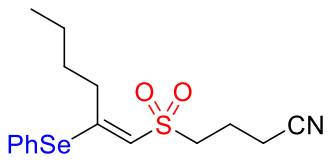
(*E*)-4-((2-Cyclohexyl-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4m)

White solid, 31% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 – 7.54 (m, 2H), 7.51 – 7.38 (m, 3H), 5.46 (s, 1H), 2.98 (t, *J* = 7.2 Hz, 2H), 2.55 (t, *J* = 7.0 Hz, 2H), 2.16-2.03 (m, 2H), 1.87 (t, *J* = 13.7 Hz, 4H), 1.75 (d, *J* = 12.8 Hz, 1H), 1.67 – 1.54 (m, 3H), 1.49 – 1.36 (m, 2H), 1.31 – 1.18 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.6, 137.3, 130.4, 130.2, 125.4, 119.1, 118.2, 54.0, 42.1, 33.3, 25.9, 25.5, 18.8, 16.3; HRMS (ESI) calcd for $C_{18}H_{23}NO_2NaSSe^+$ ($M+Na^+$): 420.0512, found: 420.0515.



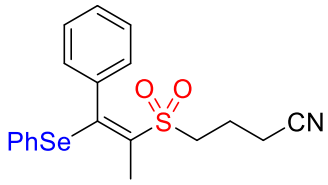
(*E*)-4-((5-Chloro-2-(phenylselanyl)pent-1-en-1-yl)sulfonyl)butanenitrile (4n)

Yellow oil, 69% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 – 7.59 (m, 2H), 7.52 – 7.43 (m, 3H), 5.67 (s, 1H), 3.63 (t, *J* = 6.4 Hz, 2H), 3.03 (t, *J* = 8.0 Hz, 4H), 2.56 (t, *J* = 7.0 Hz, 2H), 2.24 – 2.16 (m, 2H), 2.15 – 2.07 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.6, 136.9, 130.5, 130.5, 125.3, 120.7, 118.2, 53.8, 44.0, 33.3, 31.0, 18.7, 16.3; HRMS (ESI) calcd for $C_{15}H_{18}NO_2NaSClSe^+$ ($M+Na^+$): 413.9810, found: 413.9809.



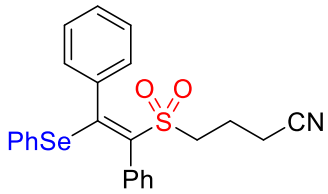
(*E*)-4-((2-(Phenylselanyl)hex-1-en-1-yl)sulfonyl)butanenitrile (4o)

Yellow oil, 72% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 – 7.58 (m, 2H), 7.52 – 7.41 (m, 3H), 5.61 (s, 1H), 3.00 (t, *J* = 7.3 Hz, 2H), 2.93 – 2.82 (m, 2H), 2.55 (t, *J* = 7.0 Hz, 2H), 2.16 – 2.00 (m, 2H), 1.78 – 1.64 (m, 2H), 1.57 – 1.36 (m, 2H), 0.95 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.8, 137.0, 130.4, 130.3, 125.6, 119.8, 118.2, 53.9, 33.2, 32.8, 22.6, 18.8, 16.3, 13.8; HRMS (ESI) calcd for $C_{16}H_{21}NO_2NaSSe^+$ ($M+Na^+$): 394.0356, found: 394.0353.



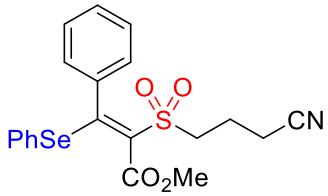
(*E*)-4-((1-Phenyl-1-(phenylselanyl)prop-1-en-2-yl)sulfonyl)butanenitrile (4p)

Yellow solid, 72% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20 – 7.12 (m, 3H), 7.06 – 6.98 (m, 5H), 6.97 – 6.92 (m, 2H), 2.77 (t, *J* = 7.3 Hz, 2H), 2.46 – 2.35 (m, 5H), 2.07 – 1.94 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.3, 137.1, 135.5, 130.5, 129.1, 129.0, 128.7, 128.2, 127.3, 126.8, 118.2, 52.6, 18.7, 18.6, 16.2; HRMS (ESI) calcd for $C_{19}H_{19}NO_2NaSSe^+$ ($M+Na^+$): 428.0199, found: 428.0202.



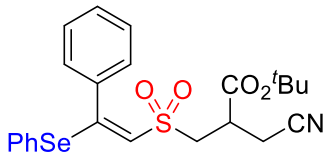
(*E*)-4-((1,2-Diphenyl-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (4q)

Yellow solid, 45% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.49 (m, 5H), 7.14 – 7.03 (m, 8H), 7.02 – 6.92 (m, 2H), 2.80 (t, *J* = 7.2 Hz, 2H), 2.38 (t, *J* = 7.1 Hz, 2H), 2.09 – 1.97 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.3, 137.2, 134.9, 134.7, 134.1, 130.6, 130.0, 129.4, 128.8, 128.6, 128.6, 128.2, 127.5, 127.3, 118.2, 52.0, 18.6, 16.1; HRMS (ESI) calcd for $C_{24}H_{21}NO_2NaSSe^+$ ($M+Na^+$): 490.0356, found: 490.0361.



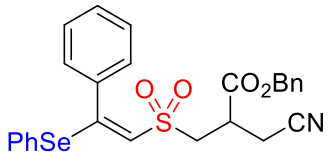
Methyl (*E*)-2-((3-cyanopropyl)sulfonyl)-3-phenyl-3-(phenylselanyl)acrylate (4r)

Yellow solid, 44% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 – 7.12 (m, 3H), 7.09 – 6.98 (m, 5H), 6.95 – 6.86 (m, 2H), 4.03 (s, 3H), 3.26 (t, *J* = 7.1 Hz, 2H), 2.49 (t, *J* = 7.0 Hz, 2H), 2.20 – 2.04 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 163.9, 137.1, 134.4, 129.2, 128.7, 128.7, 127.8, 127.7, 127.6, 127.3, 118.3, 54.3, 53.4, 18.6, 16.2; HRMS (ESI) calcd for $C_{20}H_{19}NO_4NaSSe^+$ ($M+Na^+$): 472.0098, found: 472.0100.



***tert*-Butyl (*E*)-3-cyano-2-(((2-phenyl-2 (phenylselanyl)vinyl)sulfonyl)methyl)propanoate (5a)**

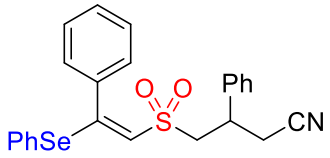
Yellow solid, 46% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.65 (m, 2H), 7.54 – 7.39 (m, 8H), 5.91 (s, 1H), 3.34 – 3.15 (m, 1H), 3.05 – 2.96 (m, 1H), 2.93 – 2.82 (m, 1H), 2.80-2.65 (m, 2H), 1.44 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.4, 161.4, 136.8, 134.2, 130.6, 130.5, 130.2, 128.4, 128.3, 126.5, 122.2, 116.6, 83.7, 54.5, 36.8, 27.8, 19.3; HRMS (ESI) calcd for $C_{23}H_{25}NO_4NaSSe^+$ ($M+Na^+$): 514.0567, found: 514.0571.



Benzyl (*E*)-3-cyano-2-(((2-phenyl-2-(phenylselanyl)vinyl)sulfonyl)methyl)propanoate (5b)

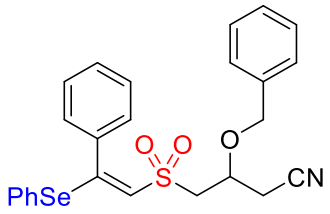
Yellow solid, 50% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 – 7.64 (m, 2H), 7.52 – 7.30 (m, 13H), 5.89 (s, 1H), 5.33 – 4.89 (m, 2H), 3.32 – 3.23 (m, 1H), 3.18 – 3.09 (m, 1H), 3.00 – 2.89 (m, 1H), 2.85-2.70 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.3,

161.9, 136.7, 134.6, 134.1, 130.6, 130.5, 130.2, 128.8, 128.8, 128.6, 128.4, 128.2, 126.5, 121.9, 116.5, 68.3, 54.3, 36.3, 19.1; HRMS (ESI) calcd for $C_{26}H_{23}NO_4NaSSe^+$ ($M+Na^+$): 548.0411, found: 548.0414.



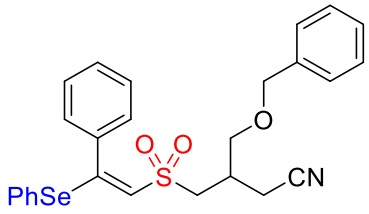
(*E*)-3-Phenyl-4-((2-phenyl-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (5c)

Yellow solid, 71% yield; ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.59 (m, 2H), 7.51 – 7.31 (m, 11H), 7.12 – 7.06 (m, 2H), 5.83 (s, 1H), 3.48 – 3.38 (m, 1H), 3.14 – 3.06 (m, 1H), 3.00 – 2.94 (m, 1H), 2.82-2.66 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.5, 139.3, 136.7, 134.3, 130.5, 130.5, 130.1, 129.3, 128.3, 128.3, 127.0, 126.5, 122.5, 117.3, 58.7, 36.2, 24.2; HRMS (ESI) calcd for $C_{24}H_{21}NO_2NaSSe^+$ ($M+Na^+$): 490.0356, found: 490.0356.



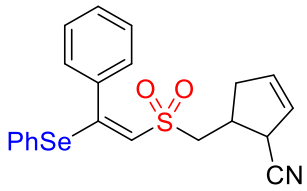
(*E*)-3-(Benzyloxy)-4-((2-phenyl-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (5d)

Yellow solid, 72% yield; ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.56 (m, 2H), 7.48 – 7.28 (m, 13H), 5.95 (s, 1H), 4.49 – 4.40 (m, 2H), 4.06 – 3.99 (m, 1H), 3.10 (dd, *J* = 14.3, 5.3 Hz, 1H), 2.87 (dd, *J* = 14.3, 6.7 Hz, 1H), 2.62 (dd, *J* = 17.0, 4.5 Hz, 1H), 2.46 (dd, *J* = 17.0, 5.3 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.1, 136.7, 136.4, 134.4, 130.5, 130.4, 130.1, 128.7, 128.4, 128.0, 126.5, 123.2, 116.2, 72.2, 69.0, 58.3, 23.6; HRMS (ESI) calcd for $C_{25}H_{23}NO_3NaSSe^+$ ($M+Na^+$): 520.0462, found: 520.0466.



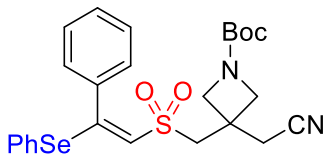
(*E*)-4-(Benzyloxy)-3-(((2-phenyl-2-(phenylselanyl)vinyl)sulfonyl)methyl)butane-nitrile (5e)

Yellow oil, 69% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 – 7.61 (m, 2H), 7.52 – 7.41 (m, 5H), 7.40 – 7.29 (m, 6H), 7.27 – 7.24 (m, 2H), 5.89 (s, 1H), 4.45 (s, 2H), 3.47 – 3.32 (m, 2H), 2.82 (dd, *J* = 14.3, 4.4 Hz, 1H), 2.74 – 2.42 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.5, 137.4, 136.7, 134.3, 130.5, 130.5, 130.1, 128.6, 128.3, 128.0, 127.7, 126.6, 122.5, 117.4, 73.4, 70.0, 55.3, 31.2, 19.1; HRMS (ESI) calcd for $C_{26}H_{25}NO_3NaSSe^+$ (M+Na$^+$): 534.0618, found: 534.0624.



(*E*)-5-(((2-Phenyl-2-(phenylselanyl)vinyl)sulfonyl)methyl)cyclopent-2-ene-1-carbonitrile (5f)

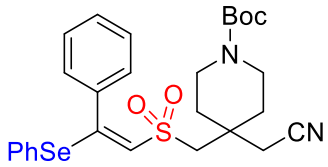
White solid, 54% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 – 7.65 (m, 2H), 7.52 – 7.40 (m, 8H), 5.81 (s, 1H), 5.76 – 5.69 (m, 1H), 5.56 – 5.49 (m, 1H), 3.40 – 3.30 (m, 1H), 3.09 – 2.98 (m, 1H), 2.65 – 2.58 (m, 2H), 2.57 – 2.51 (m, 1H), 2.39 – 2.31 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.8, 136.8, 134.5, 131.0, 130.5, 130.5, 130.2, 129.7, 128.4, 128.2, 126.8, 120.1, 117.2, 65.6, 42.7, 34.6, 23.2; HRMS (ESI) calcd for $C_{21}H_{19}NO_2NaSSe^+$ (M+Na$^+$): 452.0199, found: 452.0201.



***tert*-Butyl (*E*)-3-(cyanomethyl)-3-(((2-phenyl-2-(phenylselanyl)vinyl)sulfonyl)methyl)-azetidine-1-carboxylate (5g)**

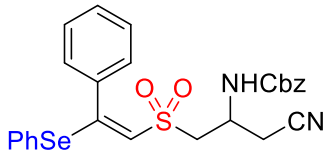
Yellow solid, 55% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 – 7.66 (m, 2H), 7.54 – 7.42 (m, 8H), 5.90 (s, 1H), 3.74 (d, *J* = 9.4 Hz, 2H), 3.67 (d, *J* = 9.4 Hz, 2H), 3.09 (s, 2H), 2.86 (s, 2H), 1.42 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.5, 155.8, 136.8, 134.1, 130.7, 130.6, 130.4, 128.5, 128.3, 126.3, 123.4, 116.5, 80.4, 59.2, 58.3, 33.4,

28.3, 25.6; HRMS (ESI) calcd for $C_{25}H_{28}N_2O_4NaSSe^+$ ($M+Na^+$): 555.0833, found: 555.0836.



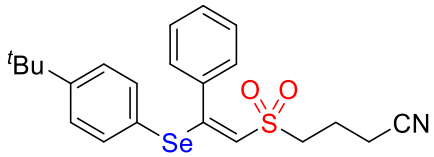
***tert*-Butyl (*E*)-4-(cyanomethyl)-4-(((2-phenyl-2-(phenylselanyl)vinyl)sulfonyl)methyl)pi -peridine-1-carboxylate (5h)**

Yellow solid, 65% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 – 7.65 (m, 2H), 7.51 – 7.41 (m, 8H), 5.95 (s, 1H), 3.51 (d, *J* = 12.2 Hz, 2H), 2.98 – 2.82 (m, 4H), 2.67 (s, 2H), 1.77 – 1.59 (m, 3H), 1.55 – 1.38 (m, 10H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.0, 154.6, 136.8, 134.4, 130.6, 130.5, 130.1, 128.4, 128.4, 126.4, 124.8, 116.9, 80.0, 57.7, 35.7, 34.3, 28.4, 27.1; HRMS (ESI) calcd for $C_{27}H_{32}N_2O_4NaSSe^+$ ($M+Na^+$): 583.1146, found: 583.1153.



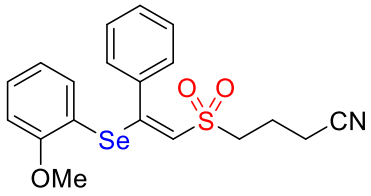
Benzyl (*E*)-(1-cyano-3-((2-phenyl-2-(phenylselanyl)vinyl)sulfonyl)propan-2-yl)carbamate (5i)

Yellow oil, 47% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.63 (m, 2H), 7.48 – 7.37 (m, 8H), 7.36 – 7.30 (m, 5H), 5.88 (s, 1H), 5.49 (d, *J* = 7.2 Hz, 1H), 5.09 (s, 2H), 4.18 (dd, *J* = 13.6, 6.2 Hz, 1H), 3.06 (dd, *J* = 14.3, 5.9 Hz, 1H), 2.90 (dd, *J* = 14.3, 5.8 Hz, 1H), 2.72 (d, *J* = 5.9 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.9, 155.2, 136.8, 135.7, 134.1, 130.6, 130.5, 130.3, 128.7, 128.4, 128.3, 128.2, 126.5, 122.1, 116.4, 67.3, 56.7, 44.3, 22.8; HRMS (ESI) calcd for $C_{26}H_{24}N_2O_4NaSSe^+$ ($M+Na^+$): 563.0520, found: 563.0524.



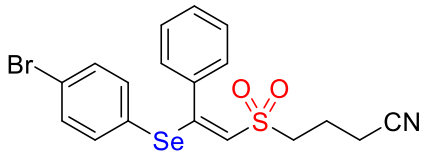
(*E*)-4-((2-((4-(*tert*-Butyl)phenyl)selanyl)-2-phenylvinyl)sulfonyl)butanenitrile (5j)

Yellow solid, 36% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 – 7.56 (m, 2H), 7.51 – 7.46 (m, 4H), 7.45 – 7.41 (m, 3H), 5.92 (s, 1H), 2.74 (t, *J* = 7.2 Hz, 2H), 2.40 (t, *J* = 7.1 Hz, 2H), 2.03 – 1.91 (m, 2H), 1.36 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.9, 154.1, 136.5, 134.4, 130.1, 128.4, 128.2, 127.7, 123.1, 121.9, 118.2, 53.3, 35.0, 31.2, 18.8, 16.1; HRMS (ESI) calcd for $C_{22}H_{25}NO_2NaSSe^+$ ($M+Na^+$): 470.0669, found: 470.0671.



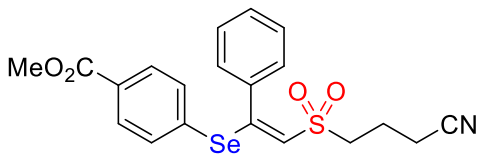
(*E*)-4-((2-((2-Methoxyphenyl)selanyl)-2-phenylvinyl)sulfonyl)butanenitrile (5k)

Yellow solid, 57% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.60 (m, 1H), 7.54 – 7.45 (m, 3H), 7.44 – 7.37 (m, 3H), 7.05 – 6.97 (m, 2H), 5.86 (s, 1H), 3.92 (s, 3H), 2.71 (t, *J* = 7.2 Hz, 2H), 2.38 (t, *J* = 7.1 Hz, 2H), 2.01 – 1.92 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.3, 159.0, 138.5, 134.4, 132.9, 130.1, 128.5, 128.3, 122.2, 121.4, 118.2, 115.6, 111.9, 56.2, 53.3, 18.9, 16.1; HRMS (ESI) calcd for $C_{19}H_{19}NO_3NaSSe^+$ ($M+Na^+$): 444.0149, found: 444.0150.



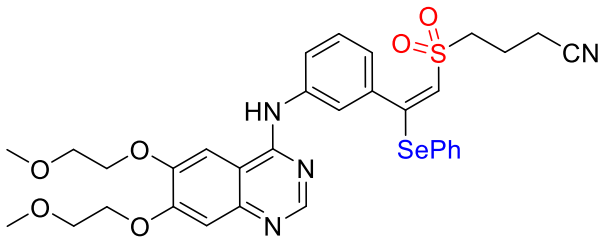
(*E*)-4-((2-((4-Bromophenyl)selanyl)-2-phenylvinyl)sulfonyl)butanenitrile (5l)

Brown solid, 43% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 – 7.55 (m, 2H), 7.54 – 7.49 (m, 2H), 7.48 – 7.41 (m, 5H), 5.93 (s, 1H), 2.76 (t, *J* = 7.2 Hz, 2H), 2.41 (t, *J* = 7.0 Hz, 2H), 2.07 – 1.83 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.5, 138.2, 134.0, 133.7, 130.3, 128.5, 128.3, 125.5, 125.2, 122.7, 118.2, 53.3, 18.7, 16.1; HRMS (ESI) calcd for $C_{18}H_{16}NO_2NaSSeBr^+$ ($M+Na^+$): 491.9148, found: 491.9149.



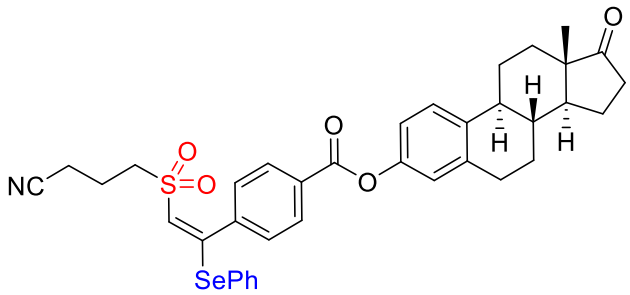
Methyl (*E*)-4-((2-((3-cyanopropyl)sulfonyl)-1-phenylvinyl)selanyl)benzoate (5m)

Yellow solid, 57% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.4 Hz, 2H), 7.74 – 7.70 (m, 2H), 7.49 – 7.44 (m, 2H), 7.44 – 7.39 (m, 3H), 6.00 (s, 1H), 3.95 (s, 3H), 2.76 (t, *J* = 7.2 Hz, 2H), 2.41 (t, *J* = 7.0 Hz, 2H), 2.02 – 1.92 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.1, 158.9, 136.449, 134.0, 132.1, 131.8, 131.2, 130.4, 128.5, 128.4, 123.1, 118.1, 53.2, 52.5, 18.7, 16.1; HRMS (ESI) calcd for $C_{20}H_{19}NO_4NaSSeBr^+$ ($M+Na^+$): 472.0098, found: 472.0105.



(*E*)-4-((2-(3-((6,7-Bis(2-methoxyethoxy)quinazolin-4-yl)amino)phenyl)-2-(phenylselanyl)vinyl)sulfonyl)butanenitrile (6)

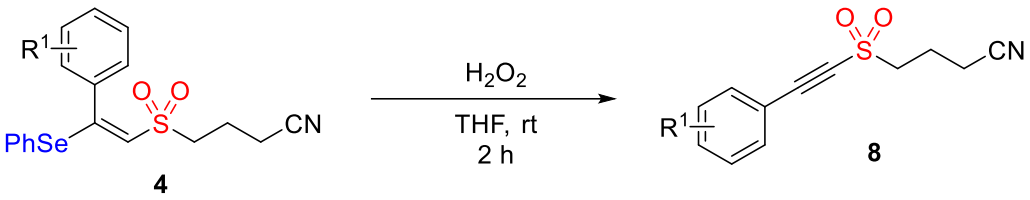
Yellow solid, 68% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30 (s, 1H), 8.06 – 7.78 (m, 2H), 7.69 – 7.60 (m, 3H), 7.53 – 7.38 (m, 5H), 7.22 (d, *J* = 7.5 Hz, 2H), 5.85 (s, 1H), 4.22 (d, *J* = 21.3 Hz, 4H), 3.81 (d, *J* = 11.7 Hz, 4H), 3.49 – 3.40 (m, 6H), 2.89 (t, *J* = 7.3 Hz, 2H), 2.47 (t, *J* = 6.7 Hz, 2H), 2.09 – 1.88 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.0, 154.3, 149.0, 139.0, 138.9, 136.7, 134.9, 130.6, 130.6, 129.1, 128.9, 127.7, 126.5, 125.2, 124.2, 124.1, 122.6, 122.5, 121.8, 121.0, 118.9, 70.8, 70.4, 68.8, 68.4, 59.3, 59.2, 53.5, 19.0, 16.2; HRMS (ESI) calcd for $C_{32}H_{35}N_4O_6SSe^+$ ($M+H^+$): 683.1443, found: 683.1445.



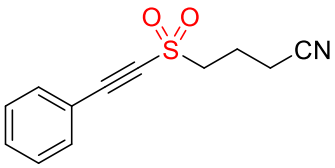
(8*R*,9*S*,13*S*,14*S*)-13-Methyl-17-oxo-7,8,9,11,12,13,14,15,16,17-decahydro-6*H*-cyclopenta[*a*]phenanthren-3-yl 4-((*E*)-2-((3-cyanopropyl)sulfonyl)-1-(phenylselanyl)vinyl)benzoate (7)

Yellow solid, 55% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (d, *J* = 8.3 Hz, 2H), 7.68 (d, *J* = 6.5 Hz, 2H), 7.57 (d, *J* = 8.3 Hz, 2H), 7.54 – 7.45 (m, 3H), 7.34 (d, *J* = 8.6 Hz, 1H), 7.02 – 6.92 (m, 2H), 5.94 (s, 1H), 3.01 – 2.91 (m, 2H), 2.86 (t, *J* = 7.2 Hz, 2H), 2.58 – 2.40 (m, 4H), 2.37 – 2.28 (m, 1H), 2.21 – 2.12 (m, 1H), 2.11 – 1.95 (m, 5H), 1.70 – 1.55 (m, 4H), 1.52 – 1.41 (m, 2H), 0.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6, 159.3, 148.7, 139.6, 138.2, 137.6, 136.7, 130.9, 130.8, 130.6, 130.0, 128.5, 126.5, 126.1, 122.3, 121.6, 118.8, 118.1, 53.6, 50.4, 48.0, 44.2, 38.0, 35.9, 31.6, 29.4, 26.3, 25.8, 21.6, 18.7, 16.1, 13.8; HRMS (ESI) calcd for $C_{37}H_{37}NO_5NaSSe^+$ ($M+Na^+$): 710.1455, found: 710.1459.

3. General Procedure for the Synthesis of Alkynyl Sulfone



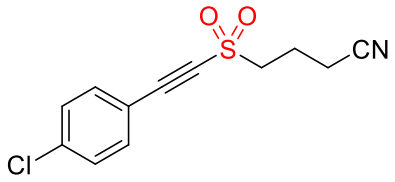
Tetrahydrofuran (4.0 mL) was added to a sealed round bottomed flask containing β-selenovinyl sulfone **4** (0.1 mmol) under air atmosphere *via* a syringe and H_2O_2 aqueous solution (30 wt%, 2.0 mL) was added into the solution slowly. The resulting mixture was stirred at room temperature for 2 hours. After completion of reaction as monitored by TLC analysis, the mixture was diluted with chloroform (10 mL) and washed with water (10 mL), brine (10 mL), and dried over anhydrous Na_2SO_4. Subsequently, the solvent was concentrated under reduced pressure, and the residue was purified by column chromatography on silica gel (petroleum ether/ethyl acetate = 4:1) to give the corresponding product **8**.



4-((Phenylethynyl)sulfonyl)butanenitrile (8a)

Yellow oil, 57% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 – 7.59 (m, 2H), 7.55 (t, *J* = 7.5 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 3.47 (t, *J* = 7.2 Hz, 2H), 2.69 (t, *J* = 7.1 Hz, 2H), 2.51 – 2.25 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 133.0, 132.1, 128.9, 118.0, 117.1,

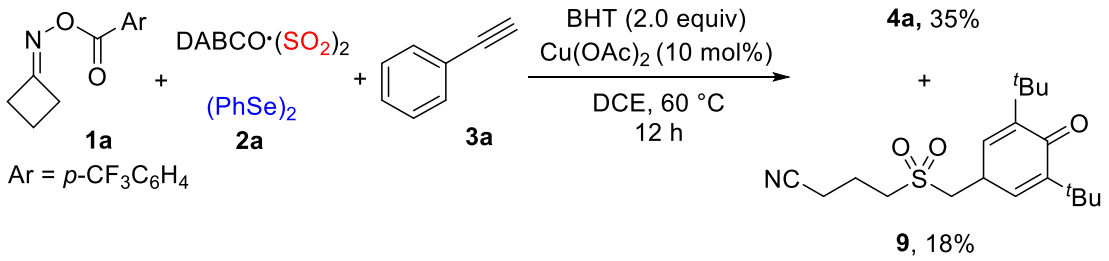
93.6, 82.7, 56.3, 19.6 16.1; HRMS (ESI) calcd for $C_{12}H_{11}NO_2NaS^+$ ($M+Na^+$): 256.0408, found: 256.0414.



4-(((4-Chlorophenyl)ethynyl)sulfonyl)butanenitrile (8b)

Yellow solid, 72% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.5 Hz, 2H), 7.43 (d, *J* = 8.4 Hz, 2H), 3.47 (t, *J* = 7.2 Hz, 2H), 2.69 (t, *J* = 7.0 Hz, 2H), 2.46 – 2.22 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.8, 134.2, 129.5, 118.0, 115.6, 92.2, 83.6, 56.3, 19.5, 16.0; HRMS (ESI) calcd for $C_{12}H_{10}NO_2NaSCl^+$ ($M+Na^+$): 290.0018, found: 290.0024.

4. Radical Trapping Experiment



To a solution of cycloketone oxime ester **1a** (0.2 mmol), DABCO·$(SO_2)_2$ (0.2 mmol), diphenyl diselenide **2a** (0.2 mmol), phenylacetylene **3a** (0.3 mmol) and $Cu(OAc)_2$ (10 mol%) in 1,2-dichloroethane (2.0 mL) was added BHT (0.4 mmol, 2.0 equiv) under a nitrogen atmosphere. The resulting mixture was stirred at 60 ℃ in an oil bath for 12 hours. After completion of reaction as monitored by TLC analysis, the mixture was diluted with DCM and washed with saturated aqueous $NaHCO_3$ (10 mL), brine (10 mL), and dried over anhydrous Na_2SO_4. Subsequently, the solvent was concentrated under reduced pressure, and the residue was purified by column chromatography on silica gel (petroleum ether/ethyl acetate = 4:1) to give the corresponding products **4a** and **9** in 35% and 18% yields, respectively.

4-((3,5-Di-*tert*-butyl-4-hydroxybenzyl)sulfonyl)butanenitrile (9)

Light yellow solid, 18% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.66 (s, 2H), 2.86 (t, *J* = 7.1 Hz, 2H), 2.57 (t, *J* = 7.0 Hz, 2H), 2.19 – 2.11 (m, 2H), 1.71 (s, 2H), 1.26 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.2, 152.3, 135.1, 117.7, 65.4, 44.2, 35.6, 29.1, 18.2, 18.1, 16.4; HRMS (ESI) calcd for $C_{19}H_{29}NO_3NaS^+$ ($M+Na^+$): 374.1766, found: 374.1767.

5. X-Ray Single Crystal Diffraction Data

The crystals of compound **4i** were grown in a mixed solution of CH_2Cl_2 and petroleum ether as the solution slowly volatilized. X-ray single crystal diffraction data were recorded on Bruker D8 VENTURE. This crystal structure has been deposited at the Cambridge Crystallographic Data Centre (CCDC 2102437).

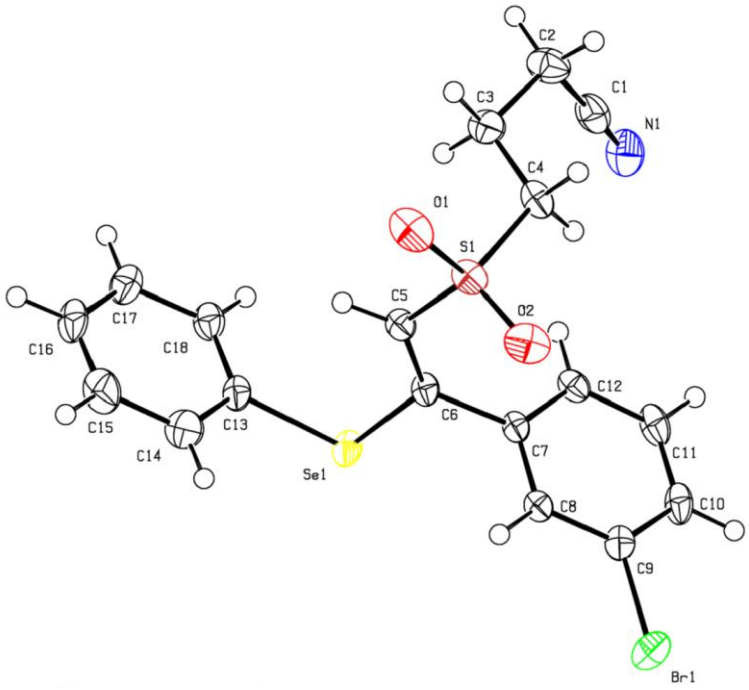


Figure S1. X-ray structure of **4i** (displacement ellipsoids are drawn at the 30% probability level).

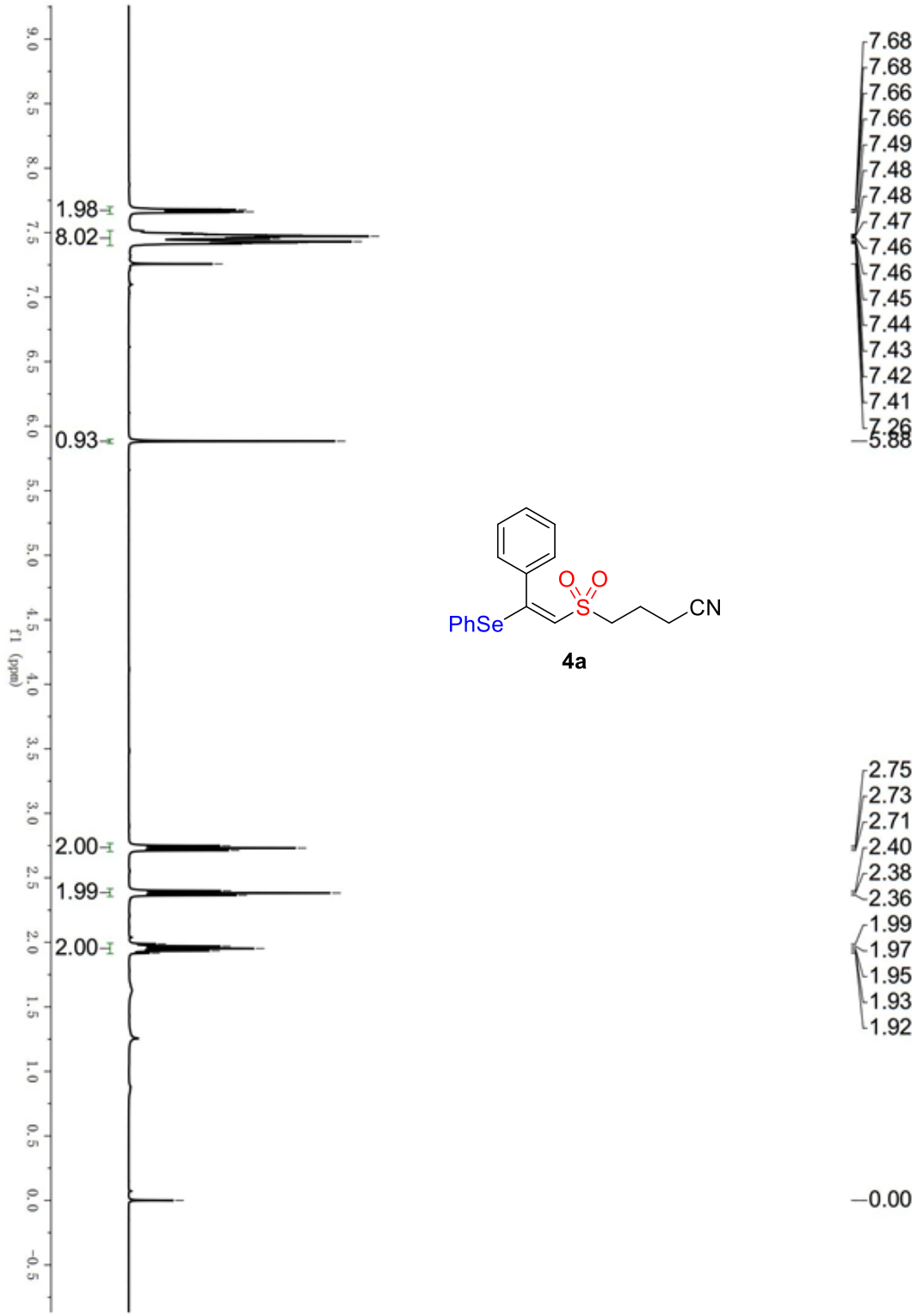
Table S1. Crystal data and structure refinement for **4i**.

Identification code	**4i**
Empirical formula	$C_{18}H_{16}BrNO_2SSe$
Formula weight	469.25
Temperature	173(2) K
Wavelength	1.34138 Å

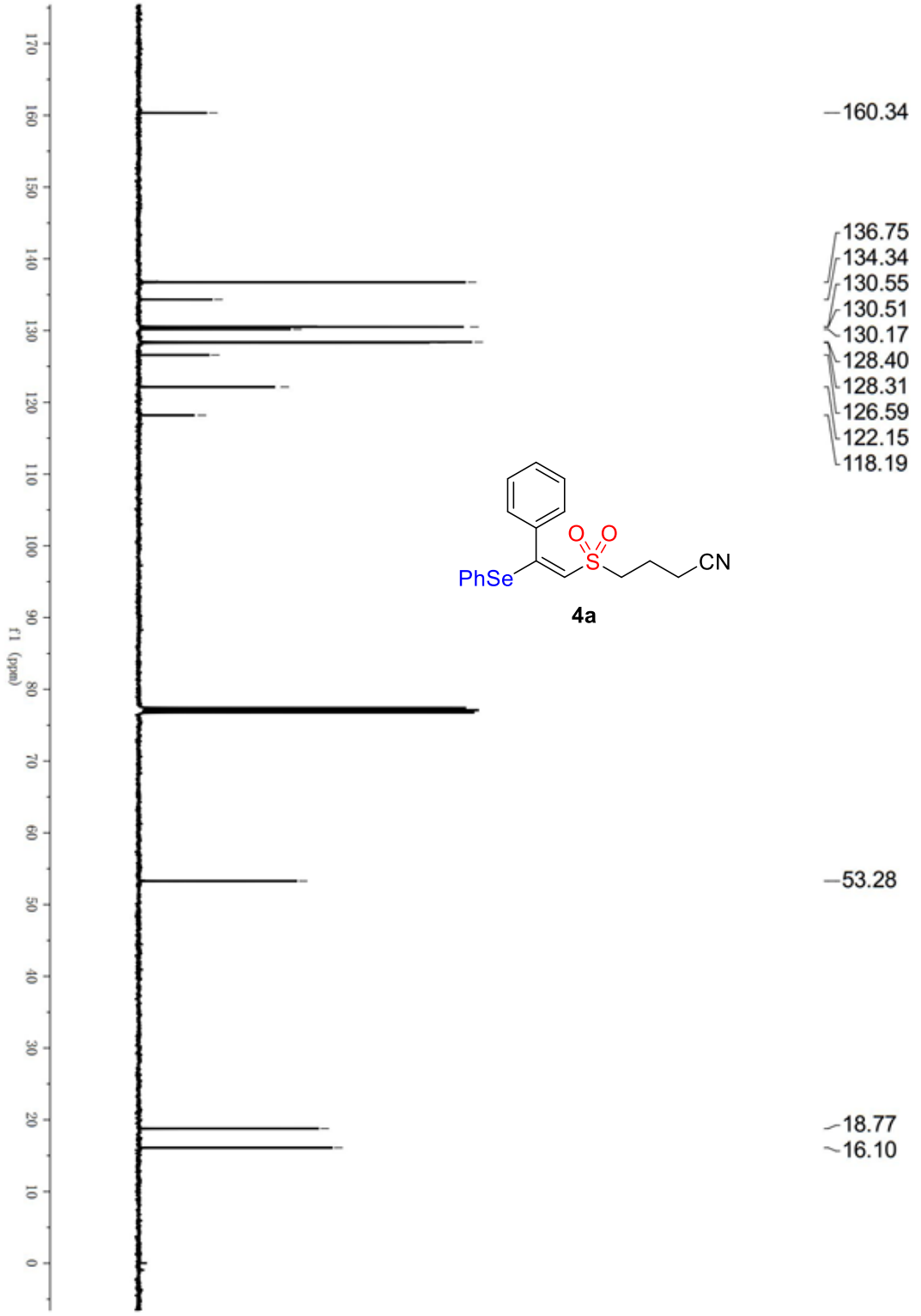
Crystal system	Monoclinic	
Space group	$P2_1/c$	
Unit cell dimensions	a = 10.3416(9) Å	a= 90 °.
	b = 18.4062(16) Å	b= 112.267(3) °.
	c = 10.3029(9) Å	g = 90 °.
Volume	1814.9(3) $Å^3$	
Z	4	
Density (calculated)	1.717 Mg/m^3	
Absorption coefficient	4.329 mm^{-1}	
F(000)	928	
Crystal size	0.100 x 0.080 x 0.030 mm^3	
Theta range for data collection	4.019 to 59.490 °.	
Index ranges	-11<=h<=13, -17<=k<=23, -13<=l<=13	
Reflections collected	15494	
Independent reflections	3975 [R(int) = 0.0744]	
Completeness to theta = 53.594 °	98.6 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.752 and 0.314	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3975 / 0 / 217	
Goodness-of-fit on F^2	1.042	
Final R indices [I>2sigma(I)]	R1 = 0.0474, wR2 = 0.1178	
R indices (all data)	R1 = 0.0525, wR2 = 0.1231	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.903 and -0.836 $e.Å^{-3}$	

6. Copies of ^{1}H and ^{13}C NMR Spectra

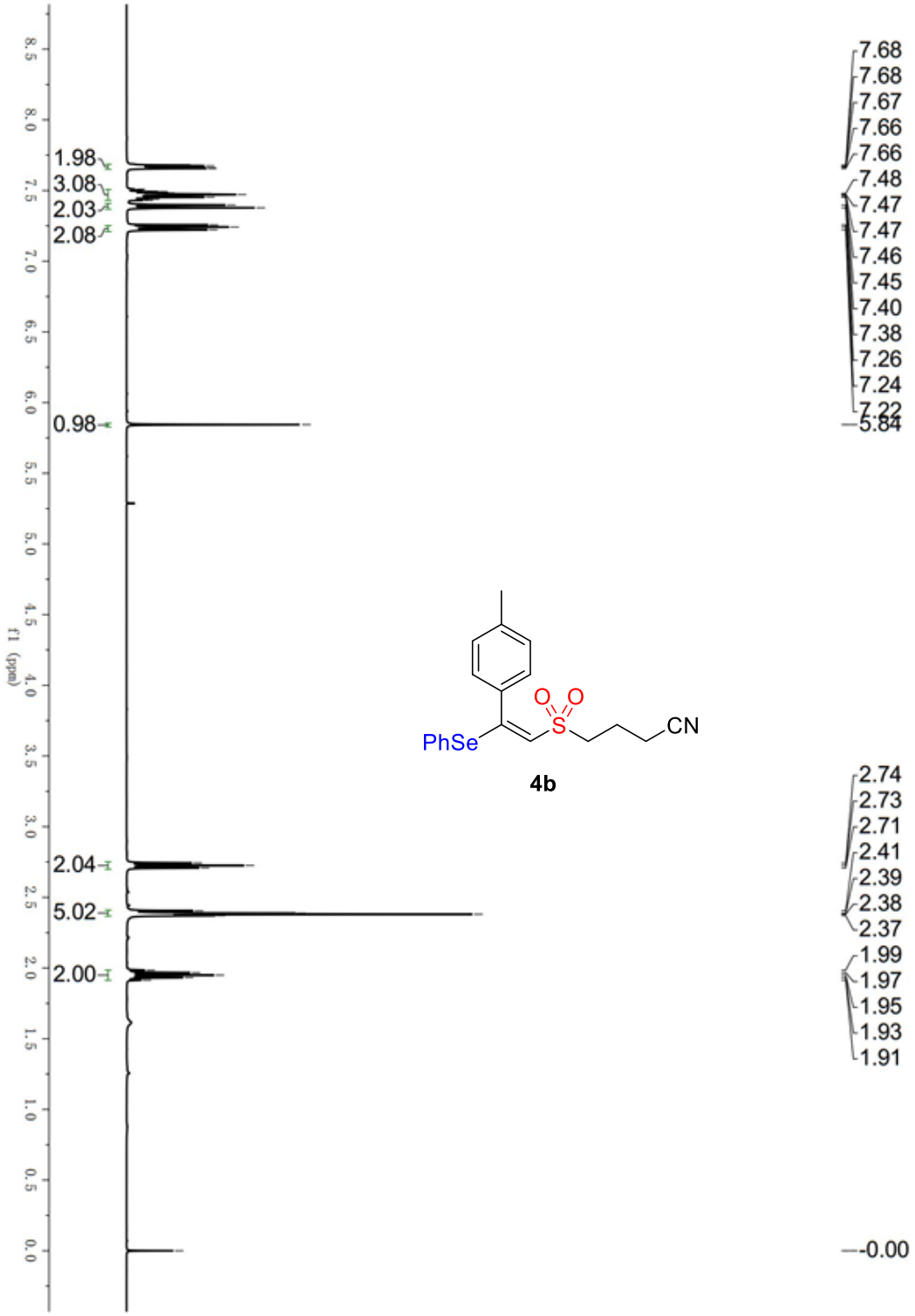
^{1}H NMR spectrum of compound **4a** (400 MHz, $CDCl_3$)



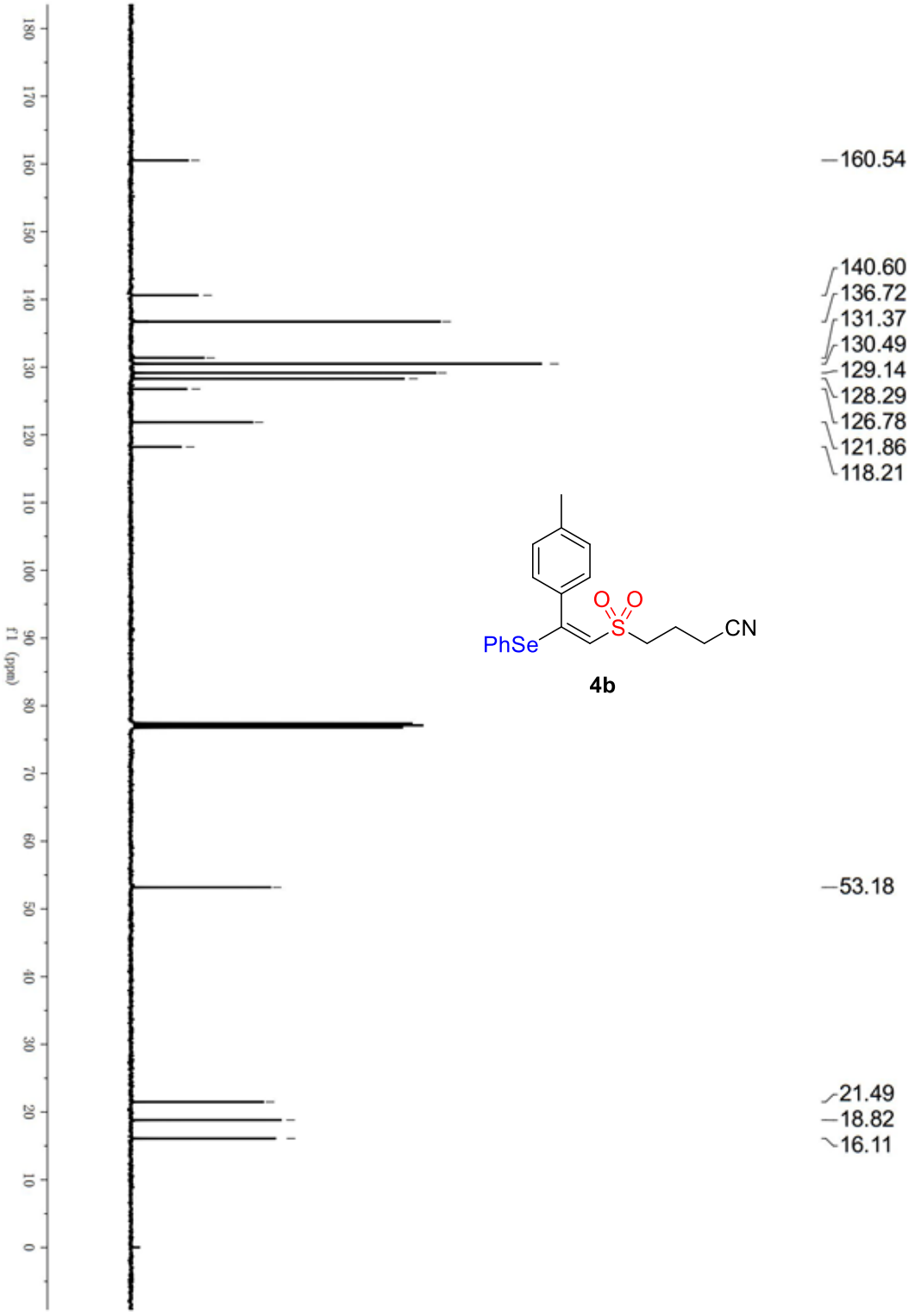
^{13}C NMR spectrum of compound **4a** (100 MHz, $CDCl_3$)



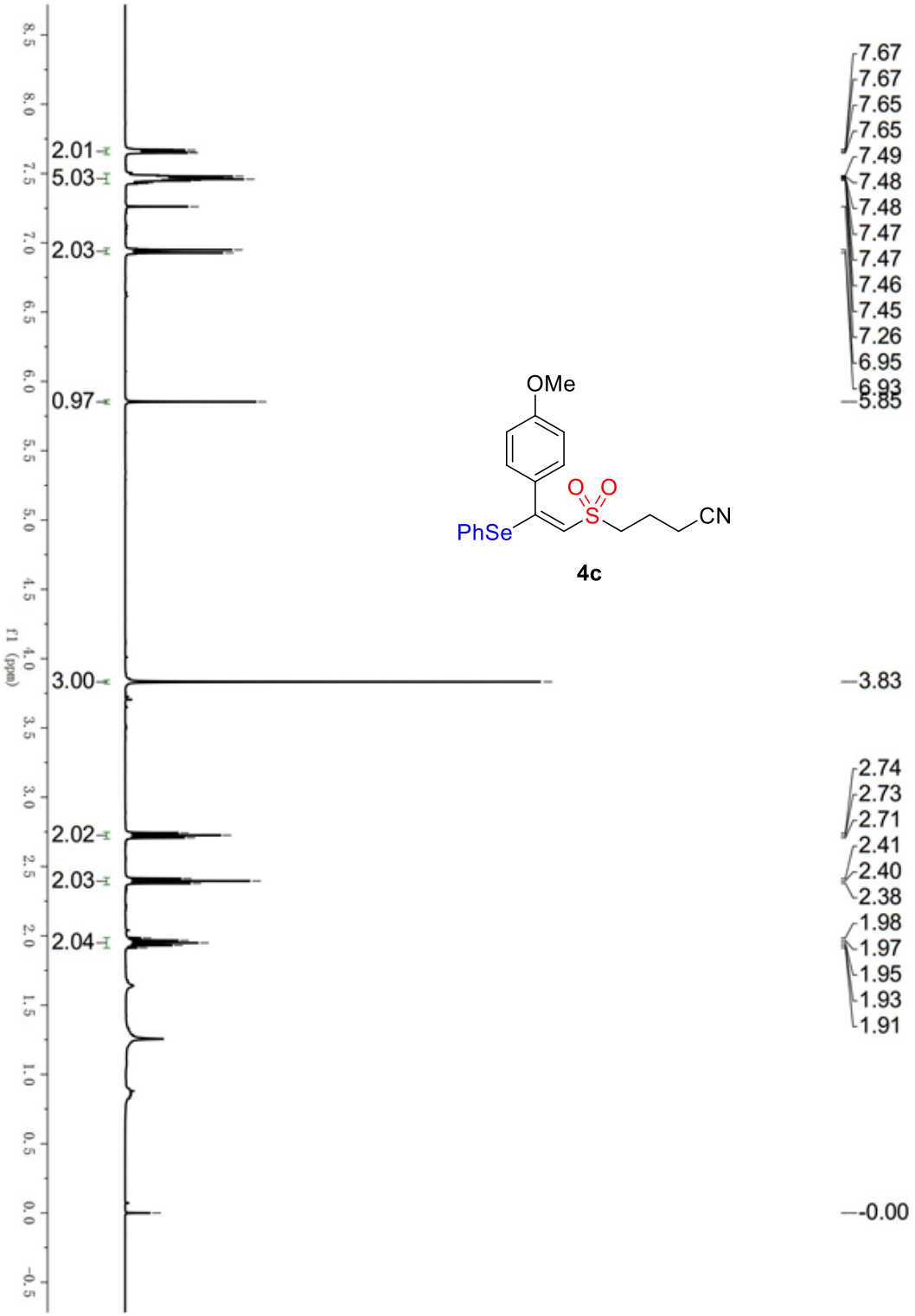
^{1}H NMR spectrum of compound **4b** (400 MHz, $CDCl_3$)



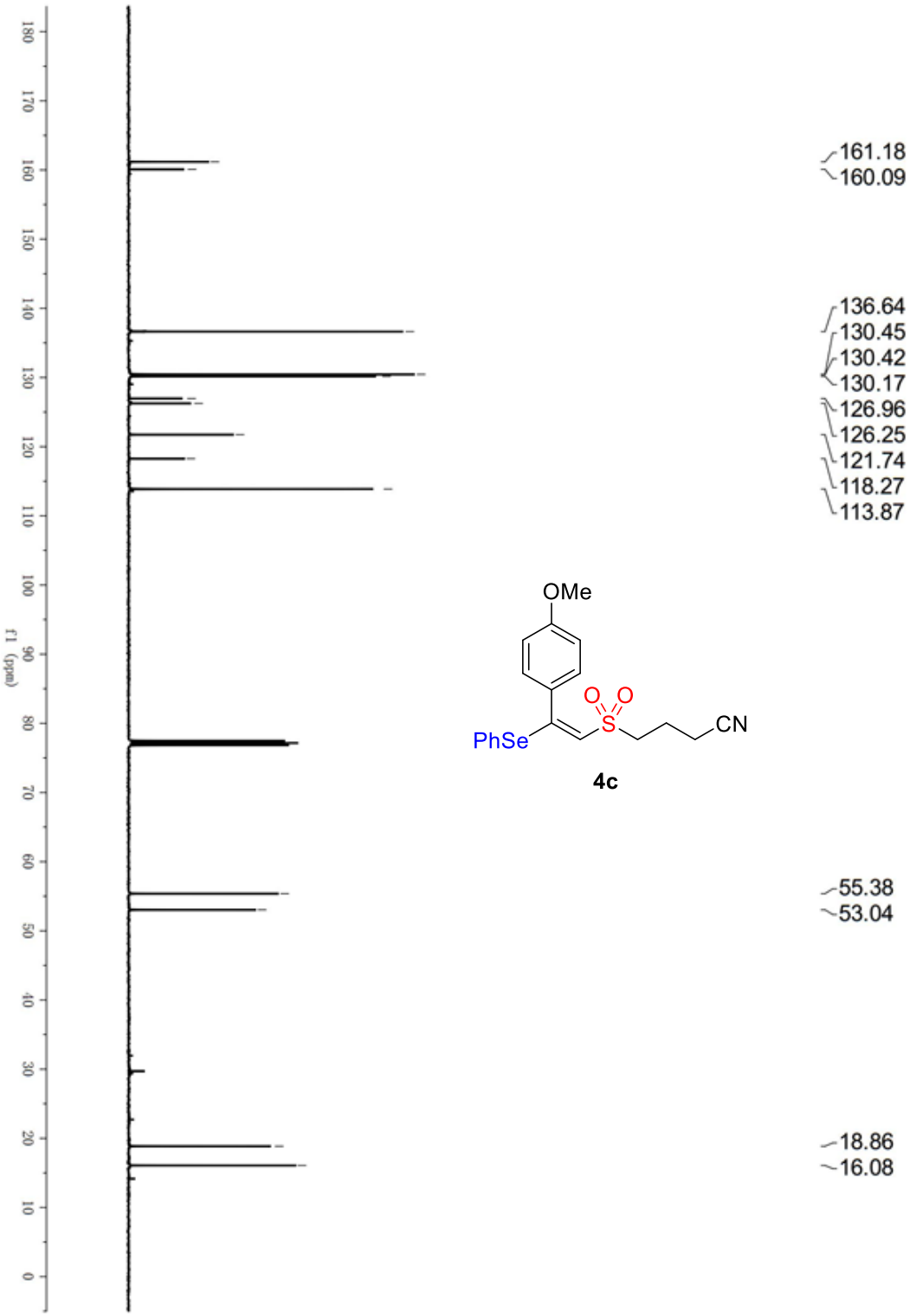
^{13}C NMR spectrum of compound **4b** (100 MHz, $CDCl_3$)



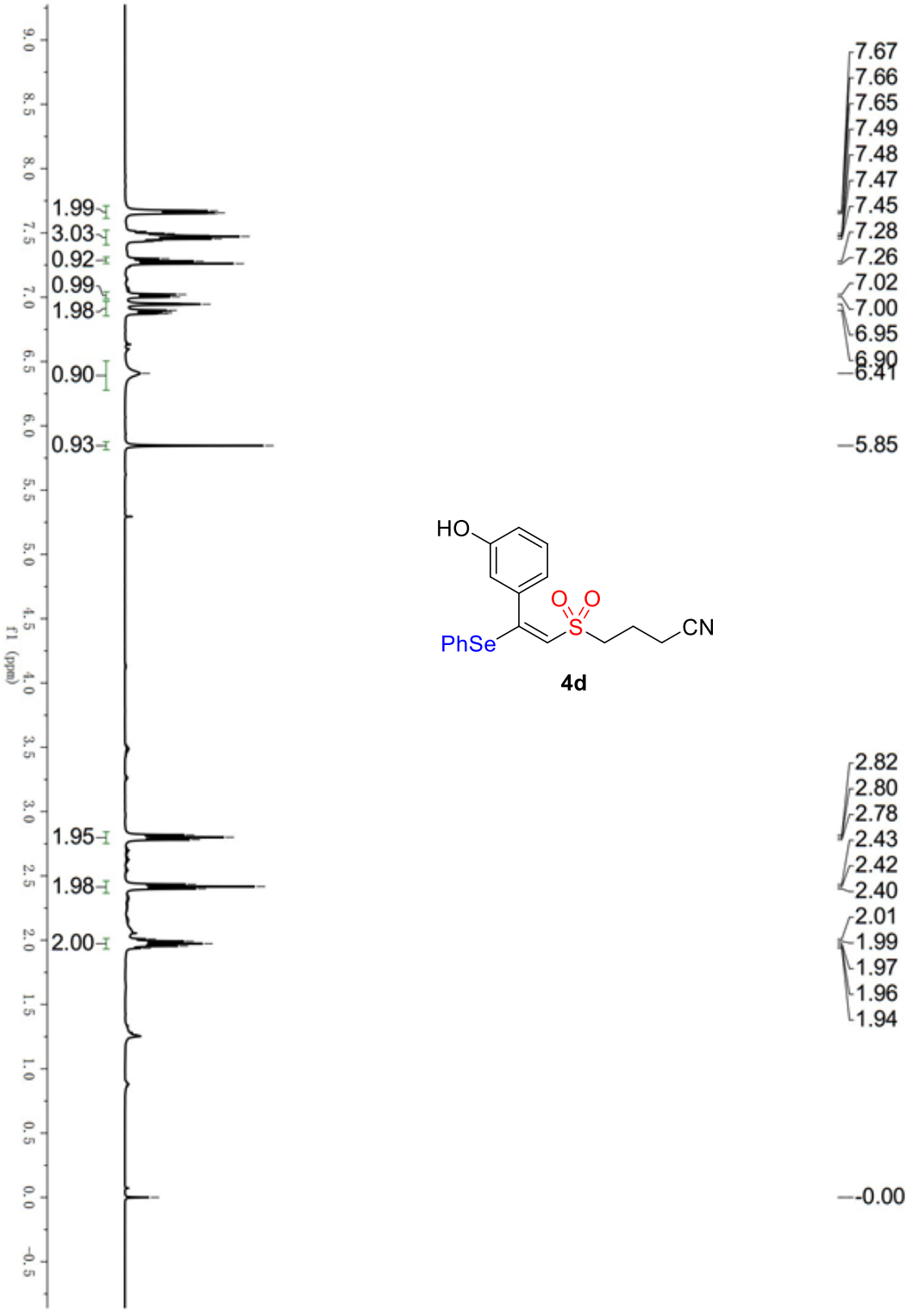
^{1}H NMR spectrum of compound **4c** (400 MHz, $CDCl_3$)



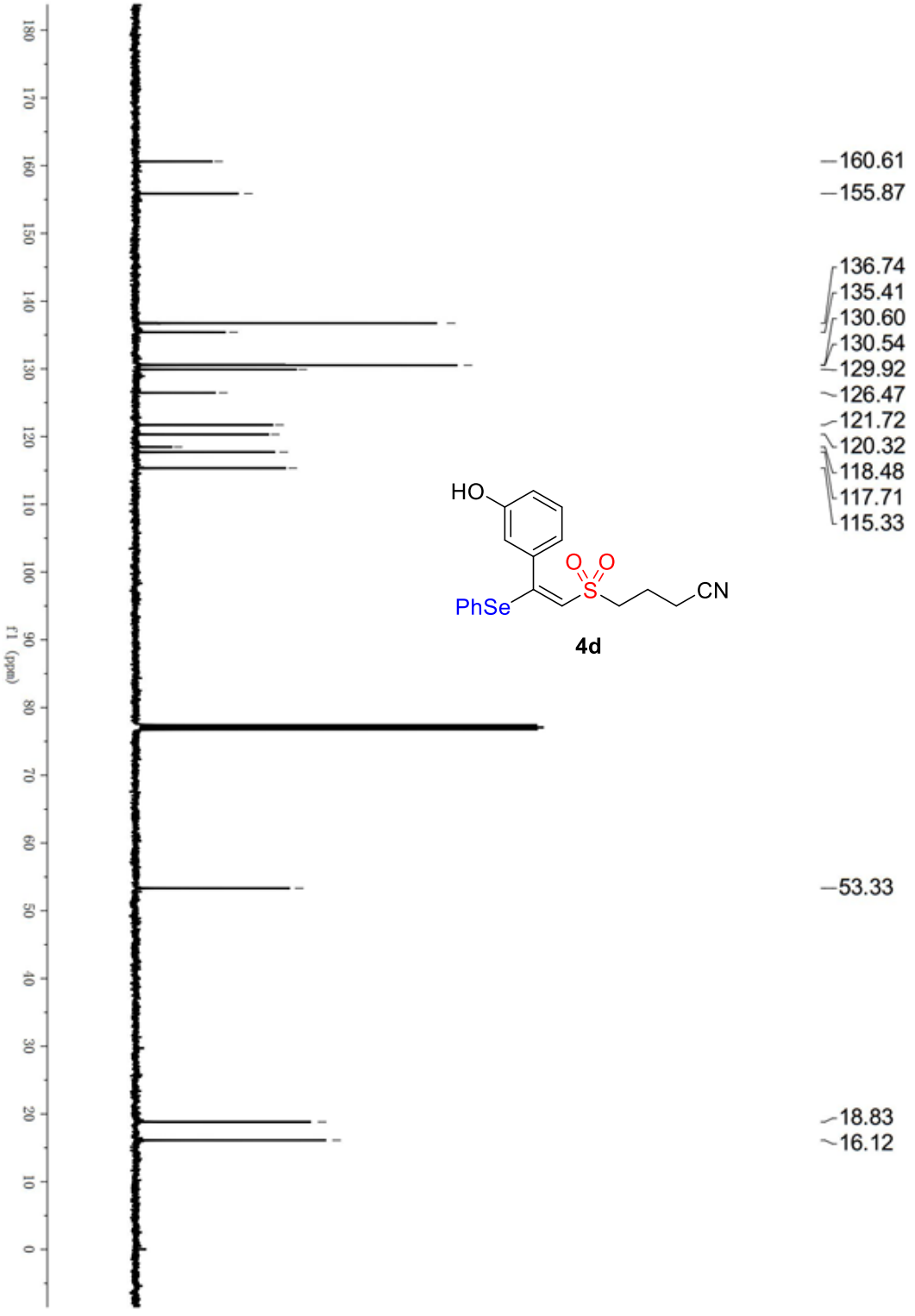
^{13}C NMR spectrum of compound **4c** (100 MHz, $CDCl_3$)



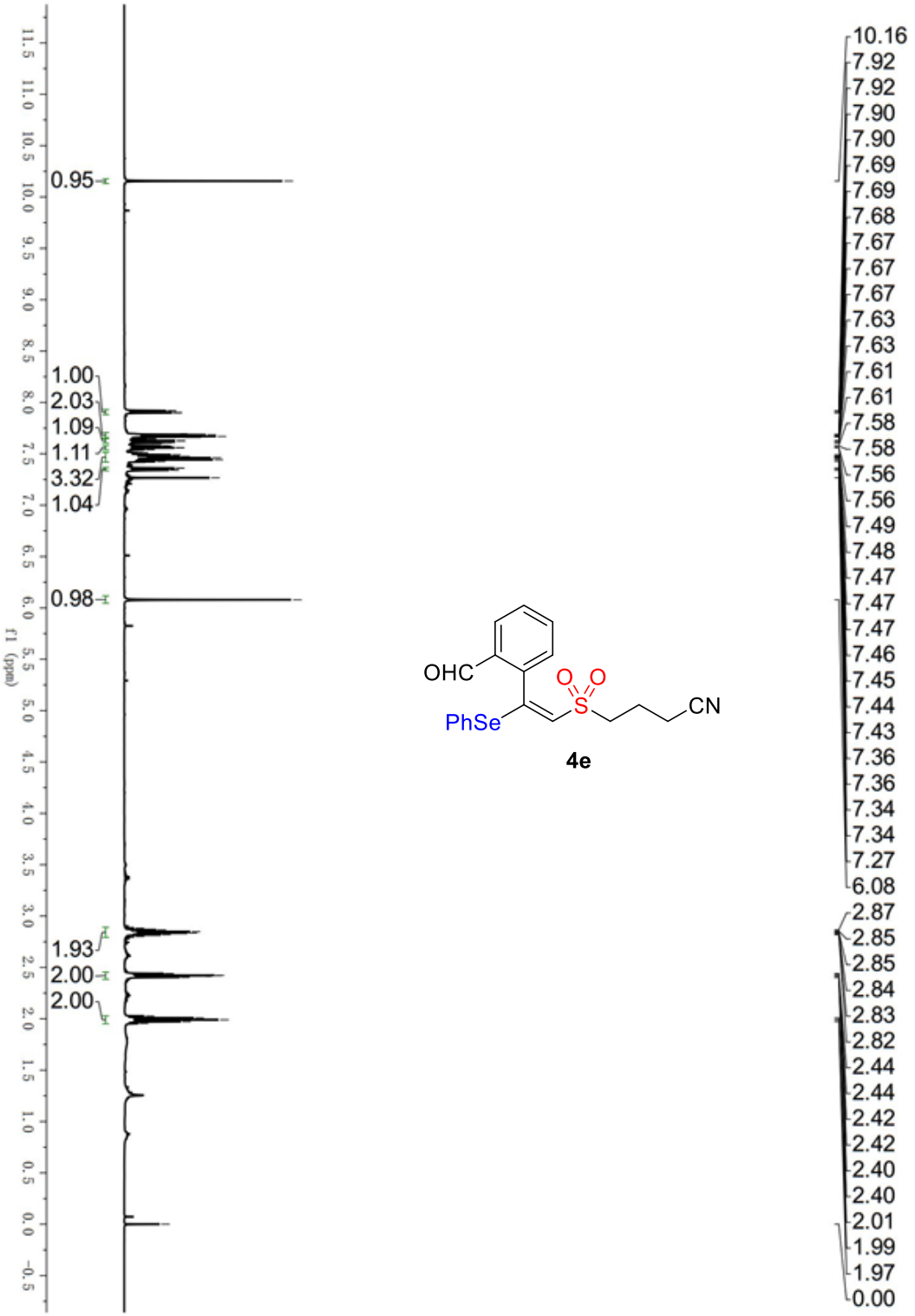
^{1}H NMR spectrum of compound **4d** (400 MHz, $CDCl_3$)



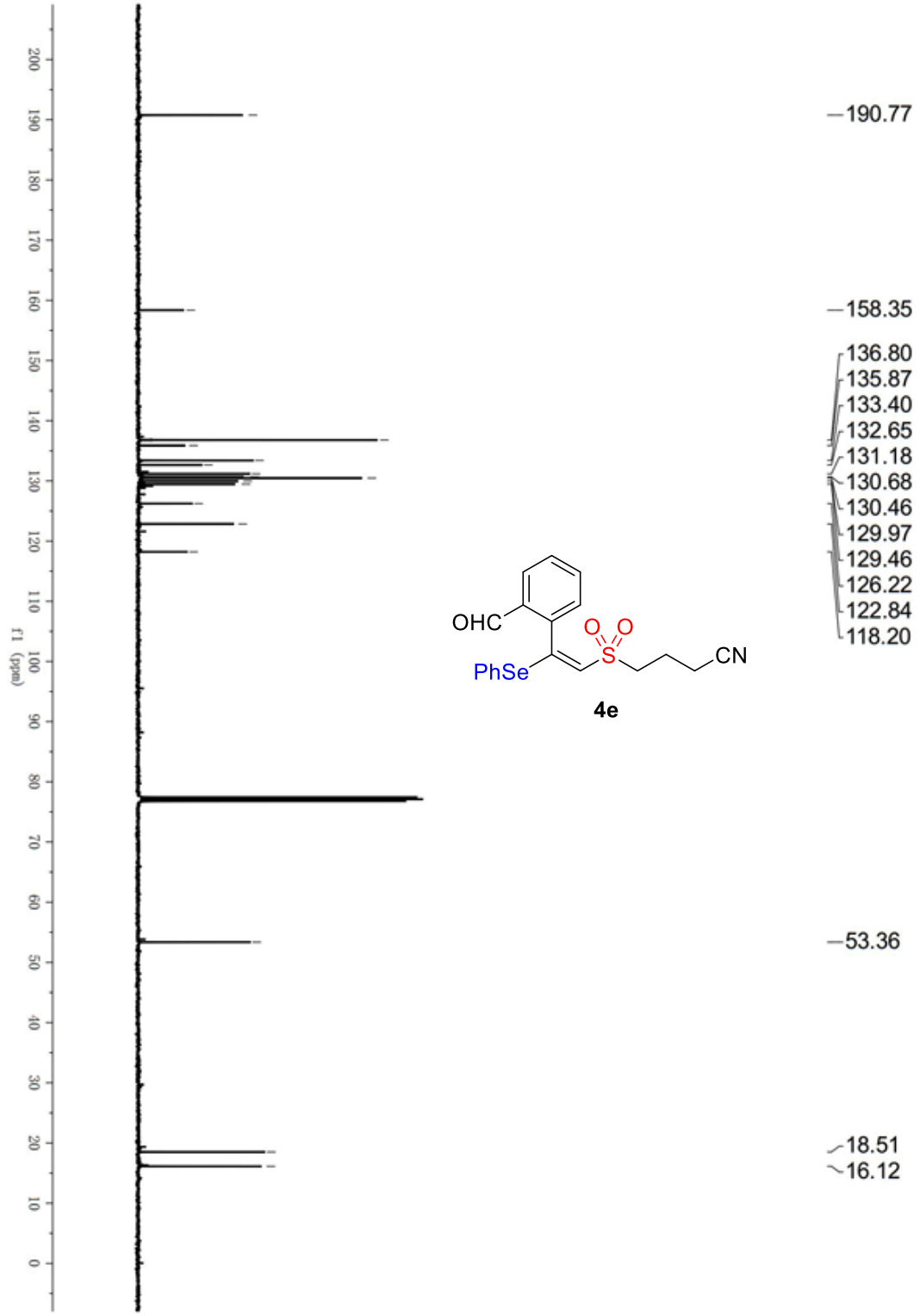
^{13}C NMR spectrum of compound **4d** (100 MHz, $CDCl_3$)



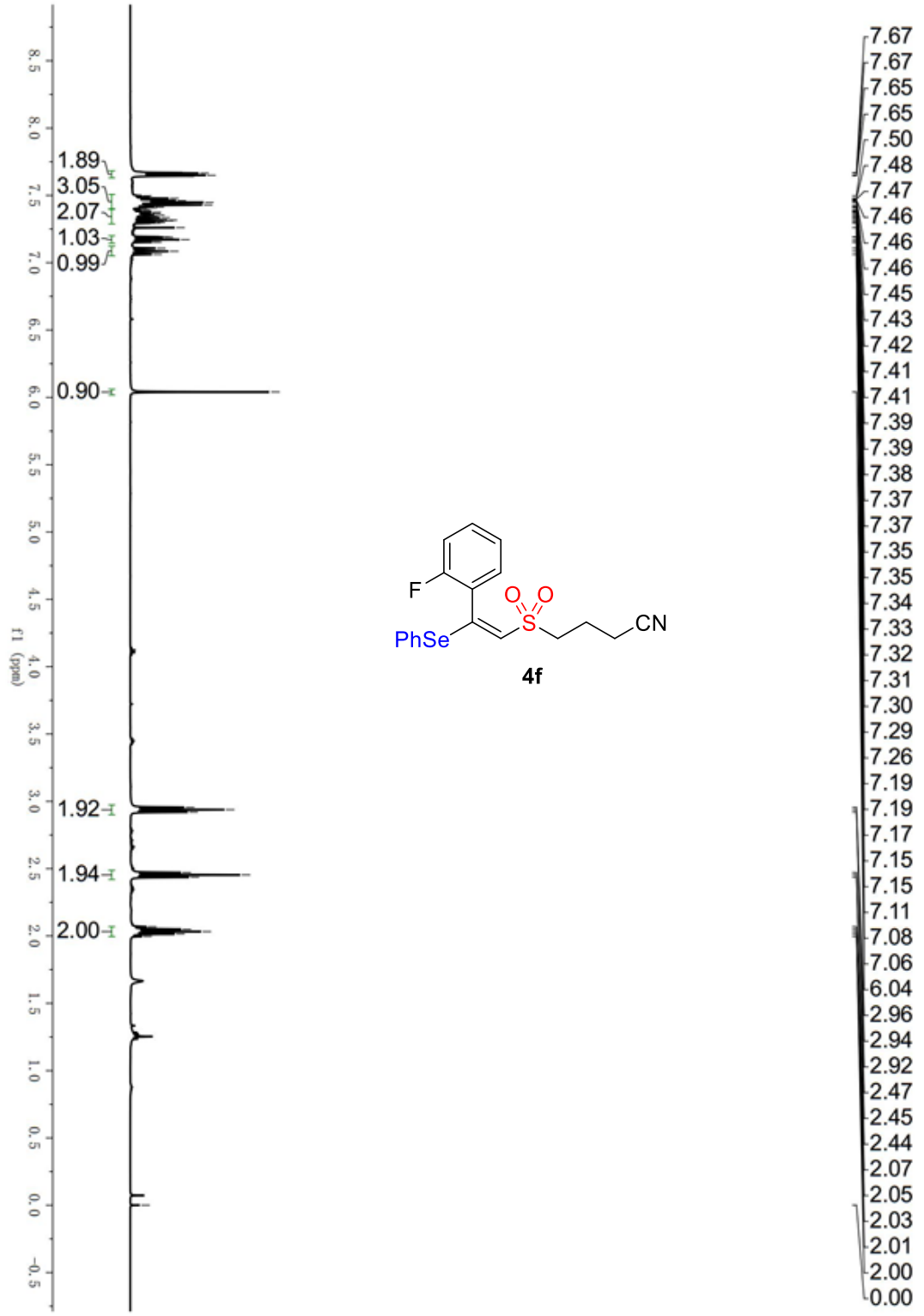
^{1}H NMR spectrum of compound **4e** (400 MHz, $CDCl_3$)



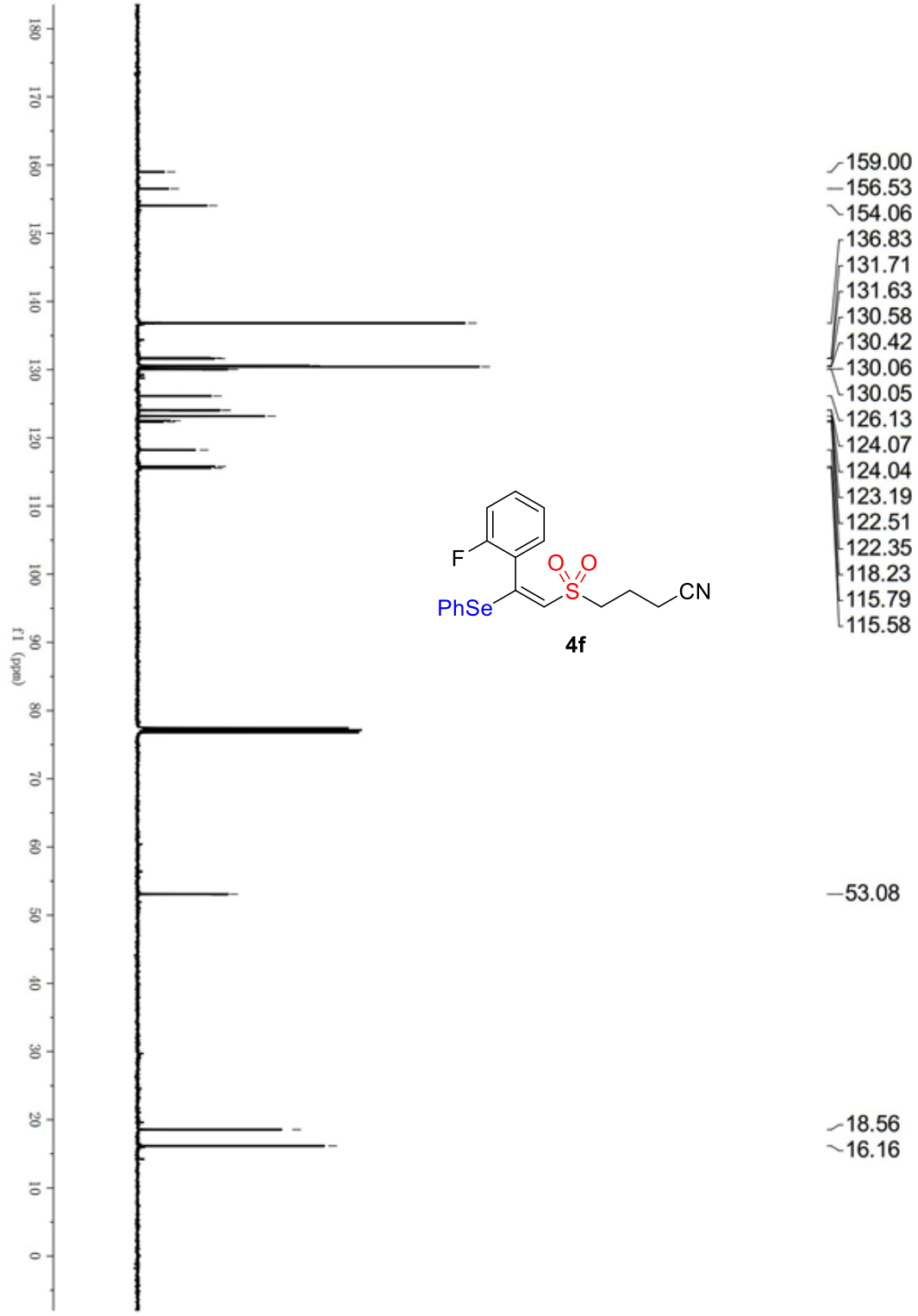
^{13}C NMR spectrum of compound **4e** (100 MHz, $CDCl_3$)



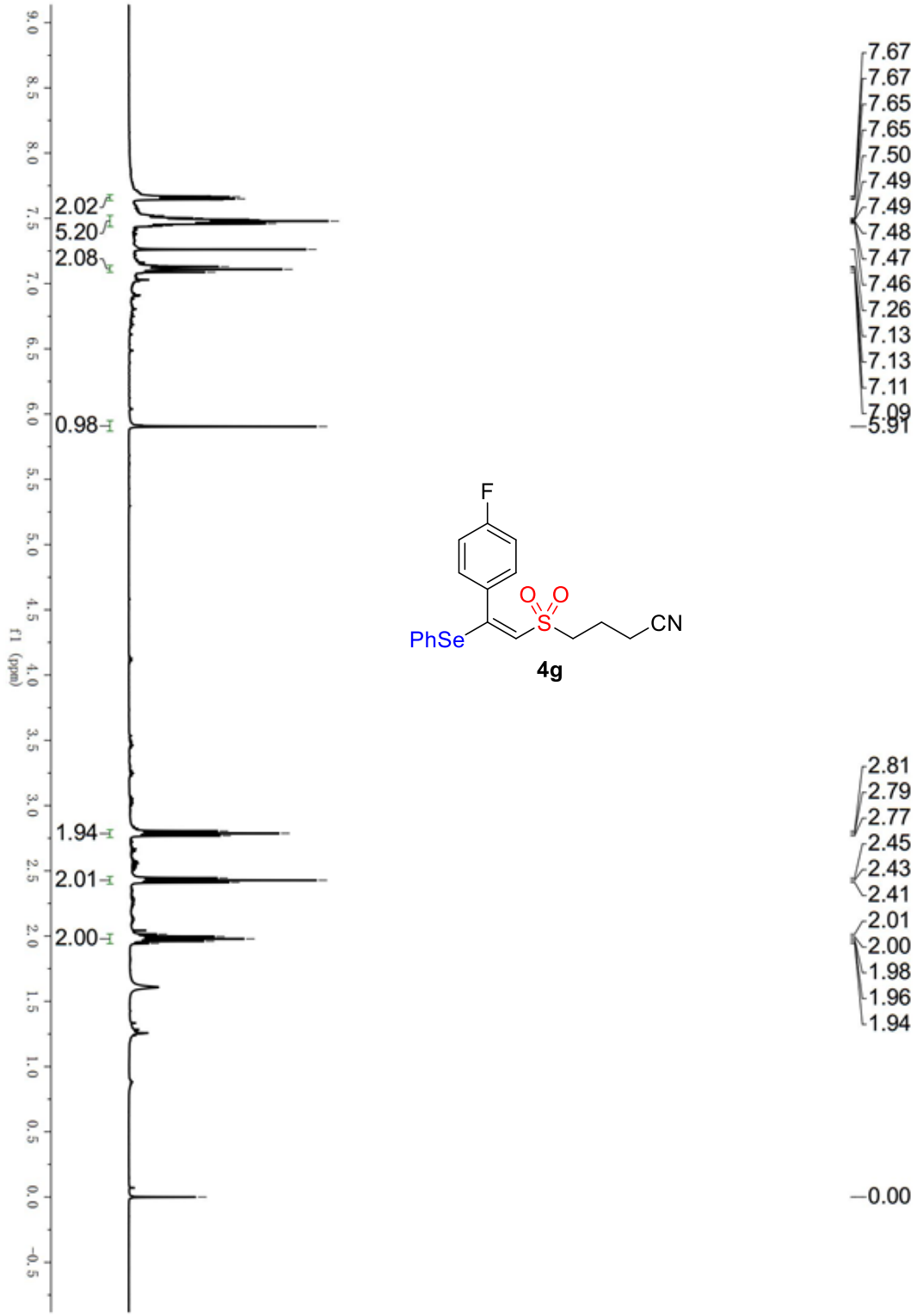
^{1}H NMR spectrum of compound **4f** (400 MHz, $CDCl_3$)



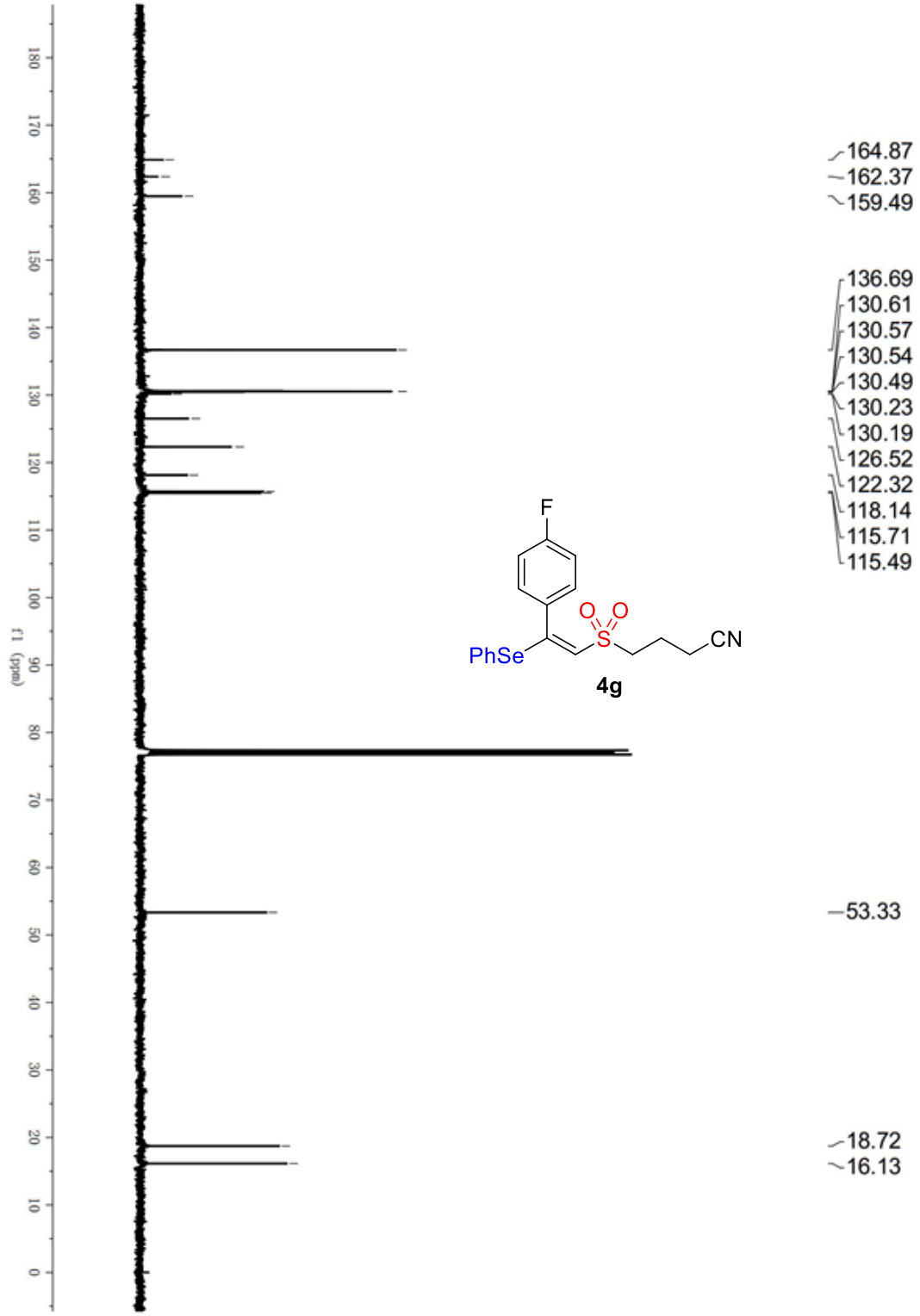
^{13}C NMR spectrum of compound **4f** (100 MHz, $CDCl_3$)



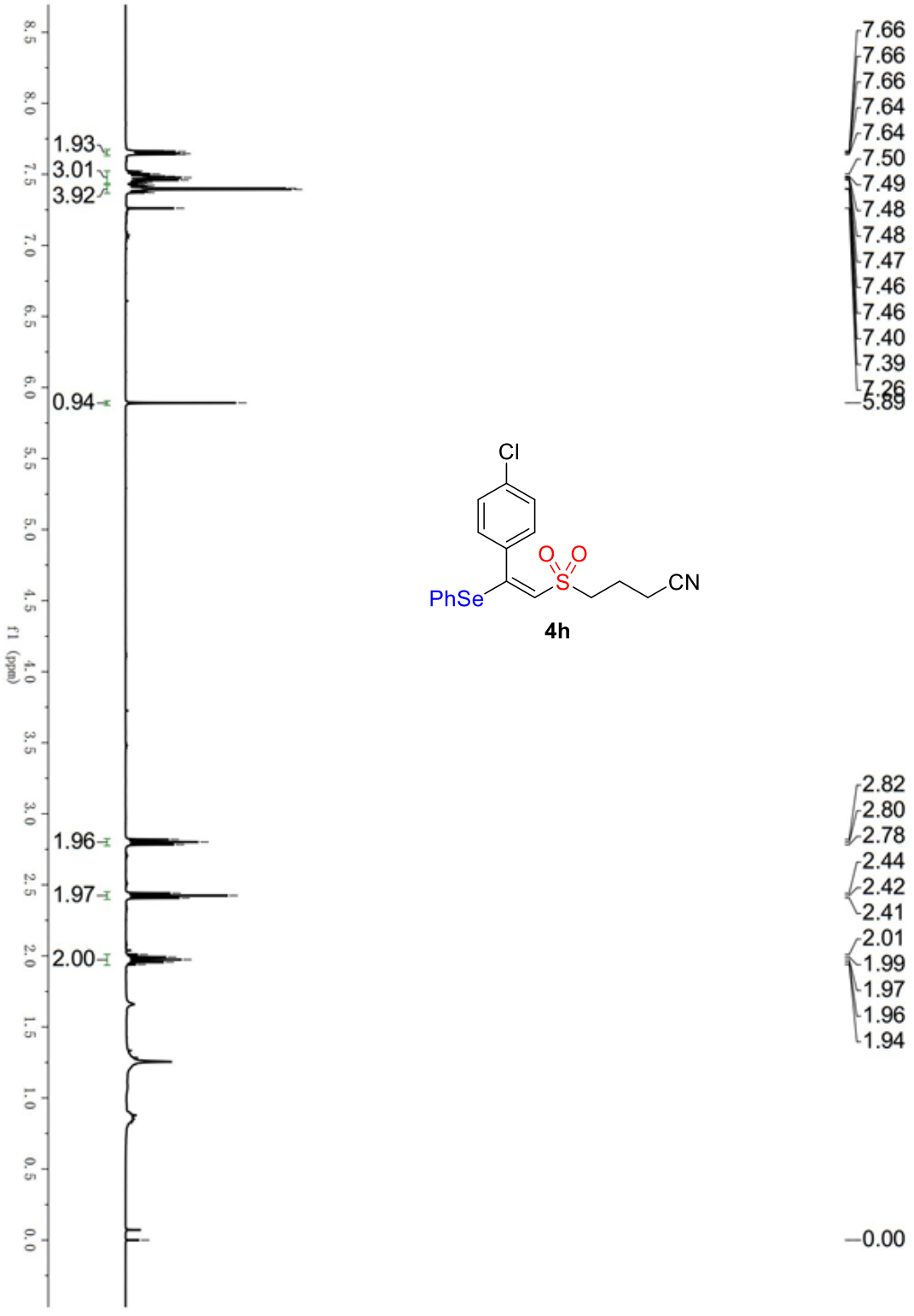
^{1}H NMR spectrum of compound **4g** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of compound **4g** (100 MHz, $CDCl_3$)

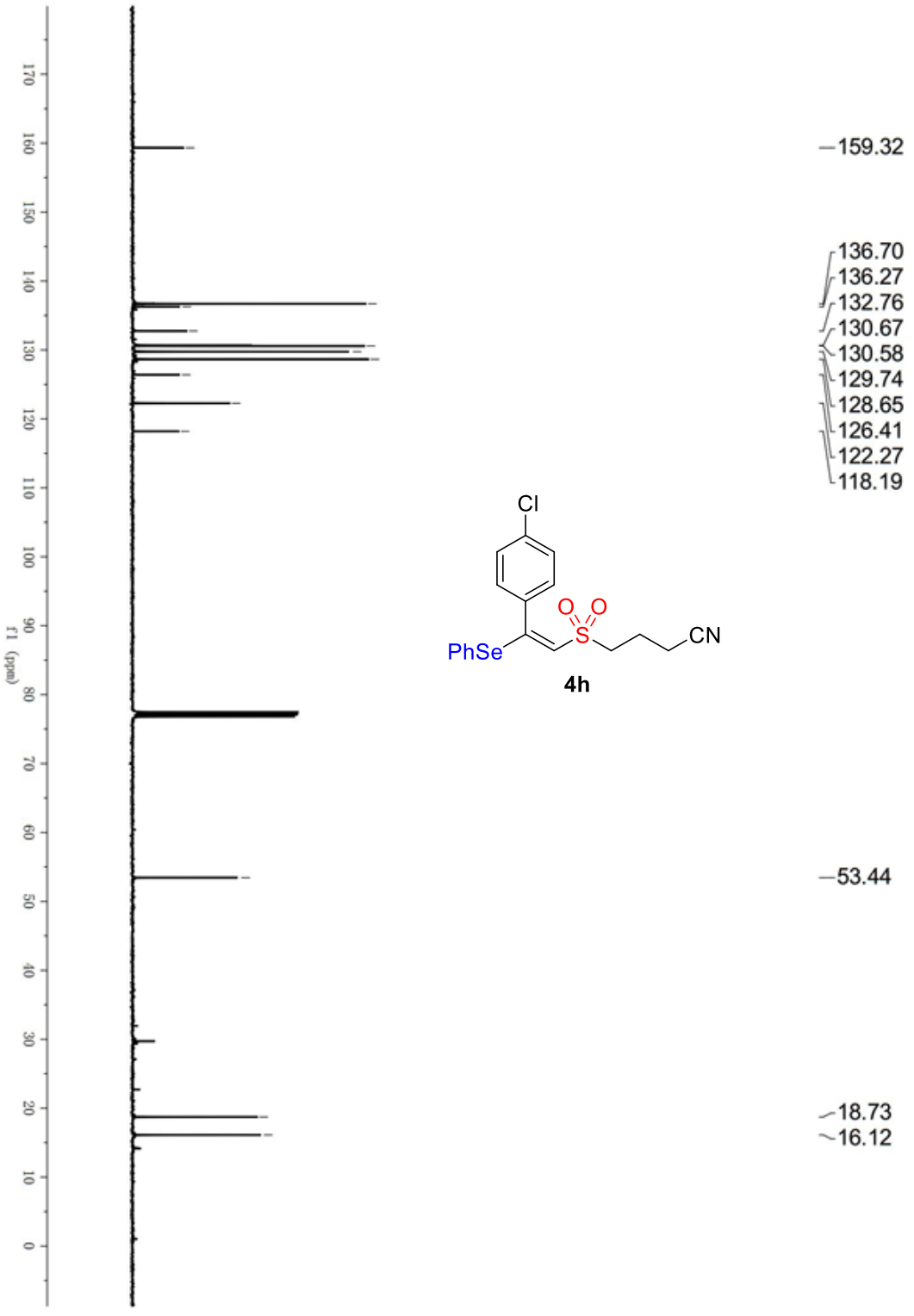


^{1}H NMR spectrum of compound **4h** (400 MHz, $CDCl_3$)

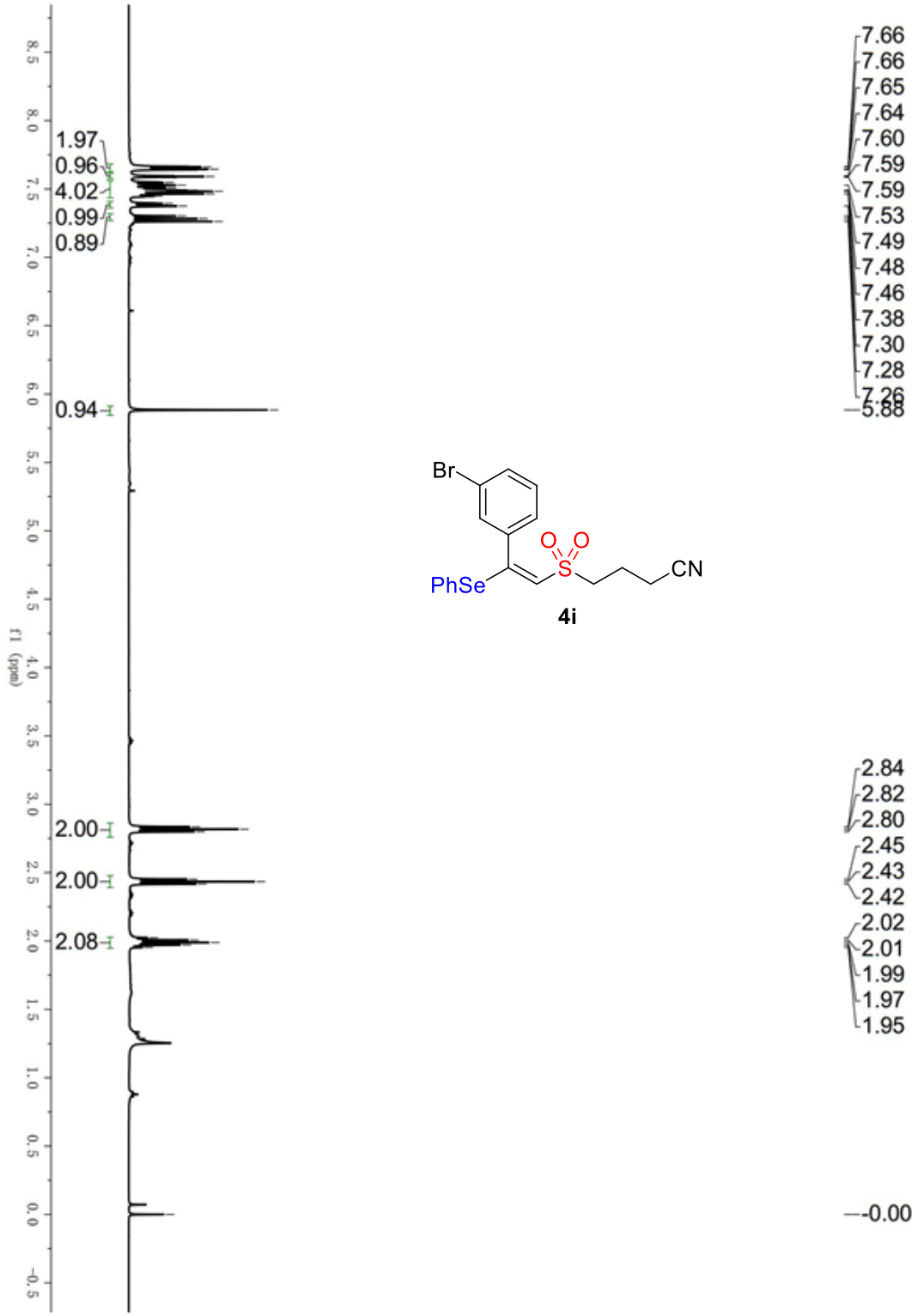


4h

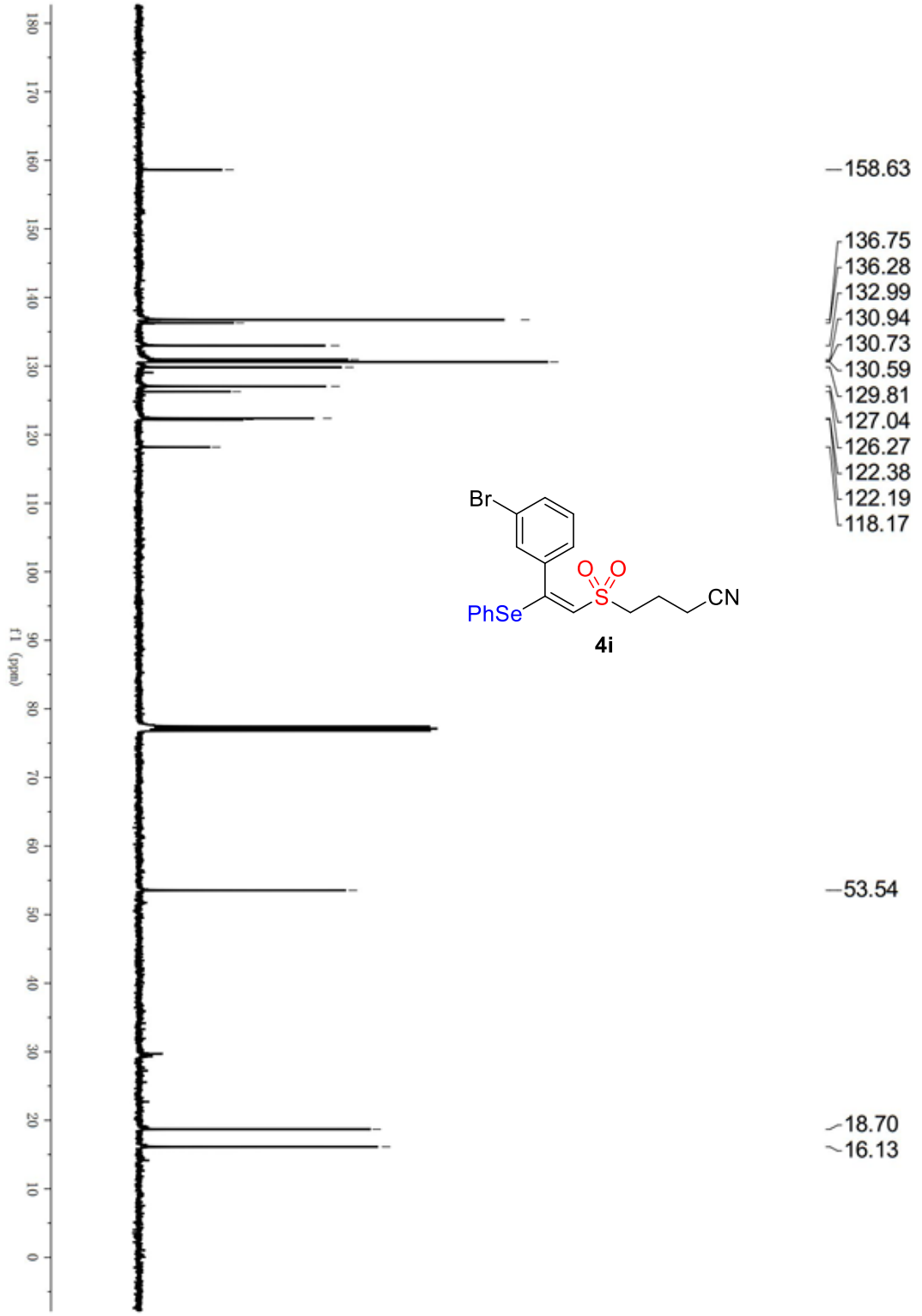
^{13}C NMR spectrum of compound **4h** (100 MHz, $CDCl_3$)



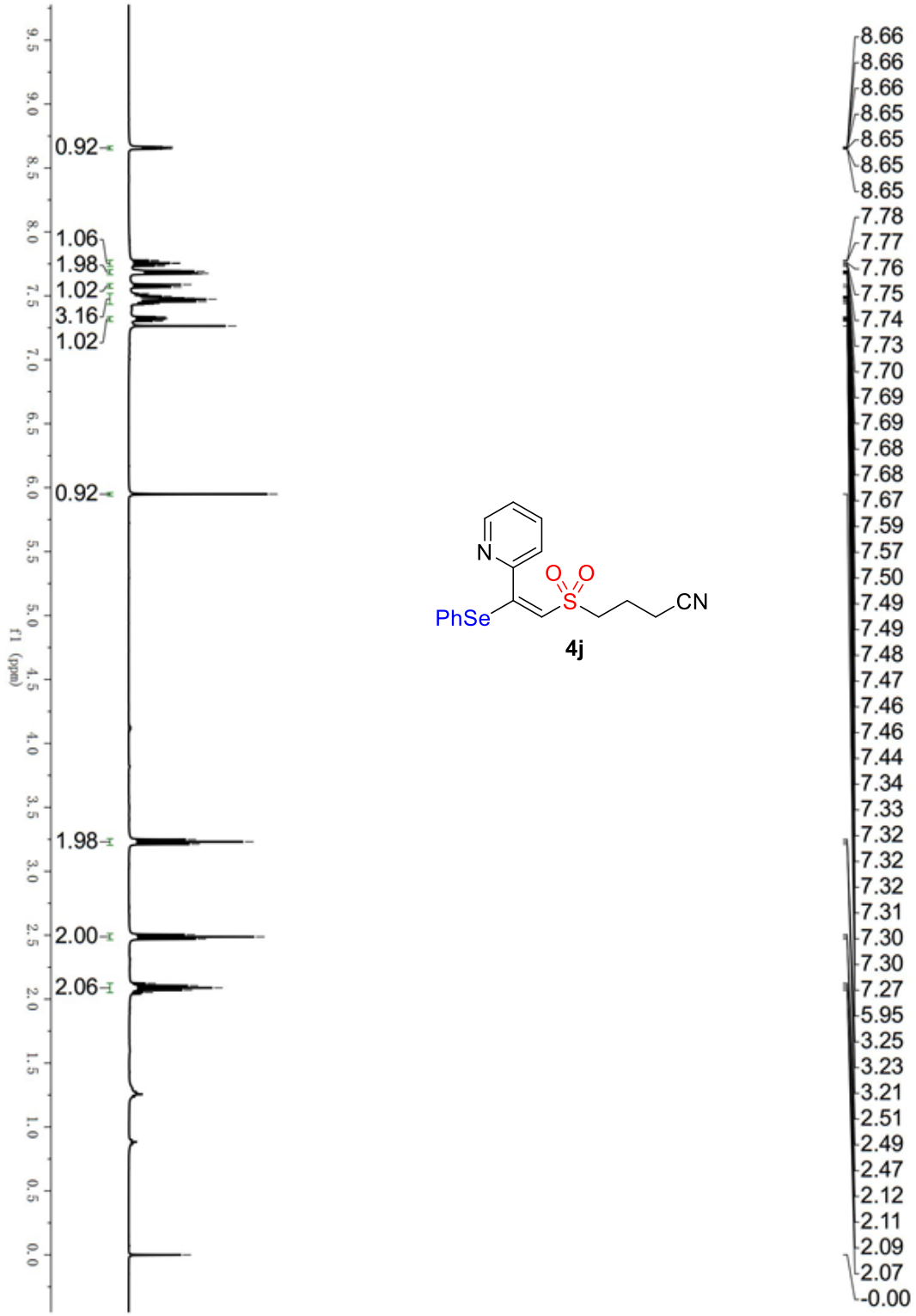
^{1}H NMR spectrum of compound **4i** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of compound **4i** (100 MHz, $CDCl_3$)

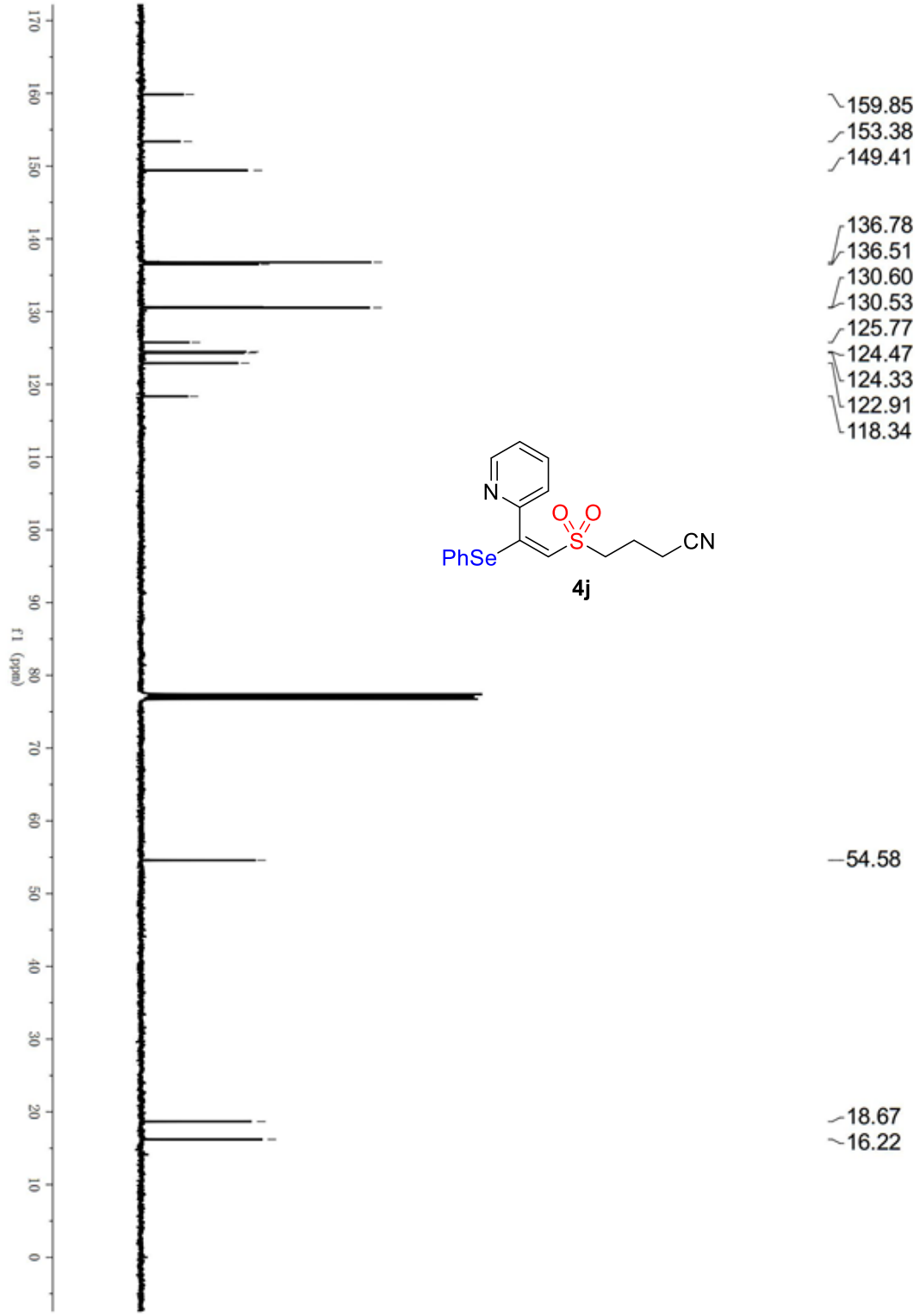


^{1}H NMR spectrum of compound **4j** (400 MHz, $CDCl_3$)

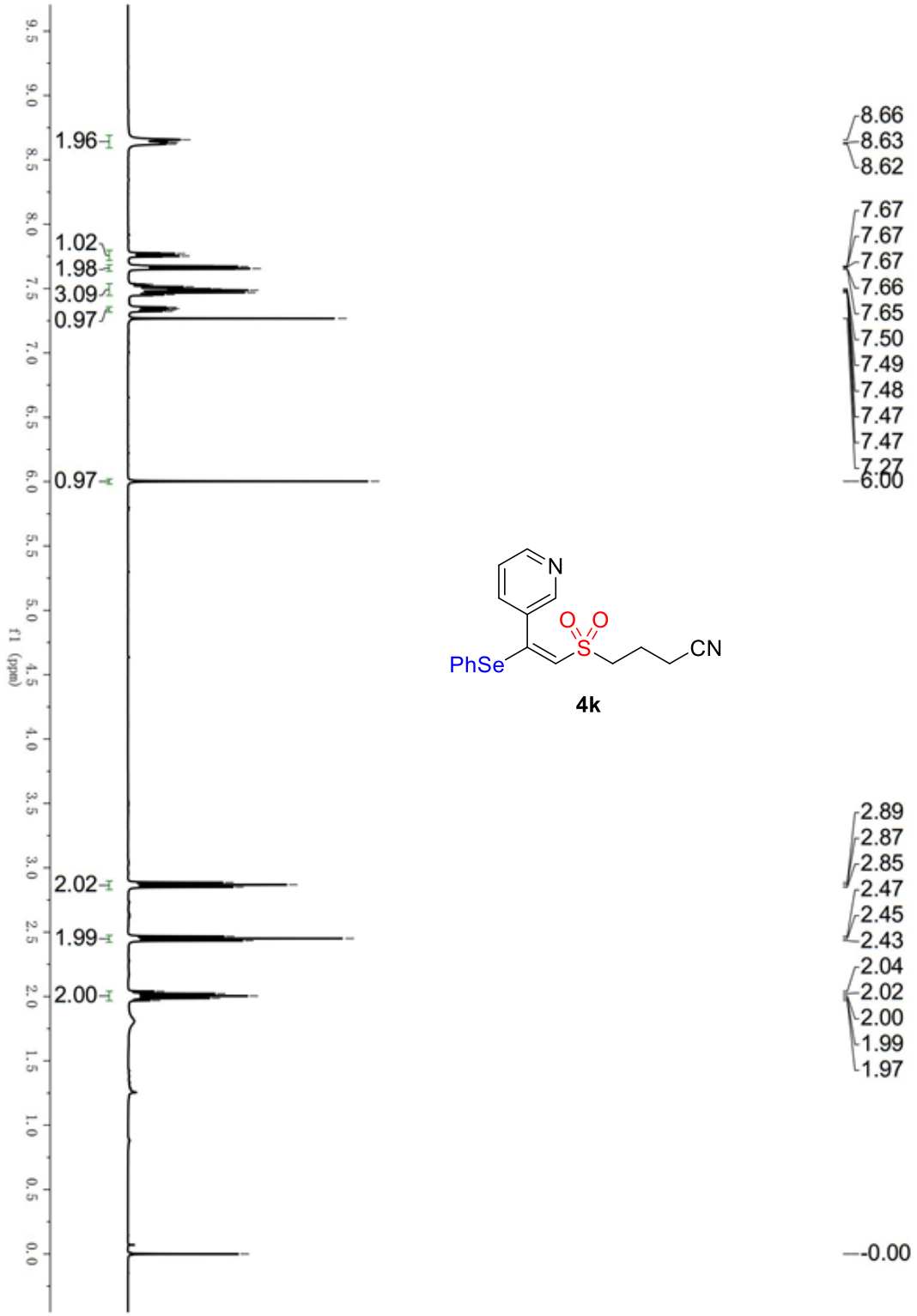


4j

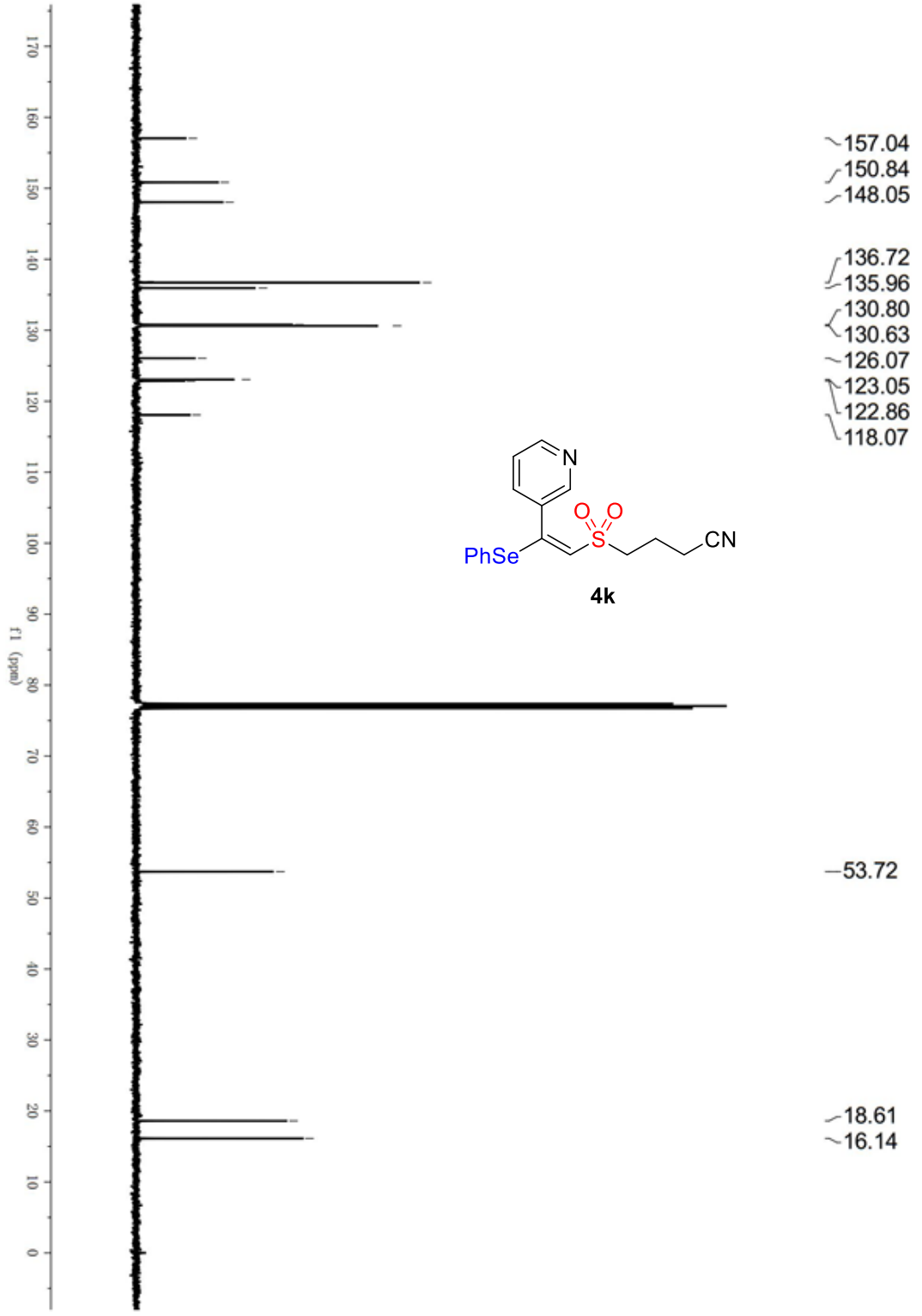
^{13}C NMR spectrum of compound **4j** (100 MHz, $CDCl_3$)



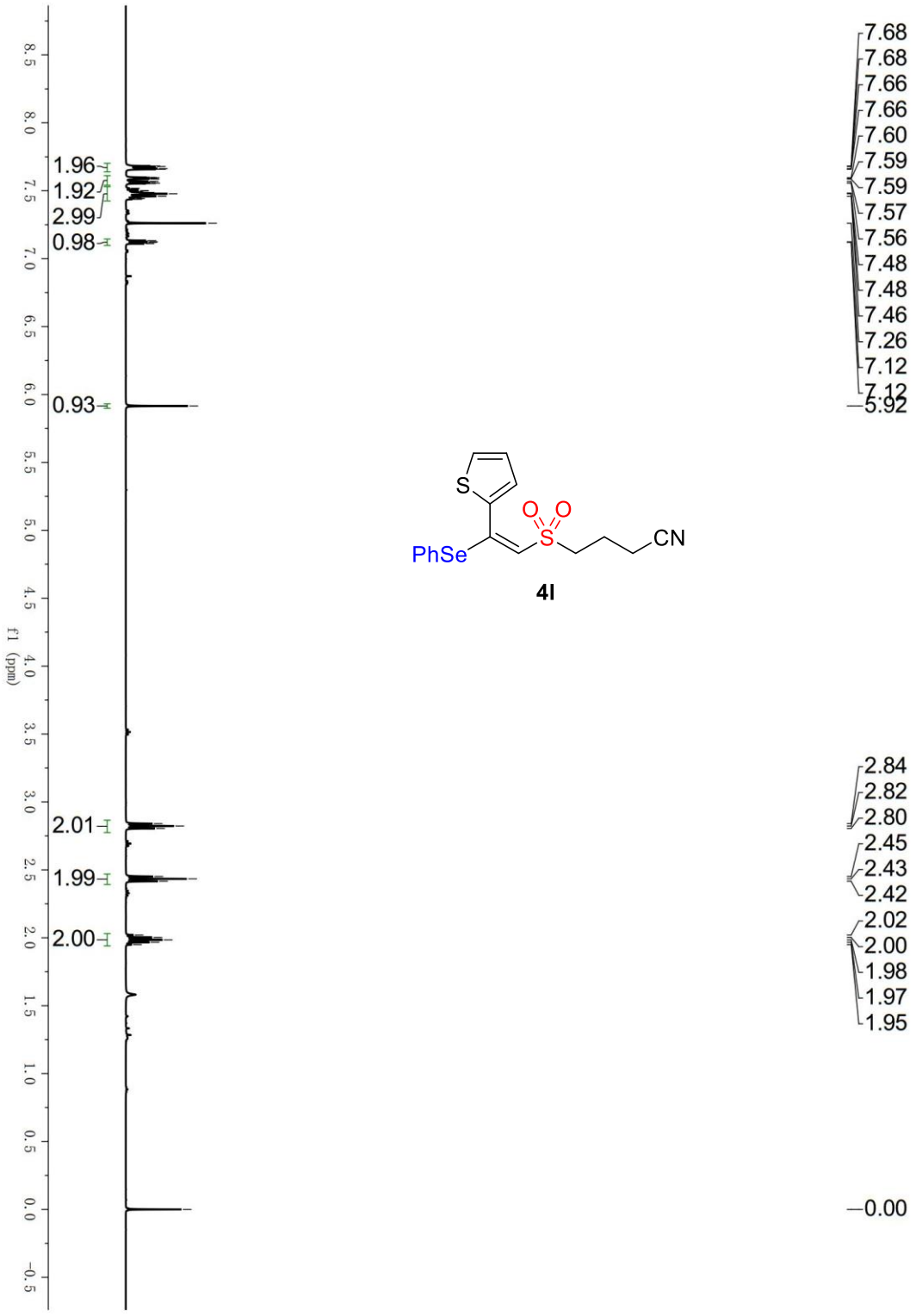
^{1}H NMR spectrum of compound **4k** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of compound **4k** (100 MHz, $CDCl_3$)

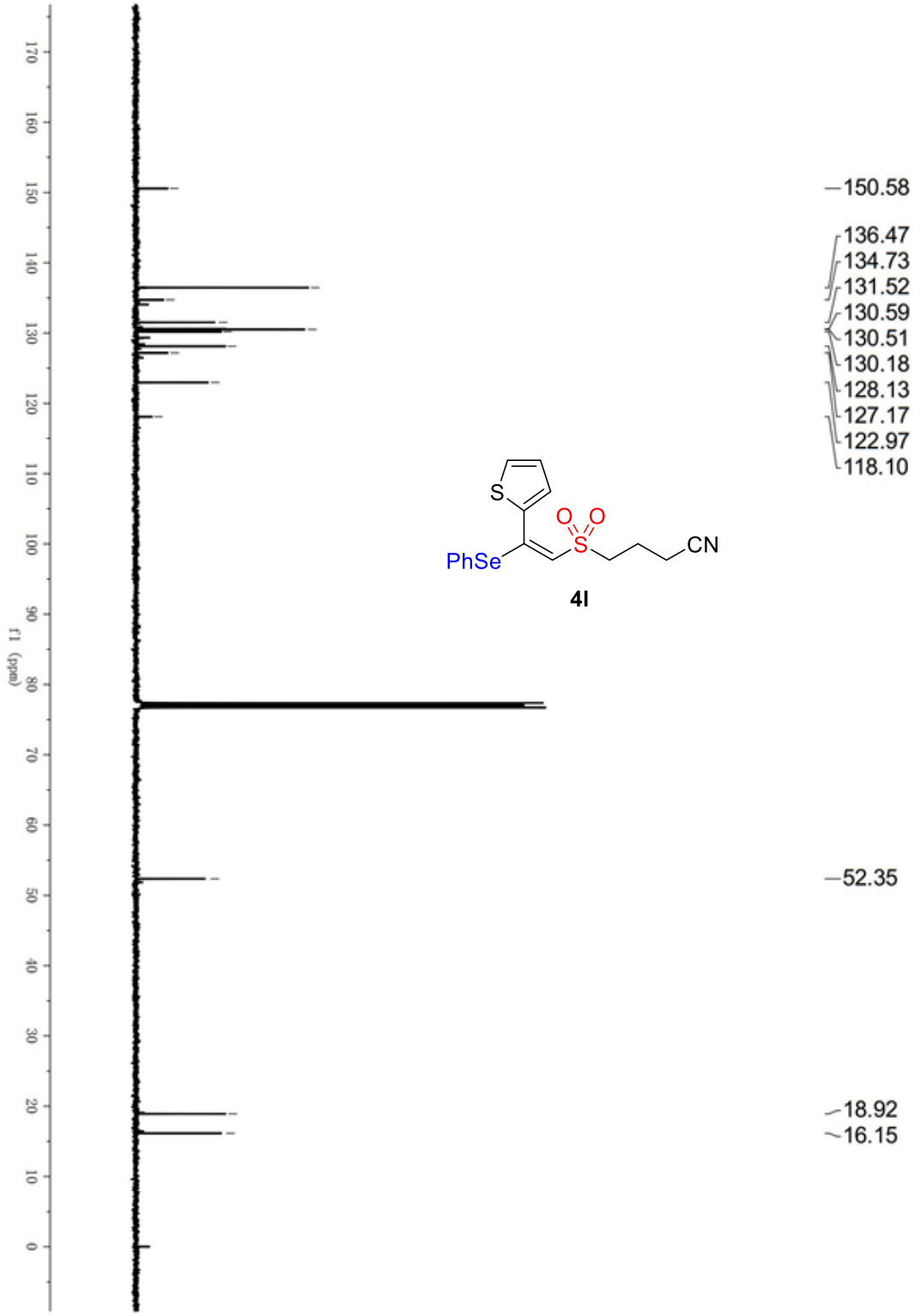


^{1}H NMR spectrum of compound **4l** (400 MHz, $CDCl_3$)

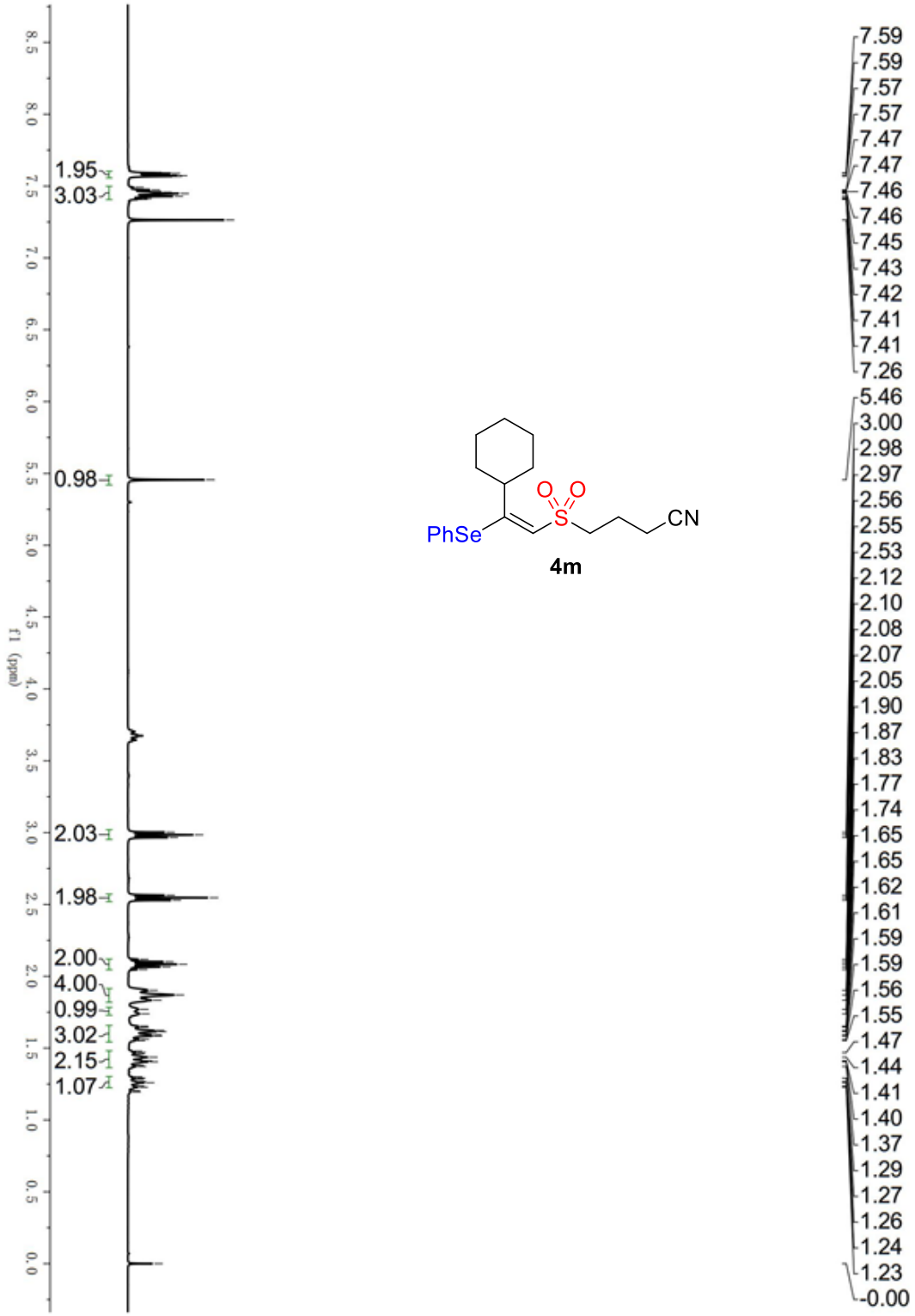


4l

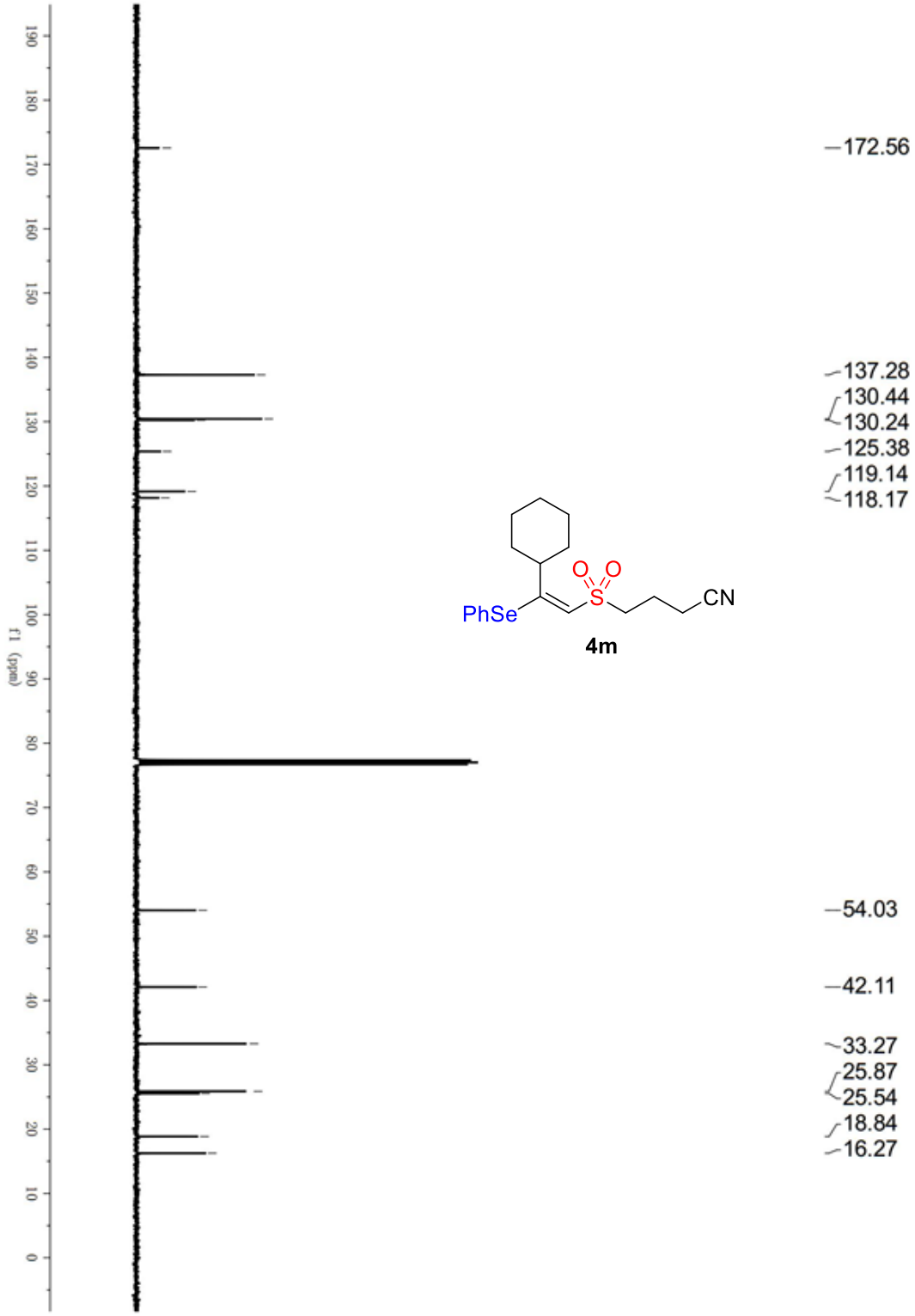
^{13}C NMR spectrum of compound **4l** (100 MHz, $CDCl_3$)



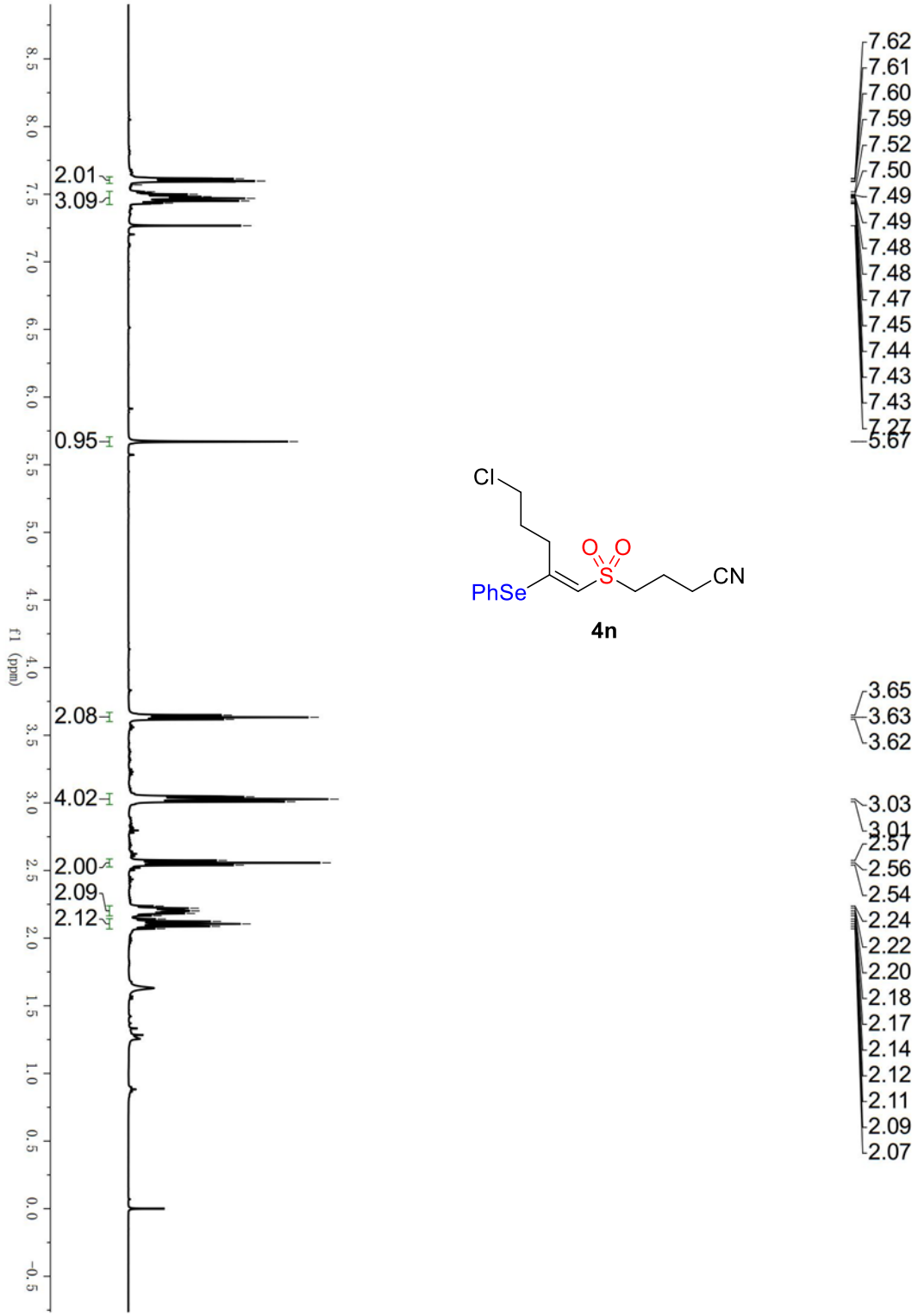
^{1}H NMR spectrum of compound **4m** (400 MHz, $CDCl_3$)



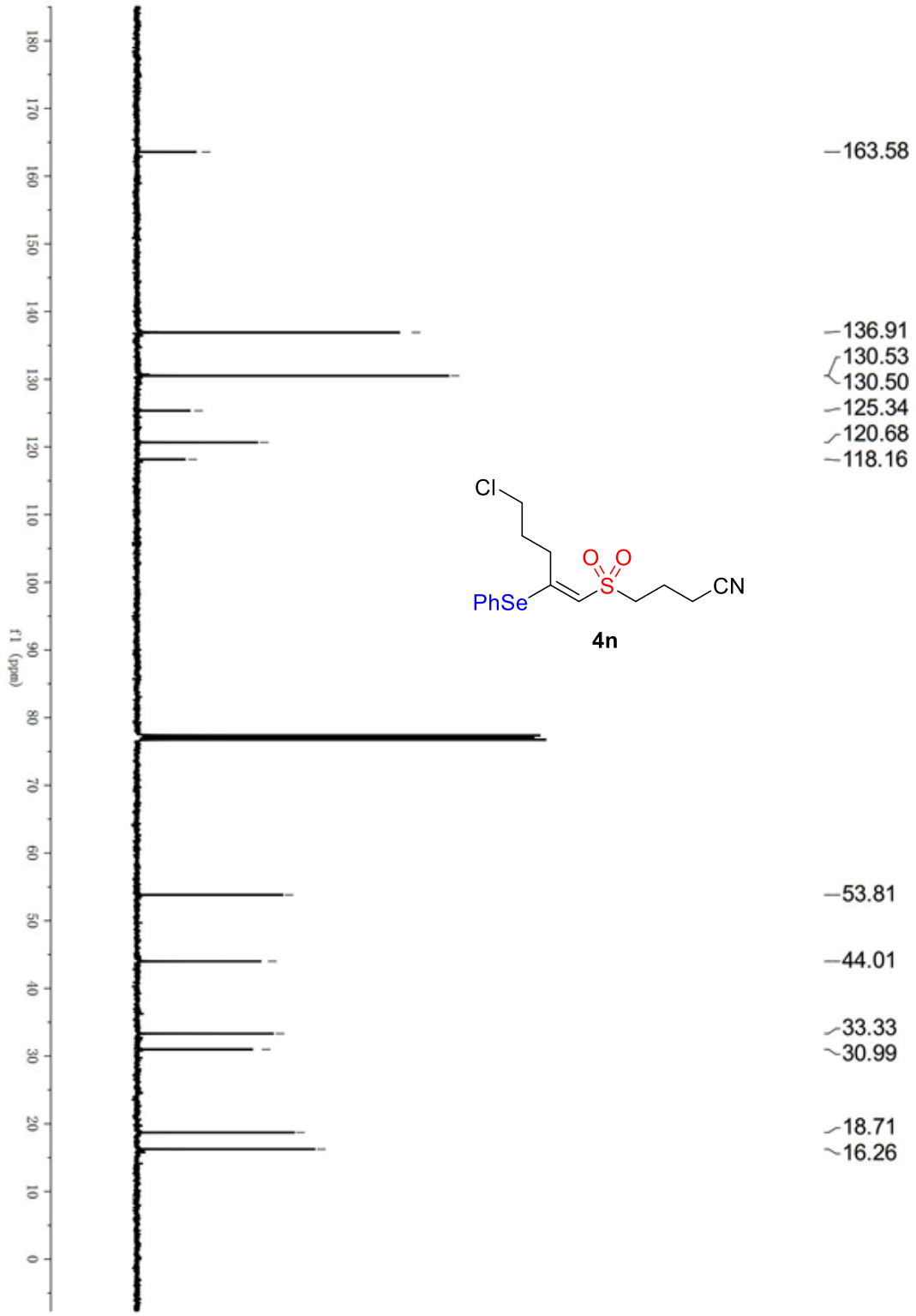
^{13}C NMR spectrum of compound **4m** (100 MHz, $CDCl_3$)



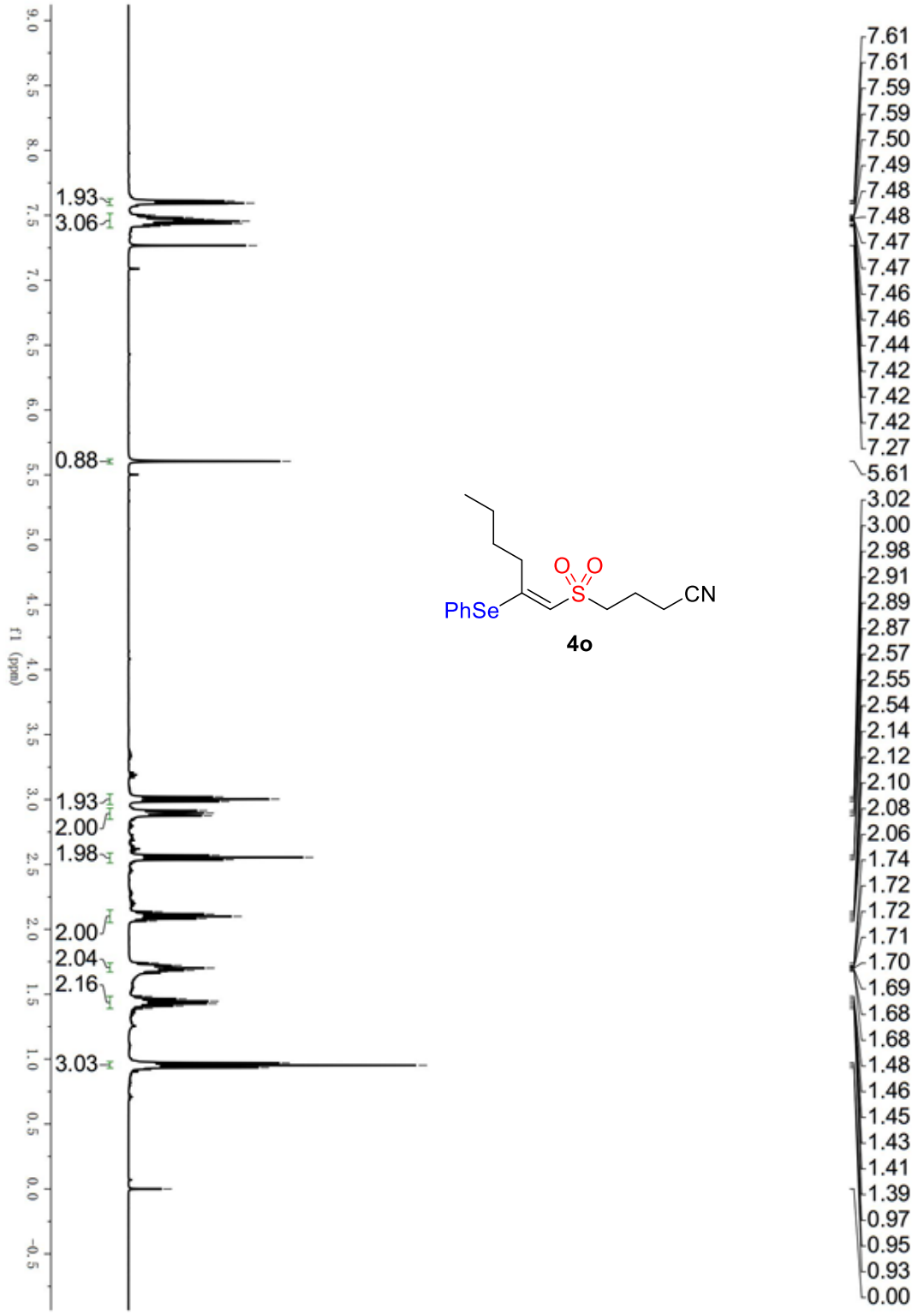
^{1}H NMR spectrum of compound **4n** (400 MHz, $CDCl_3$)



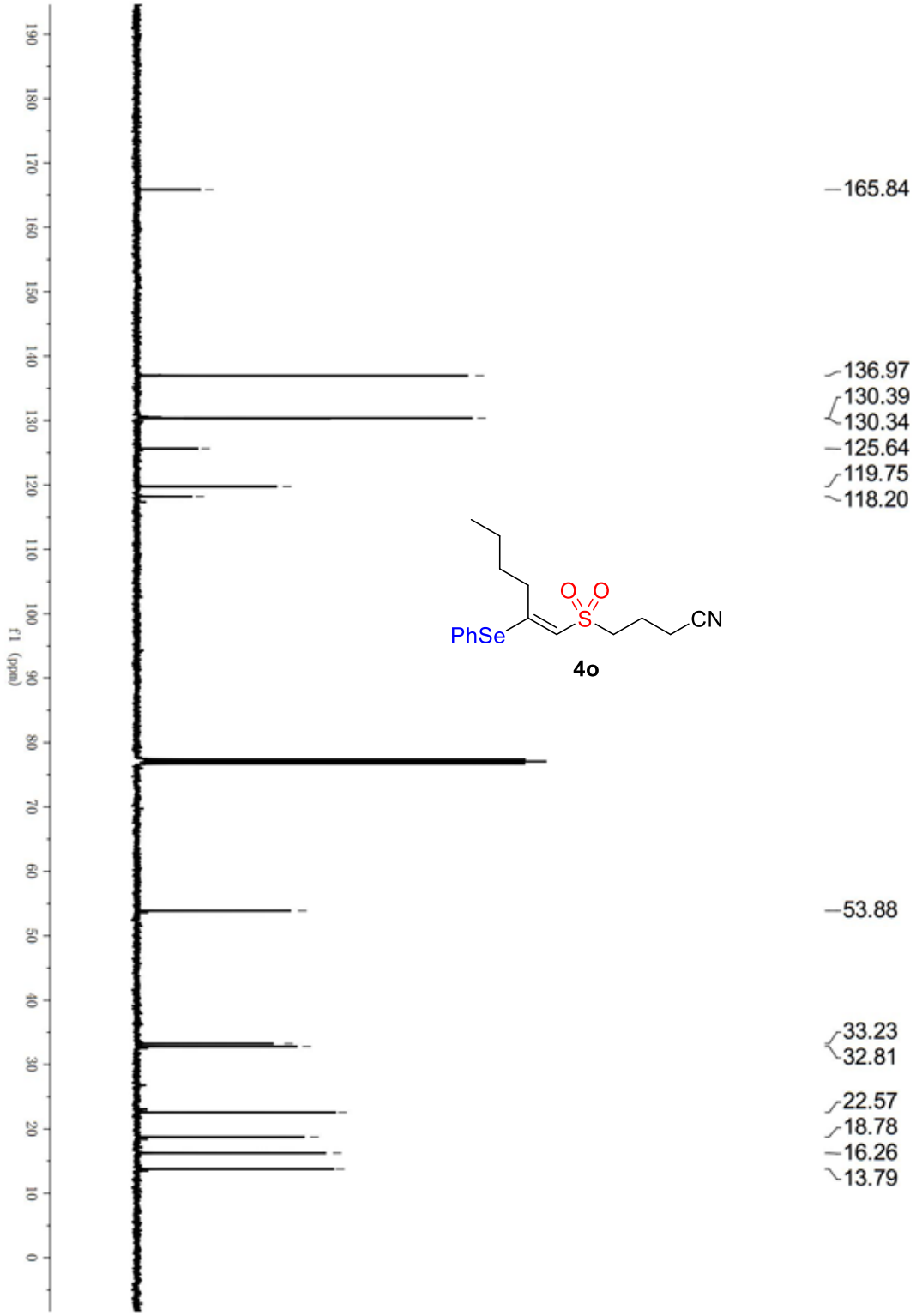
^{13}C NMR spectrum of compound **4n** (100 MHz, $CDCl_3$)



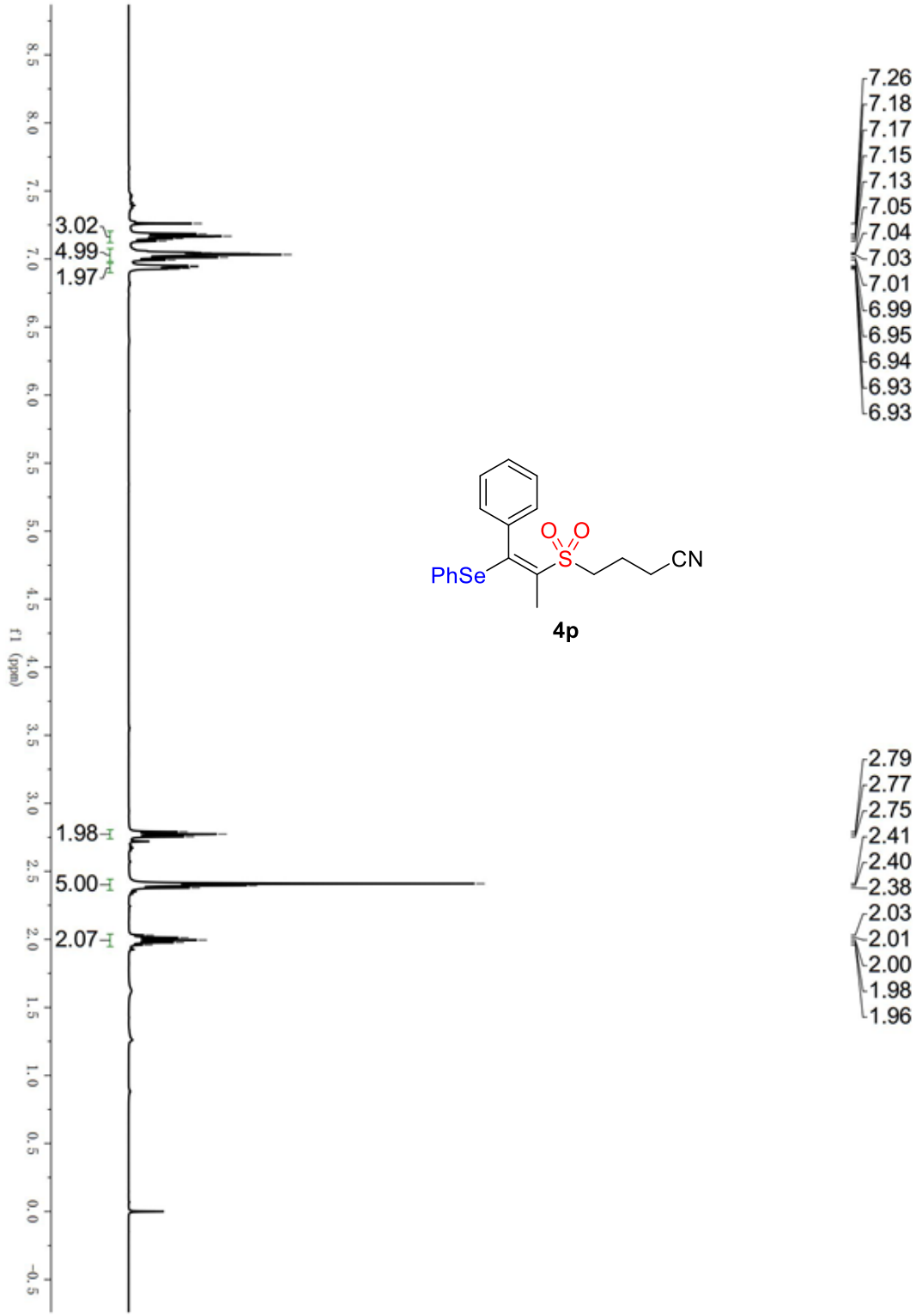
^{1}H NMR spectrum of compound **4o** (400 MHz, $CDCl_3$)



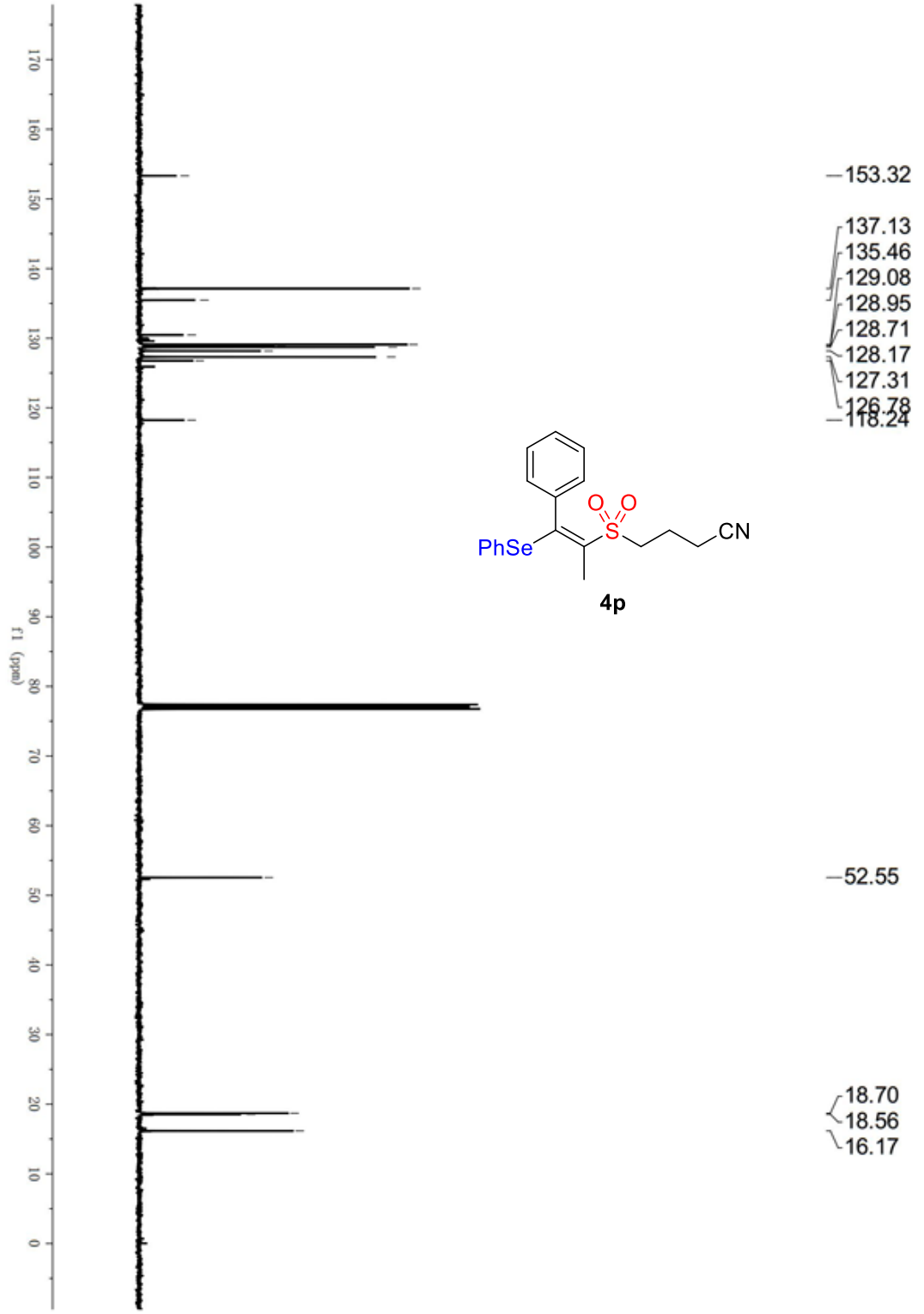
^{13}C NMR spectrum of compound **4o** (100 MHz, $CDCl_3$)



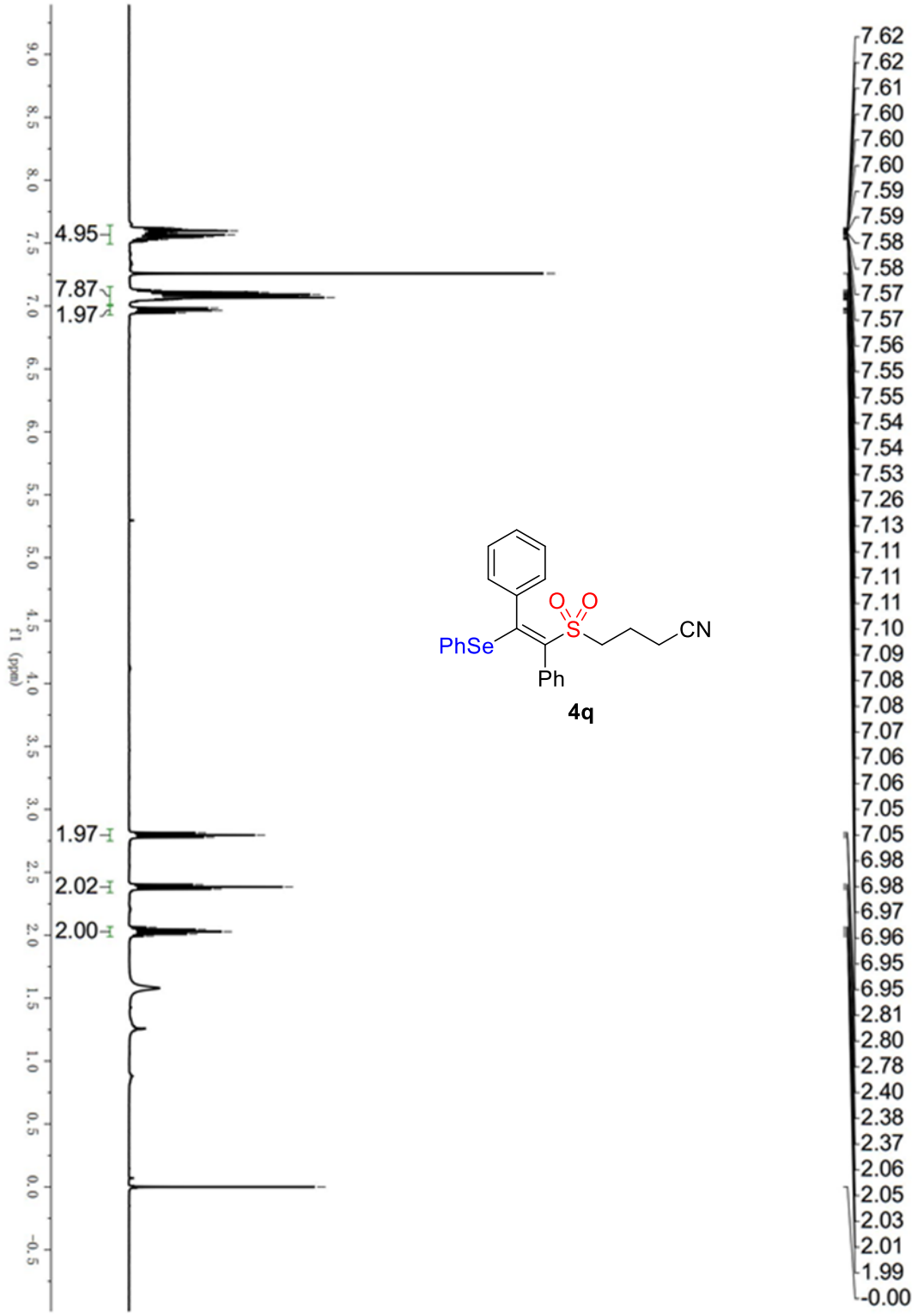
^{1}H NMR spectrum of compound **4p** (400 MHz, $CDCl_3$)



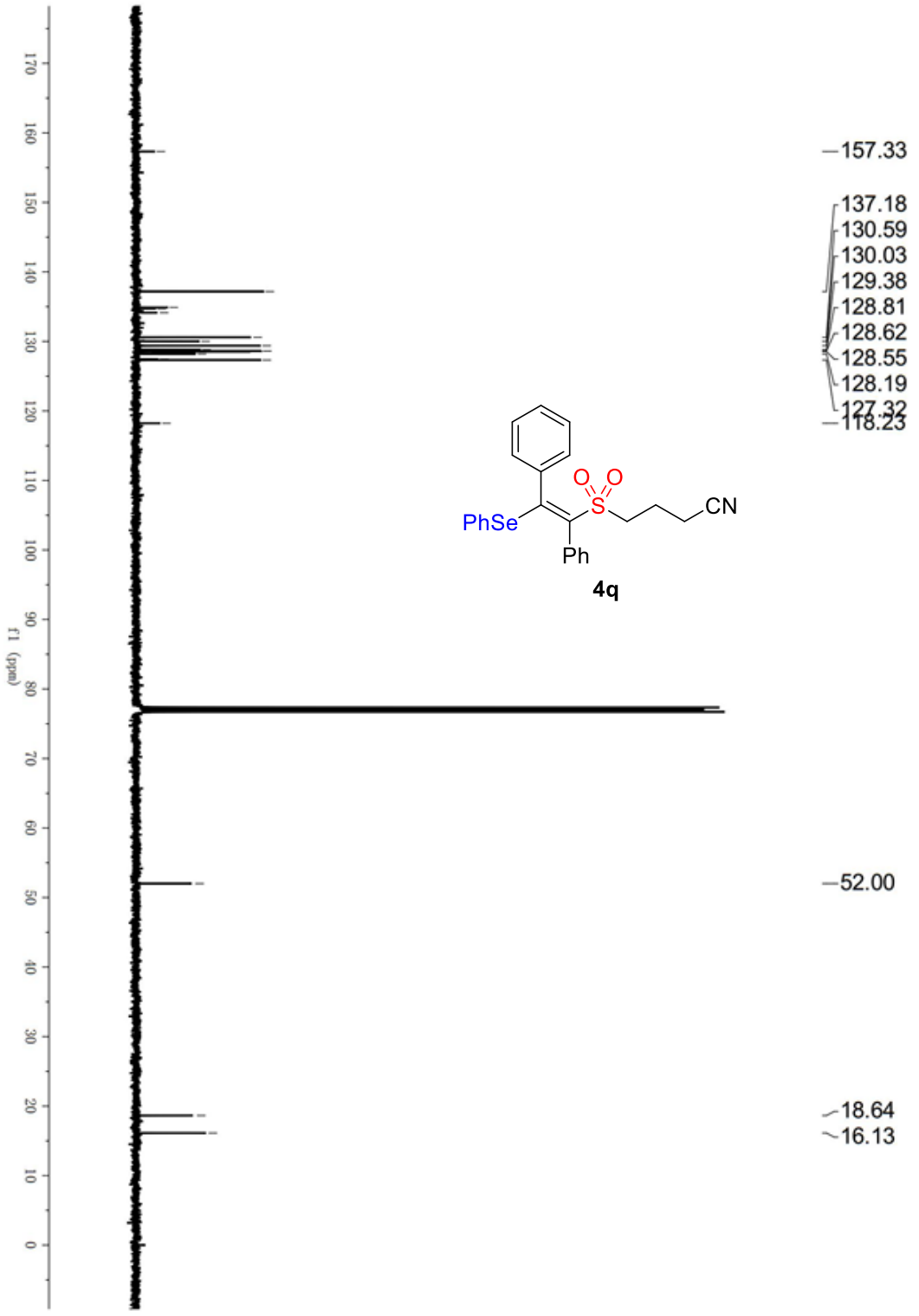
^{13}C NMR spectrum of compound **4p** (100 MHz, $CDCl_3$)



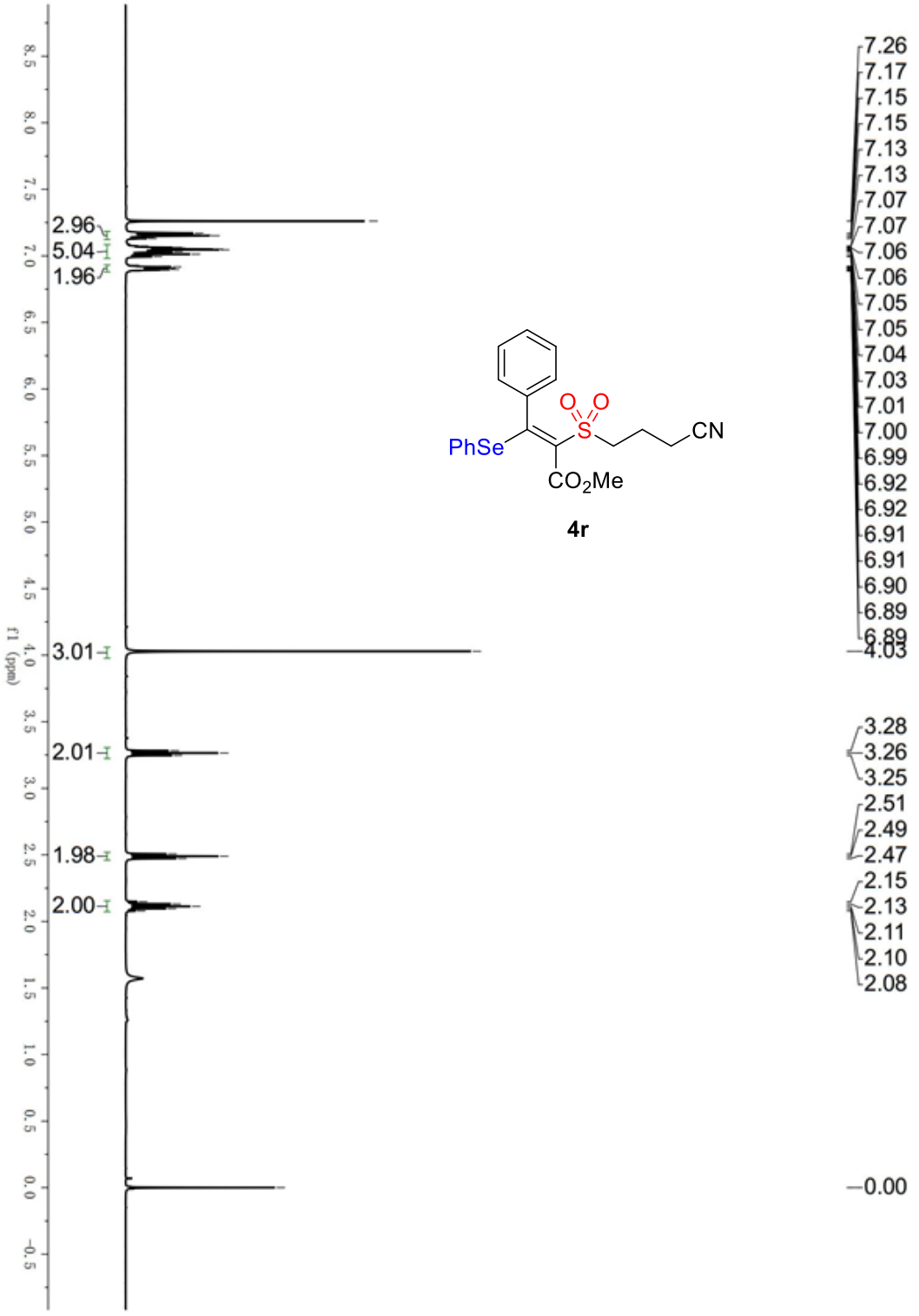
^{1}H NMR spectrum of compound **4q** (400 MHz, $CDCl_3$)



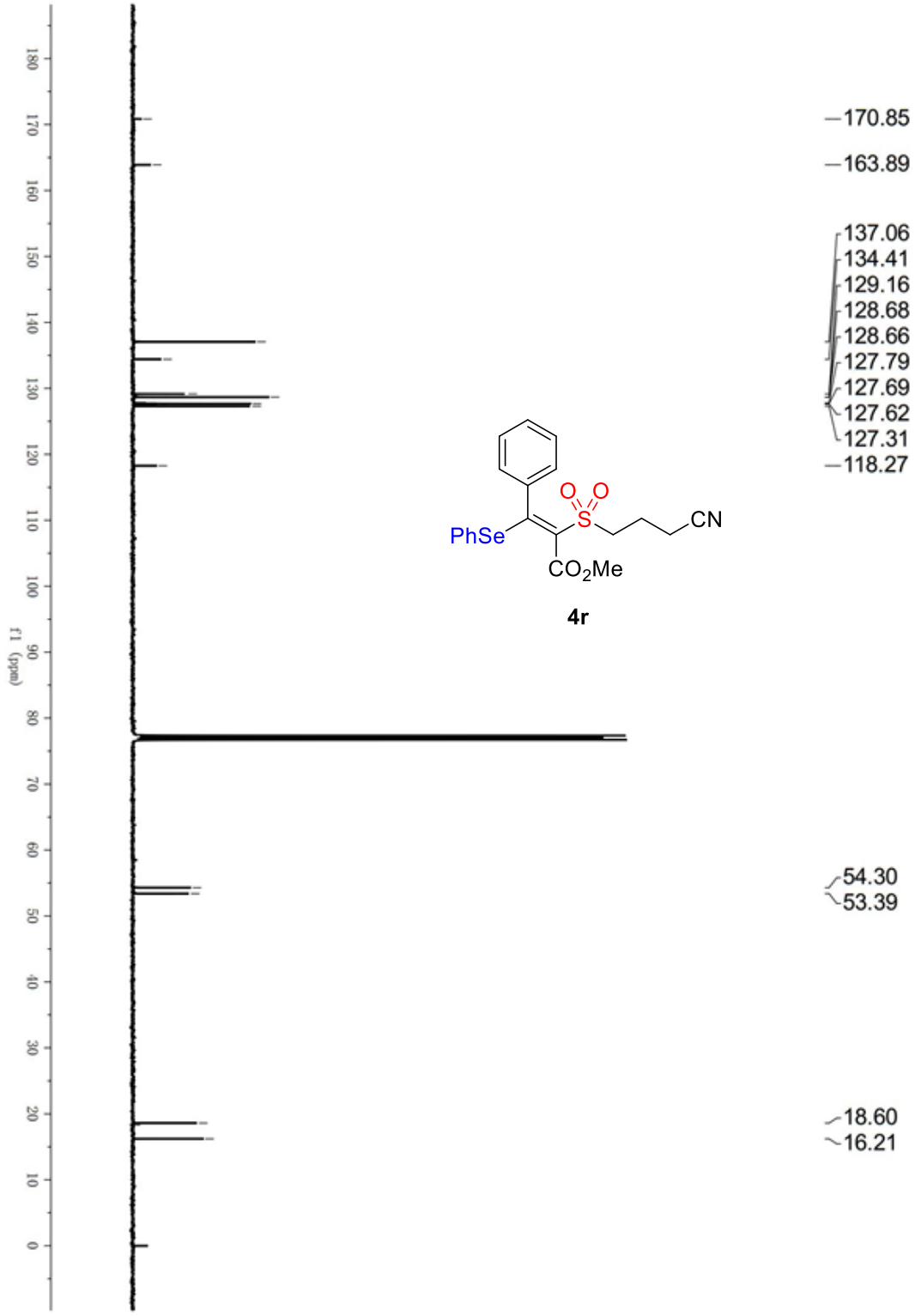
^{13}C NMR spectrum of compound **4q** (100 MHz, $CDCl_3$)



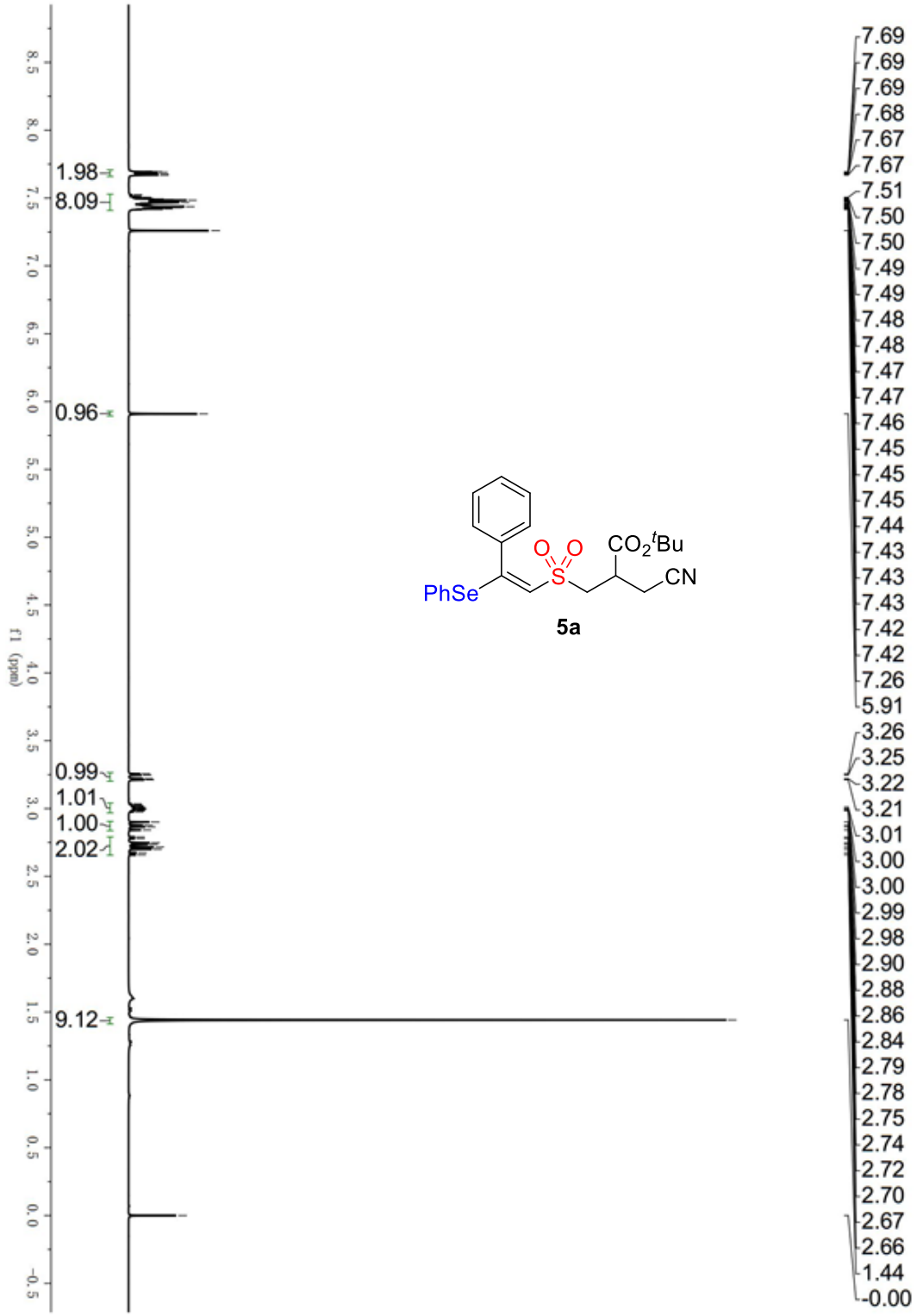
^{1}H NMR spectrum of compound **4r** (400 MHz, $CDCl_3$)



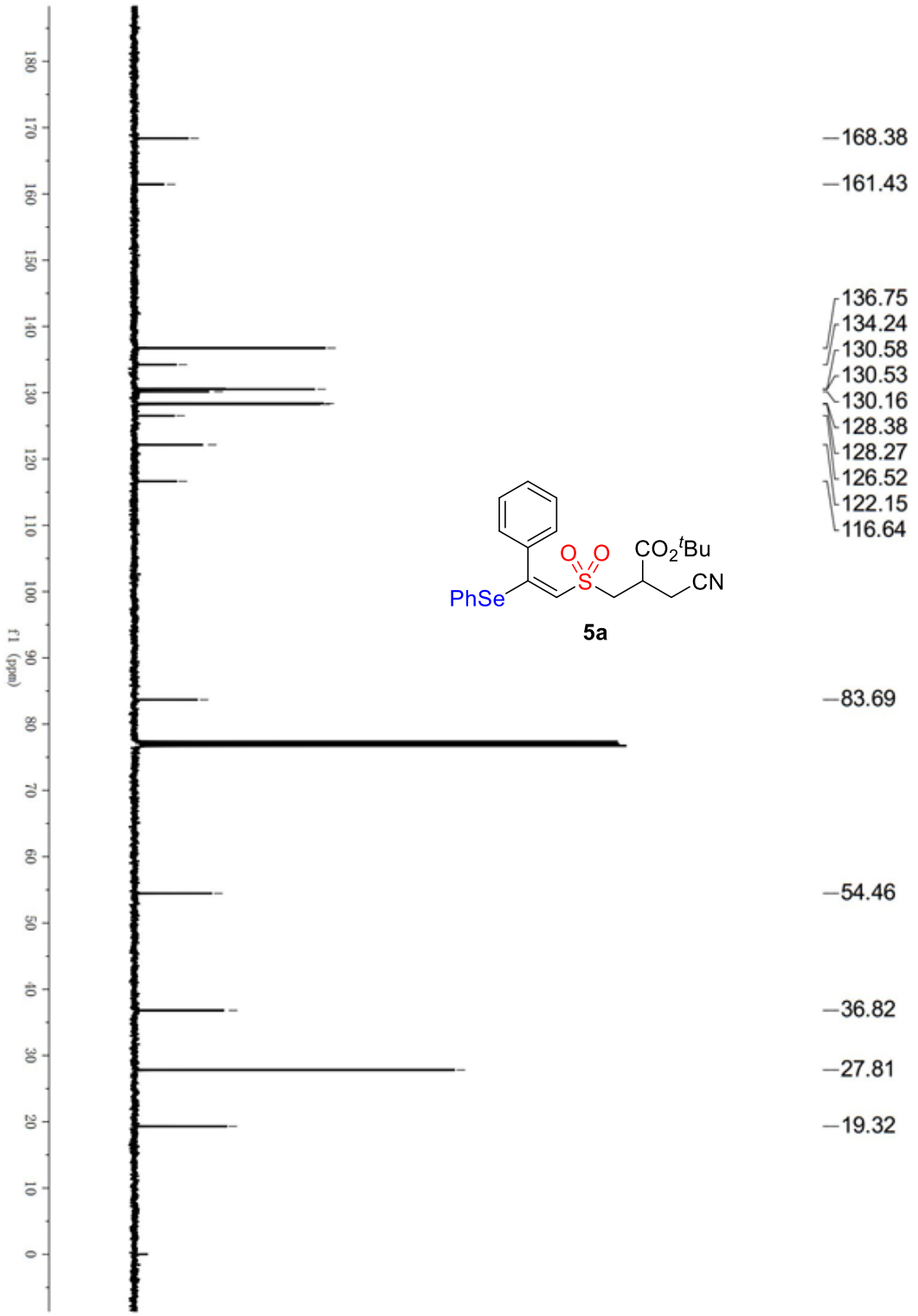
^{13}C NMR spectrum of compound **4r** (100 MHz, $CDCl_3$)



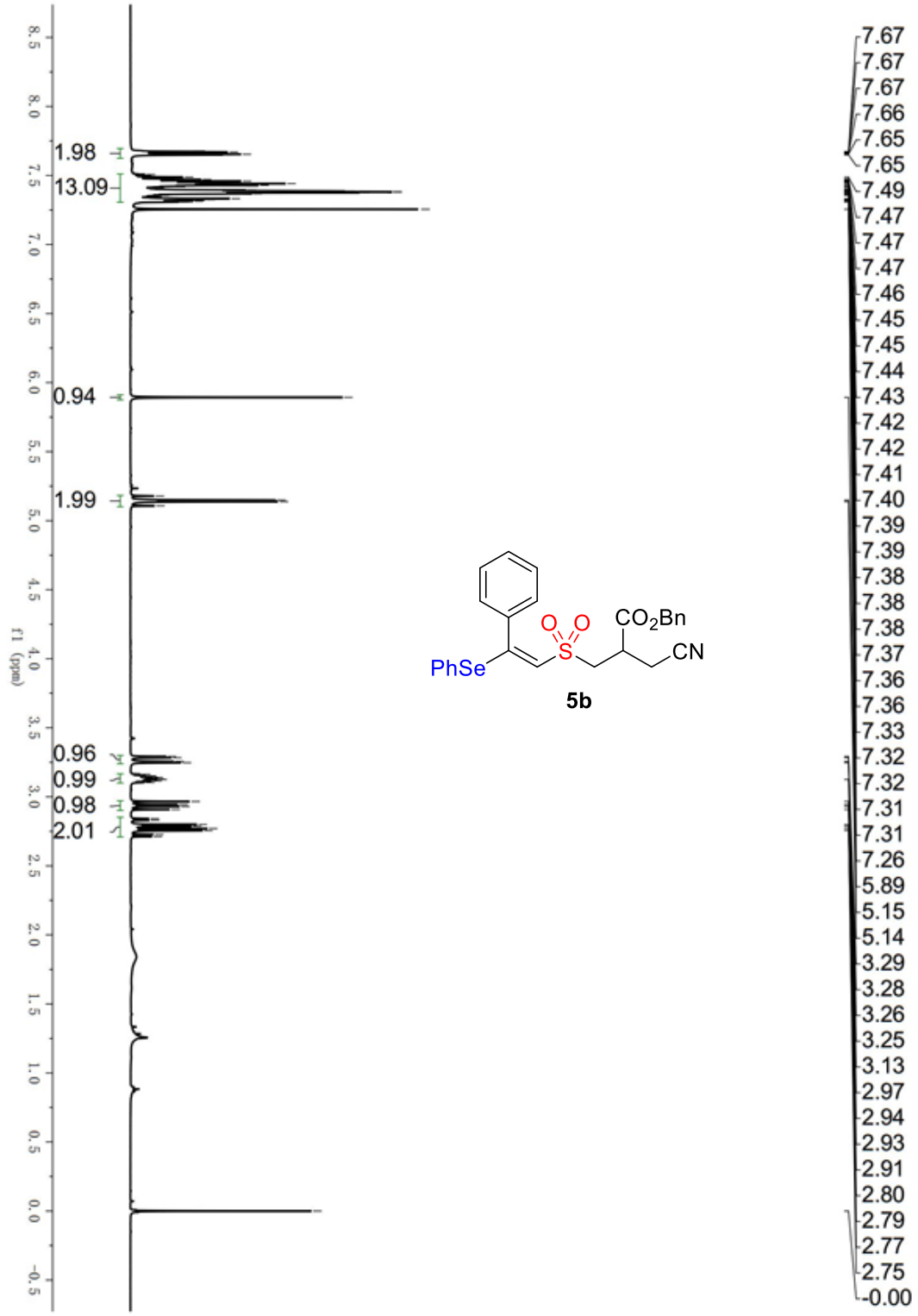
^{1}H NMR spectrum of compound **5a** (400 MHz, $CDCl_3$)



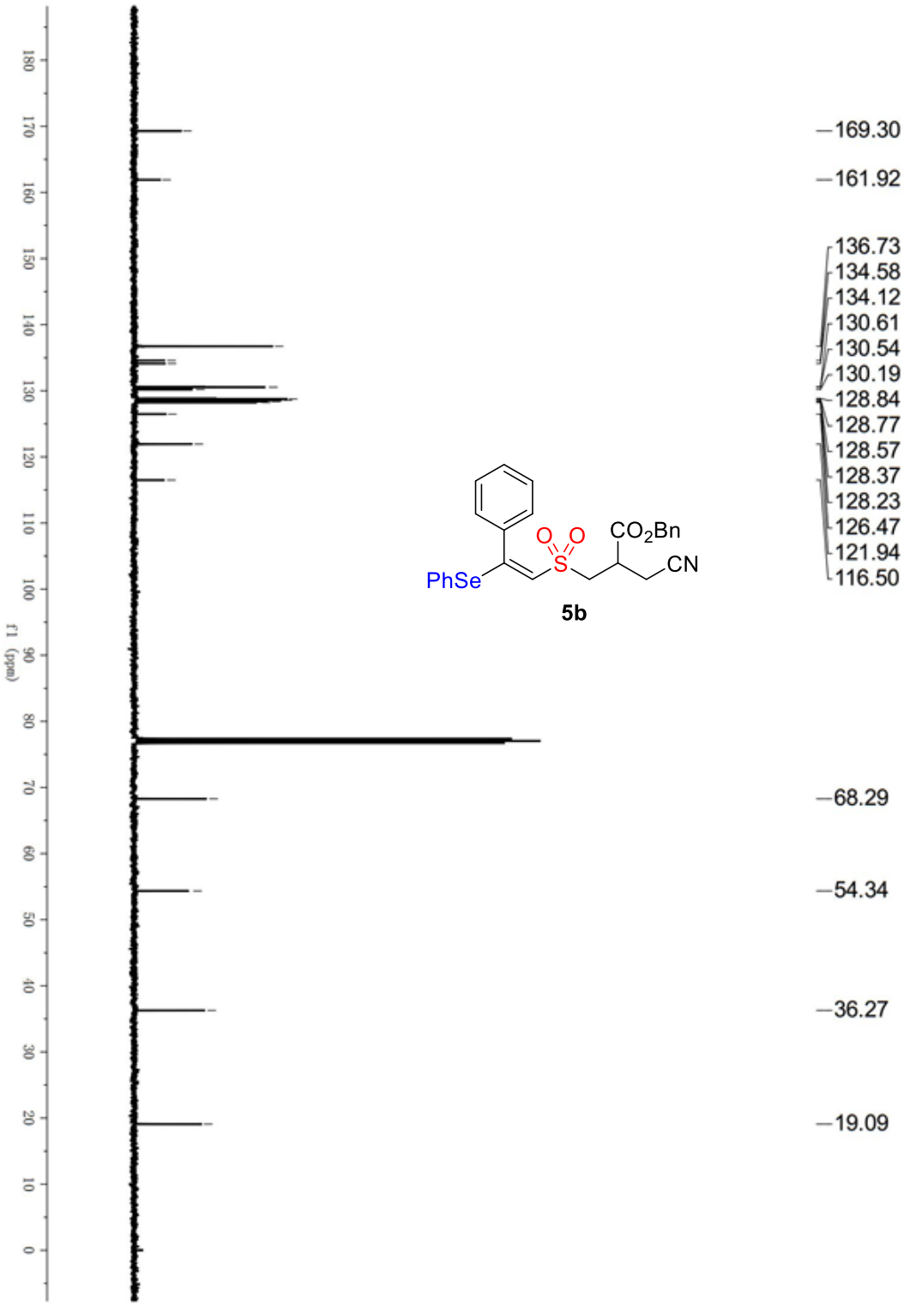
^{13}C NMR spectrum of compound **5a** (100 MHz, $CDCl_3$)



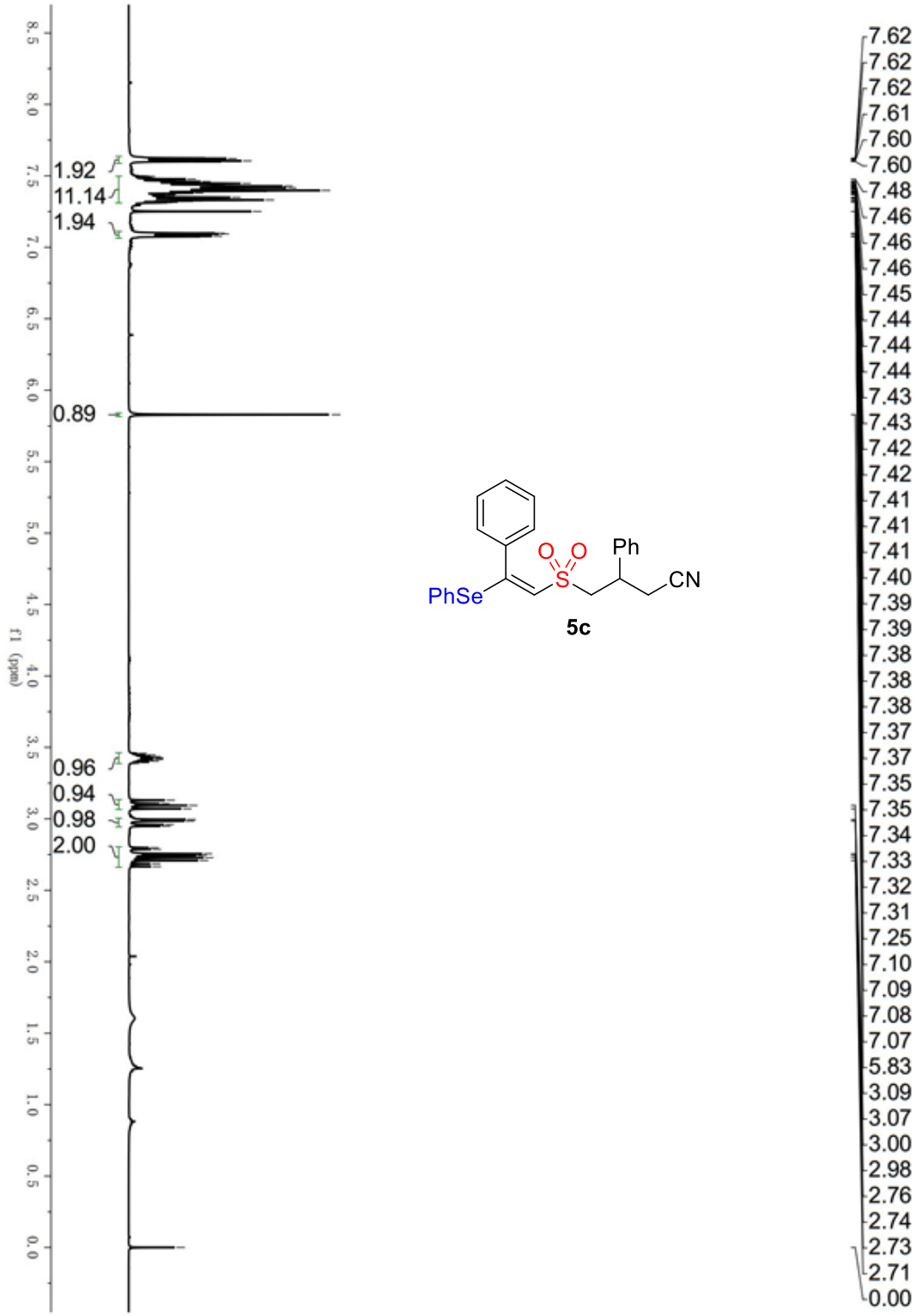
^{1}H NMR spectrum of compound **5b** (400 MHz, $CDCl_3$)



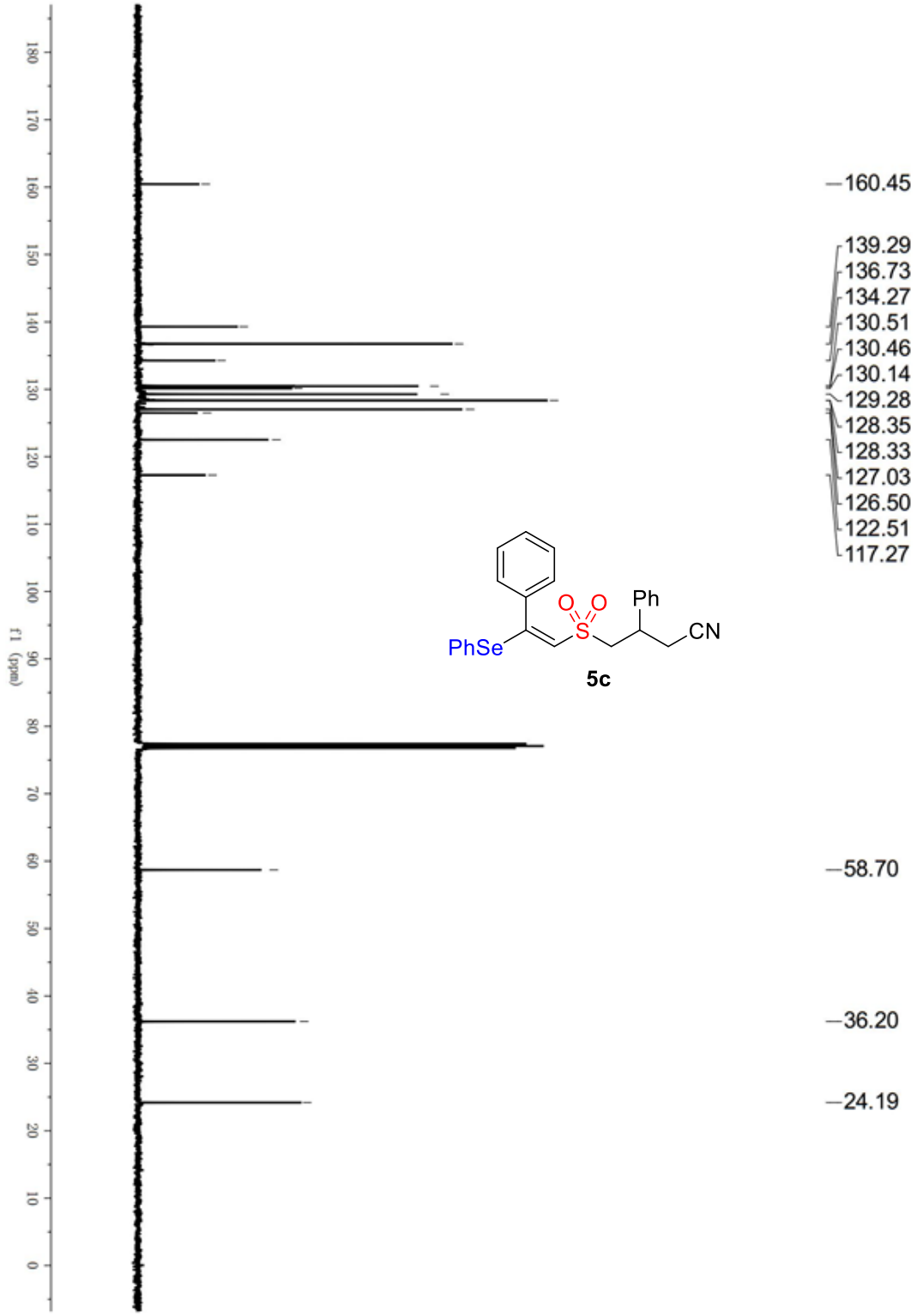
^{13}C NMR spectrum of compound **5b** (100 MHz, $CDCl_3$)



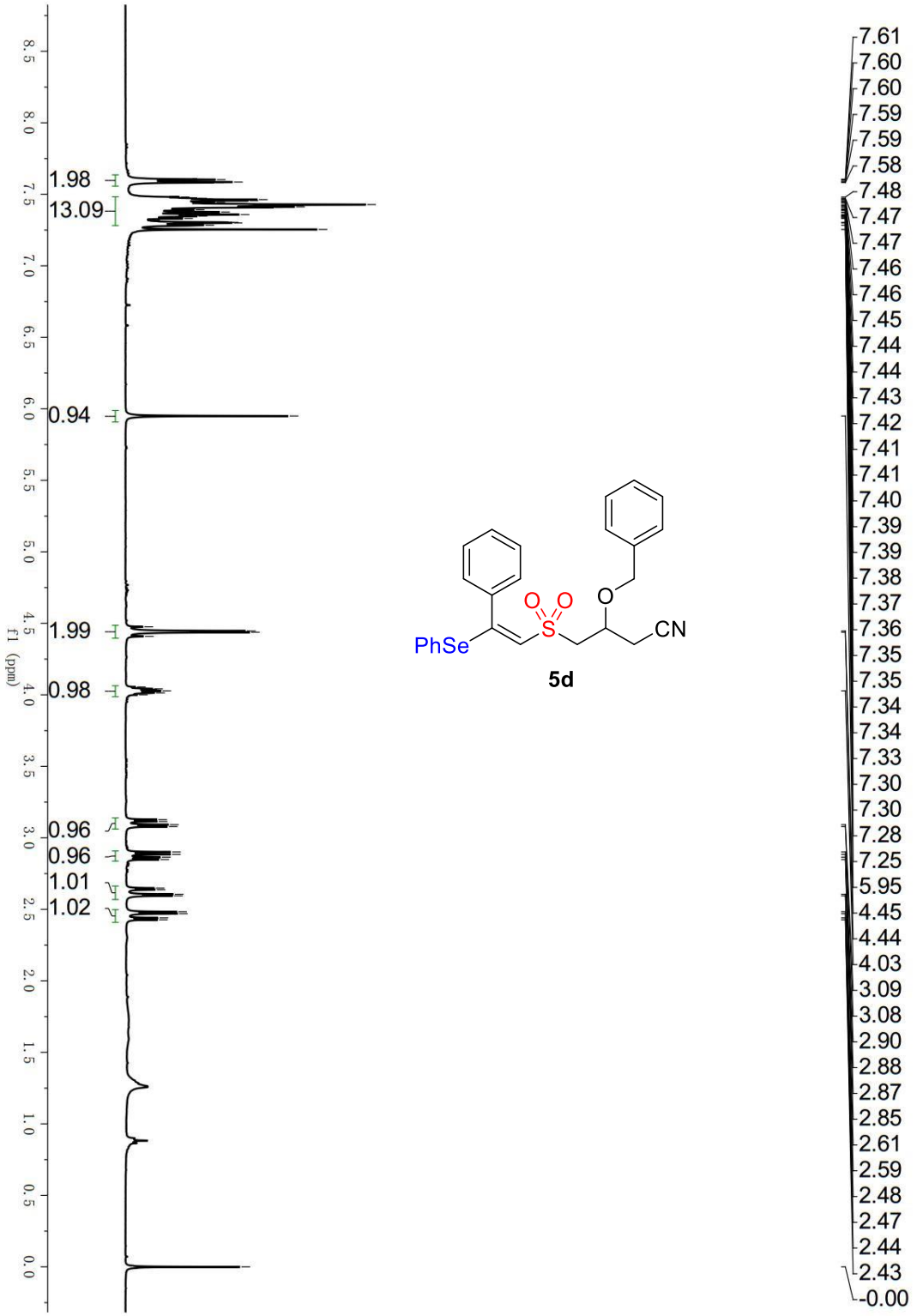
^{1}H NMR spectrum of compound **5c** (400 MHz, $CDCl_3$)



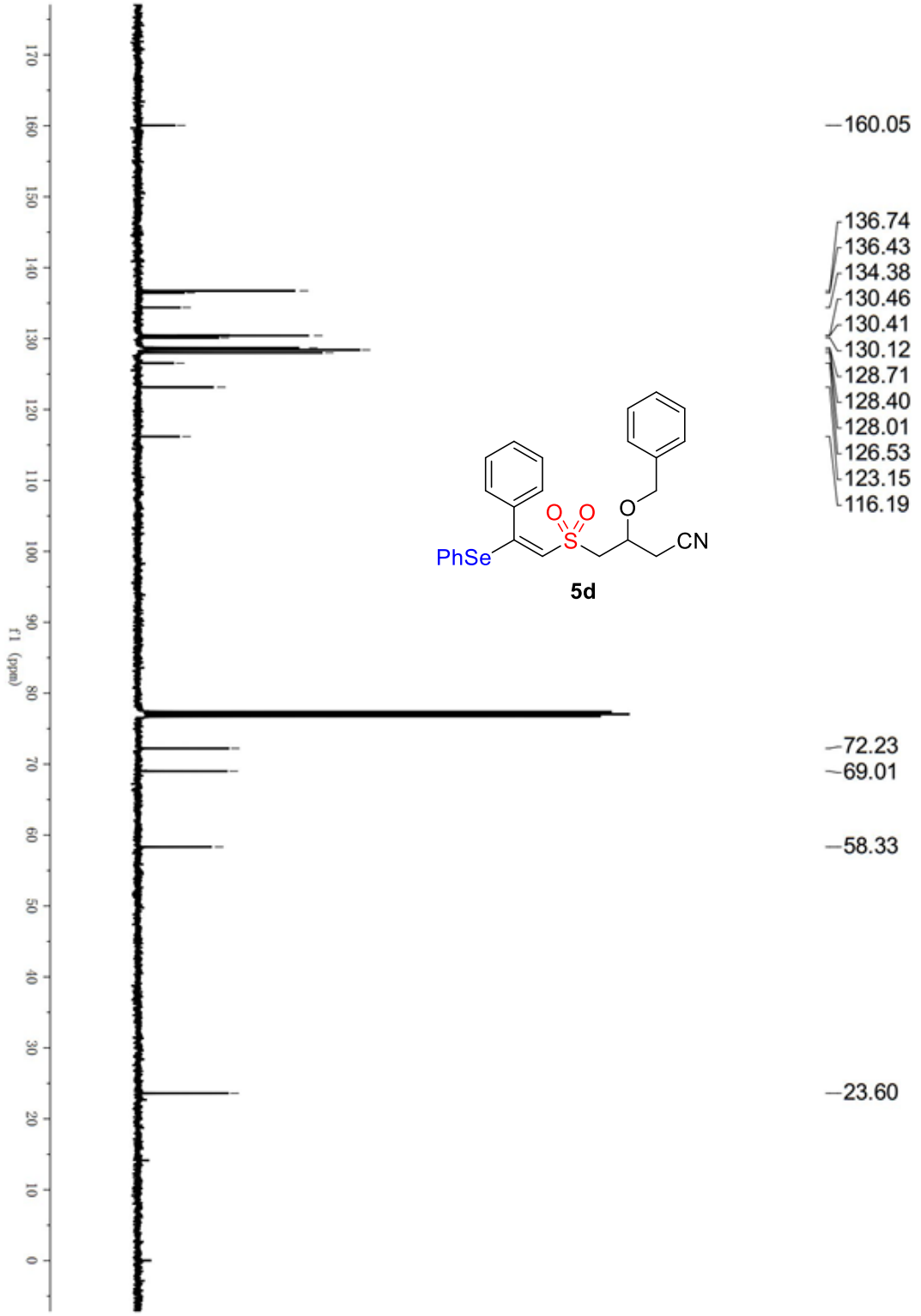
^{13}C NMR spectrum of compound **5c** (100 MHz, $CDCl_3$)



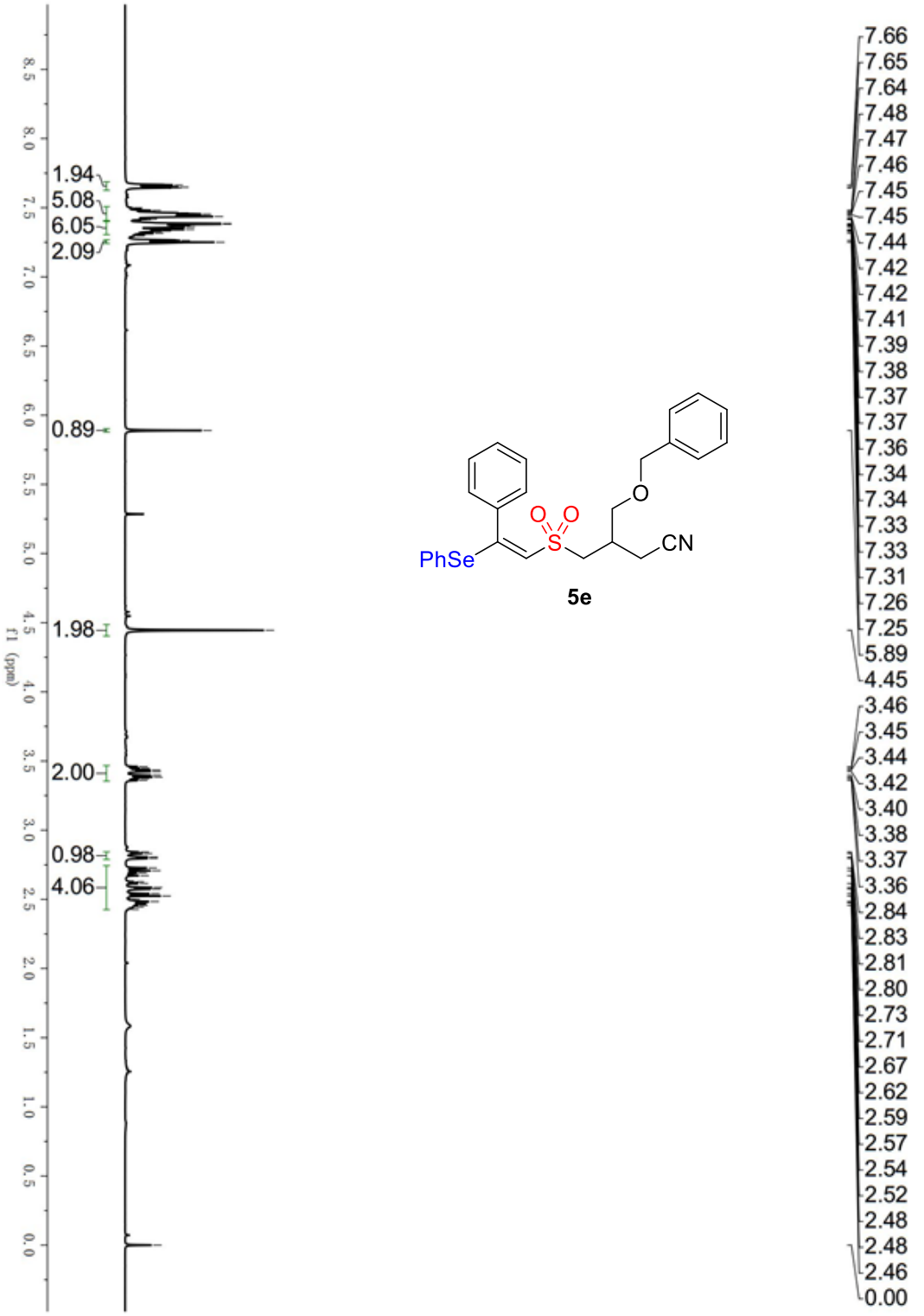
^{1}H NMR spectrum of compound **5d** (400 MHz, $CDCl_3$)



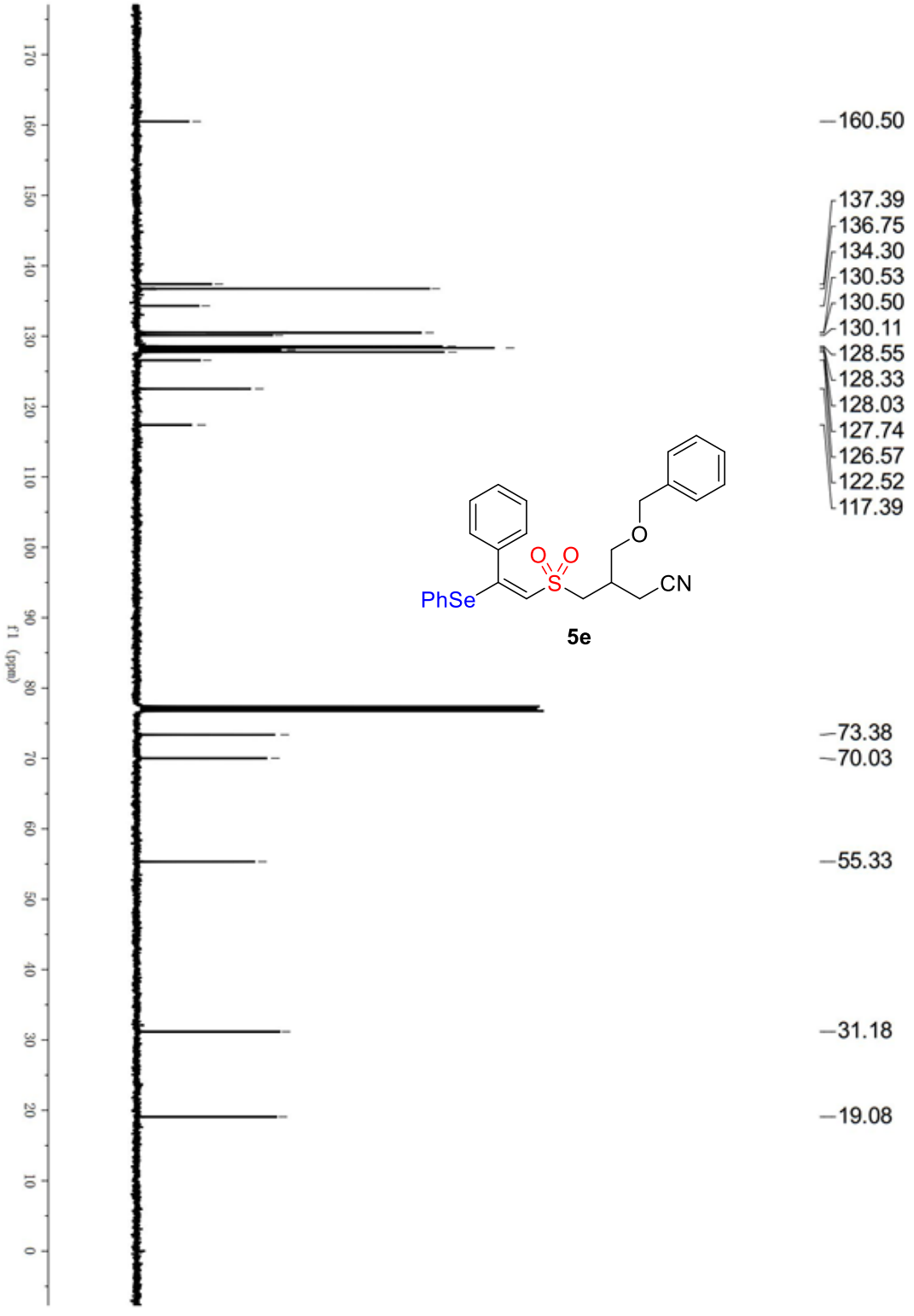
^{13}C NMR spectrum of compound **5d** (100 MHz, $CDCl_3$)



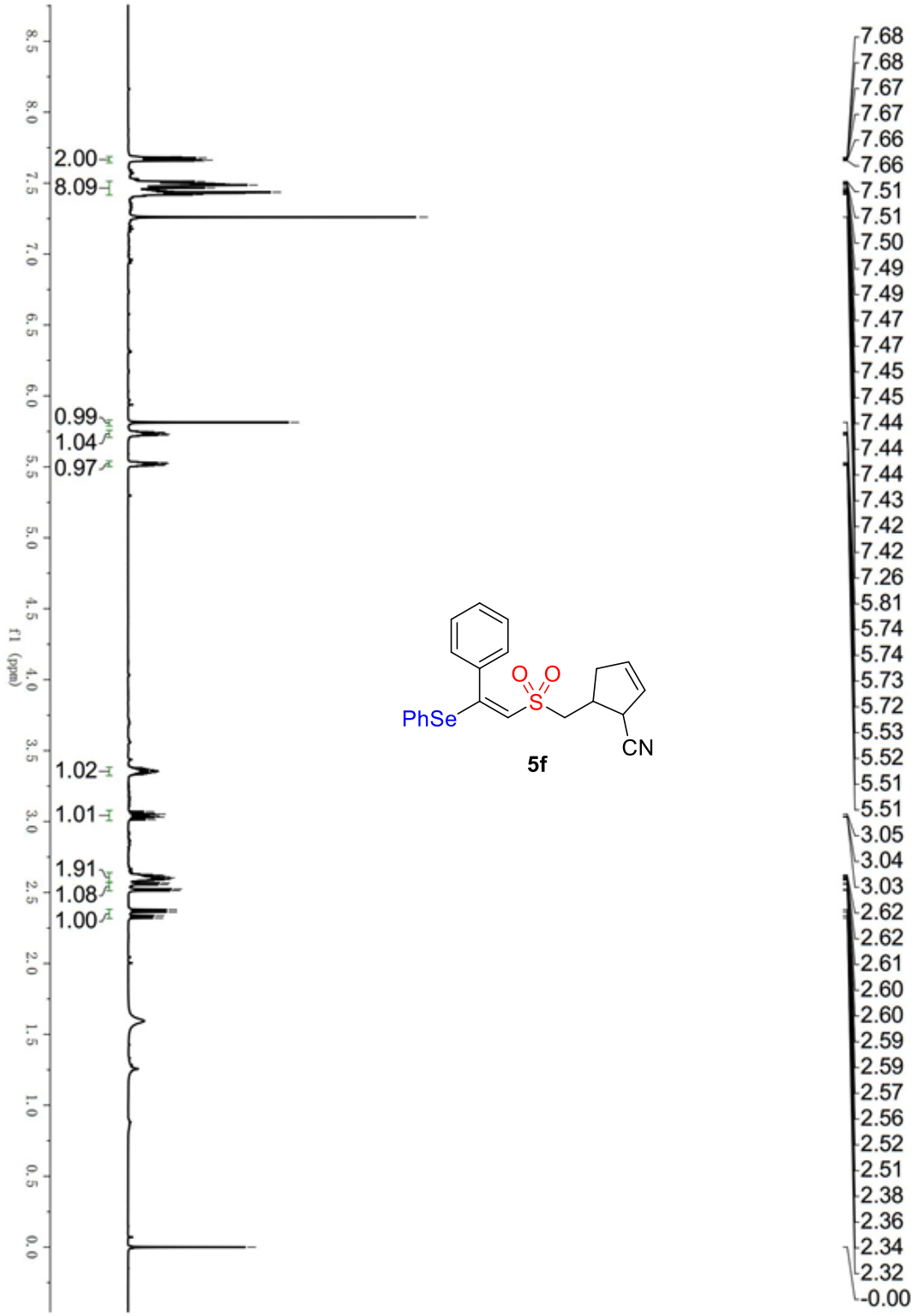
^{1}H NMR spectrum of compound **5e** (400 MHz, $CDCl_3$)



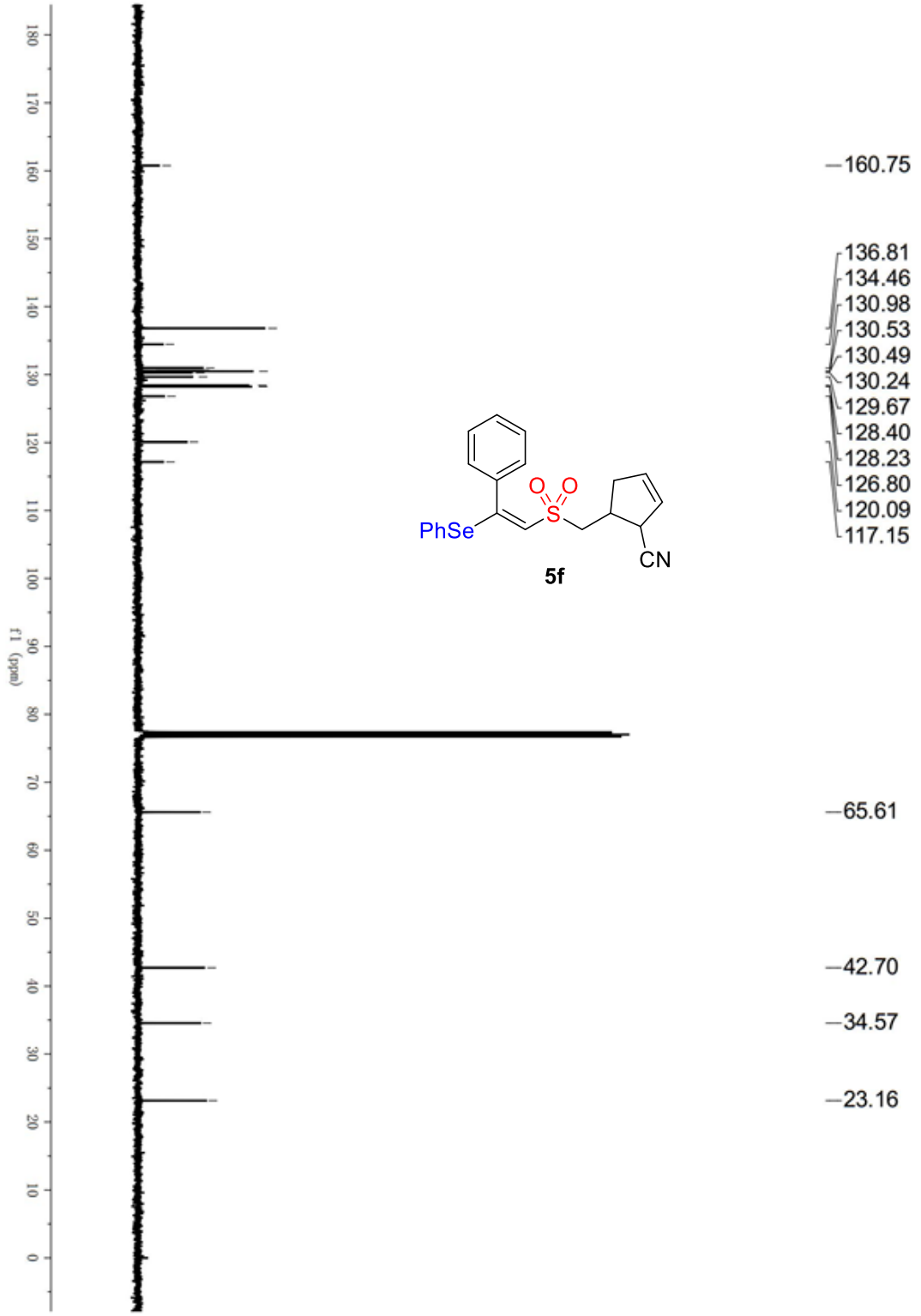
^{13}C NMR spectrum of compound **5e** (100 MHz, $CDCl_3$)



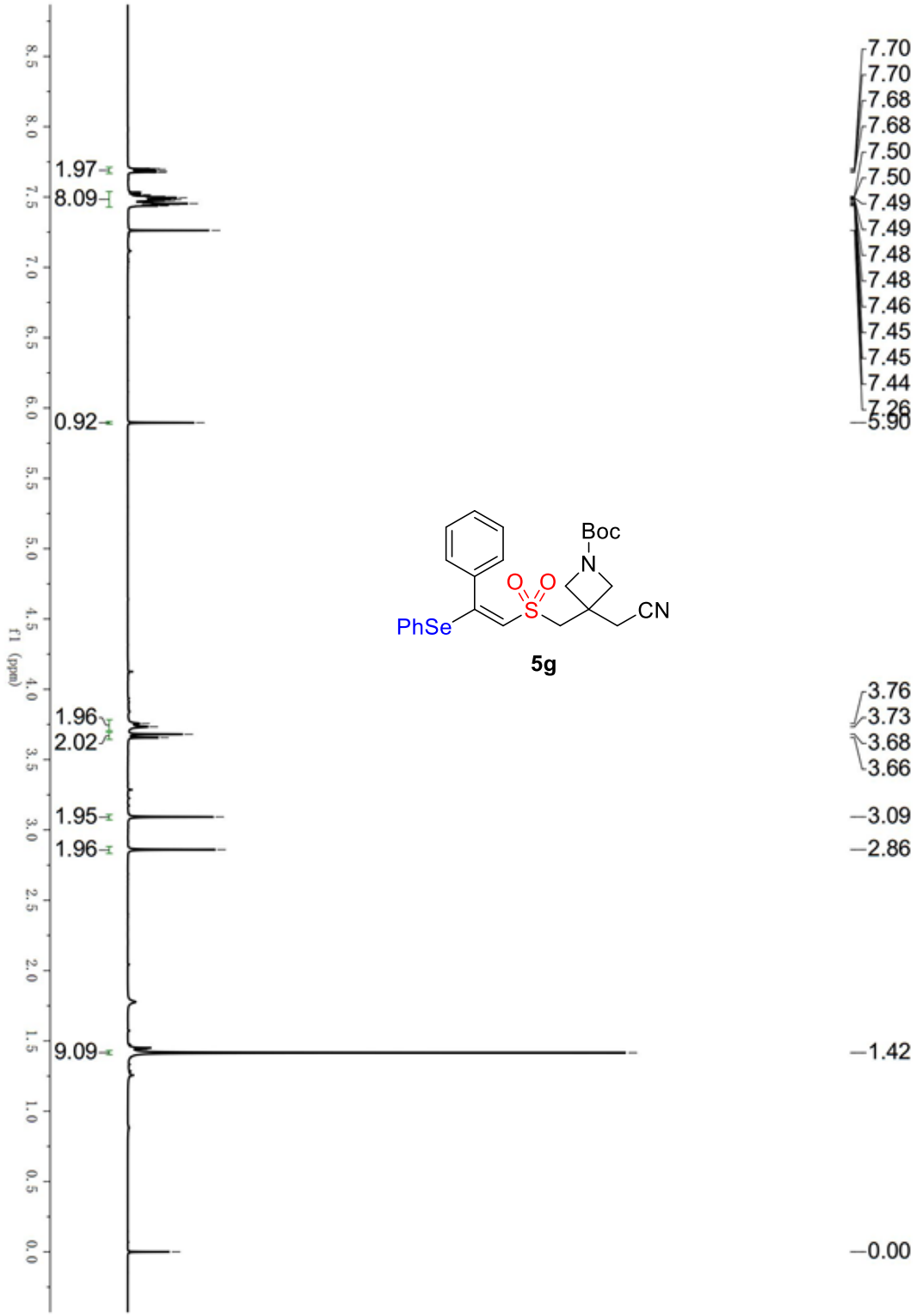
^{1}H NMR spectrum of compound **5f** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of compound **5f** (100 MHz, $CDCl_3$)

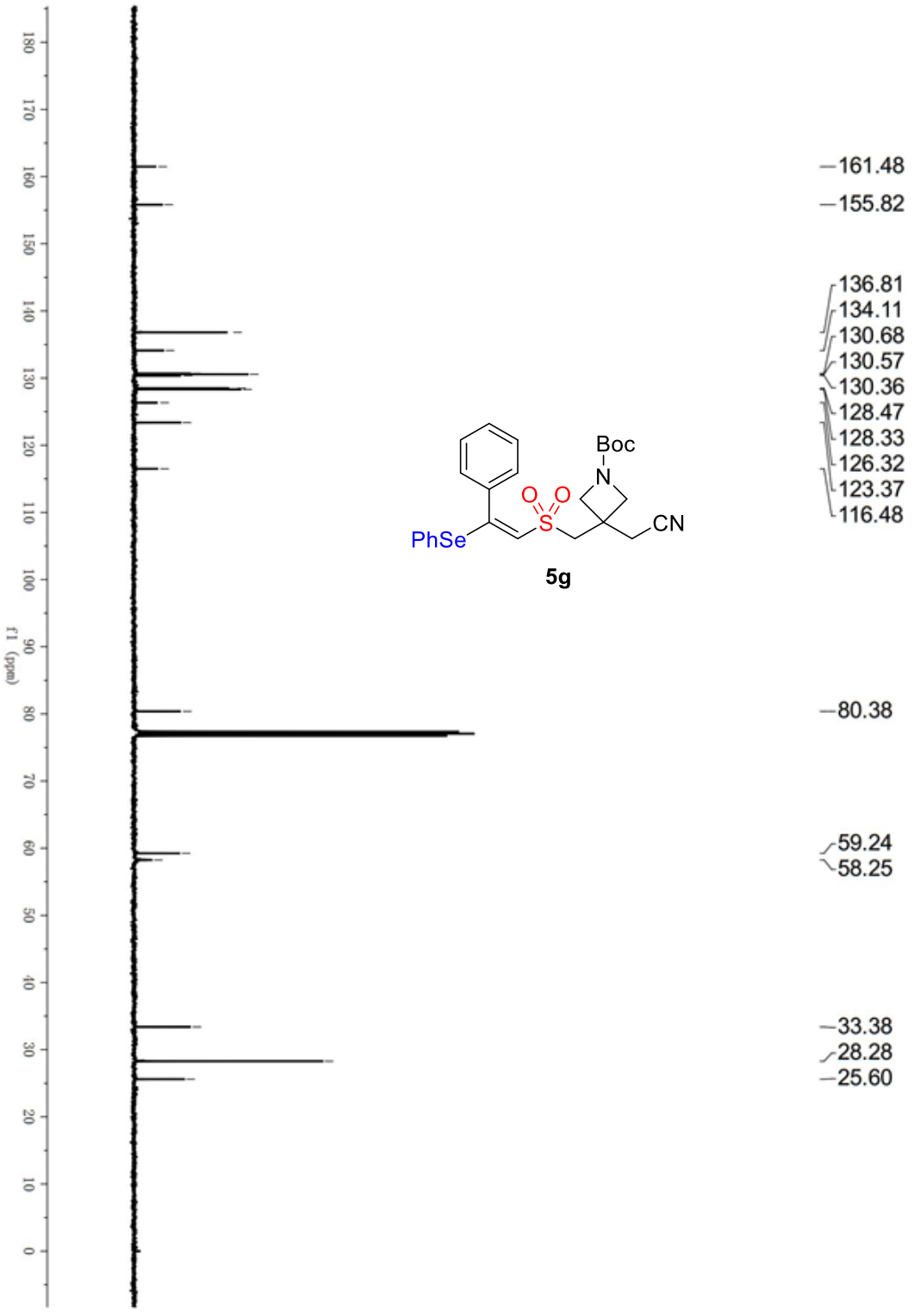


^{1}H NMR spectrum of compound **5g** (400 MHz, $CDCl_3$)

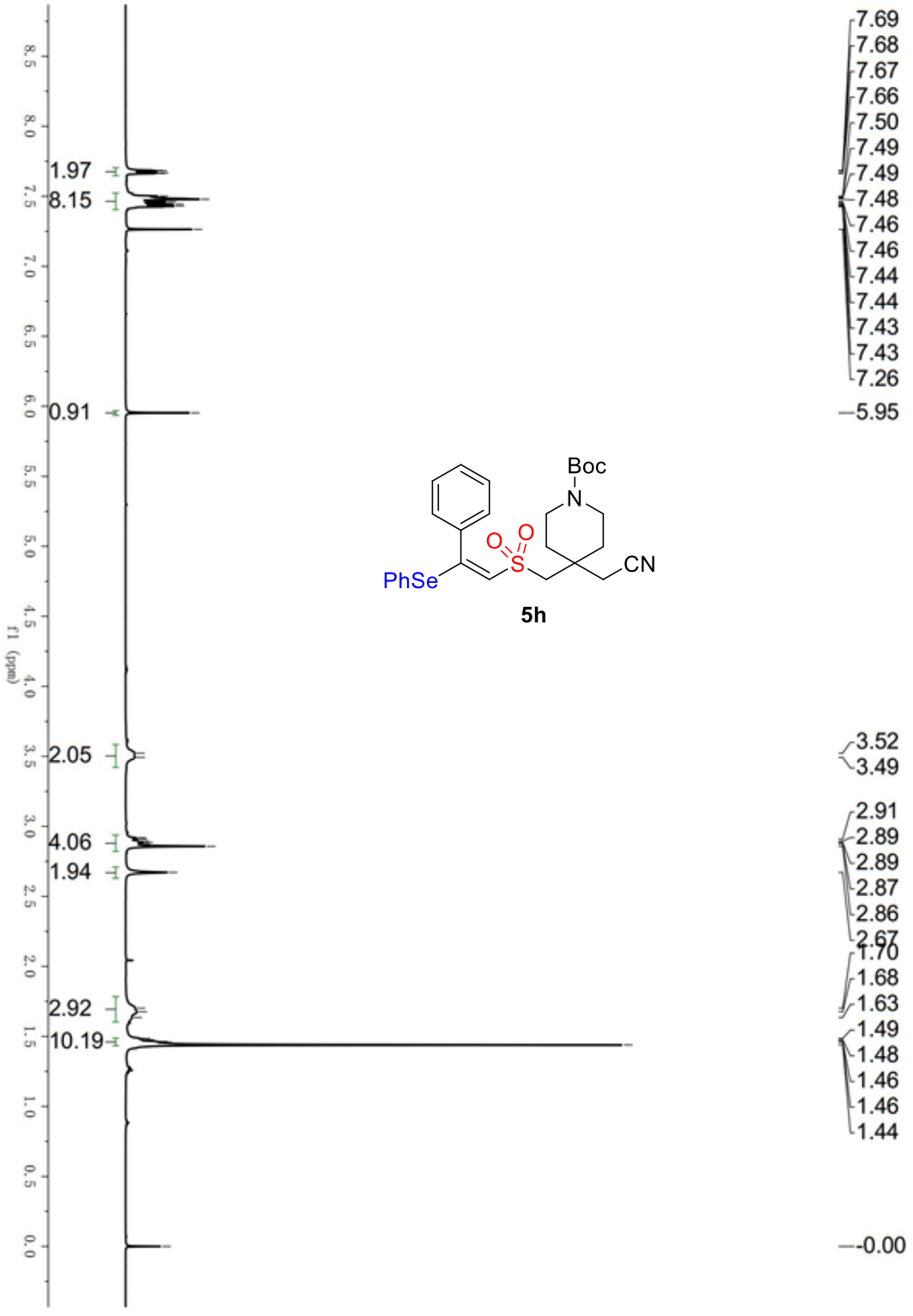


5g

^{13}C NMR spectrum of compound **5g** (100 MHz, $CDCl_3$)

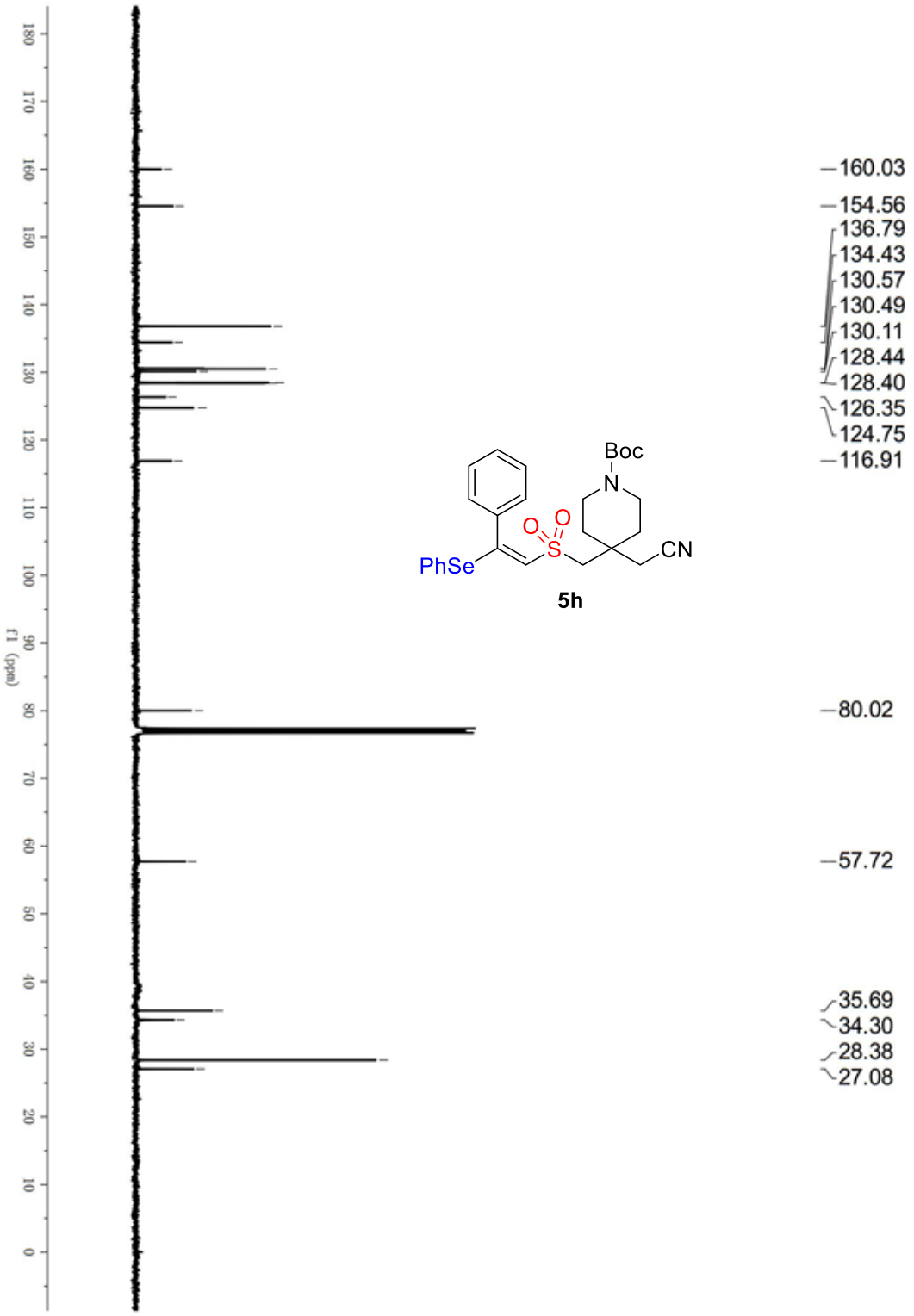


^{1}H NMR spectrum of compound **5h** (400 MHz, $CDCl_3$)

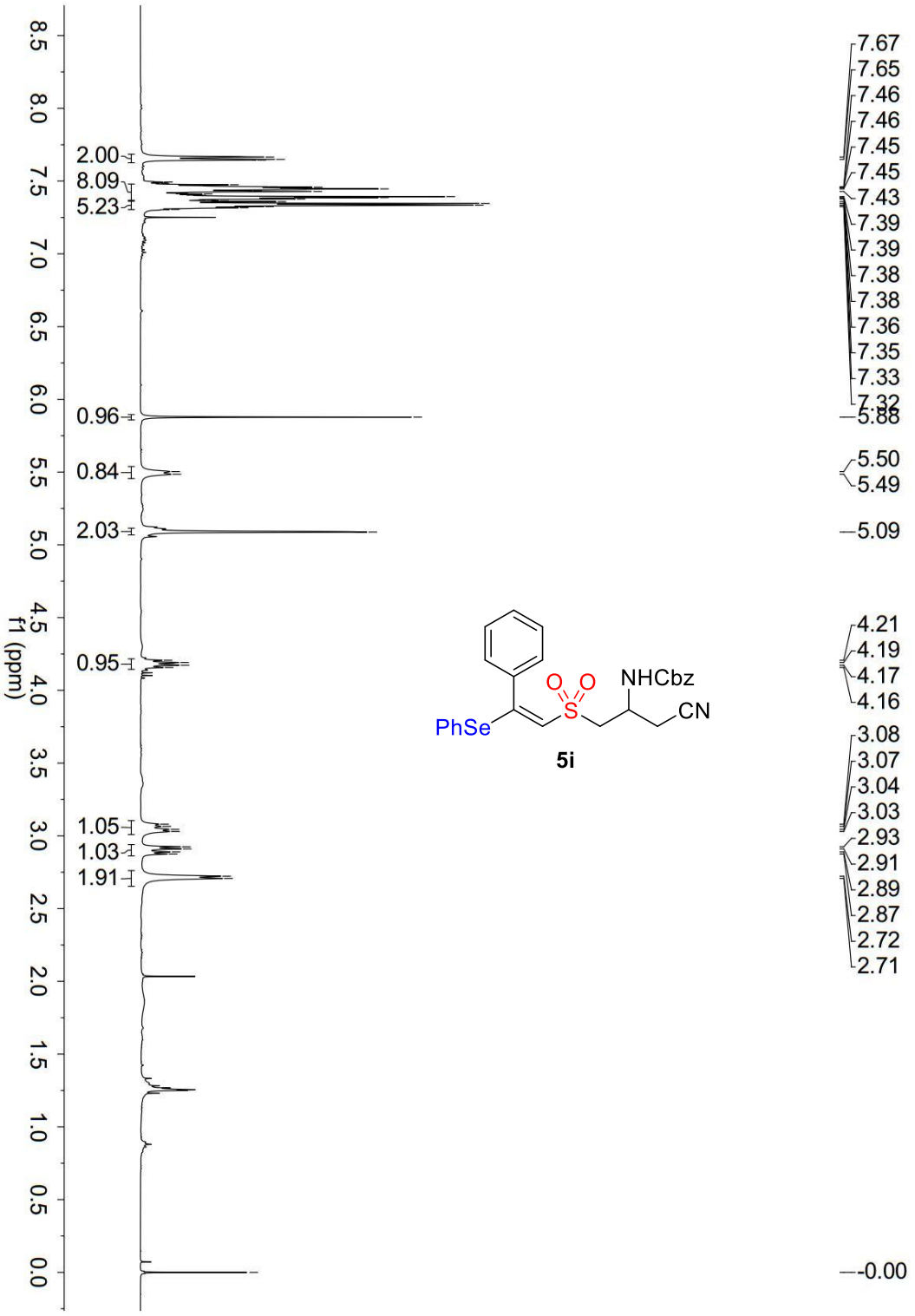


5h

^{13}C NMR spectrum of compound **5h** (100 MHz, $CDCl_3$)

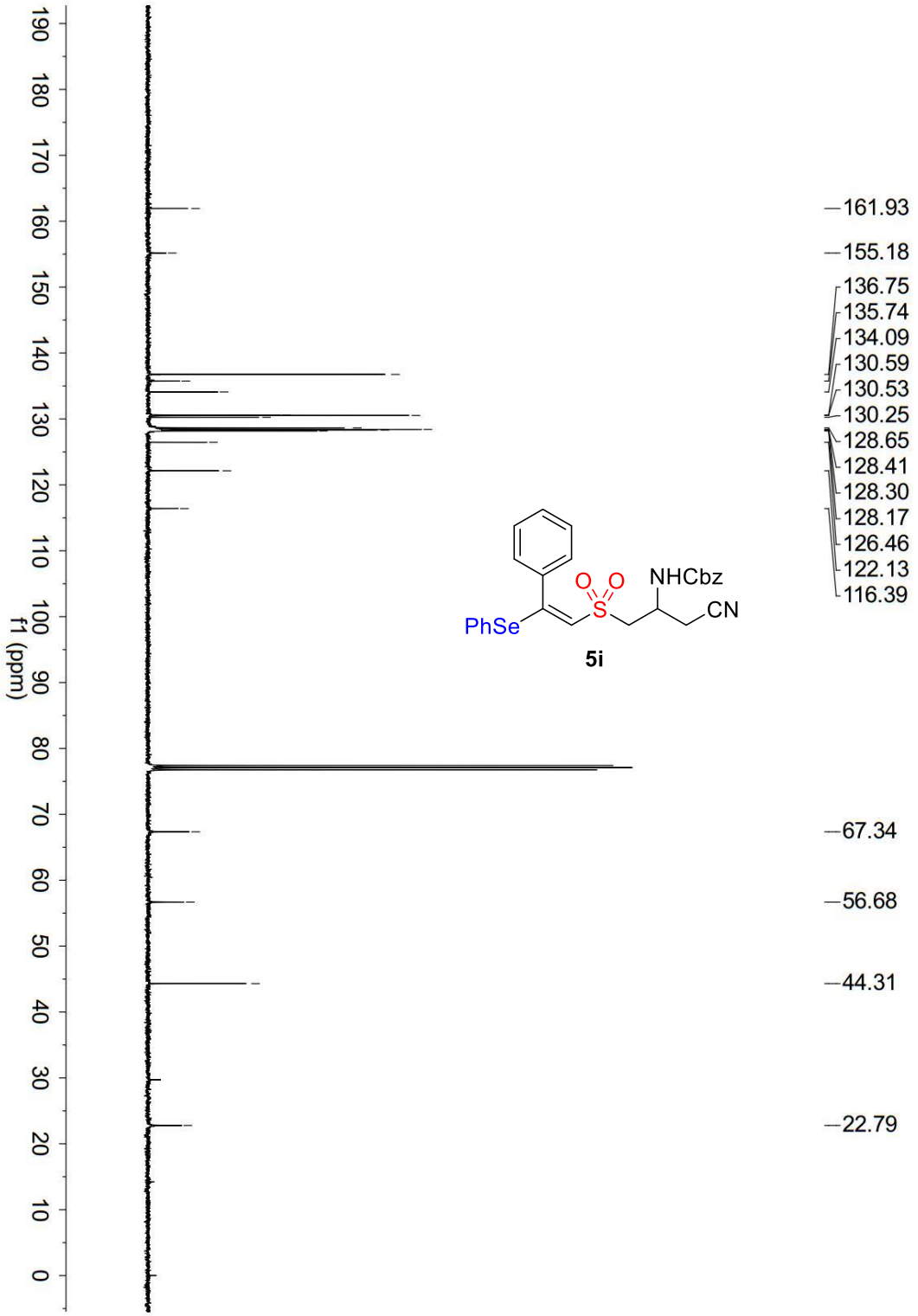


^{1}H NMR spectrum of compound **5i** (400 MHz, $CDCl_3$)

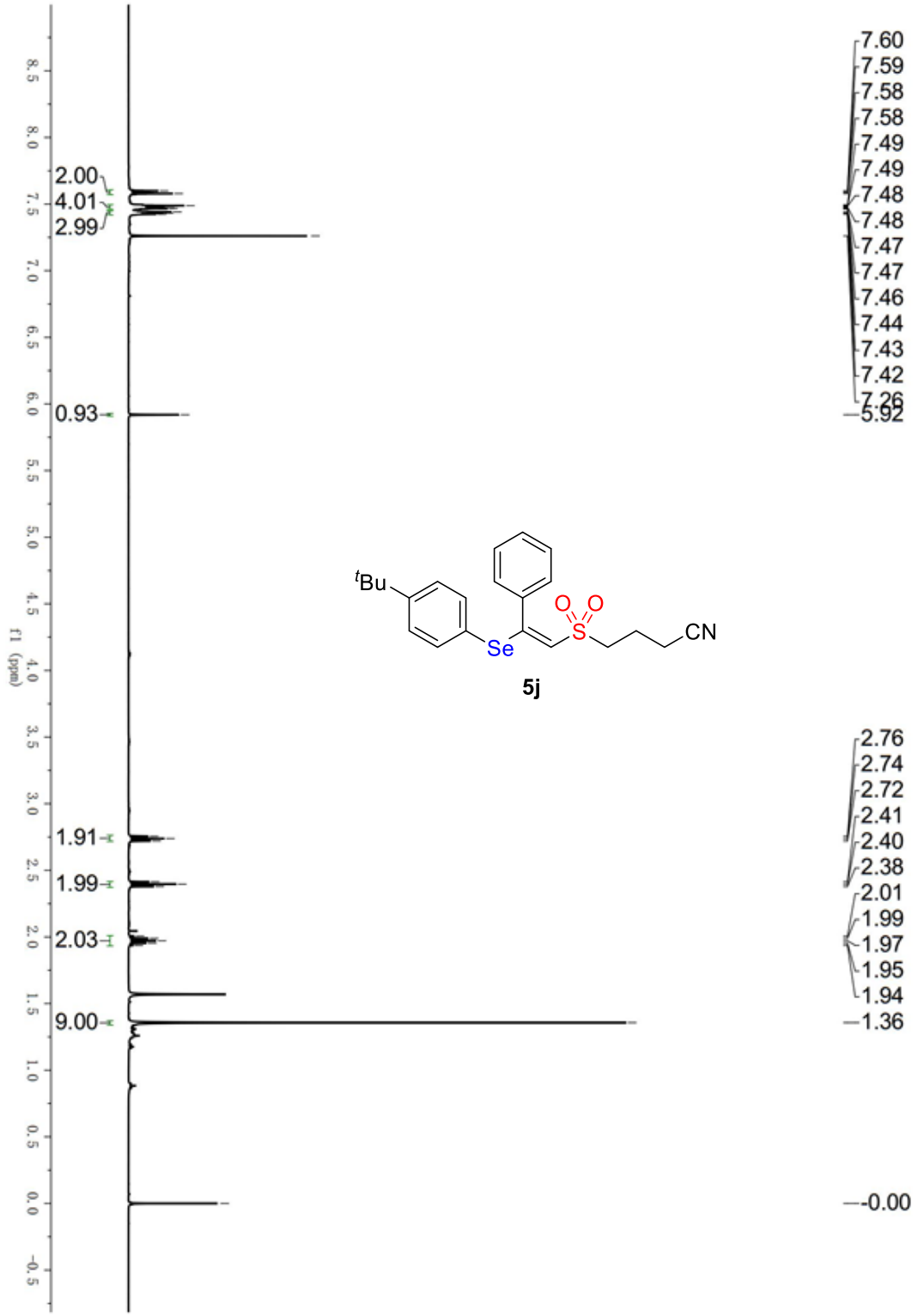


5i

^{13}C NMR spectrum of compound **5i** (100 MHz, $CDCl_3$)

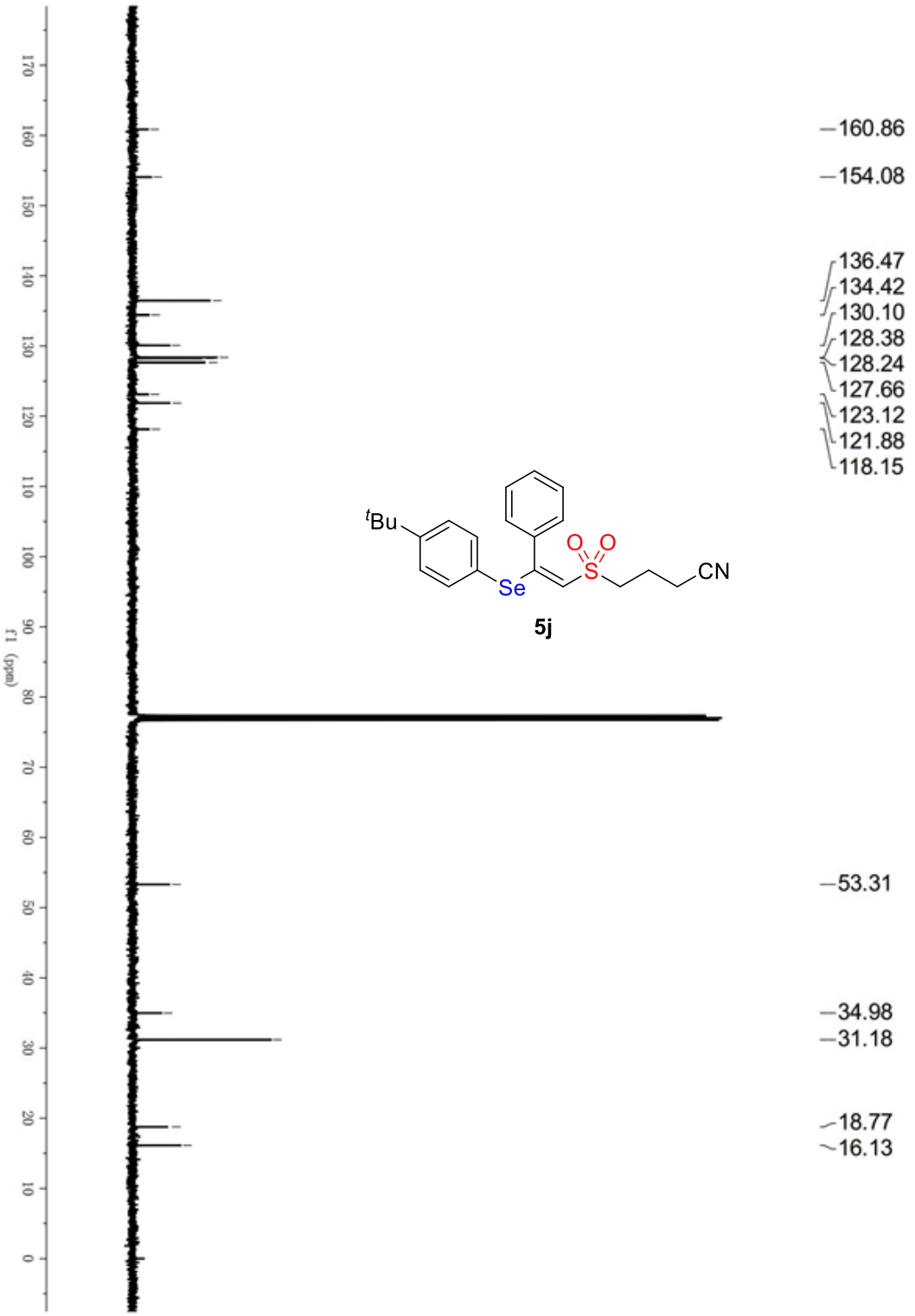


^{1}H NMR spectrum of compound **5j** (400 MHz, $CDCl_3$)

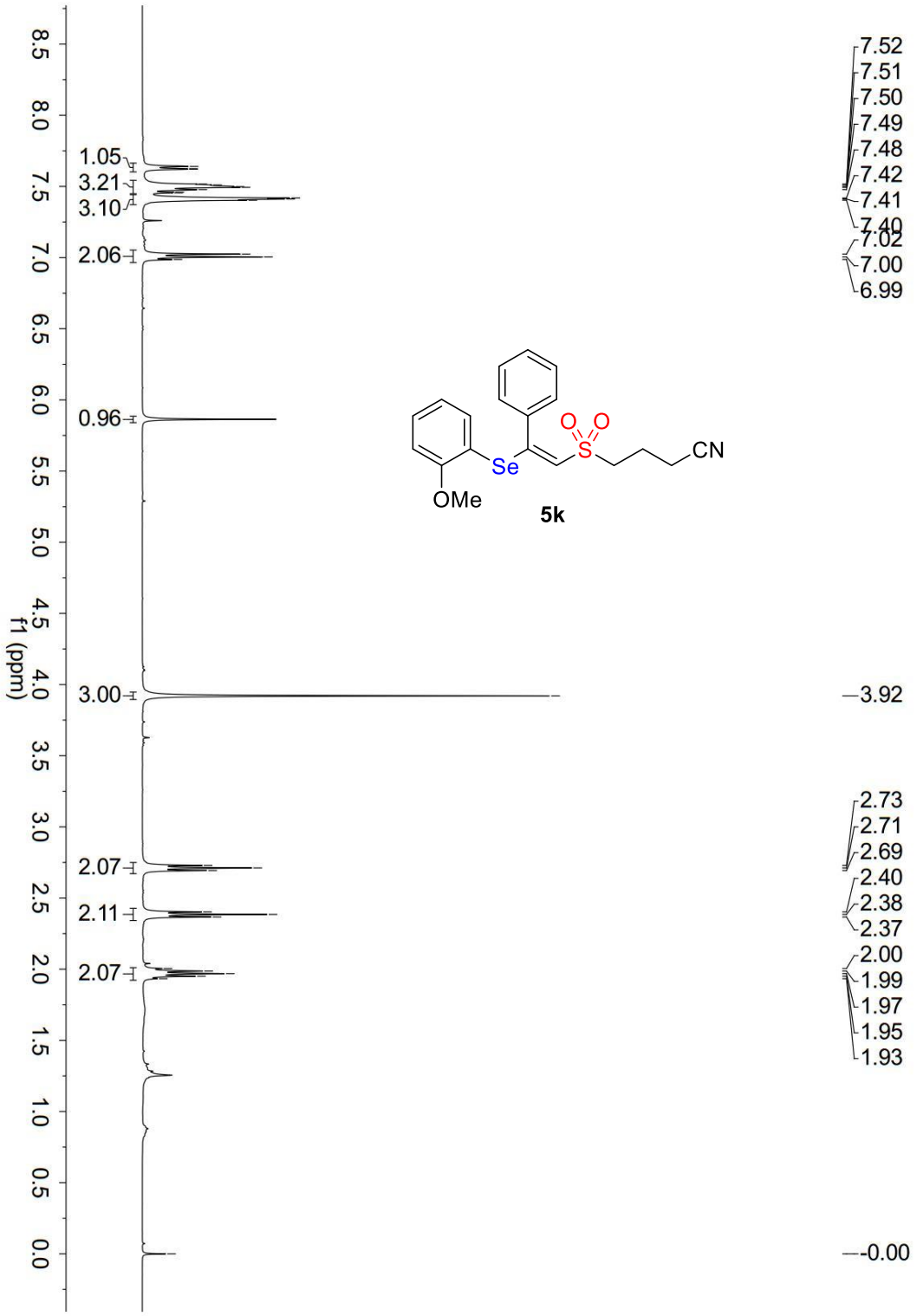


5j

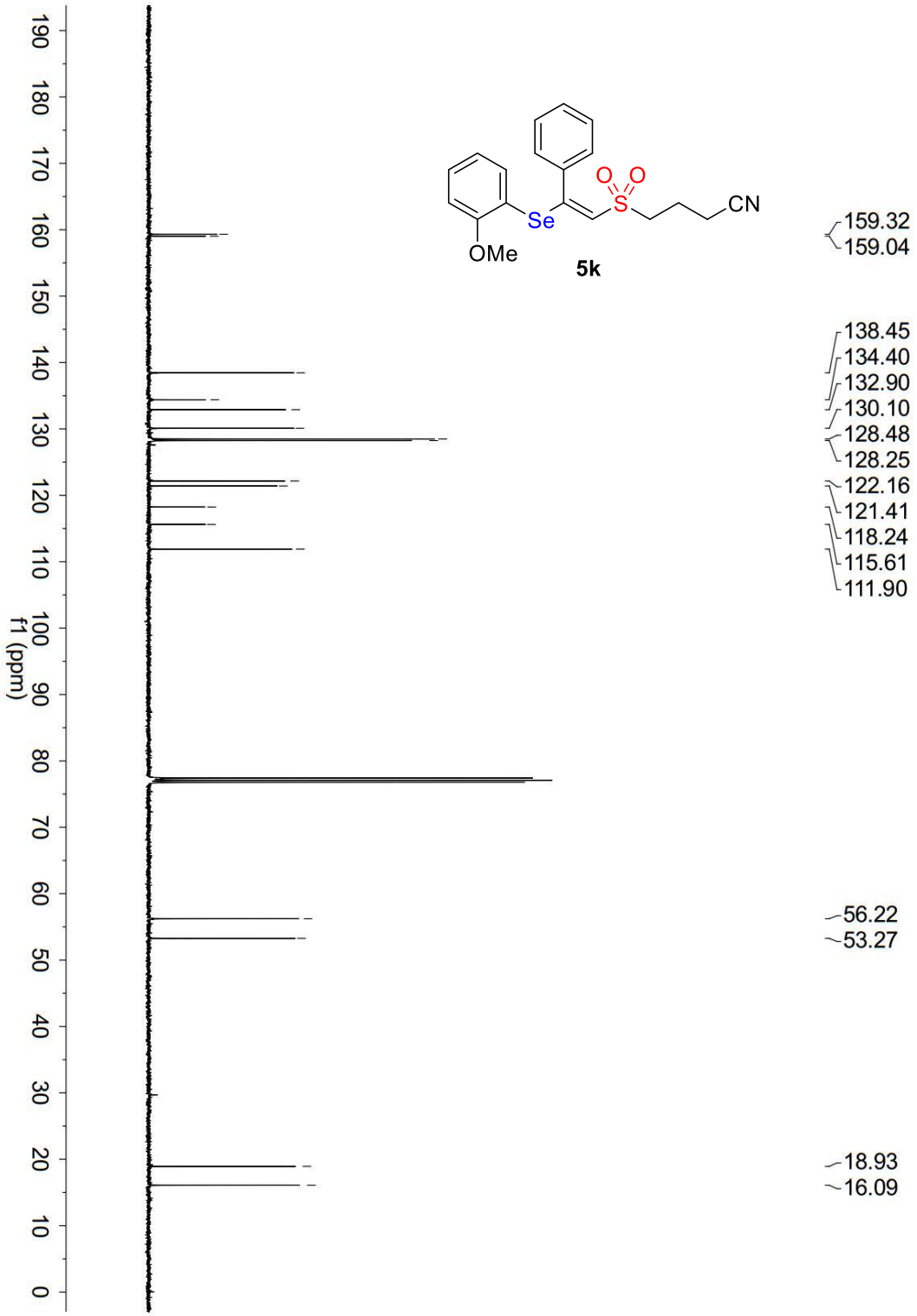
^{13}C NMR spectrum of compound **5j** (100 MHz, $CDCl_3$)



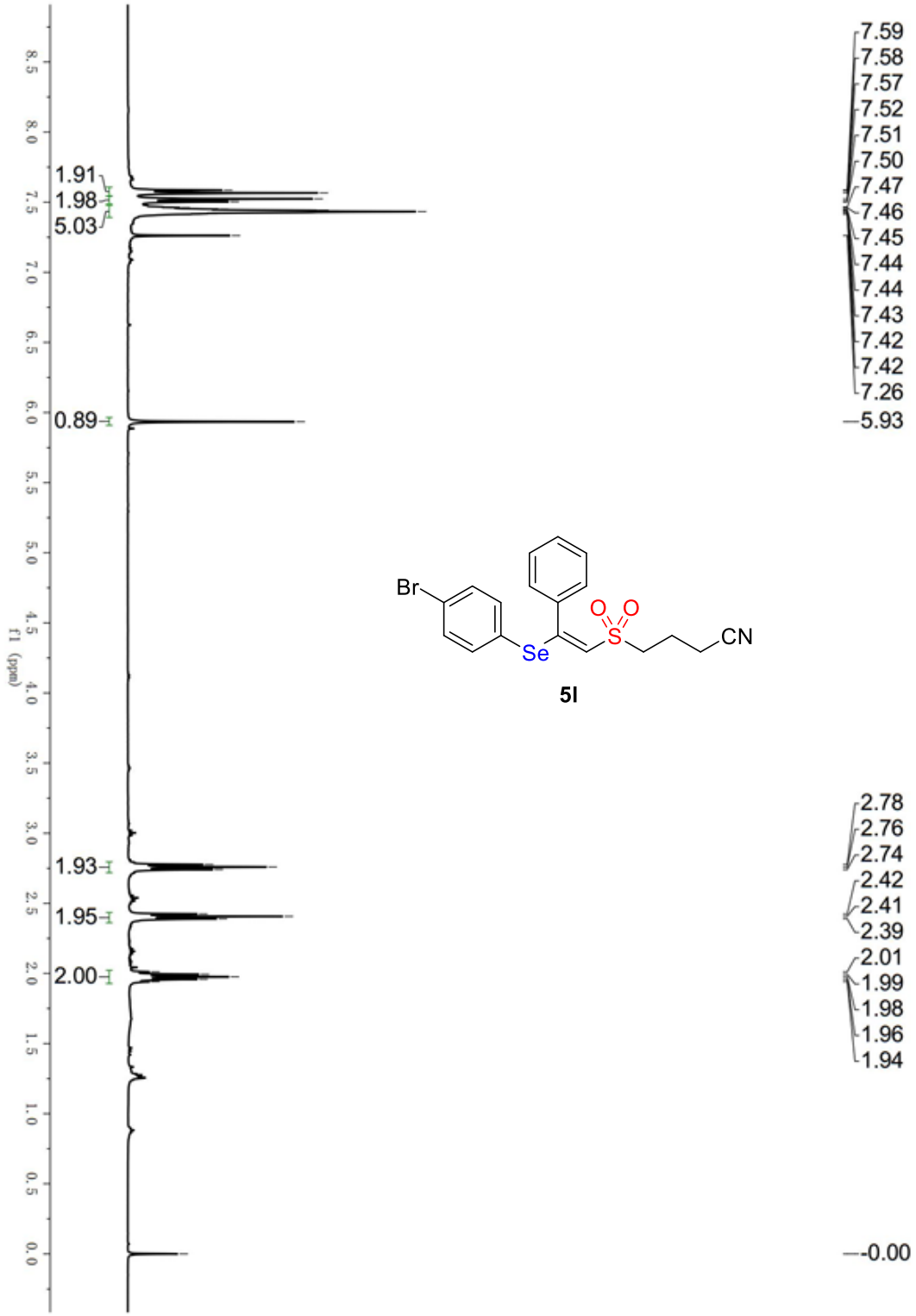
^{1}H NMR spectrum of compound **5k** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of compound **5k** (100 MHz, $CDCl_3$)

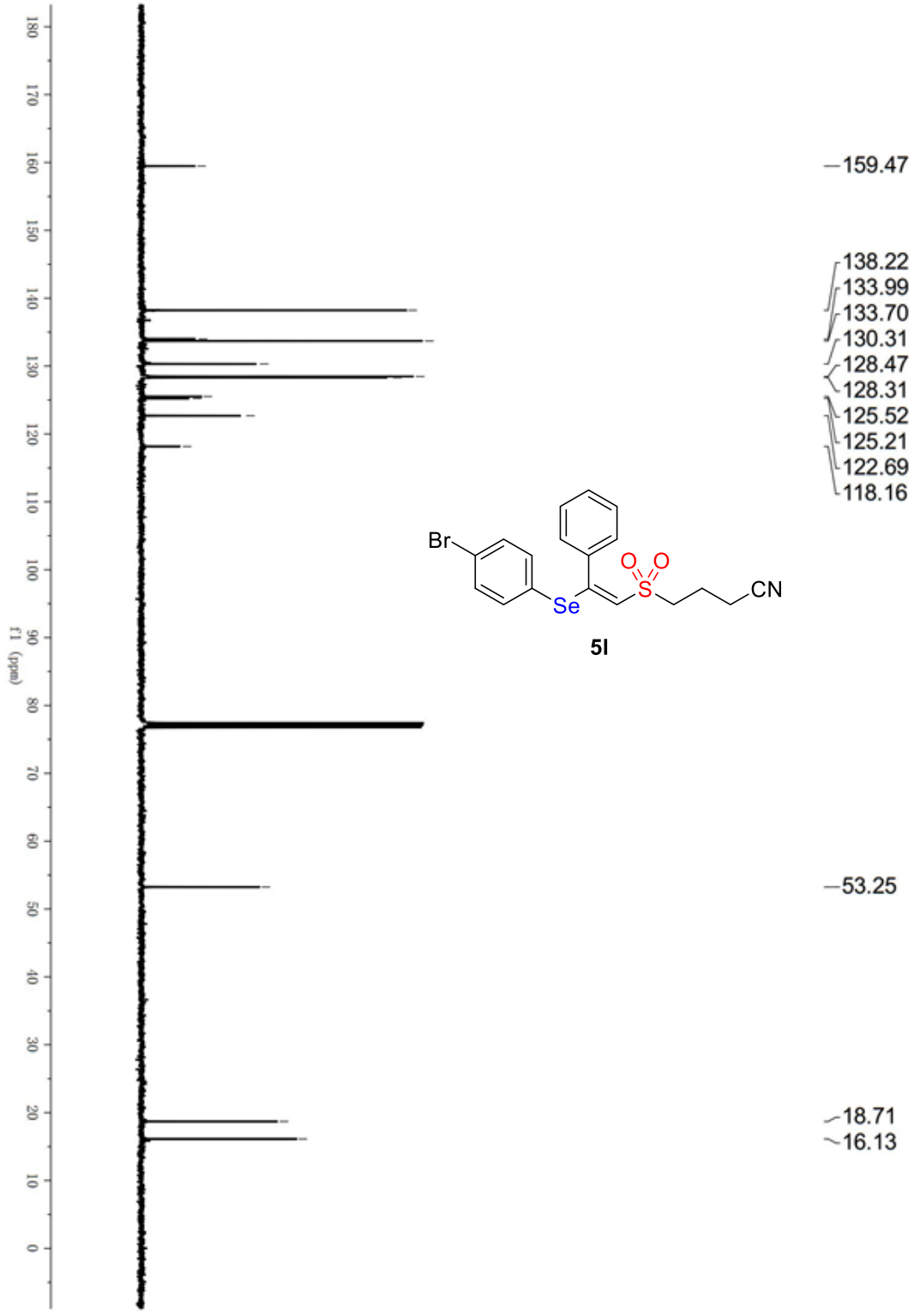


^{1}H NMR spectrum of compound **5l** (400 MHz, $CDCl_3$)

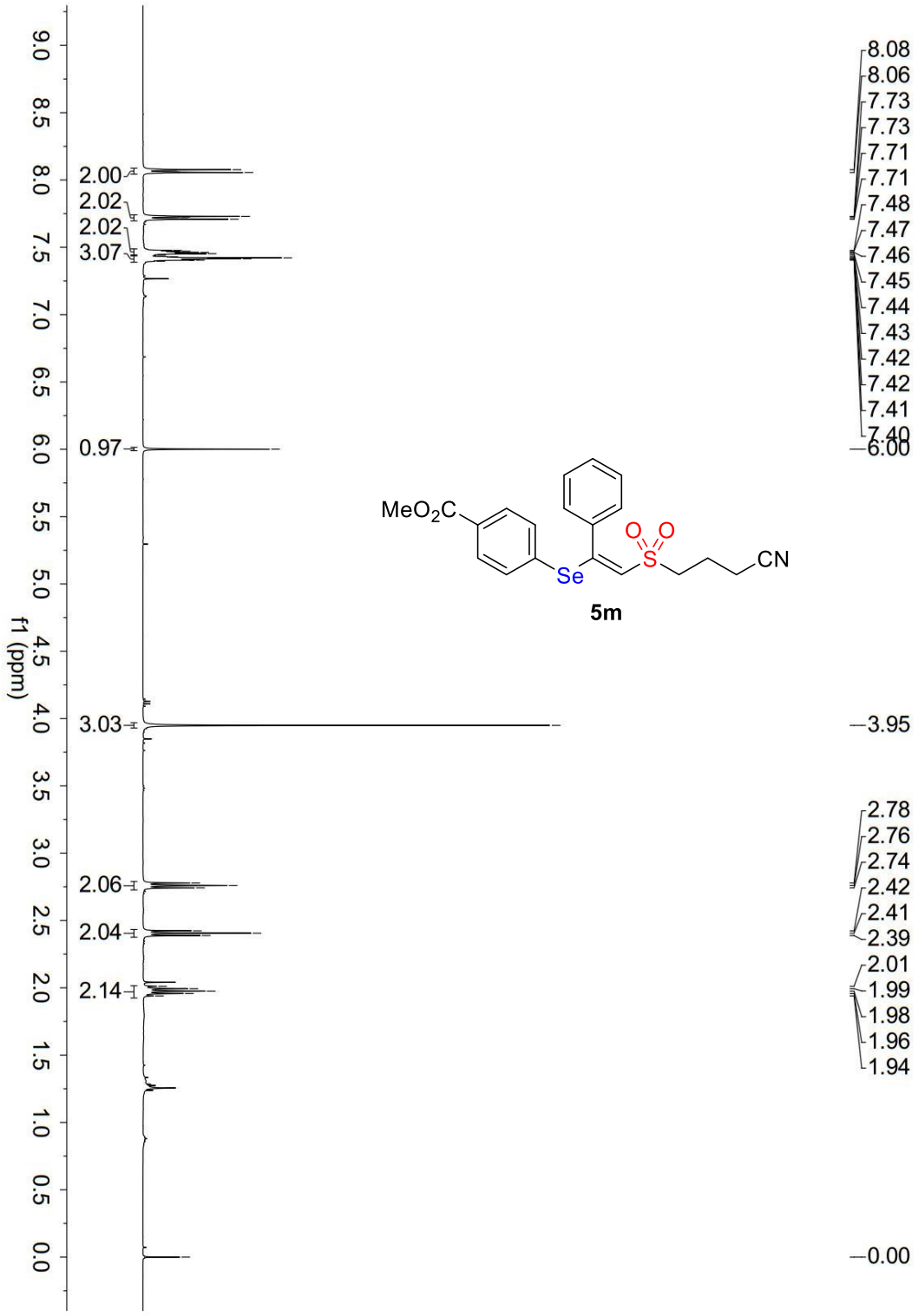


5l

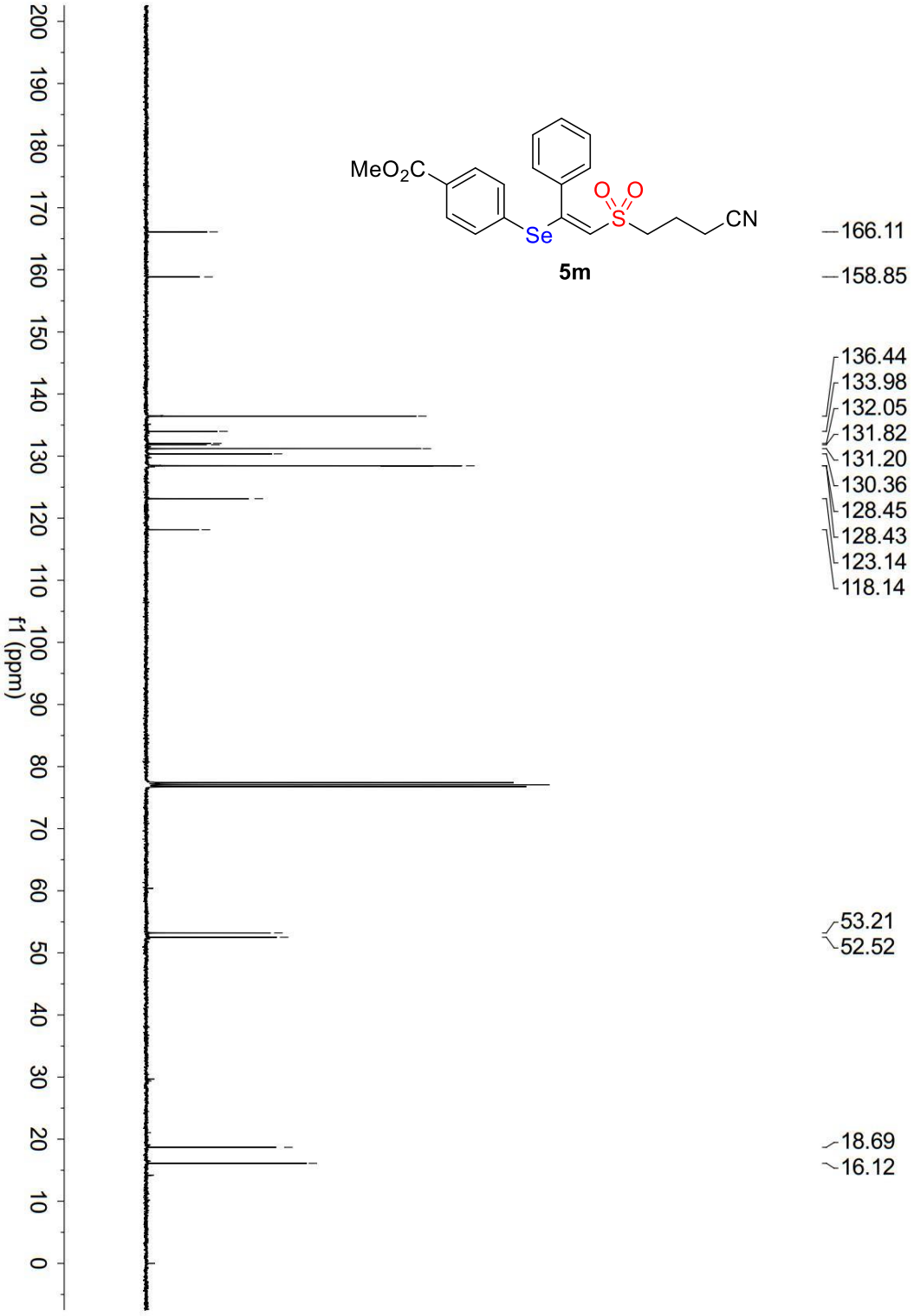
^{13}C NMR spectrum of compound **5l** (100 MHz, $CDCl_3$)



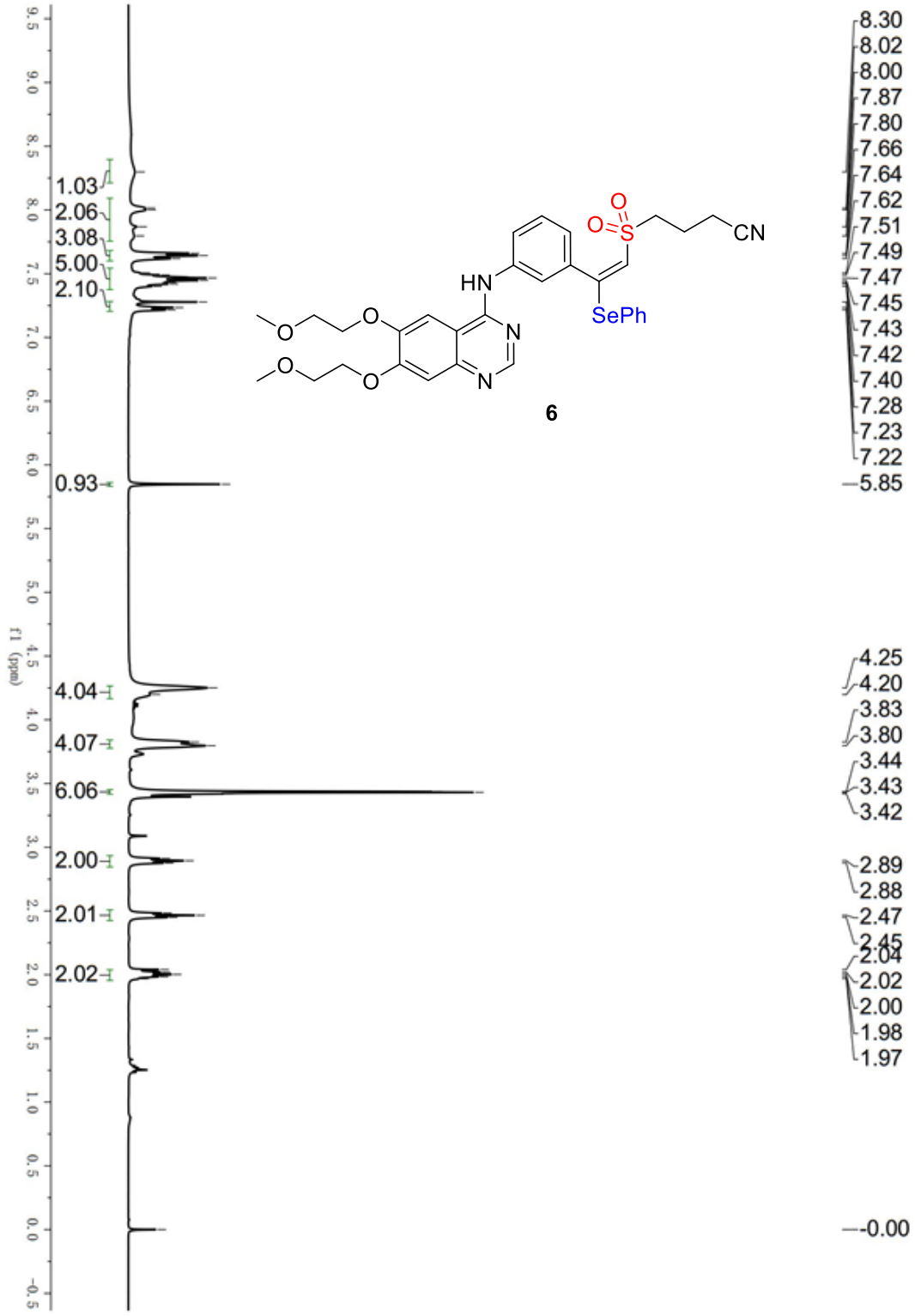
^{1}H NMR spectrum of compound **5m** (400 MHz, $CDCl_3$)



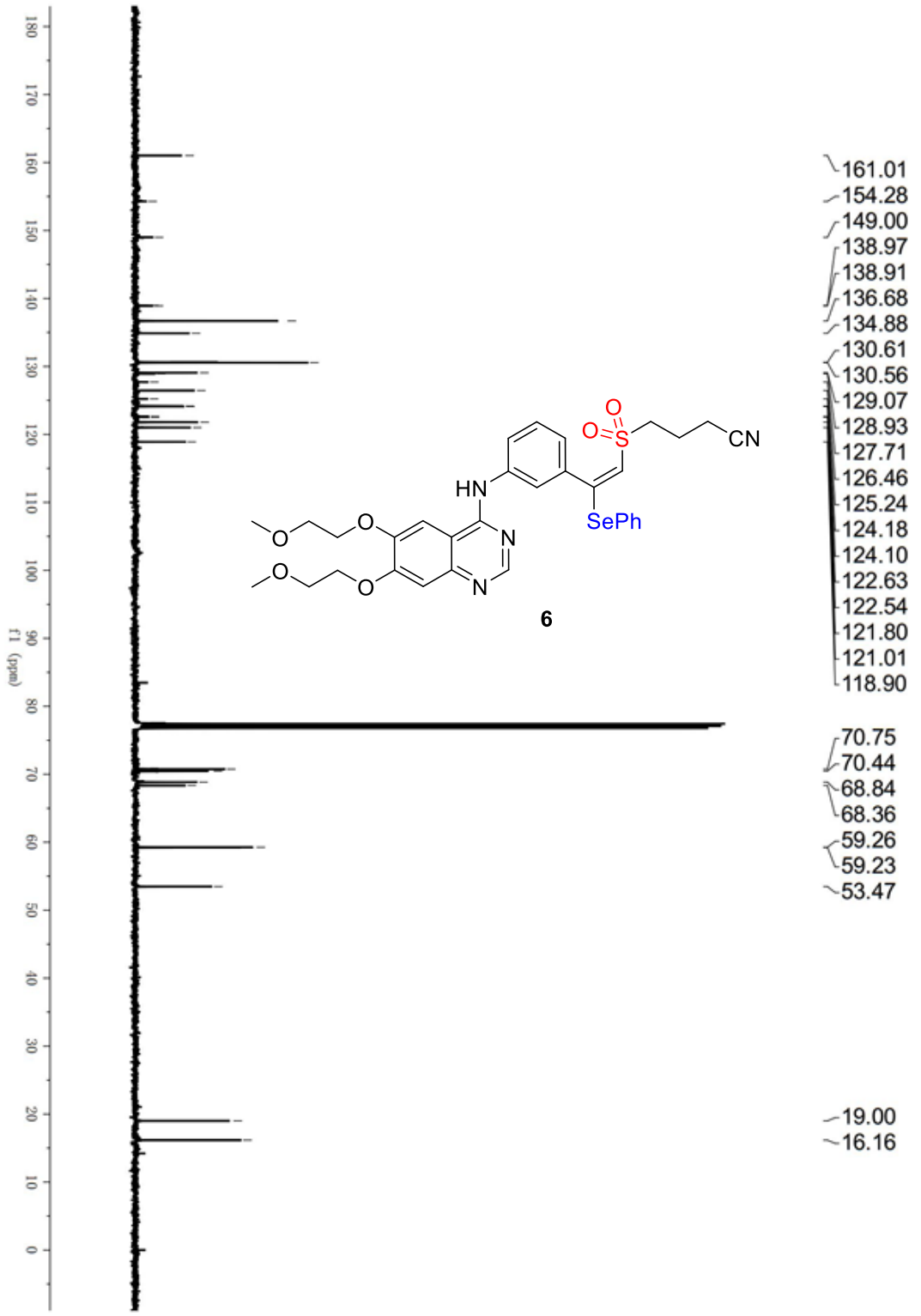
^{13}C NMR spectrum of compound **5m** (100 MHz, $CDCl_3$)



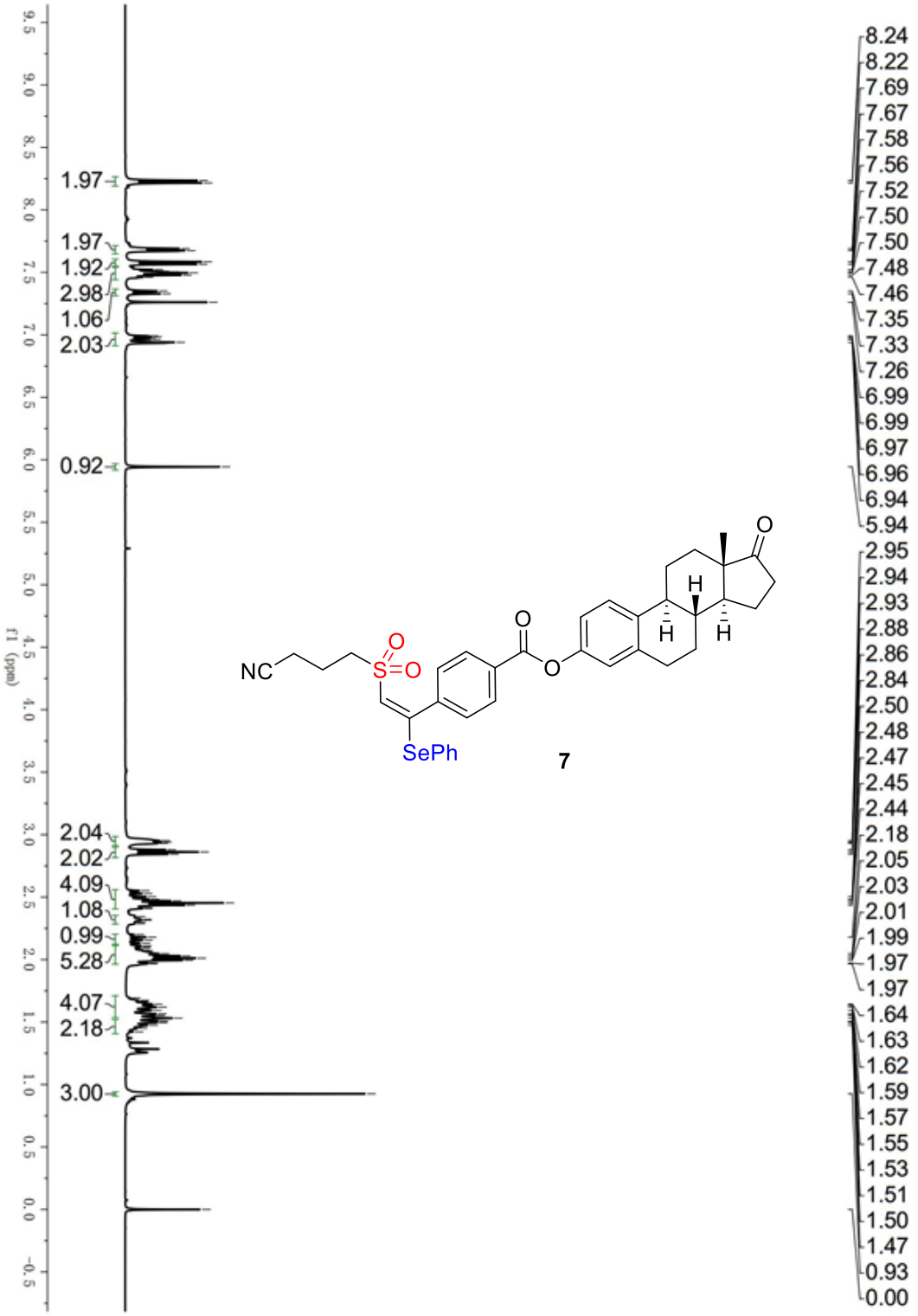
^{1}H NMR spectrum of compound **6** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of compound **6** (100 MHz, $CDCl_3$)

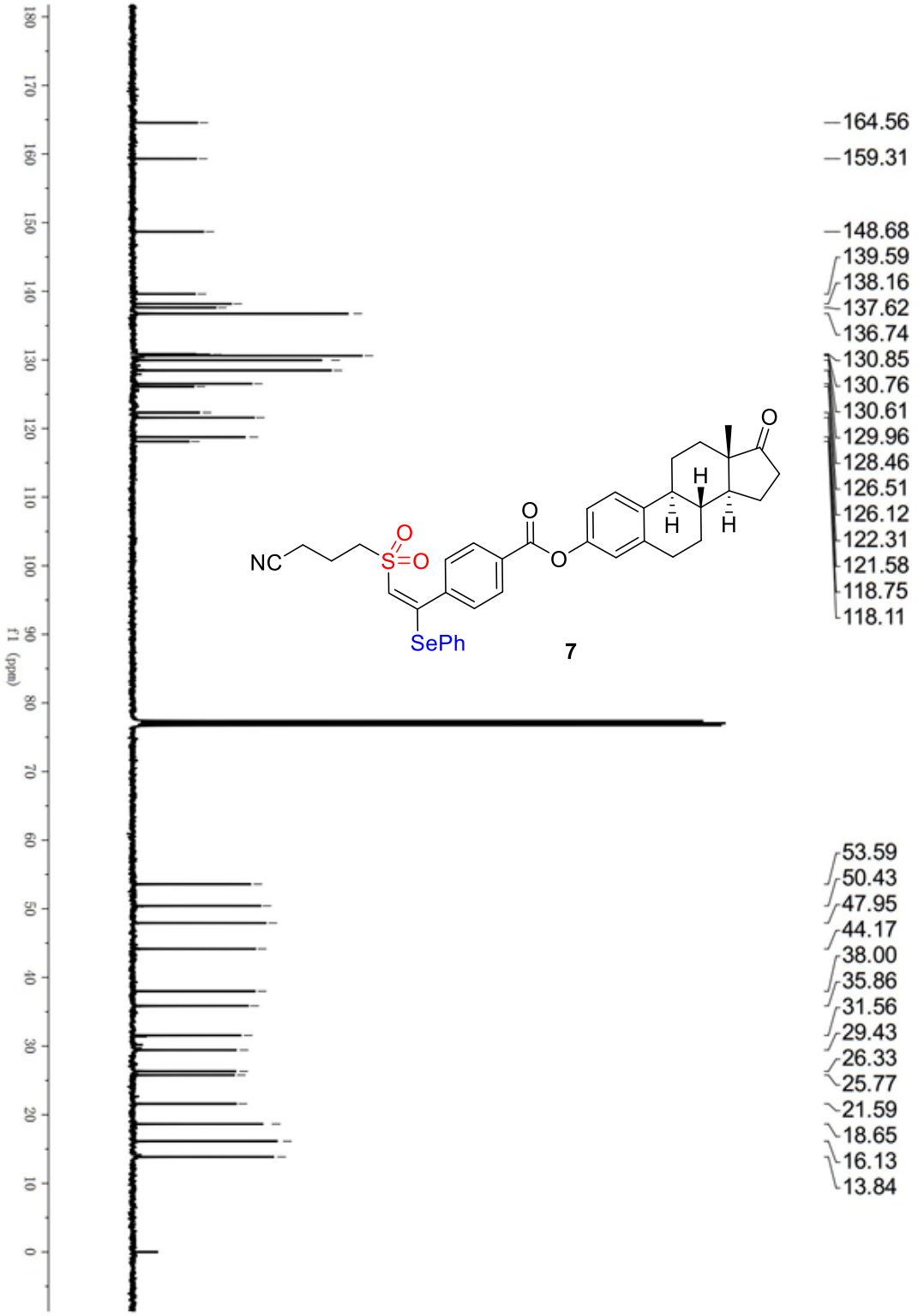


^{1}H NMR spectrum of compound **7** (400 MHz, $CDCl_3$)

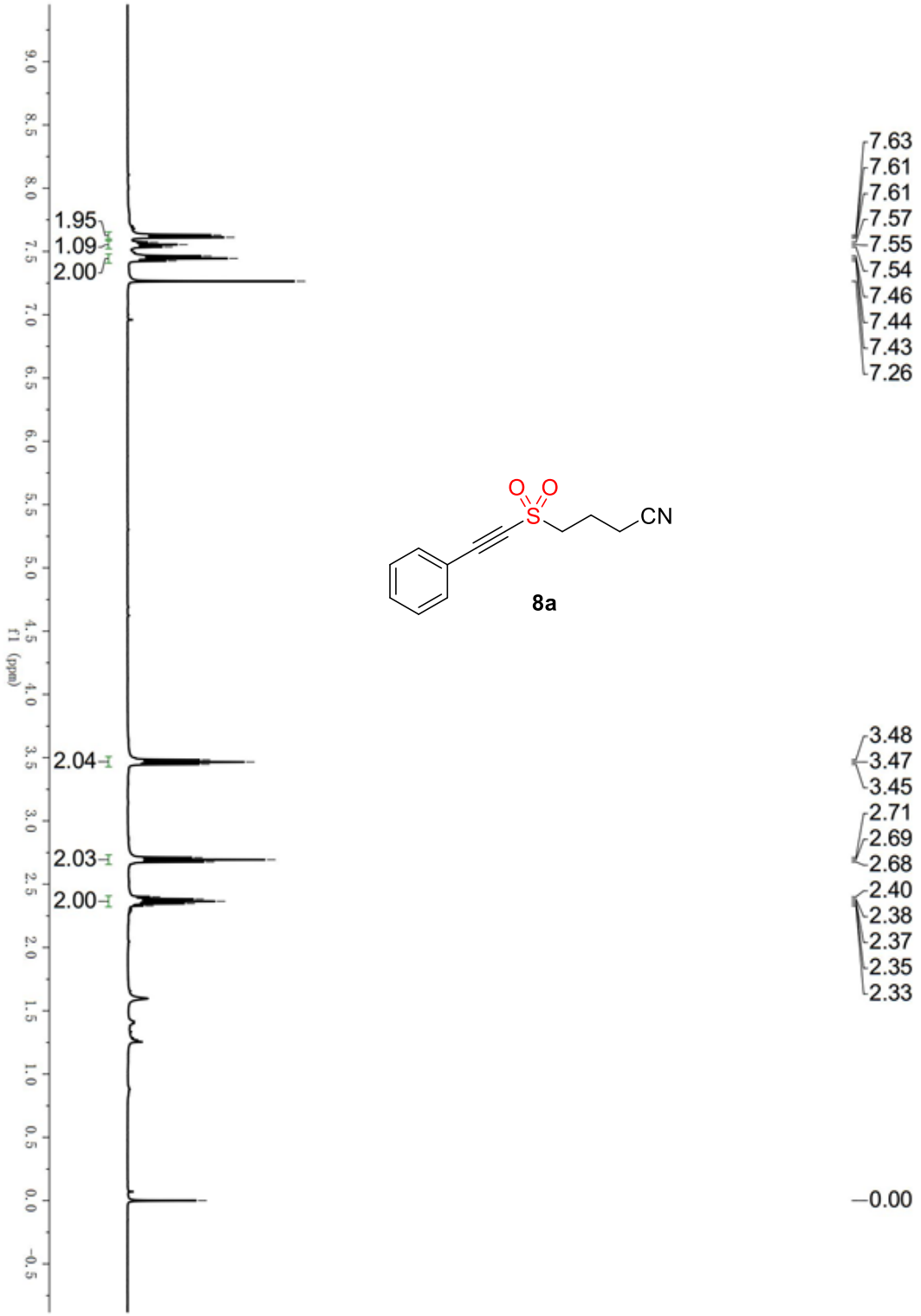


7

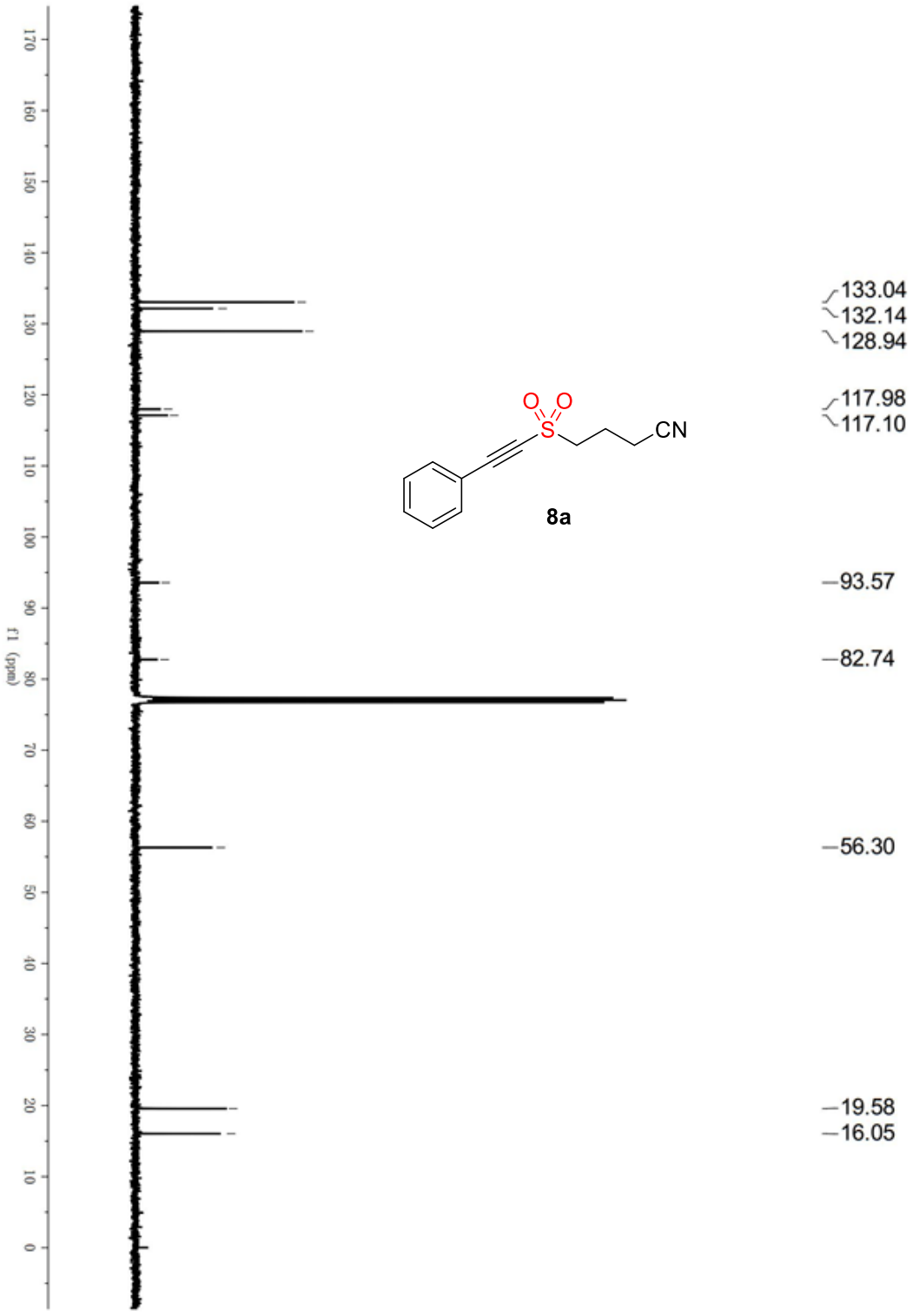
^{13}C NMR spectrum of compound **7** (100 MHz, $CDCl_3$)



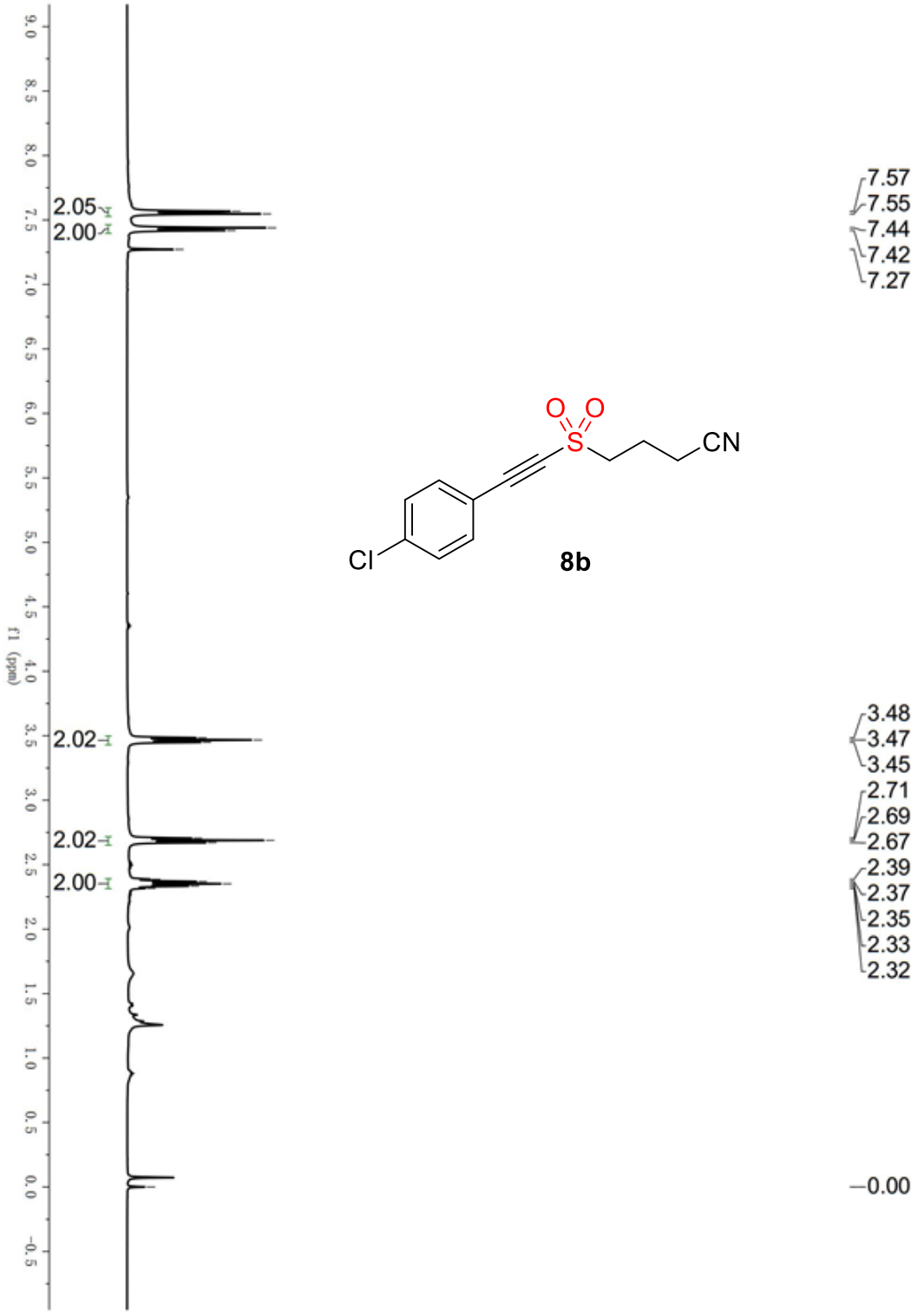
^{1}H NMR spectrum of compound **8a** (400 MHz, $CDCl_3$)



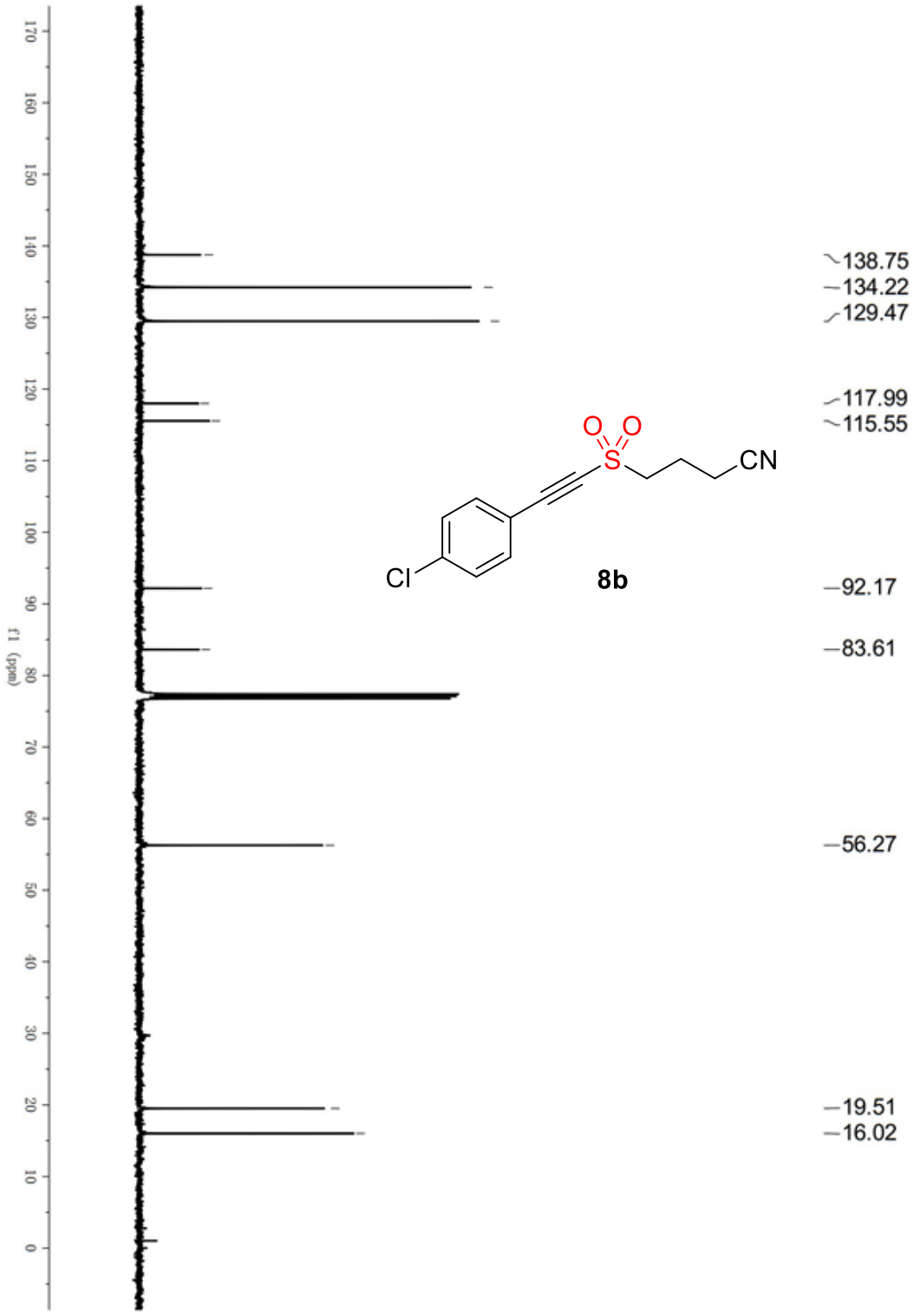
^{13}C NMR spectrum of compound **8a** (100 MHz, $CDCl_3$)



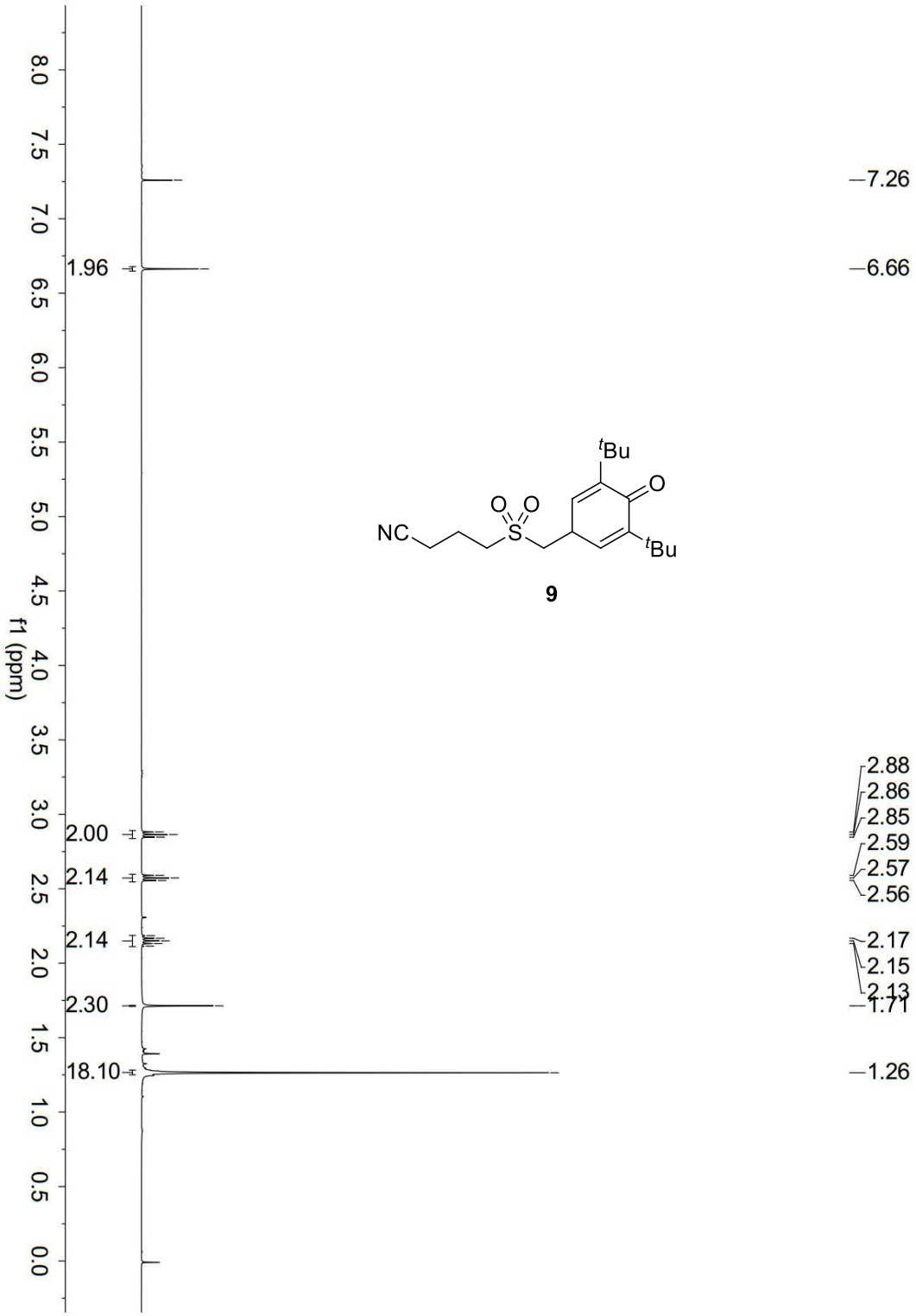
^{1}H NMR spectrum of compound **8b** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of compound **8b** (100 MHz, $CDCl_3$)

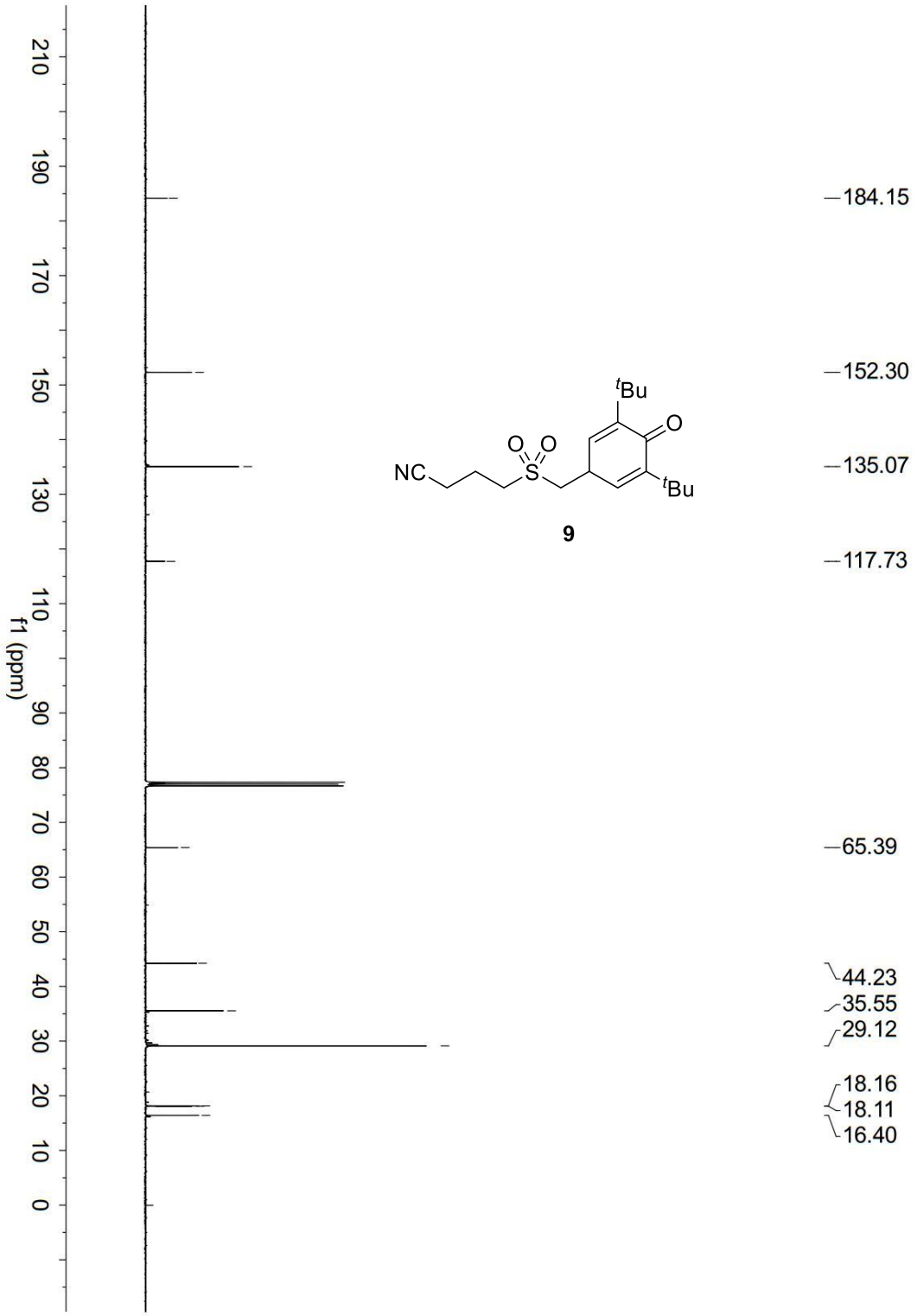


^{1}H NMR spectrum of compound **9** (400 MHz, $CDCl_3$)



9

^{13}C NMR spectrum of compound **9** (100 MHz, $CDCl_3$)



9