SUPPORTING INFORMATION

for the

communication

entitled

CHEMOSELECTIVITY-TUNABLE [5 + 2] CYCLOADDITIONS OF ALLENAMIDES AND OXIDOPYRYLIUMS

authored by

Min Yang, Liangliang Kang, and Shuzhong He*

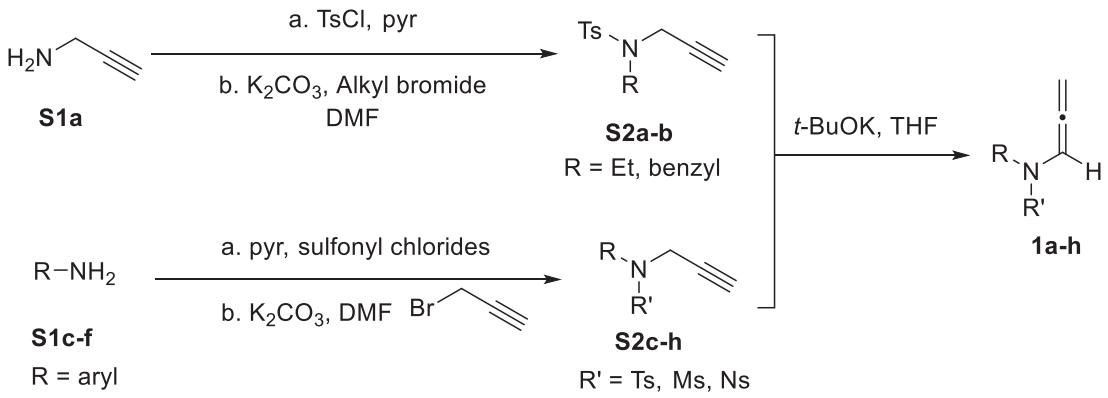
School of Pharmaceutical Sciences, and Guizhou Engineering Laboratory for Synthetic Drugs, Guizhou University, Guiyang, Guizhou 550025, China

Table of Contents

GENERAL EXPERIMENTAL INFORMATION.

All reactions were performed in flame-dried glassware under nitrogen atmosphere. Solvents were distilled prior to use. Reagents were used as purchased from Aladdin, Macklin, Innochen, or TCI unless otherwise noted. Chromatographic separations were performed using Silica Gel, AR, 200-300 mesh. ^{1}H and ^{13}C NMR spectra were obtained on Varian VI-400, VI-500 and VI-600 spectrometers using $CDCl_3$ as the solvent. Infrared spectra were obtained on Thermo Scientific Nicolet iS 50. TLC analysis was visualized using UV, p-anisoladehyde and phosphomolybdic acid stains. High-resolution mass spectra were obtained using AB SCIEX X500R QTOF. All spectral data obtained for new compounds are reported here.

PREPARATINS OF ALLENES



General procedure for Synthesis of S2a-b Using S2a as an Example.

To a solution of propargyl amine **S1a** (1.1 g, 19.1 mmol) in pyridine (20 mL) was added *p*-TsCl (4.0 g, 21.0 mmol, 1.1 equiv) at 0℃.[1] The reaction was stirred at rt overnight before being quenched with H_2O. The quenched mixture was extracted three times with AcOEt. The combined organic layers were washed with 1 *M* HCl to remove excess pyridine, and then with sat aq $NaHCO_3$, H_2O, and sat aq NaCl, and dried over anhydrous $MgSO_4$. The solution was filtered and concentrated under reduced pressure to give the crude sulfonamide that was used in the next step without further purification.

To a solution of the above crude sulfonamide (3.6 g, 17.1 mmol) in DMF (42 mL) was added K_2CO_3 (4.7 g, 34.2 mmol, 2.0 equiv) and benzyl bromide (3.5 g, 20.5

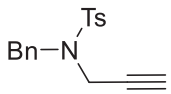
mmol, 1.2 equiv). The reaction was stirred at rt overnight before being quenched with H_2O.[1] The quenched mixture was diluted with vast water and then extracted three times with Et_2O. The combined organic layers were washed with sat aq NaCl and dried over anhydrous $MgSO_4$. After filtration and concentration under reduced pressure, the crude product was purified using silica gel flash column chromatography to give the desired propargyl amide **S2a** (4.3 g, 75% yield over two steps).

General procedure for Synthesis of S2c-h Using S2c as an Example.

To a solution of 2-iodoaniline **S1c** (3.0 g, 13.6 mmol) in pyridine (13 mL) was added *p*-TsCl (2.8 g, 14.9 mmol, 1.1 equiv) at 0 ℃. The reaction was stirred at rt overnight before being quenched with H_2O. The quenched mixture was extracted three times with Et_2O. The combined organic layers were washed with 1 *M* HCl to remove excess pyridine, and then with sat aq $NaHCO_3$, H_2O, and sat aq NaCl, and dried over anhydrous $MgSO_4$. The solution was filtered and concentrated under reduced pressure to give the crude sulfonamide that was used in the next step without further purification.

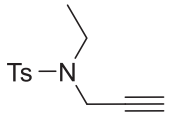
To a solution of the above crude sulfonamide (4.2 g, 11.2 mmol) in DMF (28 mL) was added K_2CO_3 (3.0 g, 22.4 mmol, 2.0 equiv) and propargyl bromide (2.0 g, 16.8 mmol, 1.5 equiv). The reaction was stirred at rt overnight before being quenched with H_2O. The quenched mixture was diluted with vast water and then extracted three times with Et_2O. The combined organic layers were washed with sat aq NaCl and dried over anhydrous $MgSO_4$. After filtration and concentration under reduced pressure, the crude product was purified using silica gel flash column chromatography to give the desired propargyl amide **S2c** (4.4 g, 79% yield over two steps).

CHARACTERIZATIONS OF PROPARGYL AMIDES S2a-h.



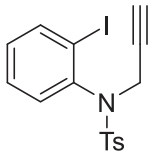
S2a

S2a: 4.3 g (75% yield over two steps from **S1a**); white solid; mp 93-94 ℃; IR (KBr) 3268, 2917, 2116, 1569, 1342, 1158, 1090, 890, 816, 738 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, *J* = 8.3 Hz, 2H), 7.42 – 7.33 (m, 7H), 4.38 (s, 2H), 3.98 (d, *J* = 2.4 Hz, 2H), 2.47 (s, 3H), 2.04 (t, *J* = 2.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.6, 136.0, 134.9, 129.5, 128.8, 128.7, 128.1, 127.8, 76.3, 74.1, 49.8, 35.5, 21.5; HRMS (ESI) Calculated for $C_{17}H_{17}NO_2S$ $[M+H]^+$: 300.1053, found 300.1044.



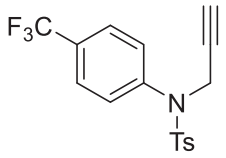
S2b

S2b: 3.3 g (75% yield over two steps form **S1a**); yellow solid; mp 54-56 ℃; IR (KBr) 3288, 2978, 2119, 1956, 1453, 1328, 1149, 1088, 1014s, 879, 815, 657 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.72 (d, *J* = 8.3 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 4.14 (d, *J* = 2.5 Hz, 2H), 3.27 (q, *J* = 7.2 Hz, 2H), 2.41 (s, 3H), 2.02 (t, *J* = 2.5 Hz, 1H), 1.17 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 143.4, 136.0, 129.4, 127.6, 76.7, 73.5, 41.2, 35.7, 21.5, 13.1; HRMS (ESI) Calculated for $C_{12}H_{15}NO_2S$ $[M+H]^+$: 238.0896, found 238.0886.



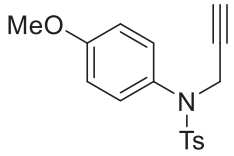
S2c

S2c: 4.4 g (79% yield over two steps form **S1c**); white solid; mp 115-116 ℃; IR (KBr) 3253, 2115, 1596, 1463, 1341, 1160, 1096, 872, 812, 714, 657 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.94 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.74 (d, *J* = 8.3 Hz, 2H), 7.34 – 7.29 (m, 3H), 7.17 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.09 (td, *J* = 7.7, 1.6 Hz, 1H), 4.79 (dd, *J* = 18.2, 2.2 Hz, 1H), 4.15 (dd, *J* = 18.2, 2.2 Hz, 1H), 2.47 (s, 3H), 2.18 (t, *J* = 2.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.9, 140.7, 140.2, 136.6, 131.2, 130.4, 129.4, 128.7, 128.3, 102.5, 74.0, 40.6, 21.6; HRMS (ESI) Calculated for $C_{16}H_{14}INO_2S$ $[M+H]^+$: 411.9863, found 411.9863.



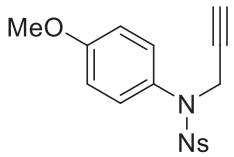
S2d

S2d: 5.4 g (83% yield over two steps form 4-(trifluoromethyl)aniline **S1d**); white solid; mp 62-63 ℃; IR (KBr) 3288, 2926, 1594, 1329, 1160, 1069, 818, 719 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.61 (d, *J* = 8.4 Hz, 2H), 7.56 (d, *J* = 8.3 Hz, 2H), 7.43 (d, *J* = 8.3 Hz, 2H), 7.28 (d, *J* = 8.5 Hz, 2H), 4.49 (d, *J* = 2.5 Hz, 2H), 2.45 (s, 3H), 2.22 (t, *J* = 2.5 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 144.2, 142.6, 135.0, 129.5, 127.9, 126.1 (d, *J* = 3.6 Hz), 77.5, 74.4, 40.6, 21.6; HRMS (ESI) Calculated for $C_{17}H14F_3NO_2S$ $[M+H]^+$: 354.0770, found 354.0768.



S2e

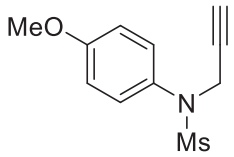
S2e: 6.1 g (80% yield over two steps form 4-methoxyaniline **S1e**); yellow solid; mp 89-90 ℃; IR (KBr) 3274, 2970, 2845, 2114, 158, 1339, 1251, 1160, 857, 819, 651, 590 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.2 Hz, 2H), 7.24 (d, *J* = 8.1 Hz, 2H), 7.11 (d, *J* = 9.0 Hz, 2H), 6.82 (d, *J* = 8.9 Hz, 2H), 4.40 (d, *J* = 2.4 Hz, 2H), 3.80 (s, 3H), 2.42 (s, 3H), 2.16 (t, *J* = 2.5 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 159.3, 143.6, 135.6, 131.7, 130.1, 129.2, 128.0, 114.2, 78.2, 73.7, 55.4, 41.3, 21.6; HRMS (ESI) Calculated for $C_{17}H_{17}NO_3S$ $[M+H]^+$: 316.1002, found 316.0995.



S2f

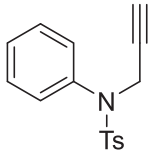
S2f: 6.6 g (79% yield over two steps form 4-methoxyaniline **S1e**); yellow viscous oil; IR (KBr) 3290, 2734, 1556, 1512, 1374, 1253, 1177, 1097, 1035, 894, 850 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.72 – 7.64 (m, 3H), 7.56 – 7.52 (m, 1H), 7.23 – 7.19 (m, 2H), 6.87 – 6.84 (m, 2H), 4.56 (d, *J* = 2.4 Hz, 2H), 3.82 (s, 3H), 2.29 (t, *J* = 2.4 Hz,

1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 159.8, 147.9, 133.8, 132.1, 131.3, 131.1, 129.8, 124.0, 114.5, 78.4, 73.7, 55.4, 42.5; HRMS (ESI) Calculated for $C_{16}H_{14}N_2O_5S$ $[M+H]^+$: 347.0696, found 347.0700.



S2g

S2g: 4.9 g (85% yield over two steps form 4-methoxyaniline **S1e**); yellow solid; mp 101-103 ℃; IR (KBr) 3249, 1606, 1515, 1341, 1159, 1079, 1035, 953, 865, 644 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 – 7.48 (m, 2H), 6.96 – 6.91 (m, 2H), 4.42 (d, J = 2.5 Hz, 2H), 3.84 (s, 3H), 3.05 (s, 3H), 2.49 (t, J = 2.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.5, 132.5, 129.3, 114.6, 79.1, 74.1, 55.5, 41.3, 38.7; HRMS (ESI) Calculated for $C_{11}H_{13}NO_3S$ $[M+H]^+$: 240.0689, found 240.0693.



S2h

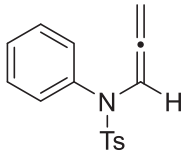
S2h: 7.1 g (78% over two steps form aniline **S1f**); brown solid; mp 85-87 ℃; IR (KBr) 3285, 2959, 2129, 1348, 1156, 867, 819, 707, 694, 650 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.57 (d, J = 8.2 Hz, 2H), 7.34 (dd, J = 5.2, 1.7 Hz, 3H), 7.26 (d, J = 7.7 Hz, 4H), 4.46 (d, J = 2.4 Hz, 2H), 2.44 (s, 3H), 2.19 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 143.7, 139.3, 135.5, 129.3, 129.0, 128.4, 128.21, 128.0, 78.0, 73.8, 41.0, 21.6; HRMS (ESI) Calculated for $C_{16}H_{15}NO_2S$ $[M+H]^+$: 286.0896, found 286.0892.

General Procedure for Synthesis of Allenamides 1a-h Using 1a as an Example.

To a solution of **S2h** (4.0 g, 14.0 mmol) in THF (70 mL) was added *t*-BuOK (1.0 *M* solution in THF, 7 mL, 7.0 mmol, 0.5 equiv) at 0 °C. The reaction was stirred at rt for 1 h before being concentrated under reduced pressure. Subsequently, the residue was first suspended in Et_2O and then filtered though CeliteTM.[1] The filtrate was concentrated under reduced pressure and the crude residue was purified using silica

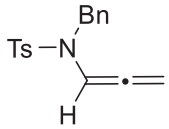
gel flash column chromatography to give the desired allenamide **1a** (3.4 g, 87% yield).

CHARACTERIZATIONS OF ALLENAMIDES 1a-h.



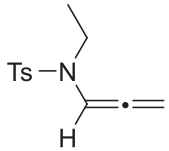
1a

1a: 3.4 g (87% yield); brown solid; mp 71-72 ℃; IR (KBr) 3038, 1593, 1487, 1351, 1161, 895, 704, 693, 661 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.58 (d, *J* = 8.2 Hz, 1H), 7.33 – 7.29 (m, 2H), 7.13 (t, *J* = 6.3 Hz, 1H), 7.03 (dd, *J* = 8.0, 1.5 Hz, 1H), 5.05 (d, *J* = 6.3 Hz, 1H), 2.47 (s, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 201.0, 143.9, 137.2, 135.3, 129.6, 129.5, 128.7, 128.6, 127.7, 102.4, 87.5, 21.6; HRMS (ESI) Calculated for $C_{16}H_{15}NO_2S$ $[M+H]^+$: 286.0896, found 286.0888.



1b

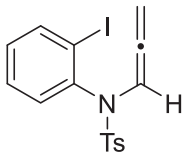
1b: 3.4 g (85% yield); white solid; mp 65-67 ℃; IR (KBr) 3033, 2919, 1596, 1445, 1347, 1161, 1090, 1021, 920, 884, 737, 665 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.74 (d, *J* = 8.3 Hz, 2H), 7.37 – 7.27 (m, 7H), 6.85 (t, *J* = 6.2 Hz, 1H), 5.16 (d, *J* = 6.2 Hz, 2H), 4.33 (s, 2H), 2.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.2, 143.8, 136.2, 135.4, 129.7, 128.3, 127.8, 127.3, 100.1, 88.0, 50.0, 21.5; HRMS (ESI) Calculated for $C_{17}H_{17}NO_2S$ $[M+H]^+$: 300.1053, found 300.1043.



1c

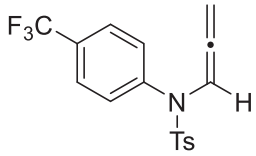
1c: 1.9 g (65% yield); Yellow solid; mp 39-42 ℃; IR (KBr) 3046, 2987, 1595, 1440, 1338, 1086, 935, 899, 811, 748, 660 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, *J* =

8.3 Hz, 2H), 7.31 (d, *J* = 8.2 Hz, 2H), 6.84 (t, *J* = 6.2 Hz, 1H), 5.31 (d, *J* = 6.3 Hz, 2H), 3.20 (q, *J* = 7.1 Hz, 2H), 2.43 (s, 3H), 1.11 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, cdcl$_3$) δ 201.1, 143.5, 135.6, 129.6, 127.0, 99.6, 87.3, 41.4, 21.5, 13.5; HRMS (ESI) Calculated for $C_{12}H_{15}NO_2S$ $[M+H]^+$: 238.0896, found 238.0891.



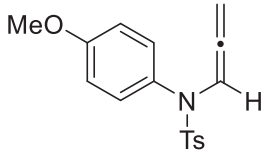
1d

1d: 3.5 g (80% yield); yellow solid; mp 79-80 ℃; IR (KBr) 3045, 1593, 1466, 1355, 1187, 1019, 823, 715, 662, 597 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.71 (d, *J* = 8.3 Hz, 2H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.25 (td, *J* = 7.7, 1.4 Hz, 1H), 7.11 (t, *J* = 6.2 Hz, 1H), 7.05 (td, *J* = 7.7, 1.5 Hz, 1H), 6.80 (dd, *J* = 7.9, 1.5 Hz, 1H), 5.03 (dd, *J* = 19.1, 6.2 Hz, 2H), 2.48 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 201.3, 144.2, 140.3, 139.9, 136.1, 130.3, 130.2, 129.7, 128.5, 127.9, 101.9, 87.7, 21.7; HRMS (ESI) Calculated for $C_{16}H_{14}INO_2S$ $[M+H]^+$: 411.9863, found 411.9861.



1e

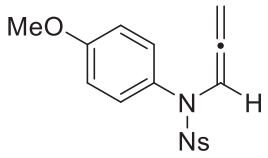
1e: 3.5 g (93% yield); gray solid; mp 84-85 ℃; IR (KBr) 3047, 2924, 1595, 1318, 1160, 1101, 1065, 944, 811, 644 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.58 (dd, *J* = 8.3, 4.6 Hz, 4H), 7.32 (d, *J* = 8.0 Hz, 2H), 7.18 (d, *J* = 8.3 Hz, 2H), 7.10 (t, *J* = 6.3 Hz, 1H), 5.09 (d, *J* = 6.3 Hz, 2H), 2.47 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 200.9, 144.4, 140.6, 134.9, 129.8, 127.6, 125.9, 101.8, 88.0, 21.6; HRMS (ESI) Calculated for $C_{17}H14F_3NO_2S$ $[M+H]^+$: 354.0254, found 354.0767.



1f

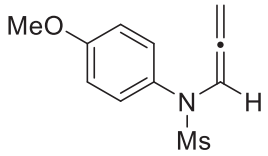
1f: 5.3 g (89% yield); yellow solid; mp 104-106 ℃; IR (KBr) 3061, 2958, 1597, 1503, 1348, 1233, 1158, 1089, 931, 834, 806, 662 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57

(d, J = 8.3 Hz, 2H), 7.28 (d, J = 8.1 Hz, 2H), 7.14 (t, J = 6.3 Hz, 1H), 6.91 (d, J = 9.0 Hz, 2H), 6.79 (d, J = 9.0 Hz, 2H), 5.03 (d, J = 6.3 Hz, 2H), 3.77 (s, 3H), 2.44 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.0, 159.5, 143.9, 135.2, 130.7, 129.5, 127.7, 113.9, 102.7, 87.5, 55.3, 21.5; HRMS (ESI) Calculated for $C_{17}H_{17}NO_3S$ $[M+H]^+$: 316.1002, found 316.0993.



1g

1g: 3.4 g (52% yield); yellow viscous oil; IR (KBr) 3102, 1545, 1515, 1374, 1253, 1174, 1144, 1035, 982, 850, 729 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.52 (m, 3H), 7.48 – 7.43 (m, 1H), 7.12 (t, J = 6.3 Hz, 1H), 7.01 – 6.96 (m, 2H), 6.76 – 6.71 (m, 2H), 5.03 (d, J = 6.3 Hz, 2H), 3.72 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.2, 159.8, 148.0, 133.9, 131.9, 131.4, 131.2, 128.3, 124.0, 114.2, 103.5, 88.2, 55.4; HRMS (ESI) Calculated for $C_{16}H_{14}N_2O_5S$ $[M+H]^+$: 347.0696, found 347.0693.

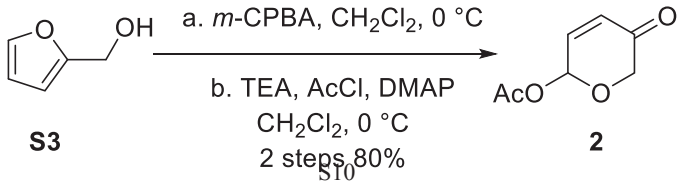


1h

1h: 4.3 g (88% yield); white solid; mp 96-98 ℃; IR (KBr) 3025, 1063, 1512, 1341, 1253, 1156, 988, 894, 759 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 – 7.16 (m, 2H), 6.89 (t, J = 6.3 Hz, 1H), 6.87 – 6.78 (m, 2H), 5.07 (d, J = 6.3 Hz, 2H), 3.74 (s, 3H), 2.92 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.7, 159.7, 130.4, 129.6, 114.4, 102.3, 87.7), 55.4, 38.0; HRMS (ESI) Calculated for $C_{11}H_{13}NO_3S$ $[M+H]^+$: 240.0689, found 240.0679.

PREPARATIONS OF OXIDOPYRYLIUMS 2.

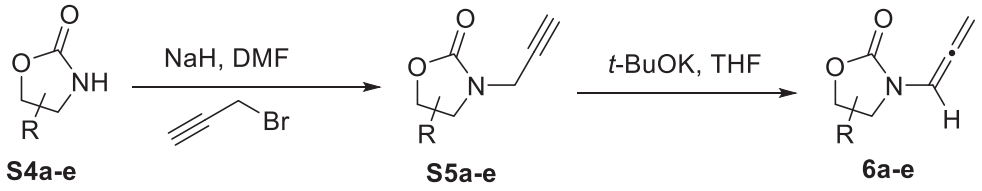
To a solution of 2-furfurylmethanol **S3** (7.0 g, 70.9 mmol) in CH_2Cl_2 (236 mL) was added 75% *m*-CPBA (21.6 g, 106.4 mmol, 1.5 equiv) at 0 ℃. The mixture was stirred



S3 **2**

for 5 h at the same temperature. The resultant white precipitates were removed by filtration and the filtrate was concentrated under reduced pressure. The obtained residue was diluted with CH_2Cl_2 (236 mL) at 0 ℃. TEA (12.2 g, 120.6 mmol, 1.7 equiv) and DMAP (433 mg, 3.5 mmol, 0.05 equiv) and AcCl (9.4 g, 120.6 mmol, 1.7 equiv) were successively added to the stirred solution at 0 ℃. The reaction was stirred at 0 ℃ for 0.5 h before being quenched with $NaHCO_3$ aqueous solution, and extracted three times with CH_2Cl_2.[2] The combined organic layers were washed with equal volume of sat aq NaCl and dried over anhydrous $MgSO_4$. After filtration and concentration under reduced pressure, the crude product was purified using silica gel flash column chromatography to give **2** (8.8 g, 80% yield); colourless oil; IR (KBr) 3455, 3087, 1745, 1374, 1224, 1177, 1000, 926 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 6.94 (dd, *J* = 10.4, 3.6 Hz, 1H), 6.49 (d, *J* = 3.6 Hz, 1H), 6.28 (d, *J* = 10.4 Hz, 1H), 4.51 (d, *J* = 17.0 Hz, 1H), 4.23 (d, *J* = 17.0 Hz, 1H), 2.15 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 193.3, 169.5, 142.2, 128.7, 86.5, 67.3, 20.9; HRMS (ESI) Calculated for $C_7H_8O_4$ $[M+H]^+$: 155.0350, found 155.0353.

PREPARATIONS OF *N*-OXAZOLIDINONE ALLENAMIDES 6a-e.

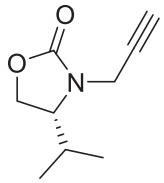


General Procedure for Synthesis of *N*-Oxazolidinone propargyl S5a-e Using 5a as an Example.

To a solution of (*R*)-4-isopropyl-2-oxazolidinone **S4a** (2.1 g, 16.2 mmol) in dry DMF (80 mL) and cooled to 0 ºC and NaH (777 mg, 19.4 mmol, 60 wt. % in mineral oil, 1.2 equiv) was added in one portion. After stirring for 25 minutes at 0 ºC, the corresponding propargyl bromide (2.8 g, 24.3 mmol, 1.5 equiv) was added and the mixture was stirred at room temperature for 16 h.[2] The resulting mixture was quenched with a saturated aqueous solution of NH_4Cl and extracted with Et_2O (3 × 40

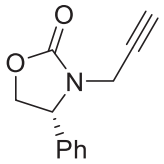
mL). The combined organic layers were washed with sat aq NaCl and dried over anhydrous $MgSO_4$. After filtration and concentration under reduced pressure, the crude product was purified using silica gel flash column chromatography to give the product **S5a** (2.1 g, 78% yield)**.**

CHARACTERIZATIONS OF *N*-OXAZOLIDINONE PROPARGYL S5a-e.



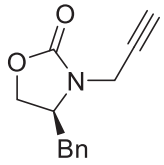
S5a

S5a: 2.1 g (78% yield); yellow oil; IR (KBr) 3235, 2965, 2875, 2117, 1739, 1431, 1410, 1254, 1090, 1037, 978 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 4.39 (dd, *J* = 17.8, 2.5 Hz, 1H), 4.26 (t, *J* = 8.9 Hz, 1H), 4.07 (dd, *J* = 8.8, 6.5 Hz, 1H), 3.93 – 3.90 (m, 1H), 3.75 (dd, *J* = 17.8, 2.4 Hz, 1H), 2.28 (t, *J* = 2.5 Hz, 1H), 2.18 – 2.09 (m, 1H), 0.93 (d, *J* = 7.0 Hz, 3H), 0.89 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.0, 73.1, 63.2, 58.7, 32.4, 27.5, 17.6, 14.6; HRMS (ESI) Calculated for $C_9H1_3NO_2$ $[M+H]^+$: 168.1019, found 168.1007.



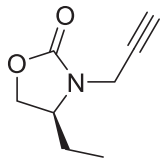
S5b

S5b: (*R*)-4-phenyl-2-oxazolidinone as starting material; 1.9 g (80% yield); yellow oil; IR (KBr) 3248, 2914, 1743, 1457, 1405, 1250, 1088, 859 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.47 – 7.41 (m, 3H), 7.36 (d, *J* = 6.9 Hz, 2H), 4.99 (t, *J* = 8.3 Hz, 1H), 4.69 (t, *J* = 8.8 Hz, 1H), 4.49 – 4.36 (m, 1H), 4.18 (t, *J* = 8.3 Hz, 1H), 3.41 (dd, *J* = 17.7, 2.3 Hz, 1H), 2.28 (t, *J* = 2.5 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 157.7, 136.6, 129.4, 129.3, 127.2, 76.6, 73.2, 69.9, 59.0, 32.0; HRMS (ESI) Calculated for $C_{12}H_{11}NO_2$ $[M+H]^+$: 202.0863, found 202.0850.



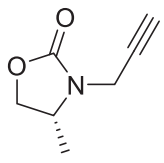
S5c

S5c: (*S*)-4-benzyl-2-oxazolidinone as starting material; 2.0 g (80% yield); yellow oil; IR (KBr) 3285, 3029, 2969, 1747, 1410, 1246, 1091, 884 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.35 (t, *J* = 7.4 Hz, 2H), 7.31 – 7.27 (m, 1H), 7.20 (d, *J* = 7.1 Hz, 2H), 4.43 (dd, *J* = 17.8, 2.5 Hz, 1H), 4.26 – 4.20 (m, 2H), 4.07 – 4.01 (m, 1H), 3.85 (dd, *J* = 17.8, 2.4 Hz, 1H), 3.24 (dd, *J* = 13.6, 4.0 Hz, 1H), 2.71 (dd, *J* = 13.5, 8.6 Hz, 1H), 2.37 (t, *J* = 2.5 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 157.7, 135.3, 129.1, 129.0, 127.3, 76.8, 73.4, 67.2, 55.6, 38.2, 32.4; HRMS (ESI) Calculated for $C_{13}H_{13}NO_2$ $[M+H]^+$: 216.1019, found 216.1016.



S5d

S5d: (*S*)-4-ethyl-2-oxazolidinone as starting material; 2.3 g (90% yield); yellow oil; $[\alpha]_D^{25}$: +55.6 (c 0.30, MeOH); IR (KBr) 3480, 3288, 2937, 1747, 1628, 1434, 1260, 1061, 1020 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.42 (t, *J* = 8.3 Hz, 1H), 4.37 (dd, *J* = 17.8, 2.5 Hz, 1H), 4.01 – 3.97 (m, 1H), 3.94 (ddd, *J* = 15.5, 8.0, 3.2 Hz, 1H), 3.79 (dd, *J* = 17.8, 2.4 Hz, 1H), 2.29 (t, *J* = 2.5 Hz, 1H), 1.87 – 1.81 (m, 1H), 1.64 – 1.54 (m, 1H), 0.94 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 157.8, 76.9, 73.0, 67.0, 55.3, 32.0, 24.2, 8.0; HRMS (ESI) Calculated for $C_8H_{11}NO_2$ $[M+H]^+$: 154.0863, found 154.0858.



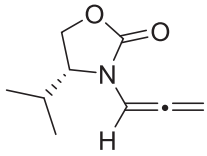
S5e

S5e: (*R*)-4-methyl-2-oxazolidinone as starting material; 2.1 g (78% yield); yellow oil; $[\alpha]_D^{25}$: -26.9 (c 1.86, MeOH); IR (KBr) 3249, 2973, 2912, 2118, 1732, 1411, 1254, 1189, 1092, 1048, 999 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 4.41 – 4.34 (m, 1H), 4.30 – 4.21 (m, 1H), 4.02 – 3.92 (m, 1H), 3.81 – 3.70 (m, 2H), 2.27 – 2.16 (m, 1H), 1.27 – 1.22 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 157.6, 76.9, 72.9, 69.1, 50.5, 31.6, 17.6; HRMS (ESI) Calculated for $C_7H_9NO_2$ $[M+H]^+$: 140.0706, found 140.0698.

General Procedure for Synthesis of *N*-Oxazolidinone allenamides 6a-e Using 6a as an Example.

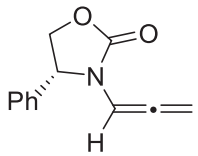
To a solution of (*R*)-4-isopropyl-3-(prop-2-yn-1-yl)-2-oxazolidinone (**S5a**) (2.0 g, 11.9 mmol) in THF (60 mL) was added *t*-BuOK (1.0 *M* solution in THF, 6 mL, 5.9 mmol, 0.5 equiv) at 0 °C. The reaction was stirred at rt for 1 h before being concentrated under reduced pressure. Subsequently, the residue was first suspended in Et_2O and then filtered though CeliteTM. The filtrate was concentrated under reduced pressure and the crude residue was purified using silica gel flash column chromatography to give the desired allenamide **6a** (1.4 g, 70% yield).

CHARACTERIZATIONS OF *N*-OXAZOLIDINONE ALLENAMIDES 6a-e.



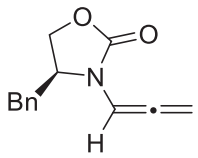
6a

6a: 1.4 g (70% yield); brown oil; IR (KBr) 2960, 1748, 1691, 1413, 1380, 1215, 1041 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 6.84 – 6.76 (m, 1H), 5.45 – 5.33 (m, 2H), 4.30 – 4.14 (m, 1H), 3.92 – 3.77 (m, 1H), 2.35 – 2.28 (m, 1H), 0.89 – 0.80 (m, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 201.3, 155.4, 95.6, 87.5, 63.0, 58.8, 26.9, 17.5, 13.7; HRMS (ESI) Calculated for $C_9H_{13}NO_2$ $[M+H]^+$: 168.1019, found 168.1009.



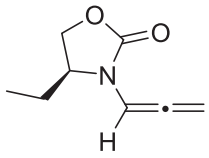
6b

6b: 1.6 g (87% yield); brown oil; IR (KBr) 3033, 2913, 1747, 1456, 1399, 1216, 1043, 879 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.41 – 7.32 (m, 3H), 7.28 – 7.23 (m, 2H), 6.92 – 6.65 (m, 1H), 5.25 – 5.14 (m, 1H), 4.96 – 4.83 (m, 2H), 4.75 – 4.69 (m, 1H), 4.21 – 4.14 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 201.9, 155.5, 138.4, 129.0, 128.7, 126.5, 95.5, 87.6, 70.5, 59.0; HRMS (ESI) Calculated for $C_{12}H_{11}NO_2$ $[M+H]^+$: 202.0863, found 202.0855.



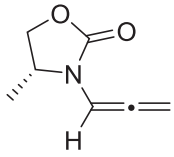
6c

6c: 1.5 g (75% yield); yellow oil; IR (KBr) 3030, 1758, 1505, 1458, 1470, 1234, 1035, 892 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.35 (t, *J* = 7.4 Hz, 2H), 7.29 (dd, *J* = 8.4, 6.3 Hz, 1H), 7.18 (d, *J* = 7.1 Hz, 2H), 6.93 (t, *J* = 6.5 Hz, 1H), 5.56 (ddd, *J* = 37.5, 10.0, 6.5 Hz, 2H), 4.26 (t, *J* = 8.6 Hz, 1H), 4.17 (dd, *J* = 8.9, 3.7 Hz, 1H), 4.15 – 4.10 (m, 1H), 3.26 (dd, *J* = 13.7, 3.2 Hz, 1H), 2.76 (dd, *J* = 13.7, 9.1 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 201.6, 154.9, 135.4, 129.3, 128.9, 127.3, 95.9, 88.0, 66.6, 55.6, 37.1; HRMS (ESI) Calculated for $C_{13}H_{13}NO_2$ $[M+H]^+$: 216.1019, found 216.1015.



6d

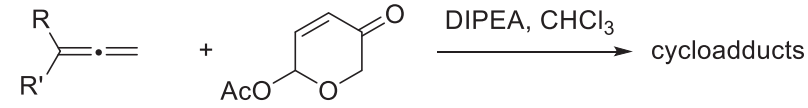
6d: 1.5 g (67% yield); yellow oil; $[\alpha]_D^{25}$: +34.2 (c 0.20, DCM); IR (KBr) 3036, 2970, 1747, 1462, 1409, 1221, 1118, 1061 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 6.74 (td, *J* = 6.5, 2.4 Hz, 1H), 5.42 – 5.31 (m, 2H), 4.37 (t, *J* = 8.7 Hz, 1H), 4.07 – 4.02 (m, 1H), 3.88 – 3.82 (m, 1H), 1.76 – 1.69 (m, 1H), 1.68 – 1.59 (m, 1H), 0.85 – 0.80 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 201.2, 155.2, 95.5, 87.4, 67.0, 55.2, 24.1, 7.2; HRMS (ESI) Calculated for $C_8H_{11}NO_2$ $[M+H]^+$: 154.0863, found 154.0865.



6e

6e: 1.5 g (70% yield); yellow oil; $[\alpha]_D^{25}$: -44.0 (c 1.20, DCM); IR (KBr) 3055, 2982, 1743, 1693, 1407, 1215, 1040, 950 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 6.73 (t, *J* = 6.5 Hz, 1H), 5.39 (dd, *J* = 10.0, 6.3 Hz, 1H), 5.32 (dd, *J* = 10.1, 6.2 Hz, 1H), 4.40 (dd, *J* = 8.1, 7.6 Hz, 1H), 3.96 – 3.87 (m, 2H), 1.28 – 1.26 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 201.3, 155.0, 95.6, 87.5, 69.4, 50.6, 18.7; HRMS (ESI) Calculated for $C_7H_9NO_2$ $[M+H]^+$: 140.0706, found 140.0699.

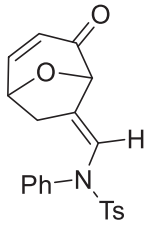
PREPARATIONS OF [5 + 2] CYCLOADDITION 3a-h AND 7a-e.



Generall Procedure for [5 + 2] Cycloaddition Using 3a As An Example.

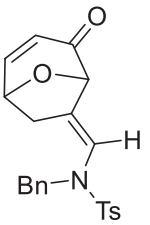
To a solution of allene **1a** (142 mg, 0.5 mmol) in dry $CHCl_3$ (2 mL) was added DIPEA (1.6 g, 12.5 mmol, 25.0 equiv) at rt. A solution of compound **2** (780 mg, 5.0 mmol, 10.0 equiv) in dry $CHCl_3$ (4 mL) was added to the above solution via syringe pump over 8 h. The reaction mixture was then quenched with a saturated aqueous solution of NH_4Cl and extracted with $CHCl_3$ (3 × 5 mL). The combined organic layers were washed with equal volume of sat aq NaCl and dried over anhydrous $MgSO_4$. After filtration and concentration under reduced pressure, the crude product was purified using silica gel flash column chromatography to give **3a** (114 mg, 60% yield).

CHARACTERIZATIONS OF [5 + 2] CYCLOADDITION 3a-h AND 7a-e.



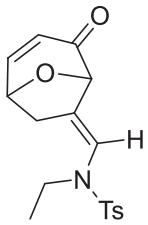
3a

3a: 114 mg (60% yield); yellow viscous oil; IR (KBr) 2918, 2253, 1744, 1686, 1491, 1354, 1166, 949, 803, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.46 (d, *J* = 8.3 Hz, 2H), 7.34 – 7.28 (m, 3H), 7.25 (t, *J* = 5.5 Hz, 2H), 7.06 (s, 1H), 7.02 – 6.98 (m, 2H), 6.98 – 6.92 (m, 1H), 5.87 (dd, *J* = 9.9, 1.2 Hz, 1H), 4.82 (s, 1H), 4.64 (dd, *J* = 6.8, 4.5 Hz, 1H), 2.42 (s, 3H), 1.97 (ddd, *J* = 15.8, 6.9, 2.6 Hz, 1H), 1.42 (d, *J* = 15.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.8, 151.2, 144.3, 138.0, 134.6, 129.7, 129.7, 129.0, 128.5, 127.6, 125.8, 125.2, 119.1, 84.5, 73.8, 31.6, 21.6; HRMS (ESI) Calculated for $C_{21}H_{19}NO_4S$ $[M+H]^+$: 382.1108, found 382.1096.



3b

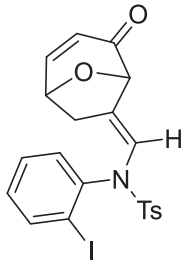
3b: 90 mg (49% yield); yellow viscous oil; IR (KBr) 2969, 1697, 1597, 1456, 1341, 1163, 1086, 942, 881, 814 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.3 Hz, 2H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.25 (dd, *J* = 5.2, 1.9 Hz, 3H), 7.20 – 7.13 (m, 2H), 6.94 (dd, *J* = 9.9, 4.5 Hz, 1H), 5.75 (dd, *J* = 9.9, 1.2 Hz, 1H), 5.64 (s, 1H), 4.79 – 4.70 (m, 2H), 4.28 (d, *J* = 13.8 Hz, 1H), 4.12 (d, *J* = 13.8 Hz, 1H), 2.60 (ddd, *J* = 15.9, 6.8, 2.7 Hz, 1H), 2.48 – 2.42 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.3, 151.1, 144.1, 139.3, 135.5, 134.3, 129.94, 128.6, 128.5, 127.8, 127.4, 125.6, 123.1, 83.6, 73.7, 54.1, 33.1, 21.5; HRMS (ESI) Calculated for $C_{22}H_{21}NO_4S$ $[M+H]^+$: 396.1264, found 396.1262.



3c

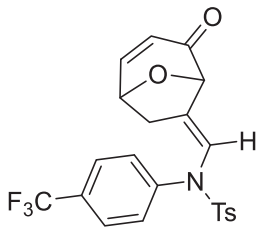
3c: 108 mg (55% yield); yellow viscous oil; IR (KBr) 2985, 2922, 1699, 1595, 1447, 1340, 1198, 1163, 1041, 855 cm^{-1}; ^1H NMR (400 MHz, CDCl3) δ 7.54 (d, *J* = 8.3 Hz,

2H), 7.30 (d, *J* = 8.1 Hz, 2H), 7.24 (dd, *J* = 9.9, 4.5 Hz, 1H), 6.00 (dd, *J* = 9.9, 1.2 Hz, 1H), 5.71 (s, 1H), 5.02 – 4.92 (m, 1H), 4.87 (s, 1H), 3.25 – 3.19 (m, 1H), 3.12 – 3.03 (m, 1H), 2.90 (ddd, *J* = 15.9, 6.5, 2.6 Hz, 1H), 2.82 (dd, *J* = 15.9, 0.9 Hz, 1H), 2.42 (s, 3H), 1.03 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, CDCl3) δ 192.6, 151.7, 143.8, 136.6, 134.4, 129.8, 127.2, 125.8, 123.2, 84.0, 73.9, 44.5, 33.2, 21.54, 13.8; HRMS (ESI) Calculated for $C_{17}H_{19}NO_4S$ $[M+H]^+$: 334.1108, found 334.1100.



3d

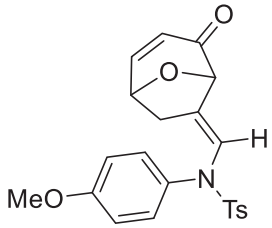
3d: 112 mg (65% yield); white solid; mp 190-192 ℃; IR (KBr) 2971, 2920s, 1683, 1595, 1467, 1360, 1173, 1146, 815, 808 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 – 7.77 (m, 1H), 7.58 (d, *J* = 8.1 Hz, 2H), 7.30 (d, *J* = 8.1 Hz, 4H), 7.14 – 7.02 (m, 2H), 6.96 (s, 1H), 5.92 (d, *J* = 9.2 Hz, 1H), 4.84 (s, 1H), 4.64 (dd, *J* = 6.7, 4.5 Hz, 1H), 2.44 (s, 3H), 1.92 (d, *J* = 13.7 Hz, 1H), 1.22 (d, *J* = 15.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.6, 150.8, 144.6, 140.2, 135.5, 132.2, 130.4, 129.9, 128.7, 128.0, 126.2, 123.7, 115.9, 84.9, 73.9, 31.2, 21.6; HRMS (ESI) Calculated for $C_{21}H_{18}INO_4S$ $[M+H]^+$: 508.0074, found 508.0094.



3e

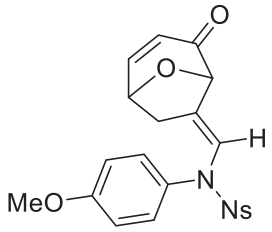
3e: 89 mg (50% yield); brown viscous oil; IR (KBr) 2919, 2657, 1698, 1606, 1359, 1330, 1177, 1127, 944, 806 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.5 Hz, 2H), 7.39 (d, *J* = 8.2 Hz, 2H), 7.21 (d, *J* = 8.2 Hz, 2H), 7.13 (d, *J* = 8.4 Hz, 2H), 6.97 (dd, *J* = 9.9, 4.5 Hz, 1H), 6.90 (s, 1H), 5.81 (d, *J* = 9.9 Hz, 1H), 4.78 (s, 1H), 4.64 (dd, *J* = 6.8, 4.5 Hz, 1H), 2.35 (s, 3H), 1.99 (ddd, *J* = 15.7, 6.9, 2.5 Hz, 1H), 1.52 (d, *J* =

15.8 Hz, 1H). ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.4, 151.4, 144.8, 141.8, 134.1, 132.5, 129.9, 129.1, 127.4, 126.2, 125.7, 124.6, 123.5, 84.2, 73.7, 32.2, 21.5; HRMS (ESI) Calculated for $C_{22}H_{18}F_3NO_4S$ $[M+H]^+$: 450.0987, found 450.0987.



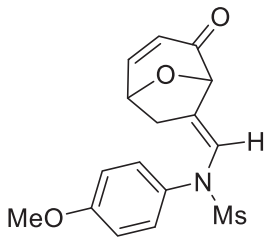
3f

3f: 135 mg (74% yield); yellow viscous oil; IR (KBr) 2919, 2840, 1686, 1598, 1500, 1341, 1244, 1162, 1085, 1024, 797 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (d, *J* = 8.3 Hz, 2H), 7.25 (d, *J* = 8.1 Hz, 2H), 7.08 (s, 1H), 6.97 (dd, *J* = 9.9, 4.5 Hz, 1H), 6.92 – 6.87 (m, 2H), 6.81 – 6.77 (m, 2H), 5.87 (dd, *J* = 9.9, 1.3 Hz, 1H), 4.80 (s, 1H), 4.64 (dd, *J* = 6.8, 4.5 Hz, 1H), 3.81 (s, 3H), 2.42 (s, 3H), 1.98 (ddd, *J* = 15.8, 7.0, 2.6 Hz, 1H), 1.49 – 1.36 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.9, 159.5, 151.1, 144.2, 134.7, 131.2, 130.1, 129.6, 127.6, 125.8, 125.4, 117.0, 114.1, 84.6, 73.8, 55.4, 31.6, 21.6; HRMS (ESI) Calculated for $C_{22}H_{21}NO_5S$ $[M+H]^+$: 412.1213, found 412.1209.



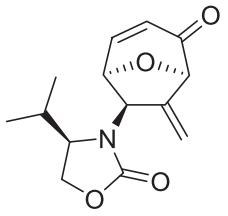
3g

3g: 89 mg (50% yield); yellow viscous oil; IR (KBr) 2931, 1695, 1515, 1344, 1250, 1156, 1035, 973, 803 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 – 7.20 (m, 2H), 7.06 (s, 1H), 7.02 (dd, *J* = 9.9, 4.5 Hz, 1H), 6.94 – 6.89 (m, 2H), 5.92 (dd, *J* = 9.9, 1.3 Hz, 1H), 4.85 – 4.78 (m, 1H), 4.69 (dd, *J* = 6.6, 4.5 Hz, 1H), 3.84 (s, 3H), 2.95 (s, 3H), 2.07 – 2.00 (m, 1H), 1.44 (d, *J* = 15.7 Hz, 1H)**;** ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.91, 159.82, 151.20, 130.99, 129.91, 125.91, 124.99, 116.62, 114.69, 84.73, 73.89, 55.56, 38.17, 31.55; HRMS (ESI) Calculated for $C_{16}H_{17}NO_5S$ $[M+H]^+$: 336.0900, found 336.0907.



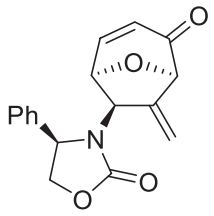
3h

3h: 108 mg (55% yield) brown viscous oil; IR (KBr) 2916, 2578, 1698, 1545, 1515, 1374, 1250, 1174, 1035, 741 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.73 – 7.69 (m, 1H), 7.65 (dd, *J* = 7.9, 0.9 Hz, 1H), 7.56 - 7.51 (m, 2H), 7.18 (s, 1H), 7.07 (d, *J* = 8.9 Hz, 2H), 7.00 (dd, *J* = 9.9, 4.5 Hz, 1H), 6.81 (d, *J* = 8.9 Hz, 2H), 5.90 (dd, *J* = 9.9, 1.0 Hz, 1H), 4.88 (s, 1H), 4.67 (dd, *J* = 6.8, 4.5 Hz, 1H), 3.81 (s, 3H), 1.99 (ddd, *J* = 15.7, 6.9, 2.5 Hz, 1H), 1.45 (d, *J* = 15.7 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.7, 160.0, 151.0, 147.9, 134.4, 132.2, 131.7, 131.4, 130.6, 128.5, 125.8, 125.2, 124.2, 114.4, 84.7, 73.9, 55.5, 31.4; HRMS (ESI) Calculated for $C_{21}H_{18}N_2O_7S$ $[M+H]^+$: 443.0907, found 3443.0900.



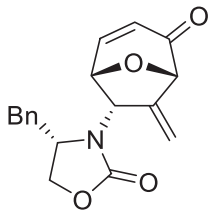
7a

7a: 198 mg (90% yield); white solid; mp 150-151 ℃; $[\alpha]_D^{25}$: -19.3 (c 0.10, MeOH); IR (KBr) 2952, 2929, 1741, 1688, 1484, 1421, 1240, 1046 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.30 (dd, *J* = 10.0, 4.5 Hz, 1H), 6.12 (dd, *J* = 10.0, 1.2 Hz, 1H), 5.61 (s, 1H), 5.39 (s, 1H), 5.21 – 5.16 (m, 1H), 4.87 – 4.80 (m, 2H), 4.20 – 4.17 (m, 1H), 4.17 – 4.15 (m, 1H), 3.84 – 3.79 (m, 1H), 2.19 – 2.13 (m, 1H), 0.95 (d, *J* = 6.8 Hz, 3H), 0.86 (d, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.9, 157.6, 149.3, 139.8, 128.1, 113.7, 85.2, 74.7, 62.7, 61.36, 58.7, 28.0, 18.1, 14.0; HRMS (ESI) Calculated for $C_{14}H_{17}NO_4$ $[M+H]^+$: 264.1230, found 264.1218.



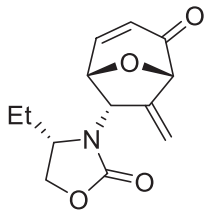
7b

7b: 167 mg (81% yield); yellow viscous oil; $[\alpha]_D^{25}$: +63.1 (c 0.28, MeOH); IR (KBr) 2982, 2936, 1748, 1691, 1473, 1413, 1215, 1040, 829, 704 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.45 – 7.40 (m, 3H), 7.30 (dd, *J* = 10.0, 4.6 Hz, 1H), 7.28 – 7.23 (m, 2H), 6.20 (dd, *J* = 10.0, 1.2 Hz, 1H), 5.42 (s, 1H), 5.05 (dd, *J* = 5.9, 4.8 Hz, 1H), 4.87 – 4.82 (m, 1H), 4.81 (d, *J* = 1.0 Hz, 1H), 4.79 (dd, *J* = 8.3, 3.2 Hz, 1H), 4.71 (s, 1H), 4.57 (t, *J* = 8.5 Hz, 1H), 4.18 (dd, *J* = 8.7, 3.2 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.7, 157.5, 149.9, 139.6, 138.0, 129.6, 129.3, 128.7, 126.1, 116.2, 85.6, 74.9, 70.8, 60.8, 58.4; HRMS (ESI) Calculated for $C_{17}H_{15}NO_4$ $[M+H]^+$: 298.1074, found 298.1068.



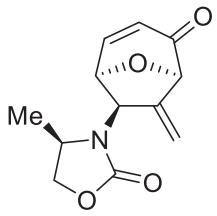
7c

7c: 190 mg (94% yield); yellow viscous oil; $[\alpha]_D^{25}$: -285.5 (c 0.48, MeOH); IR (KBr) 2974, 2249, 1741, 1691, 1411, 1348, 1090, 891 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.48 (dd, *J* = 10.0, 4.6 Hz, 1H), 7.29 (t, *J* = 3.7 Hz, 2H), 7.26 (dd, *J* = 4.9, 3.6 Hz, 1H), 7.08 – 7.01 (m, 2H), 6.24 (dd, *J* = 10.0, 1.2 Hz, 1H), 5.64 (d, *J* = 0.5 Hz, 1H), 5.53 (s, 1H), 5.28 – 5.21 (m, 1H), 4.99 (dd, *J* = 6.3, 4.7 Hz, 1H), 4.88 (d, *J* = 1.0 Hz, 1H), 4.04 – 3.98 (m, 3H), 3.24 – 3.16 (m, 1H), 2.54 – 2.45 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.6, 158.2, 149.1, 139.8, 135.2, 129.0, 128.7, 128.5, 127.3, 114.1, 85.0, 73.9, 66.6, 59.2, 57.8, 38.9; HRMS (ESI) Calculated for $C_{18}H_{17}NO_4$ $[M+H]^+$: 312.1230, found 312.1219.



7d

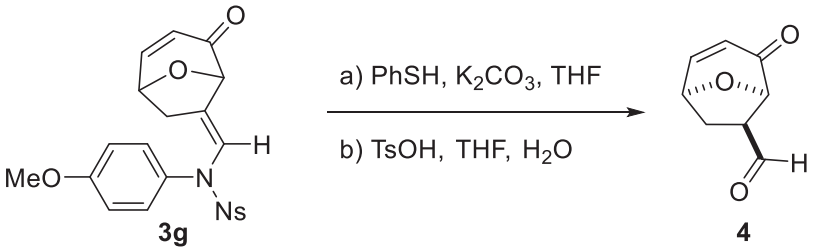
7d: 209 mg (92% yield); yellow solid; mp 146-147 ℃; $[\alpha]_D^{25}$: -45.1 (c 0.14, MeOH); IR (KBr) 2972, 1731, 1692, 1420, 1228, 1107, 1017 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.34 (dd, *J* = 10.0, 4.5 Hz, 1H), 6.13 (dd, *J* = 10.0, 1.2 Hz, 1H), 5.61 (s, 1H), 5.42 (d, *J* = 0.7 Hz, 1H), 5.11 – 5.05 (m, 2H), 4.86 (d, *J* = 1.2 Hz, 1H), 4.34 (t, *J* = 8.3 Hz, 1H), 4.03 (dd, *J* = 8.6, 4.9 Hz, 1H), 3.75 – 3.69 (m, 1H), 1.83 – 1.75 (m, 1H), 1.49 – 1.41 (m, 1H), 0.84 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.8, 158.1, 148.9, 139.8, 128.4, 114.0, 85.2, 74.2, 67.1, 58.7, 58.0, 25.5, 8.7; HRMS (ESI) Calculated for $C_{13}H_{15}NO_4$ $[M+H]^+$: 250.1074, found 250.1069.



7e

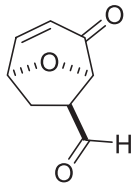
7e: 205 mg (87% yield); white solid; mp 143-144 ℃; $[\alpha]_D^{25}$: -52.3 (c 0.12, MeOH); IR (KBr) 2999, 2947, 1719, 1691, 1487, 1417, 1254, 1131, 1037 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.34 (dd, *J* = 10.0, 4.6 Hz, 1H), 6.15 (dd, *J* = 10.0, 1.0 Hz, 1H), 5.62 (s, 1H), 5.45 (s, 1H), 5.21 – 5.14 (m, 1H), 5.05 – 4.99 (m, 1H), 4.87 (s, 1H), 4.36 (t, *J* = 7.7 Hz, 1H), 3.91 (ddt, *J* = 13.5, 7.9, 5.8 Hz, 2H), 1.22 (d, *J* = 6.0 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.8, 158.3, 148.8, 139.6, 128.6, 114.3, 85.1, 74.0, 69.1, 58.8, 52.7, 19.5; HRMS (ESI) Calculated for $C_{12}H_{13}NO_4$ $[M+H]^+$: 236.0917, found 236.0910.

PREPARATIONS OF 4-Oxo-8-oxabicyclo[3.2.1]oct-2-ene-6-carbaldehyde 4.



To a solution of **3g** (50 mg, 0.11 mmol) in THF (1 mL) was added K_2CO_3 (30.40 mg, 0.22 mmol, 2.0 equiv), and then PhSH (24.23 mg, 0.22 mmol, 2.0 equiv) was added at rt. The reaction was stirred at rt for 3 h and monitored by TLC before being filtered though CeliteTM. Subsequently, the filtrate was added TsOH (9.50 mg, 0.05 mmol, 0.5 equiv), H_2O (0.1 mL). The reaction was stirred at rt for 8 h before being quenched with aq $NaHCO_3$ and extracted with Et_2O, dried over anhydrous $MgSO_4$. After filtration and concentration under reduced pressure, the crude product was purified using silica gel flash column chromatography to give **4** (11 mg, 71% yield).

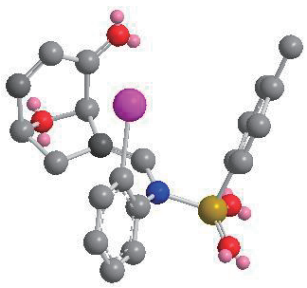
CHARACTERIZATIONS OF 4.



4

4: 11 mg (71% yield); colourless oil; IR (KBr) 2950, 2750, 1669, 1075, 1037 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 9.79 (d, J = 1.6 Hz, 1H), 7.34 (dd, J = 9.9, 4.6 Hz, 1H), 6.05 (dd, J = 9.9, 1.0 Hz, 1H), 4.95 (dd, J = 6.9, 4.6 Hz, 1H), 4.83 (s, 1H), 2.98 – 2.89 (m, 1H), 2.54 – 2.49 (m, 1H), 2.09 (dd, J = 12.5, 9.2 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 197.5, 194.5, 153.1, 126.0, 81.6, 73.7, 50.8, 29.8; HRMS (ESI) Calculated for $C_8H_8O_3$ $[M+H]^+$: 153.0546, found 153.0555.

CRYSTALLOGRAPHIC DATA OF 3a .

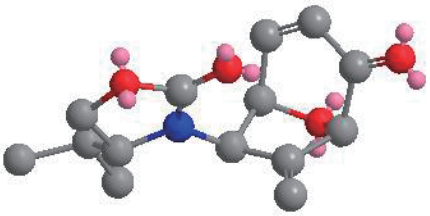


Supplementary Figure 1. X-ray structure of **3a** (dimer in a unit cell).

Identification code	exp_5562
Empirical formula	$C_{21}H_{18}INO_4S$
Formula weight	507.32
Temperature / K	108.90(14)
Crystal system	monoclinic
Space group	$P2_1/n$
a / Å, b / Å, c / Å	9.5291(4), 11.4617(3), 18.1649(5)
α/°, β/°, γ/°	90.00, 95.358(3), 90.00
Volume / Å^3	1975.29(11)
Z	4
ρ_{calc} / mg mm^{-3}	1.706
μ / mm^{-1}	13.964
F(000)	1008
Crystal size / mm^3	0.14 × 0.14 × 0.13
2Θ range for data collection	9.14 to 142.18°
Index ranges	$-11 \leq h \leq 11$, $-13 \leq k \leq 13$, $-22 \leq l \leq 15$
Reflections collected	7301
Independent reflections	3724[R(int) = 0.0444 (inf-0.9Å)]
Data/restraints/parameters	3724/12/254
Goodness-of-fit on F^2	1.076
Final R indexes [$I>2\sigma(I)$ i.e. $F_o>4\sigma(F_o)$]	$R_1 = 0.0417$, $wR_2 = 0.1026$
Final R indexes [all data]	$R_1 = 0.0463$, $wR_2 = 0.1067$
Largest diff. peak/hole / e Å^{-3}	2.237/-1.322

Flack Parameters	N
Completeness	0.9992

CRYSTALLOGRAPHIC DATA OF 7a .



Supplementary Figure 1. X-ray structure of **7a**.

Identification code	exp_5648
Empirical formula	$C_{14}H_{17}NO_4$
Formula weight	263.29
Temperature / K	107.65(10)
Crystal system	monoclinic
Space group	$P2_1$
a / Å, b / Å, c / Å	8.5560(8), 8.0464(6), 10.0674(6)
α/°, β/°, γ/°	90.00, 109.133(8), 90.00
Volume / $Å^3$	654.80(9)
Z	2
ρ_{calc} / mg mm^{-3}	1.335
μ / mm^{-1}	0.098
F(000)	280
Crystal size / mm^3	0.25 × 0.23 × 0.14
2Θ range for data collection	6.64 to 52°
Index ranges	$-9 \leq h \leq 10$, $-9 \leq k \leq 9$, $-12 \leq l \leq 12$

Reflections collected	4612
Independent reflections	2580[R(int) = 0.0295 (inf-0.9Å)]
Data/restraints/parameters	2580/1/174
Goodness-of-fit on F^2	1.056
Final R indexes [I>2σ (I) i.e. F_o>4σ (F_o)]	R_1 = 0.0382, wR_2 = 0.0806
Final R indexes [all data]	R_1 = 0.0444, wR_2 = 0.0853
Largest diff. peak/hole / e $Å^{-3}$	0.127/-0.161
Flack Parameters	-0.2(11)
Completeness	0.9972

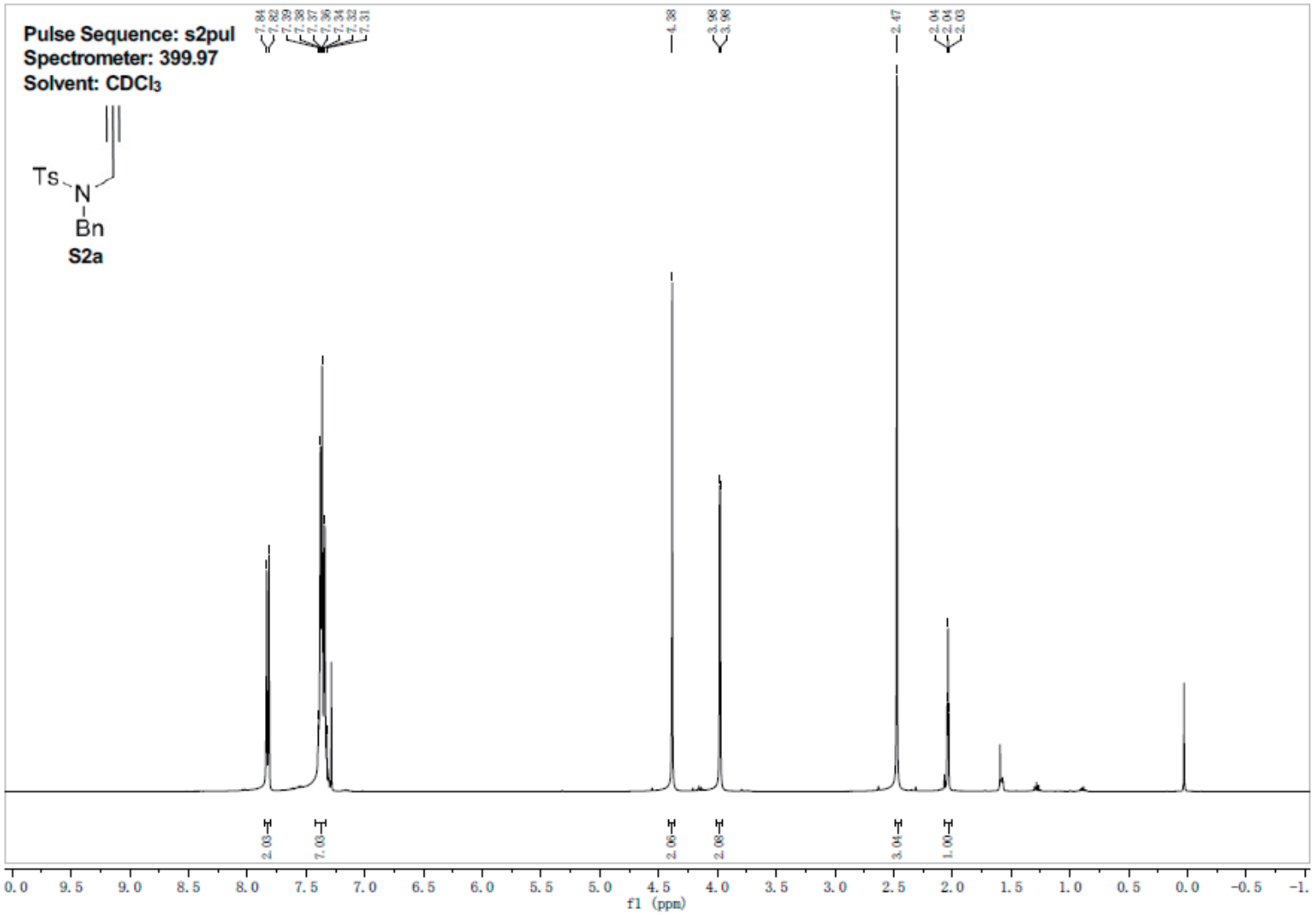
REFERENCES

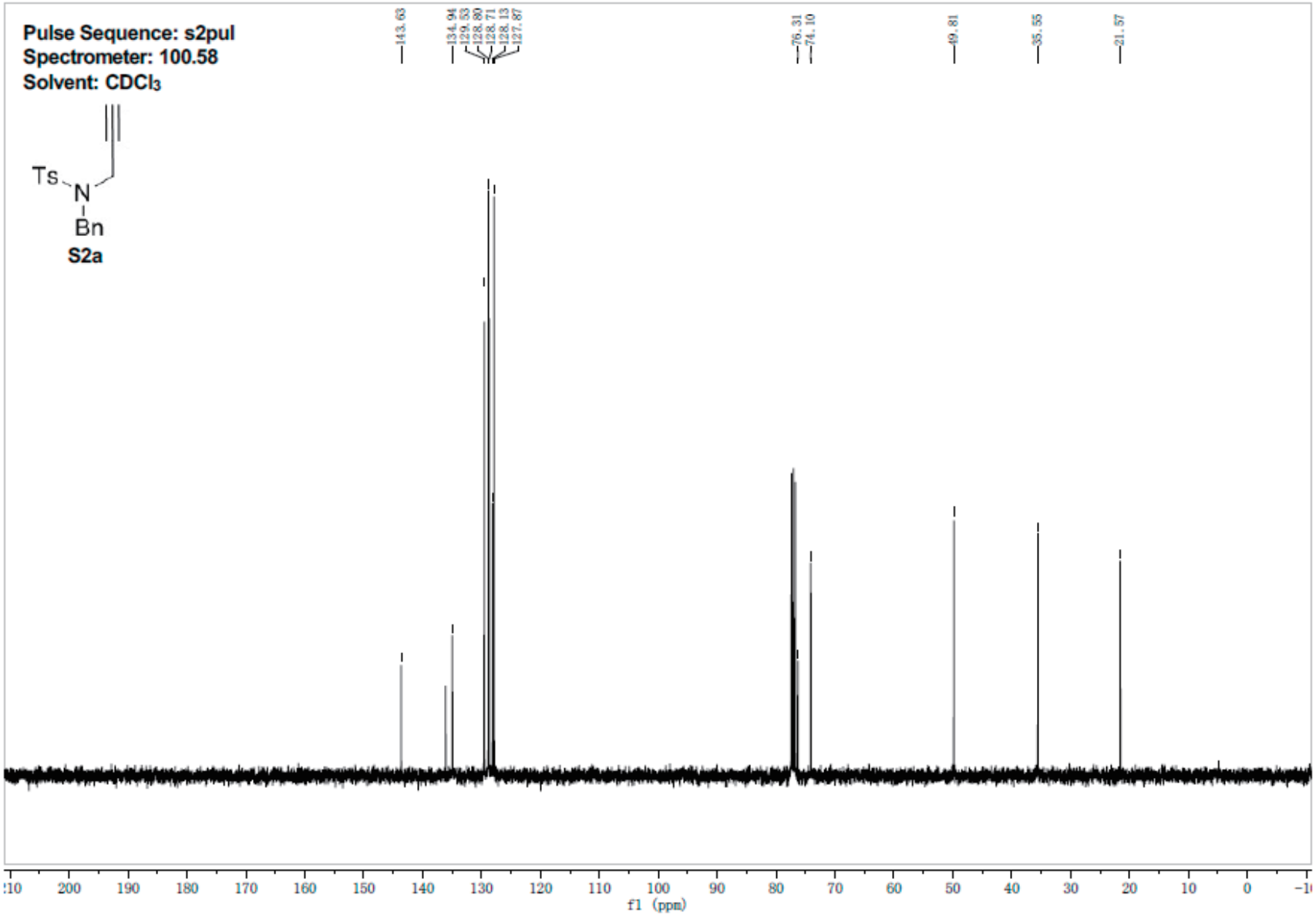
1. (a) H. Xiong, R. P. Hsung, L.-L. Wei, C. R. Berry, J. A. Mulder, and B. Stockwell, *Org. Lett*., 2000, **2**, 2869; (b) S.-Z. He, R. P. Hsung, W. R. Presser, Z.-X. Ma, and B. J. Haugen, *Org. Lett*., 2014, **16**, 2180; (c) R. Blieck, L. A. Perego, C. Ilaria, G. Laurence, T. Marc, and M. Florian, *Synthesis*, 2019, **51**, 1225.

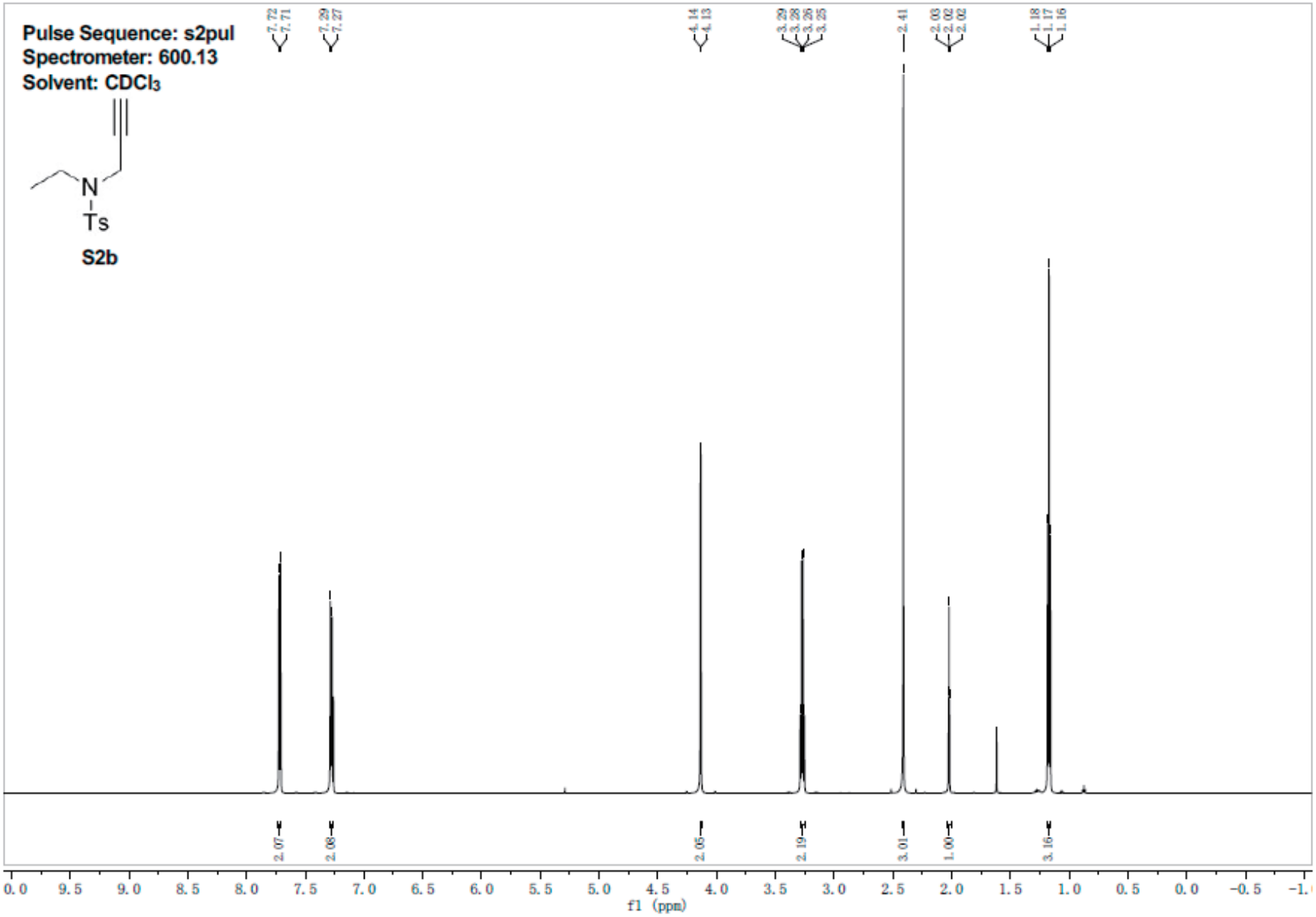
2. N. Ryohei, K. Mayumi, M. Hiroaki, M. Noritada, and T. Yoo, *Tetrahedron Lett*., 2008, **49**, 4509.

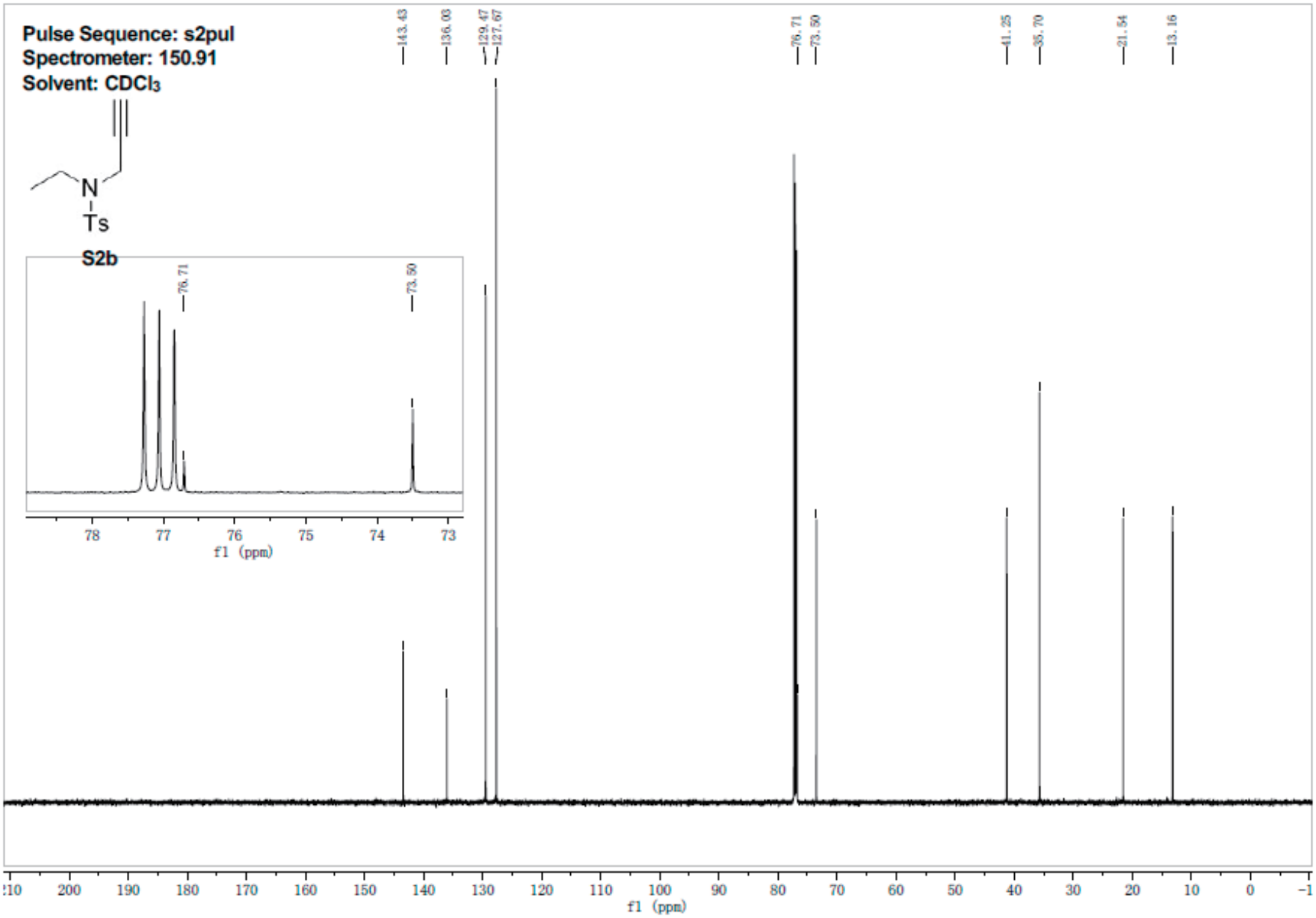
3. (a) Y. Masahiro, M. Yohei, and S. Kozo, *Tetrahedron*, 2012, **68**, 9962; (b) S. Kim and S. H. Hong, *Advanced Synthesis & Catalysis*., 2015, **357**, 1004.

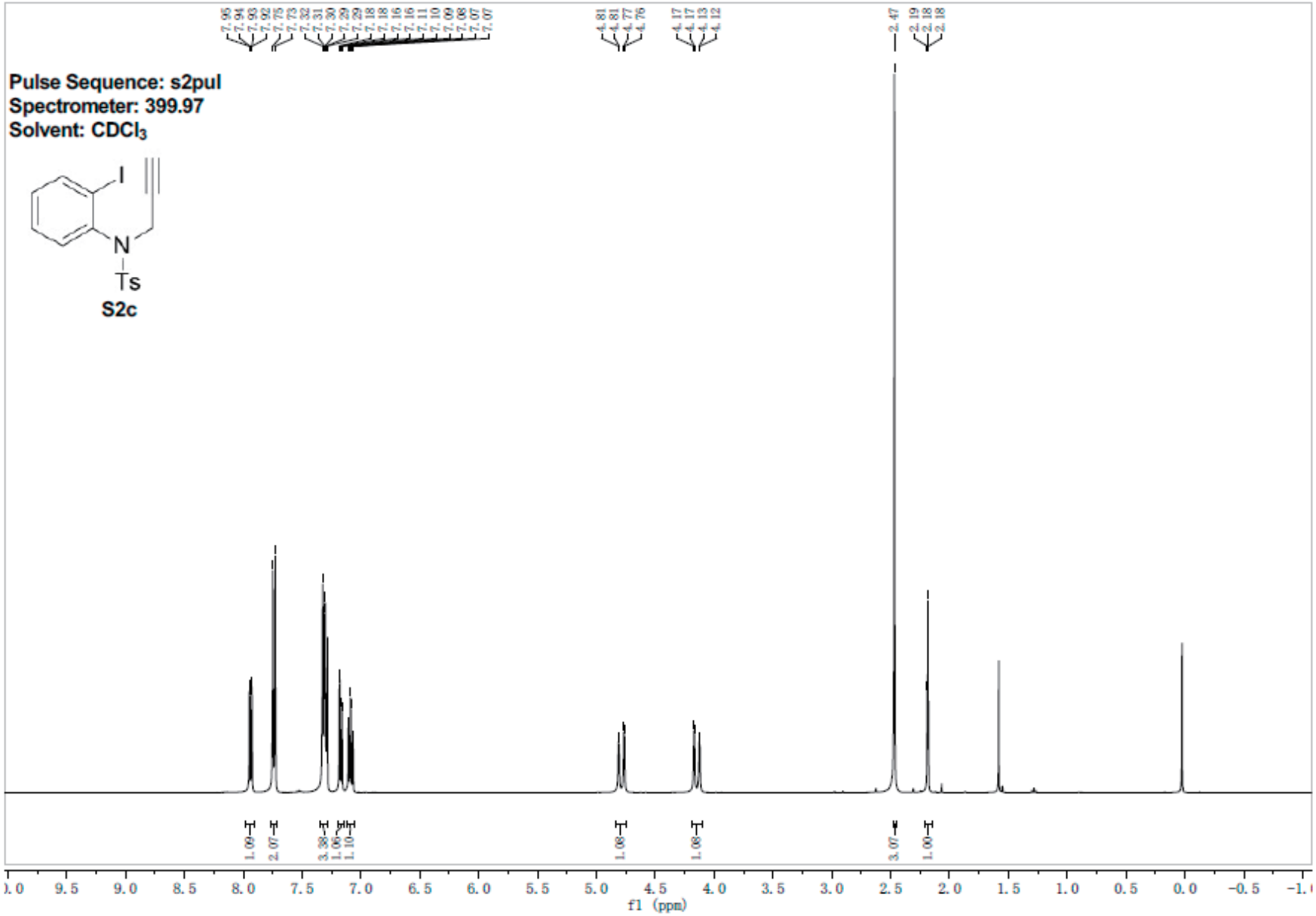
NMR SPECTRA

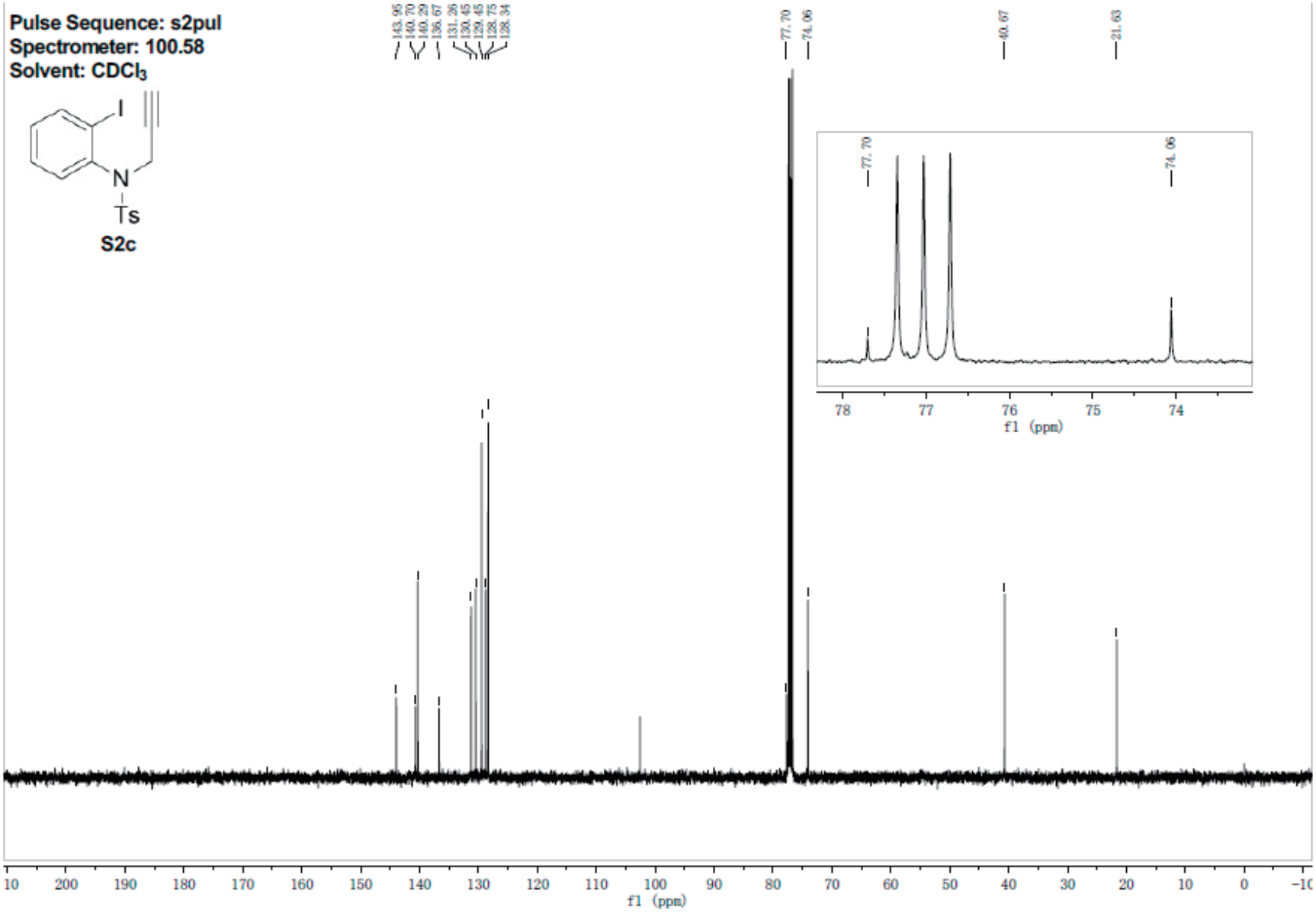

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
Ts
N
Bn
S2a
7.84
7.82
7.39
7.38
7.37
7.36
7.34
7.32
7.31
4.38
3.98
3.98
2.47
2.04
2.04
2.03
2.03
7.00
2.06
2.08
3.04
1.00
f1 (ppm)

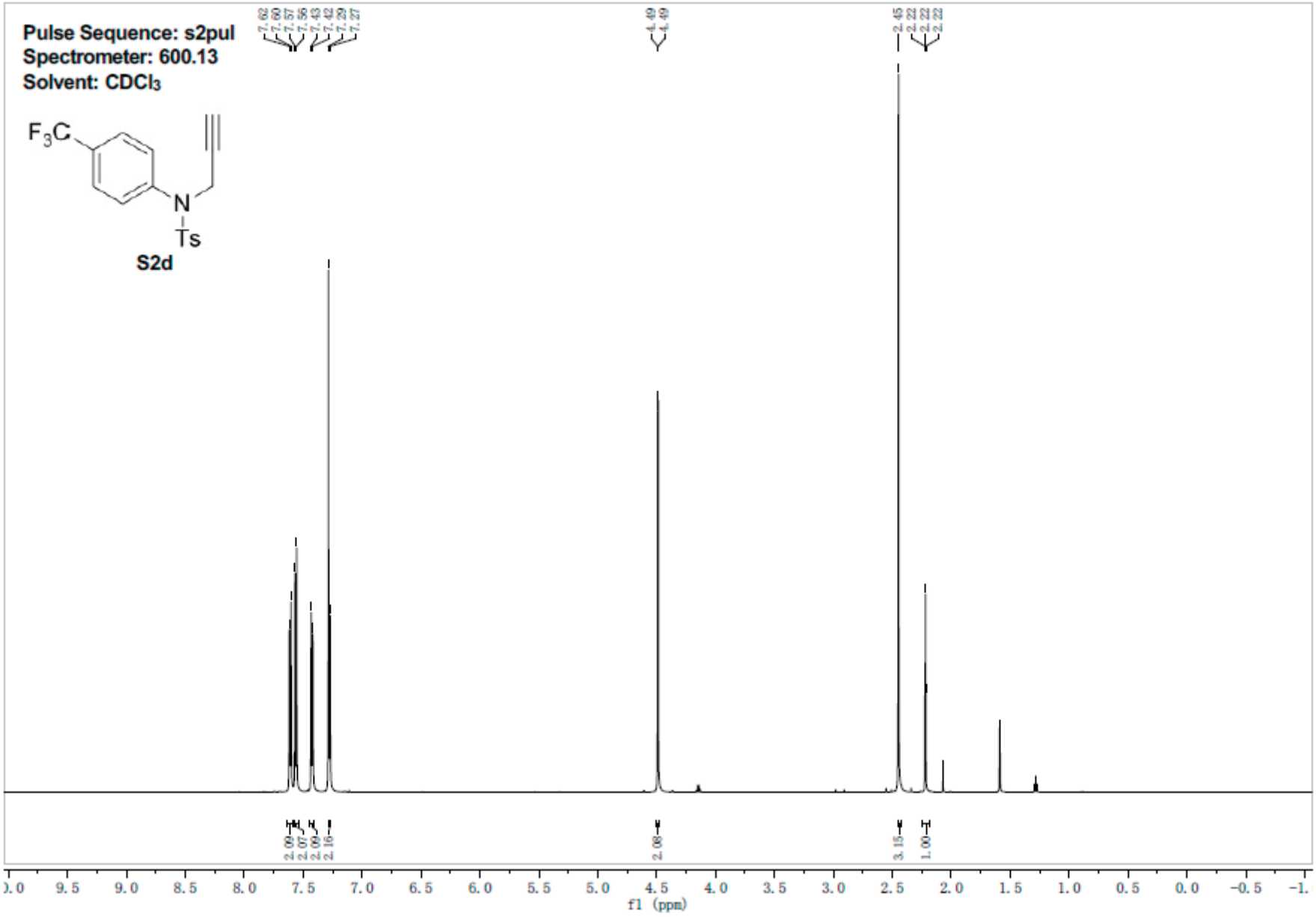

Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
Ts
N
Bn
S2a
143.63
134.94
129.53
128.80
128.71
128.13
127.87
76.31
74.10
69.81
35.55
21.57
f1 (ppm)

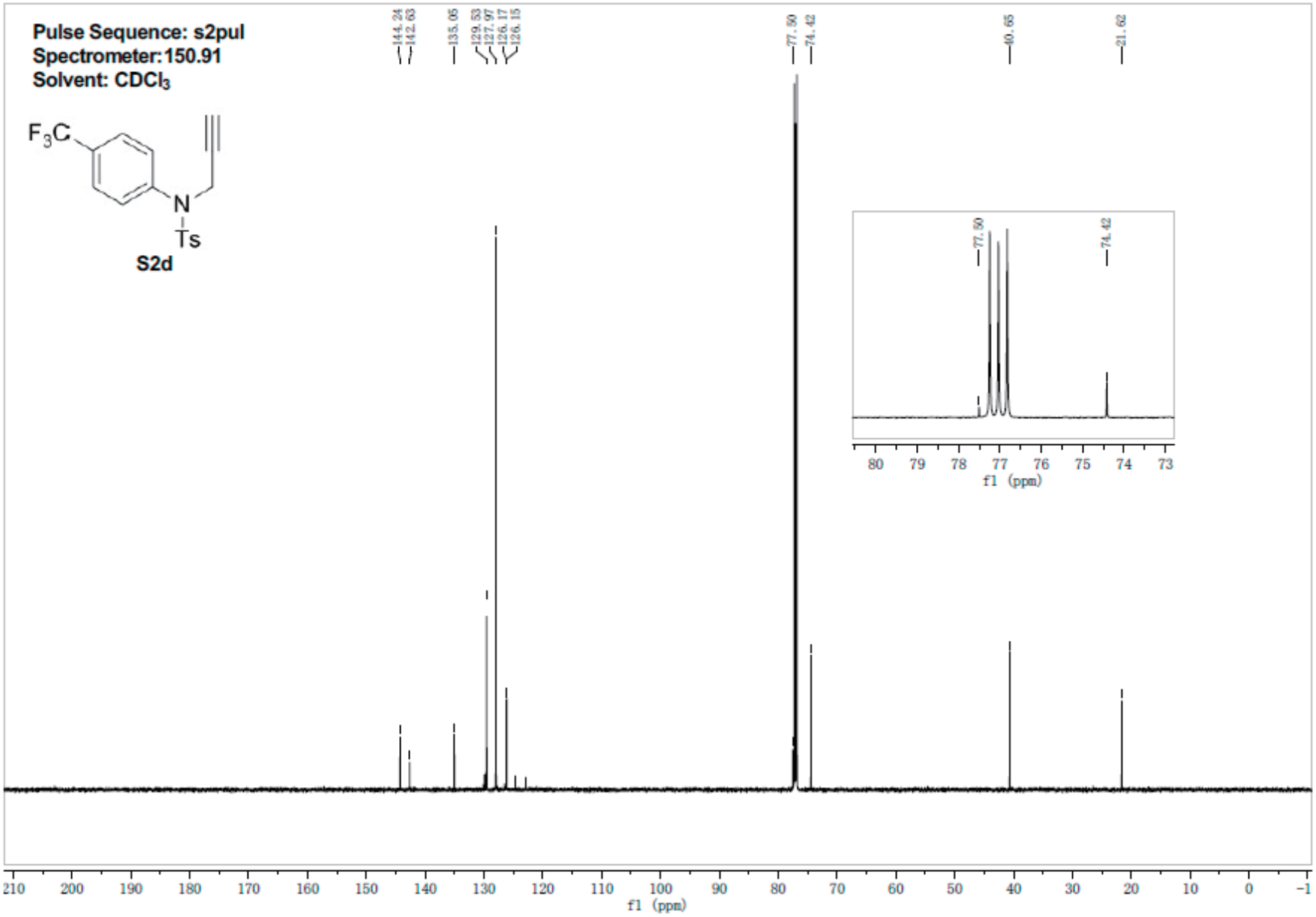

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
N
Ts
S2b
7.72
7.71
7.29
7.27
4.14
4.13
3.29
3.28
3.26
3.25
2.41
2.03
2.02
2.02
1.18
1.17
1.16
2.07
2.08
2.05
2.19
3.01
1.00
3.16
f1 (ppm)

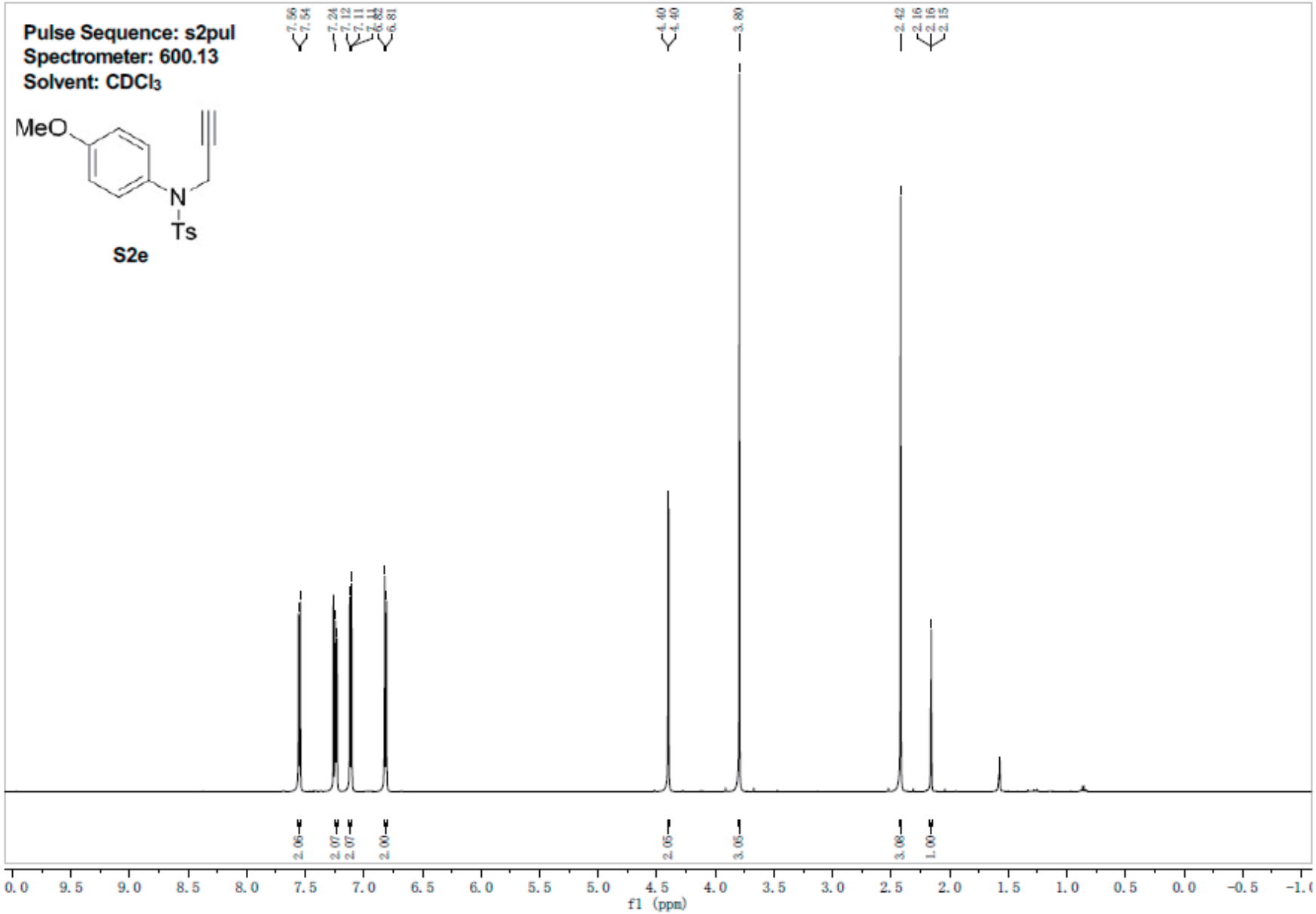

Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
N
Ts
S2b
143.43
136.03
129.47
127.67
76.71
73.50
41.25
35.70
21.54
13.16
f1 (ppm)

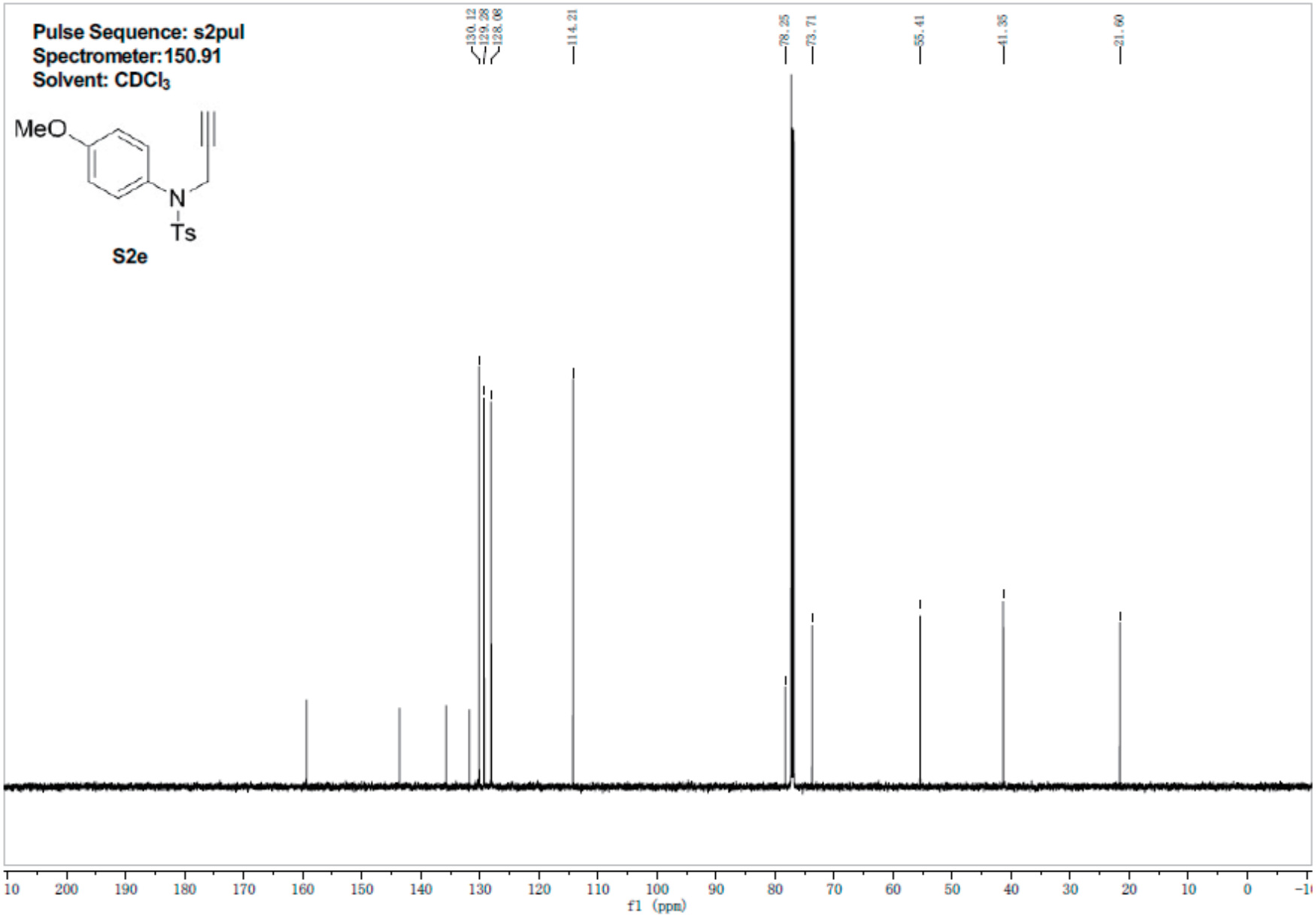

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
I
N
Ts
S2c
f1 (ppm)

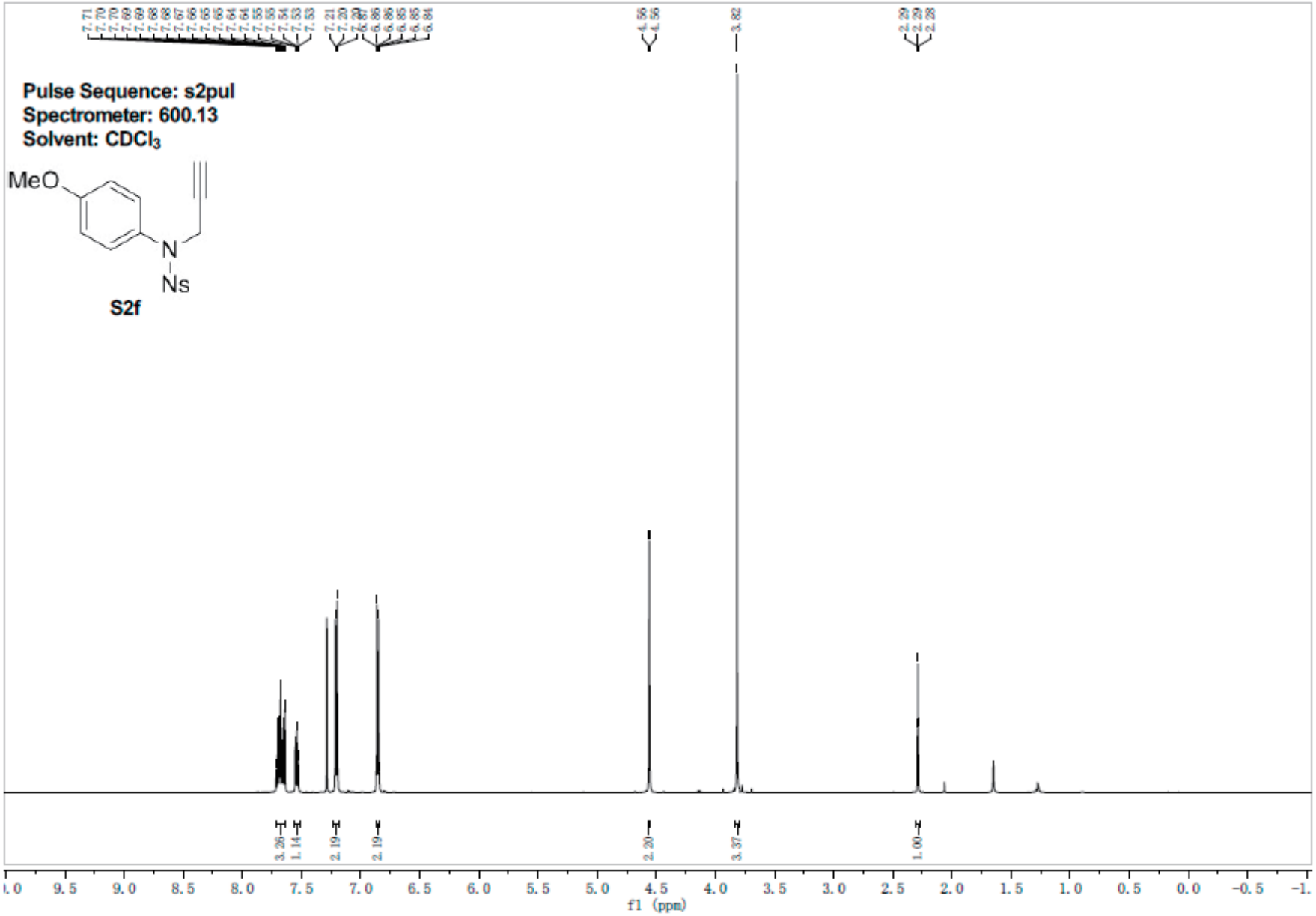

Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
I
N
Ts
S2c
143.95
140.70
140.29
136.67
131.26
130.45
129.45
128.75
128.34
77.70
74.06
40.67
21.63
77.70
74.06
78
77
76
75
74
f1 (ppm)
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

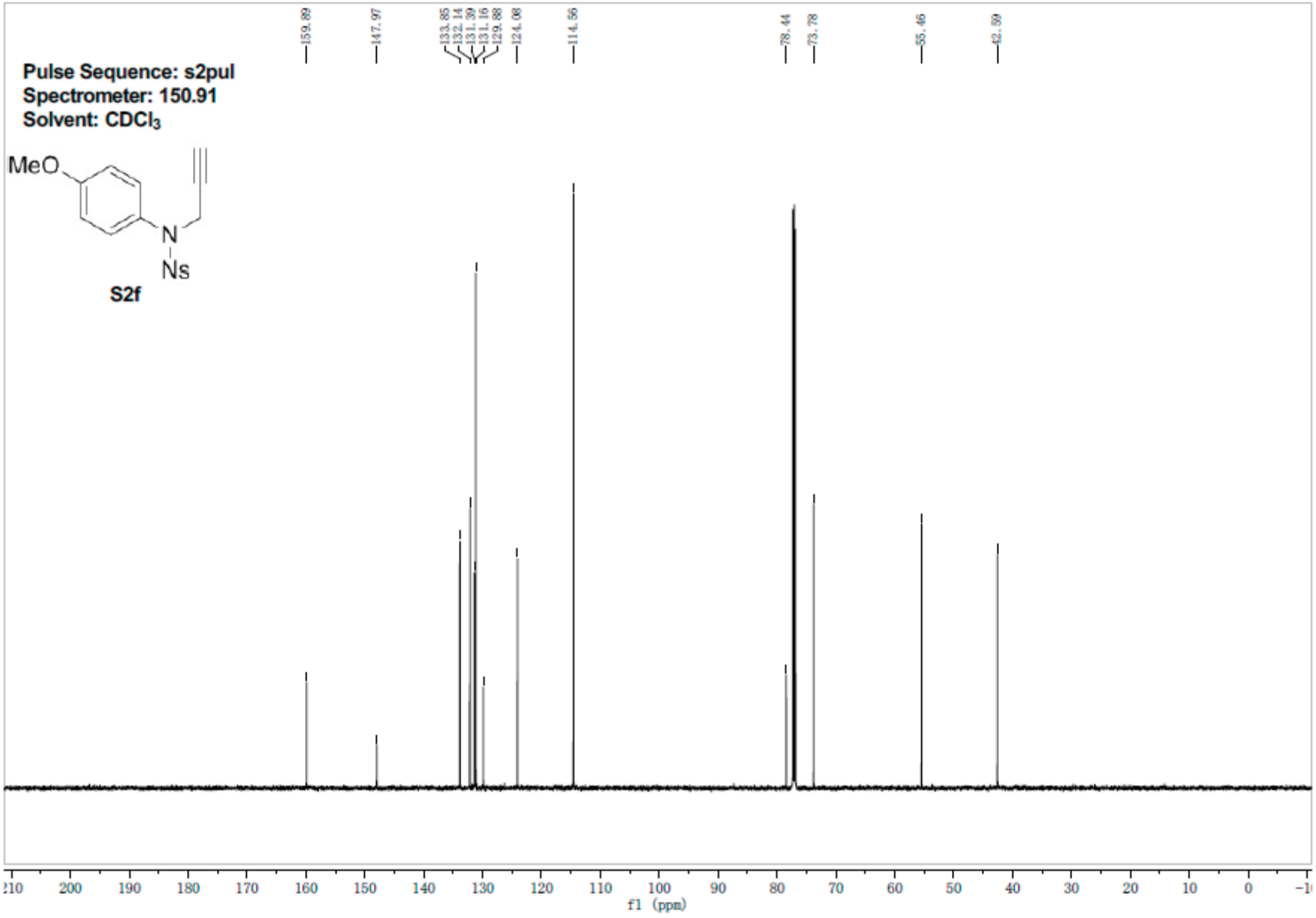

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
F3C
N
Ts
S2d
7.62
7.60
7.57
7.56
7.43
7.42
7.29
7.27
4.49
4.49
2.45
2.22
2.22
2.22
2.22
2.09
2.07
2.09
2.16
2.08
3.15
1.00
f1 (ppm)

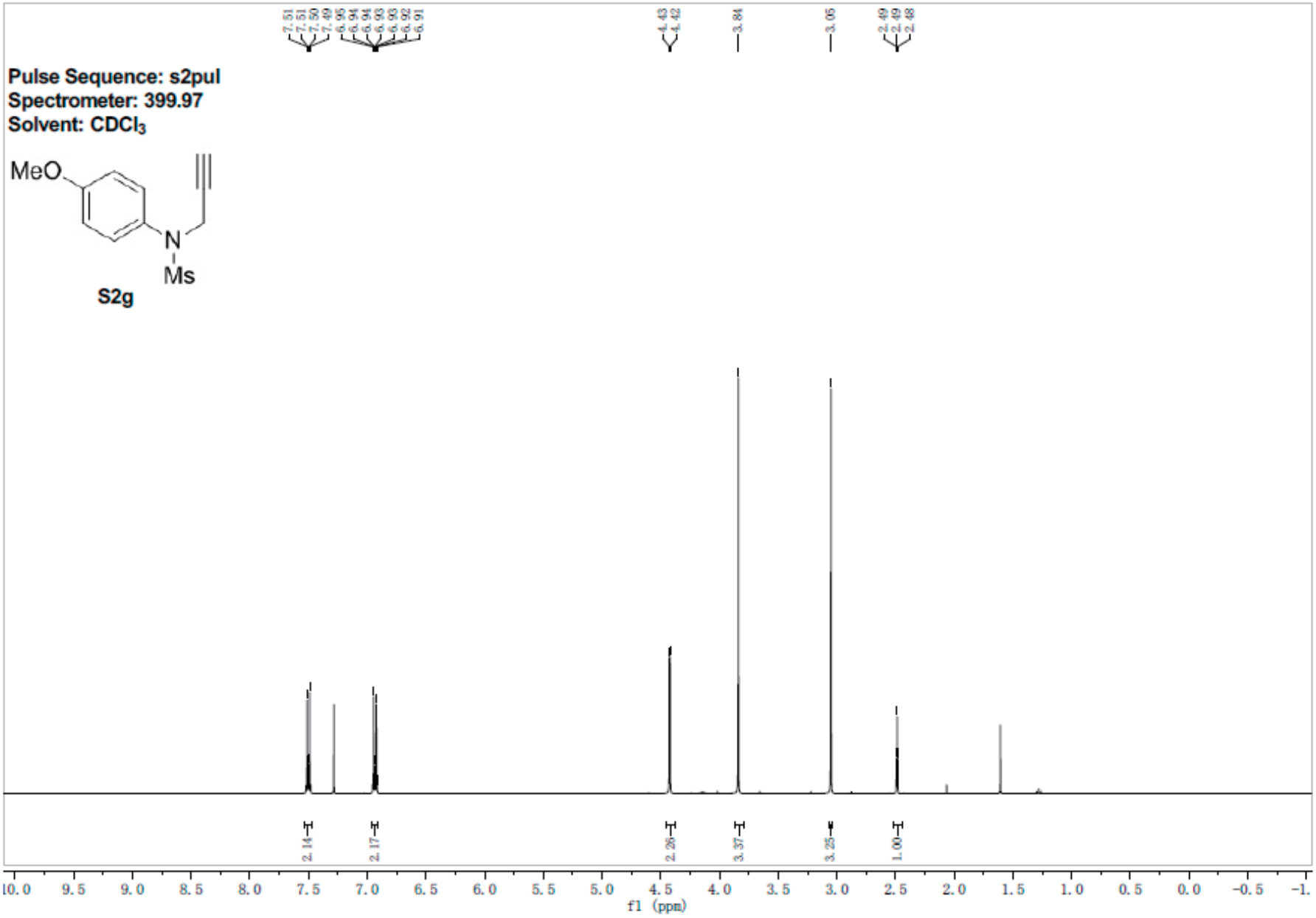

Pulse Sequence: s2pul
Spectrometer:150.91
Solvent: CDCl3
F3C
N
Ts
S2d
144.24
142.63
135.05
129.53
127.97
126.17
126.15
77.50
74.42
40.65
21.62
f1 (ppm)

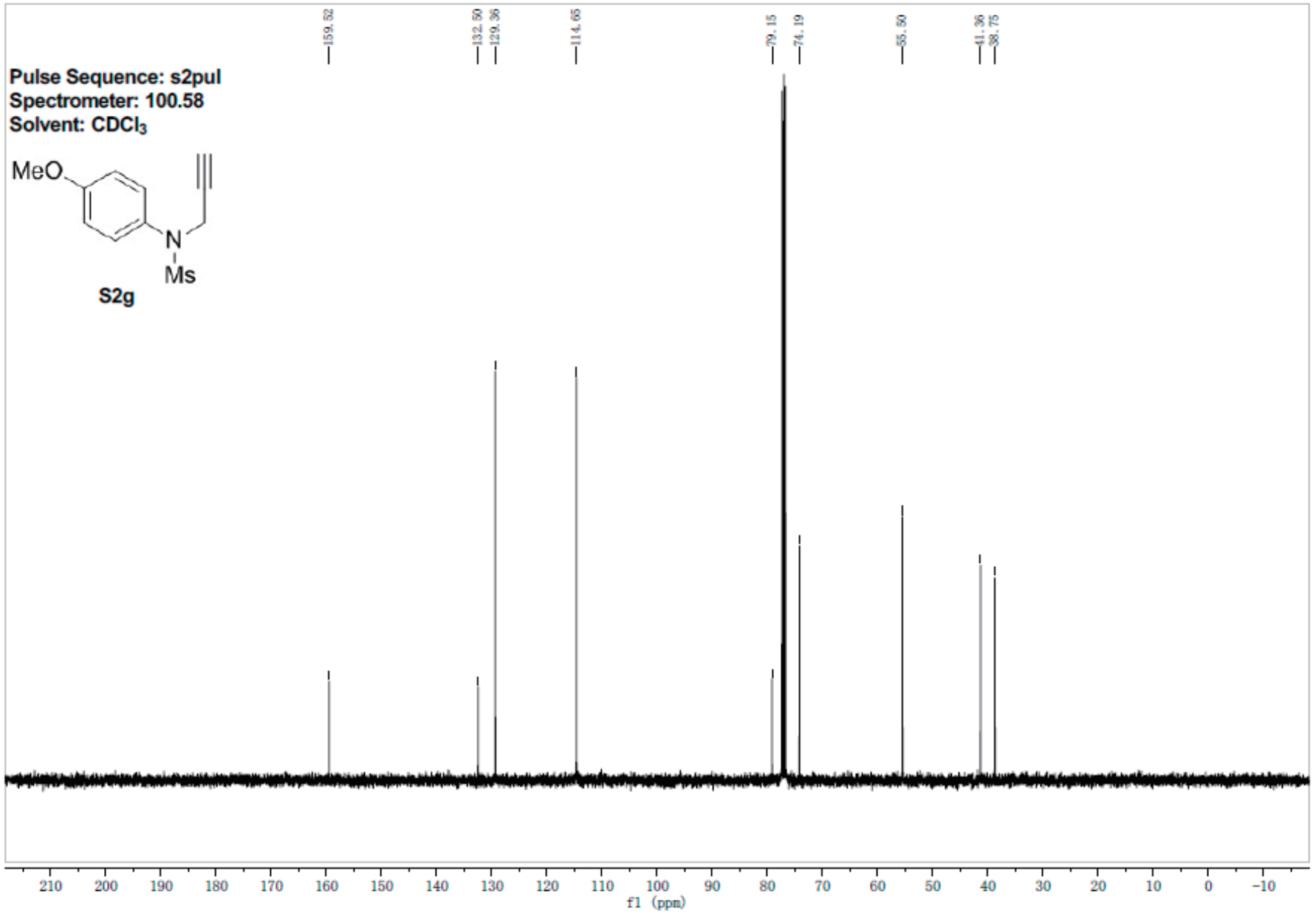

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
MeO
N
Ts
S2e
7.56
7.54
7.24
7.12
7.11
6.82
6.81
4.40
4.40
3.80
2.42
2.16
2.16
2.15
2.06
2.07
2.07
2.00
2.05
3.05
3.08
1.00
0.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

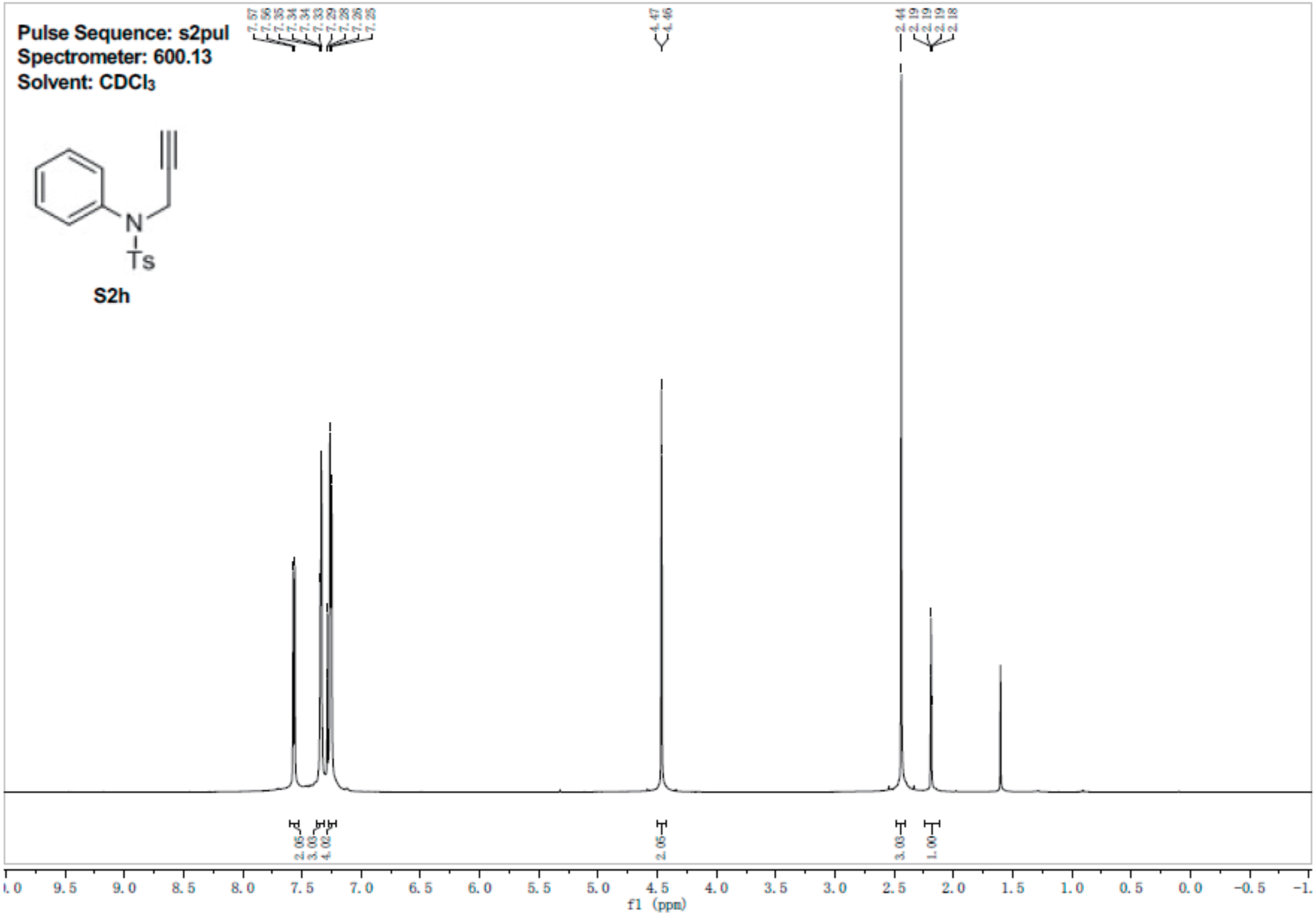

Pulse Sequence: s2pul
Spectrometer:150.91
Solvent: CDCl3
MeO
N
Ts
S2e
130.12
129.28
128.08
114.21
78.25
73.71
55.41
41.35
21.60
f1 (ppm)

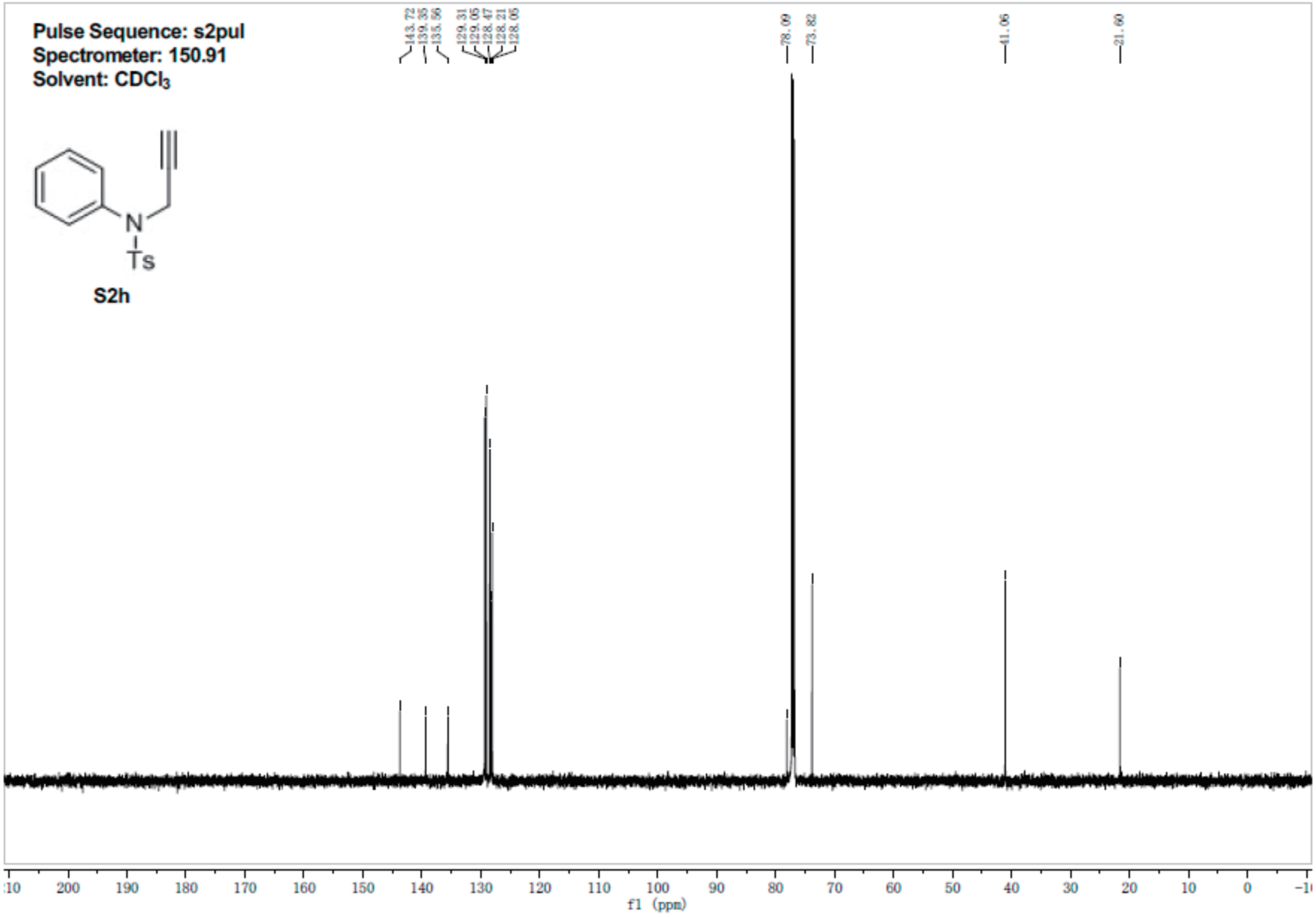

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
MeO
N
Ns
S2f
f1 (ppm)

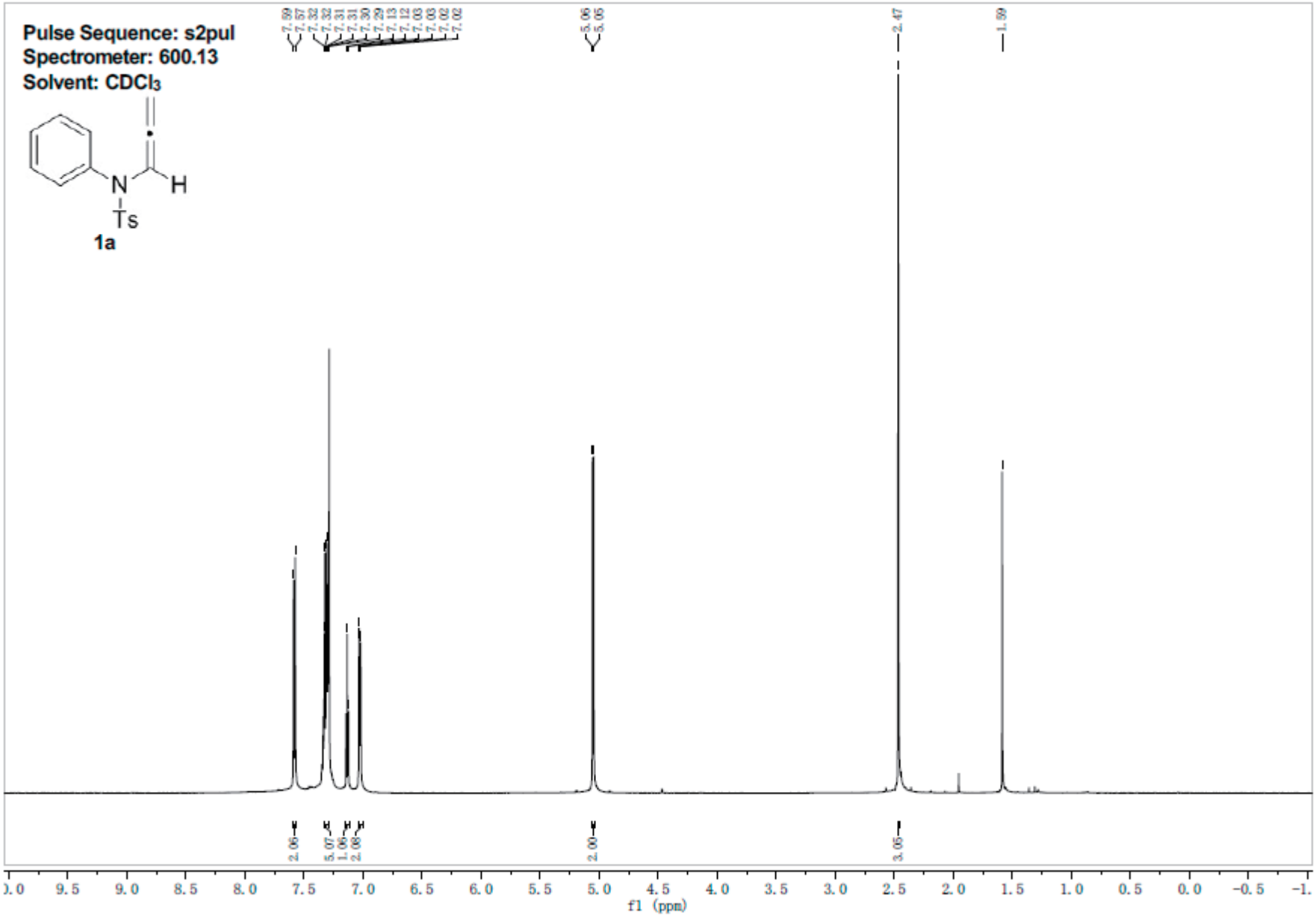

159.89
147.97
133.85
132.14
131.39
131.16
129.88
124.08
114.56
78.44
73.78
55.46
42.59
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
MeO
N
Ns
S2f
f1 (ppm)

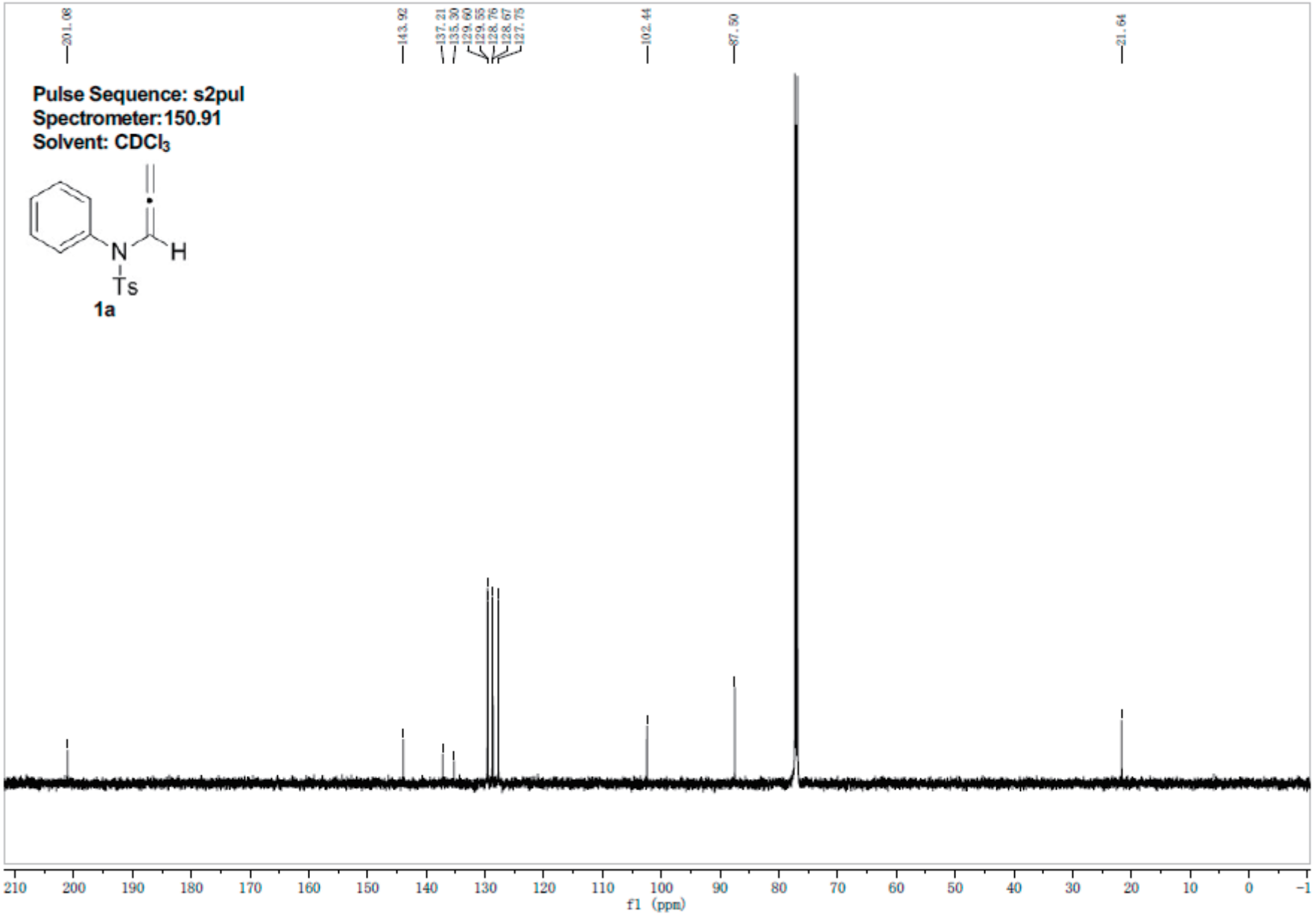

7.51
7.51
7.50
7.49
6.95
6.94
6.94
6.93
6.93
6.92
6.91
4.43
4.42
3.84
3.05
2.49
2.49
2.48
Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
MeO
N
Ms
S2g
2.14
2.17
2.26
3.37
3.25
1.00
f1 (ppm)

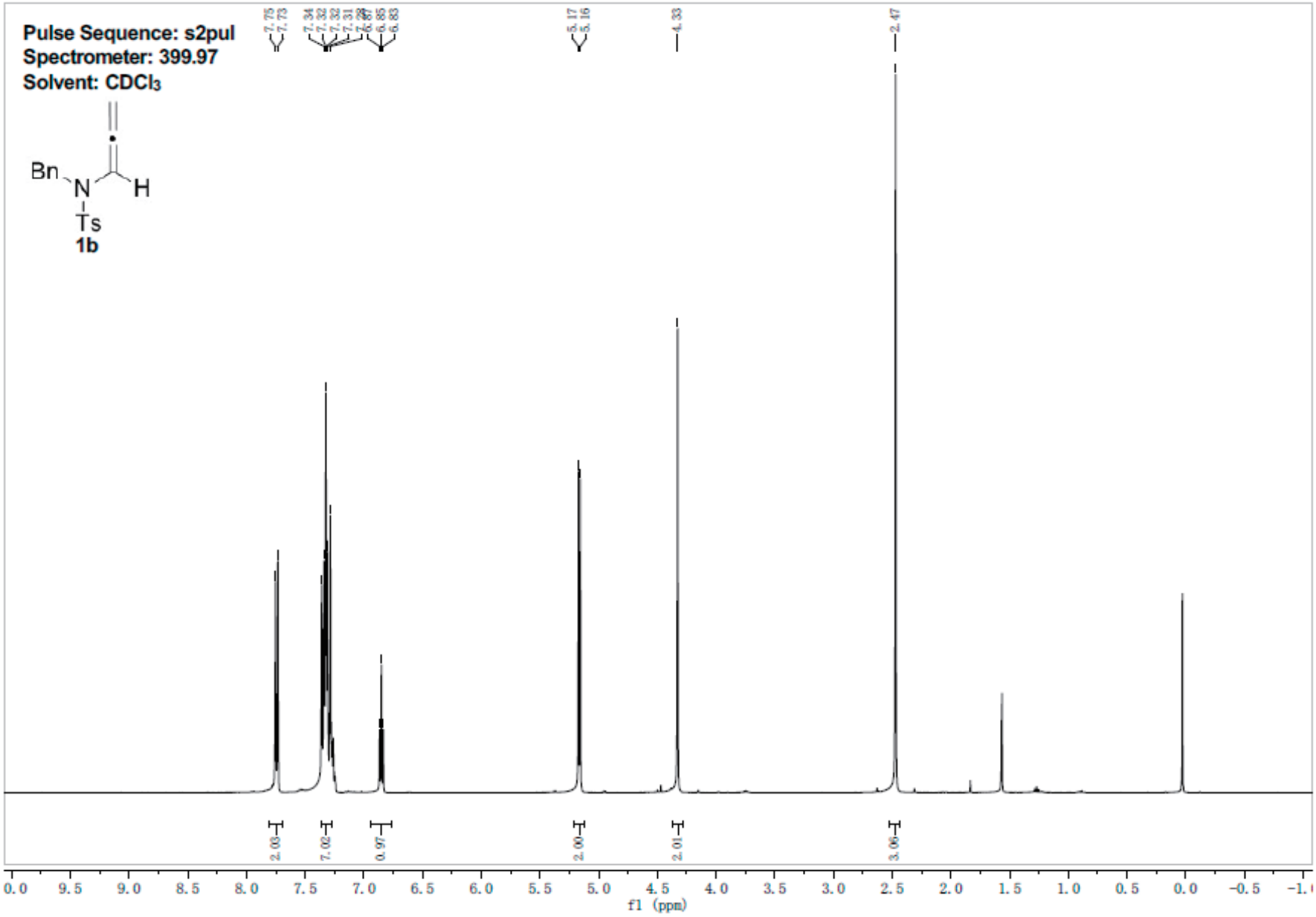

159.52
132.50
129.36
114.65
79.15
74.19
55.50
41.36
38.75
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
MeO
N
Ms
S2g
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10
f1 (ppm)

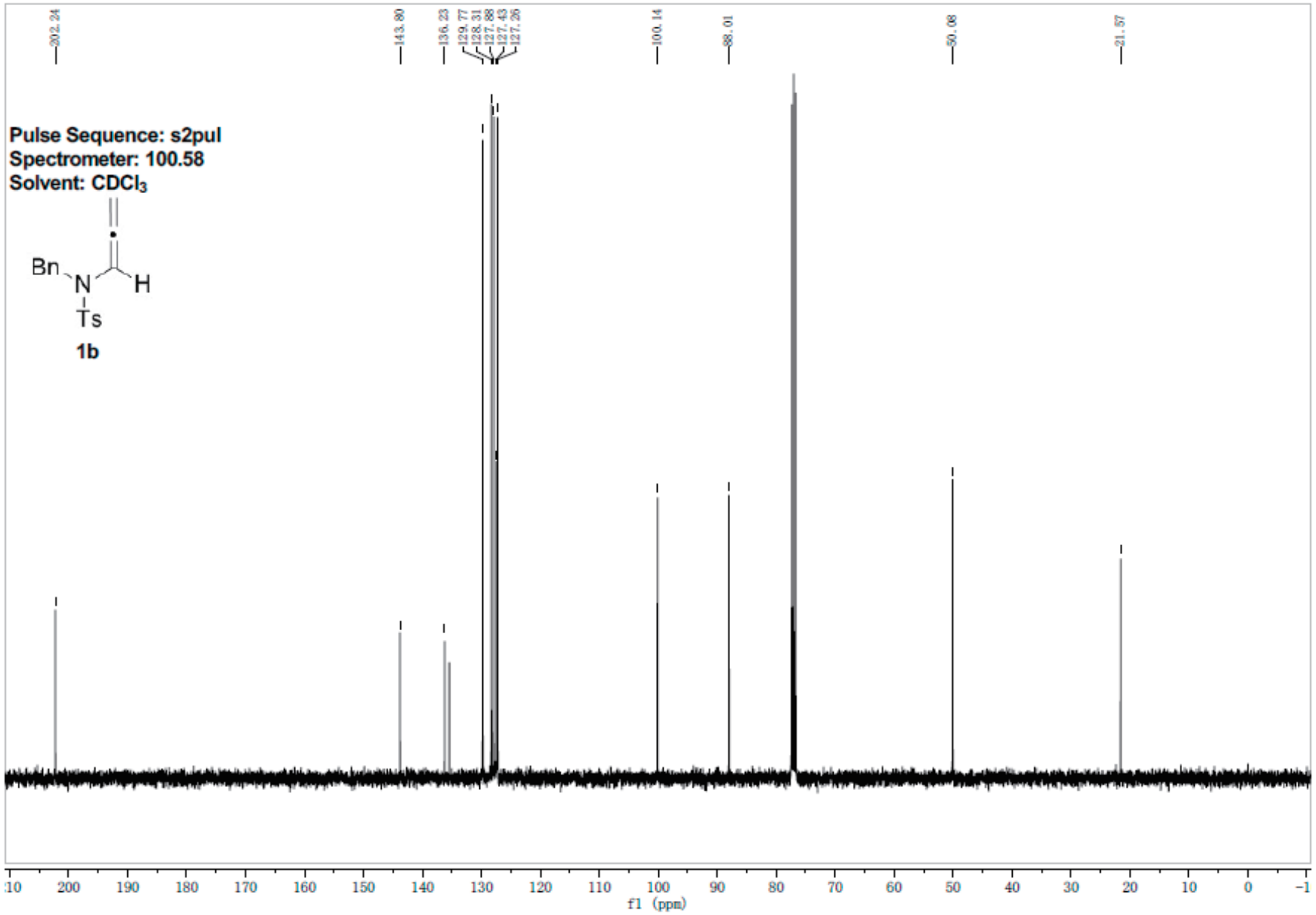

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
N
Ts
S2h
7.57
7.56
7.35
7.34
7.34
7.33
7.29
7.28
7.26
7.25
4.47
4.46
2.44
2.19
2.19
2.19
2.18
2.05
3.03
4.02
2.05
3.03
1.00
f1 (ppm)

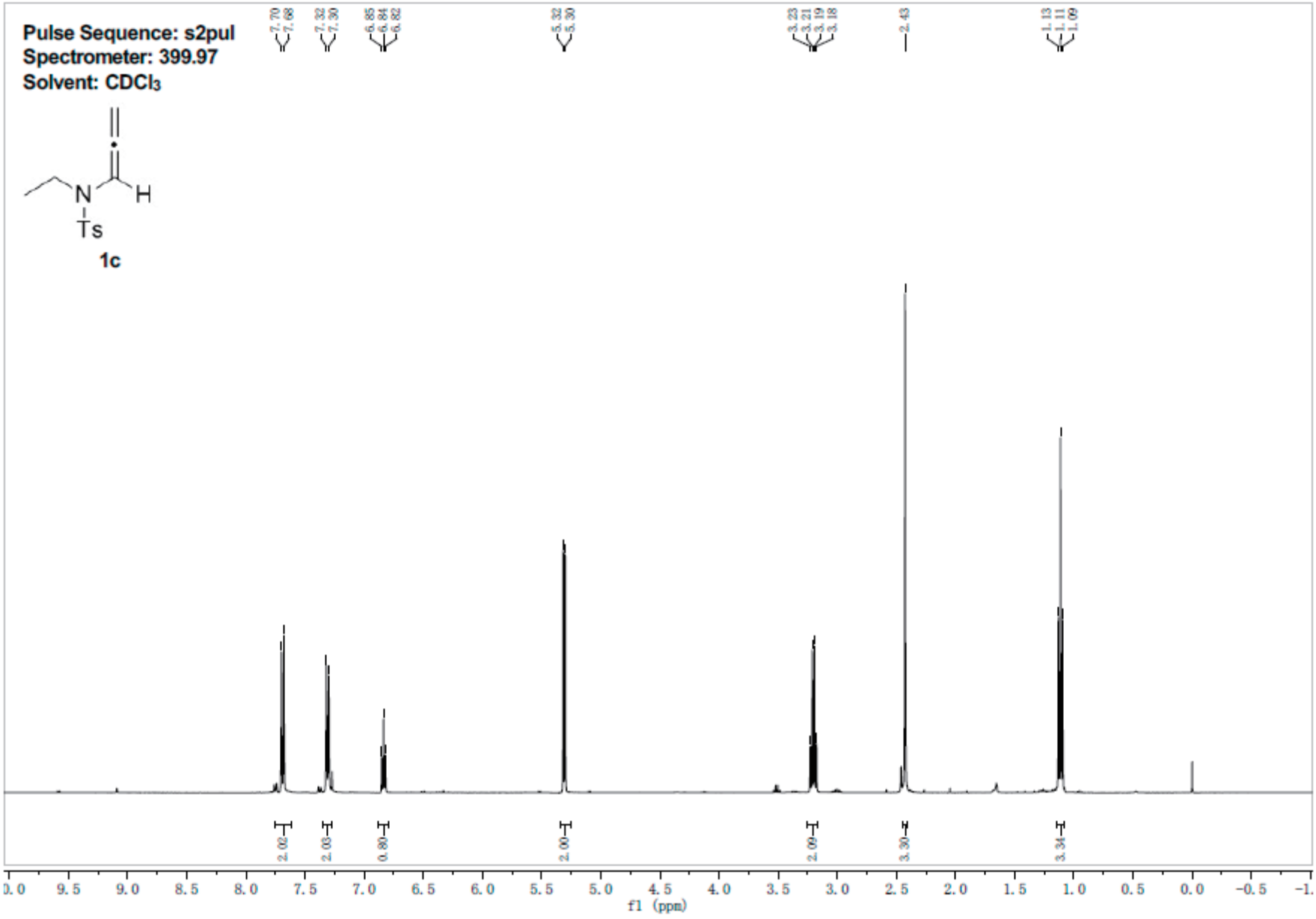

Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
143.72
139.35
135.56
129.31
129.05
128.47
128.21
128.05
78.09
73.82
41.06
21.60
N
Ts
S2h
f1 (ppm)

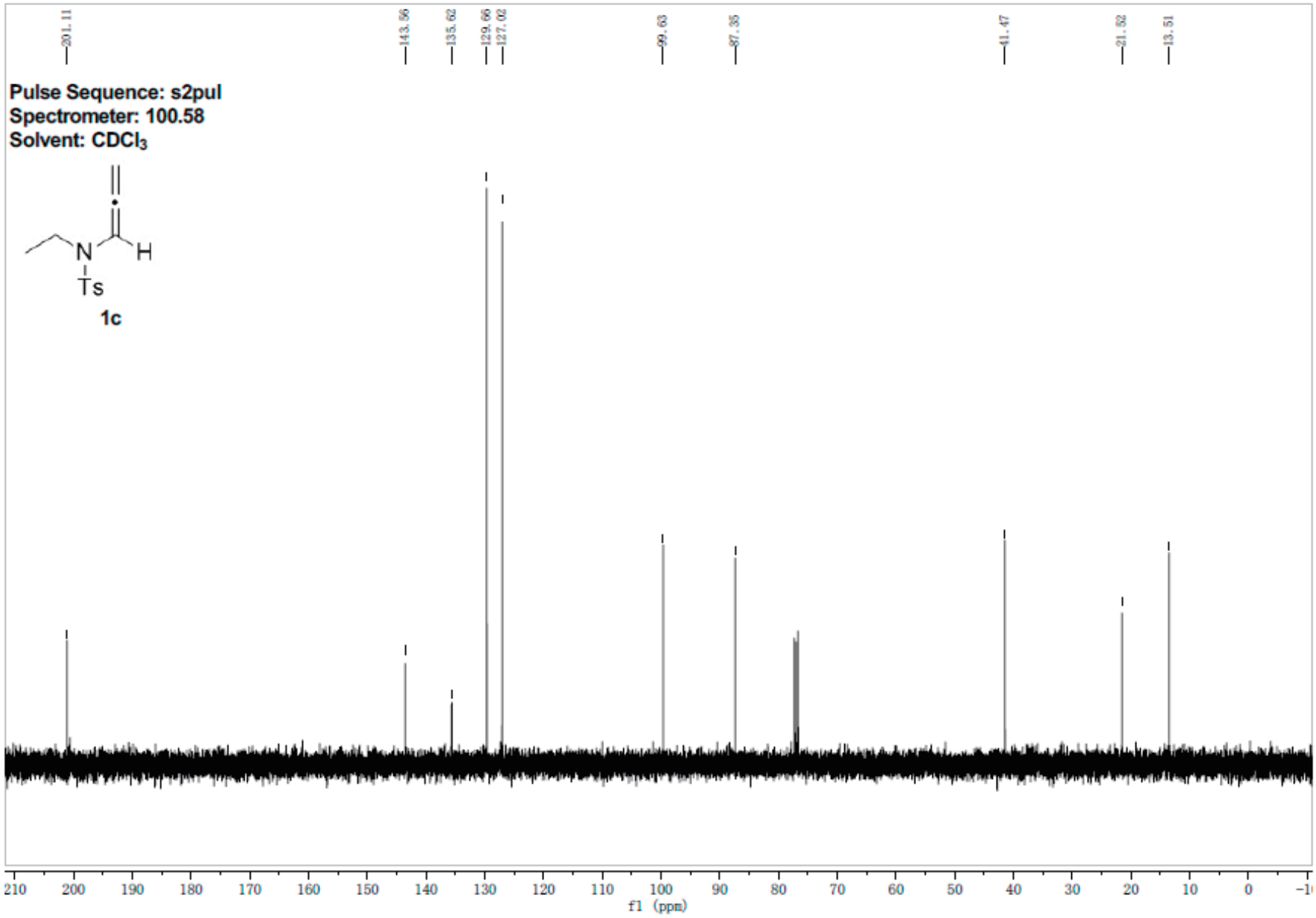

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
N
H
Ts
1a
7.59
7.57
7.32
7.32
7.31
7.31
7.30
7.29
7.13
7.12
7.03
7.03
7.02
7.02
5.06
5.05
2.47
1.99
2.06
5.07
1.06
2.08
2.00
3.05
f1 (ppm)

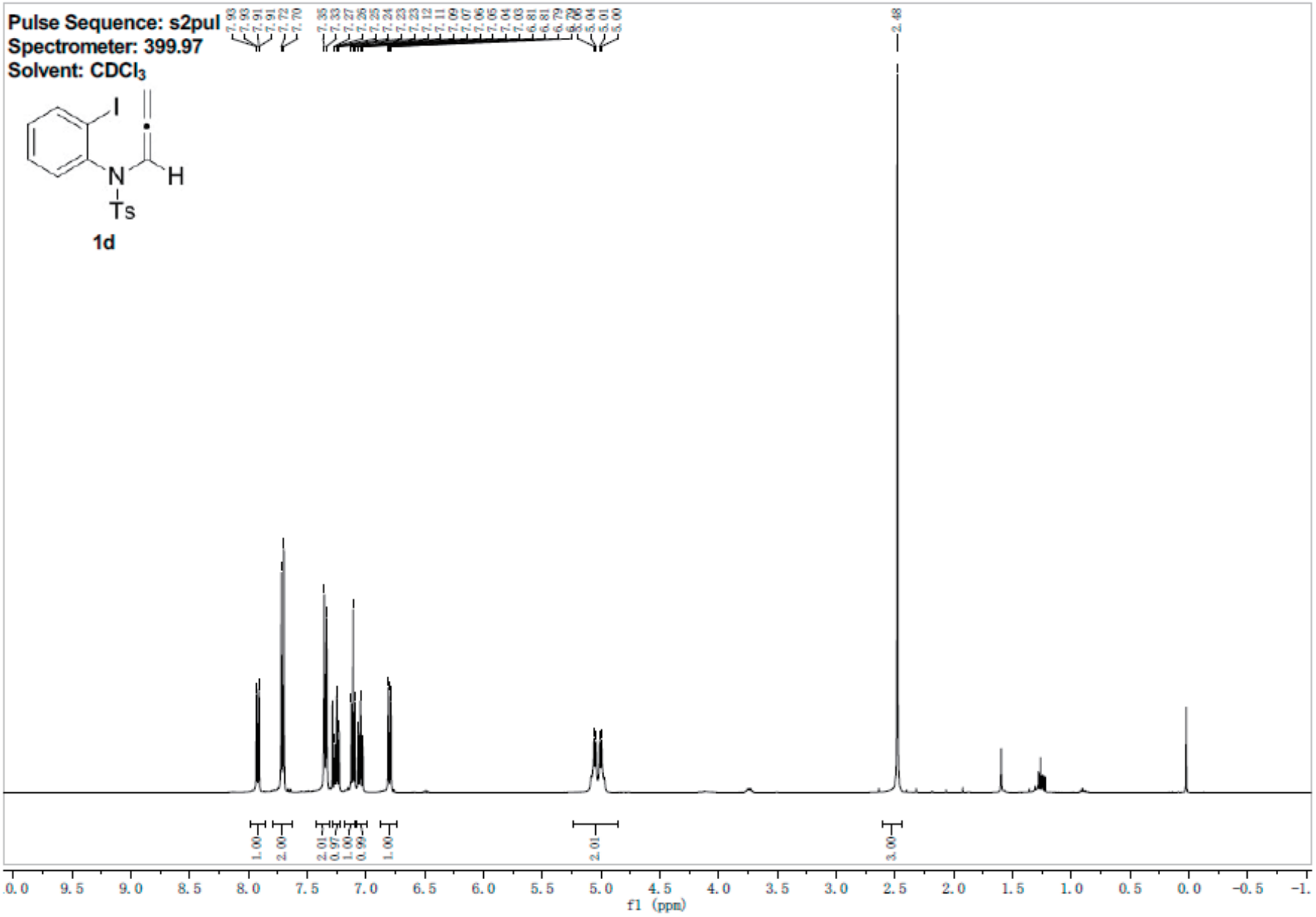

201.08
143.92
137.21
135.30
129.60
129.55
128.76
128.67
127.75
102.44
87.50
21.64
Pulse Sequence: s2pul
Spectrometer:150.91
Solvent: CDCl3
N
H
Ts
1a
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−1
f1 (ppm)

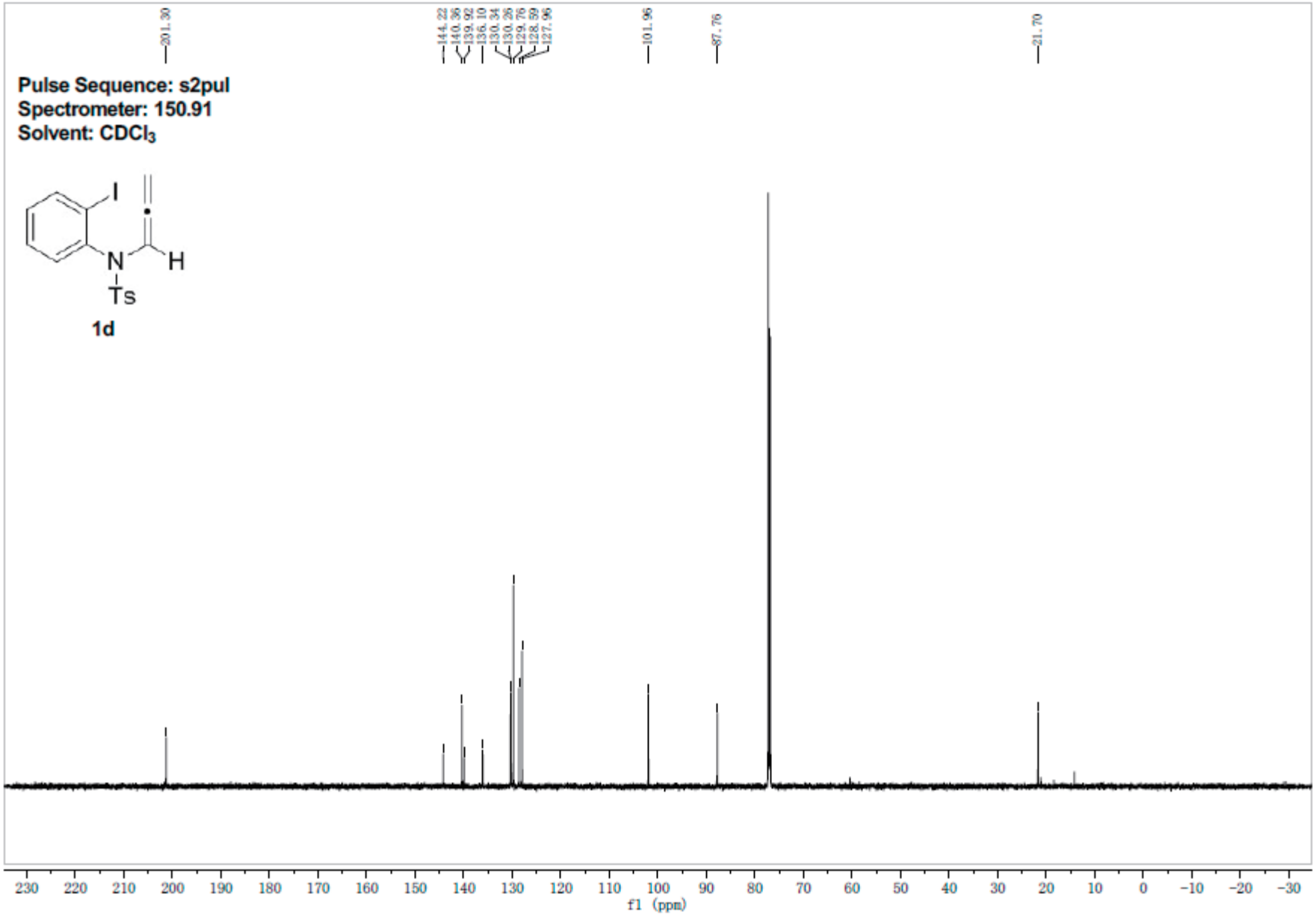

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
Bn
N
H
Ts
1b
7.75
7.73
7.34
7.32
7.32
7.31
6.85
6.83
5.17
5.16
4.33
2.47
2.03
7.02
0.97
2.00
2.01
3.06
f1 (ppm)

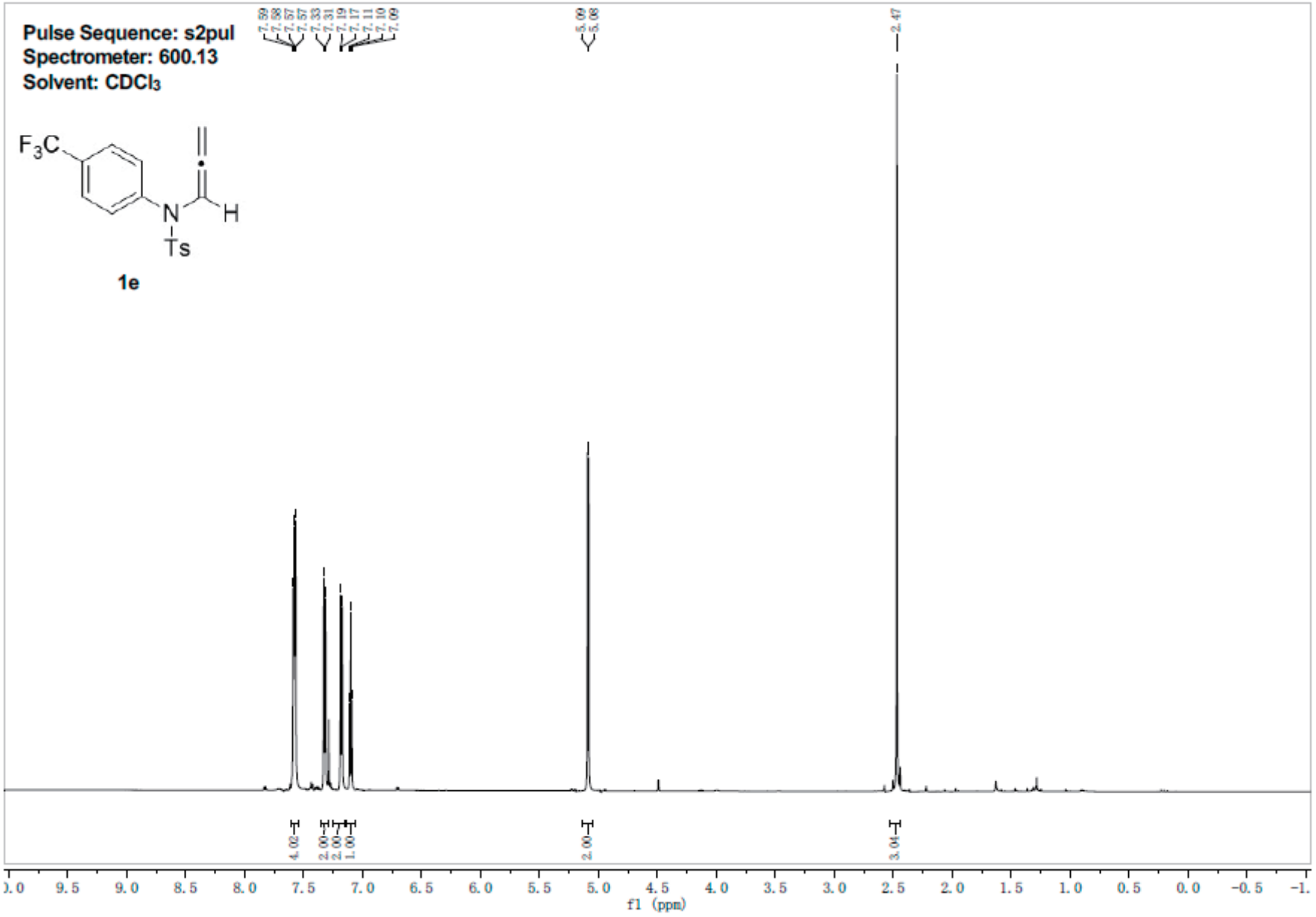

202.24
143.80
136.23
129.77
128.31
127.88
127.43
127.26
100.14
88.01
50.08
21.57
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
Bn
N
H
Ts
1b
f1 (ppm)

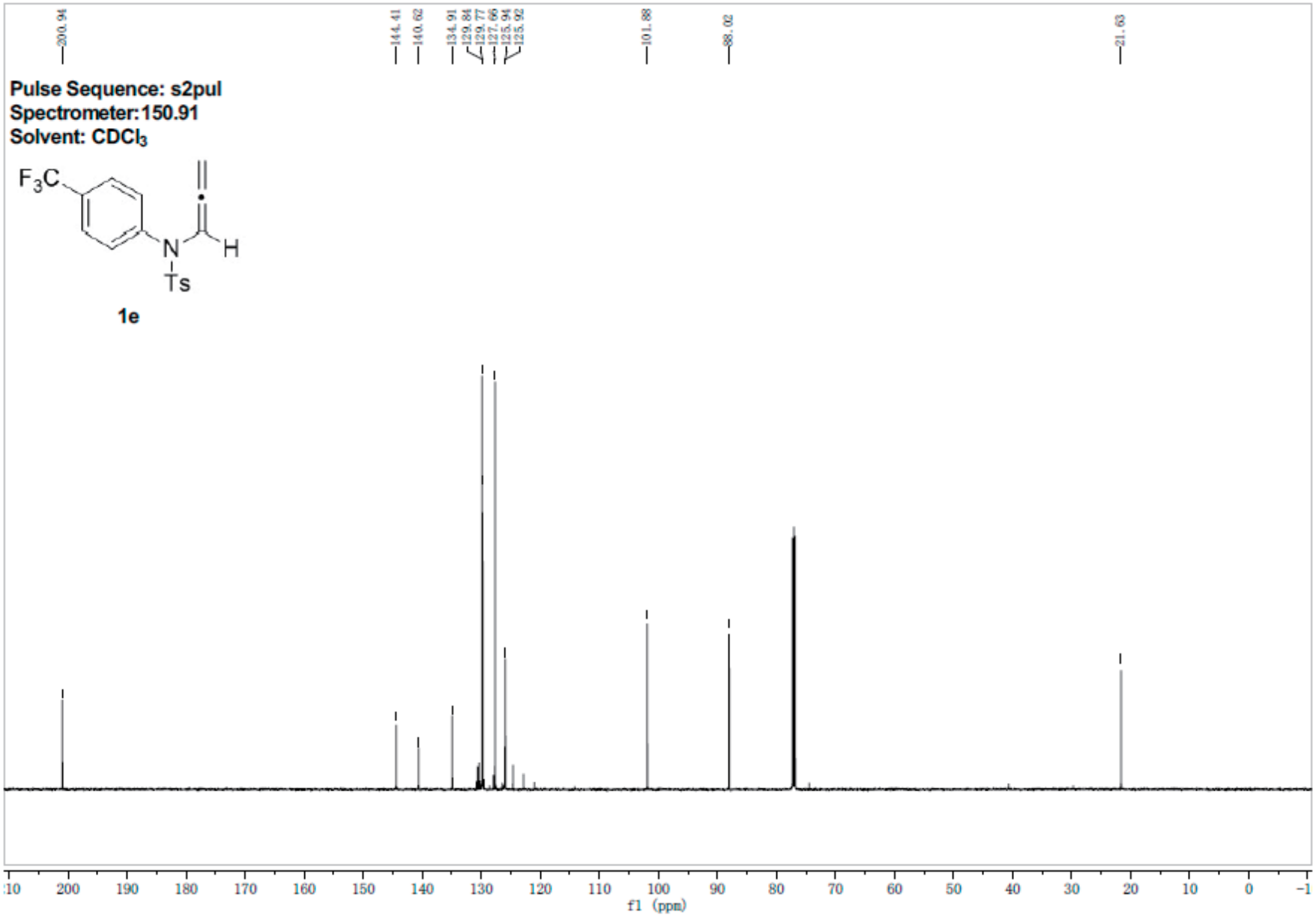

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
N
H
Ts
1c
7.70
7.68
7.32
7.30
6.85
6.84
6.82
5.32
5.30
3.23
3.21
3.19
3.18
2.43
1.13
1.11
1.09
2.02
2.03
0.80
2.00
2.09
3.30
3.34
f1 (ppm)

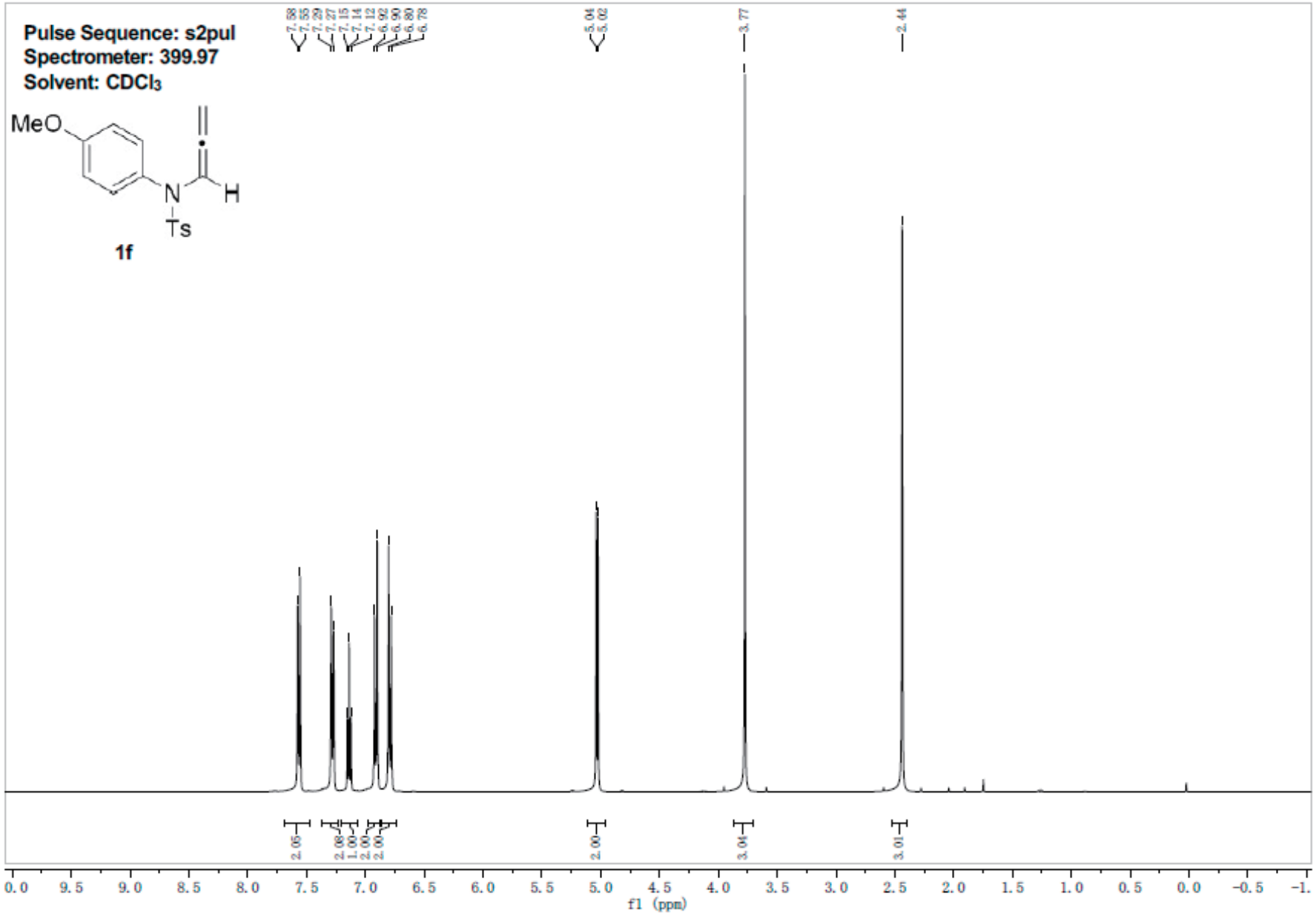

201.11
143.56
135.62
129.66
127.02
99.63
87.35
41.47
21.52
13.51
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
N
H
Ts
1c
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)

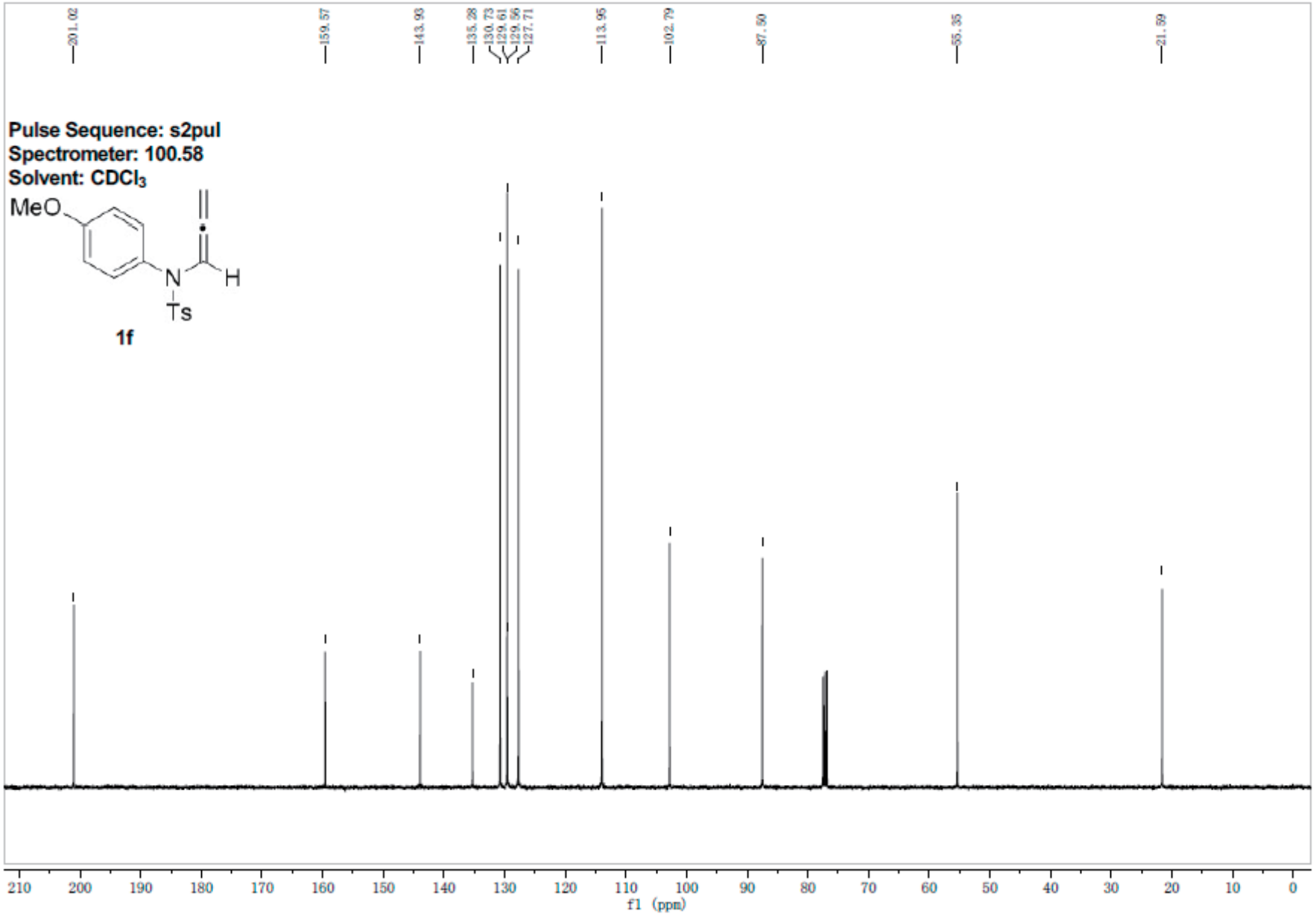

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
I
N
H
Ts
1d
7.93
7.93
7.91
7.91
7.72
7.70
7.35
7.33
7.27
7.26
7.25
7.24
7.23
7.23
7.12
7.11
7.09
7.07
7.06
7.05
7.04
7.03
6.81
6.81
6.79
6.78
5.04
5.01
5.00
2.48
1.00
2.00
2.01
0.97
1.00
0.99
1.00
2.01
3.00
0.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.
f1 (ppm)

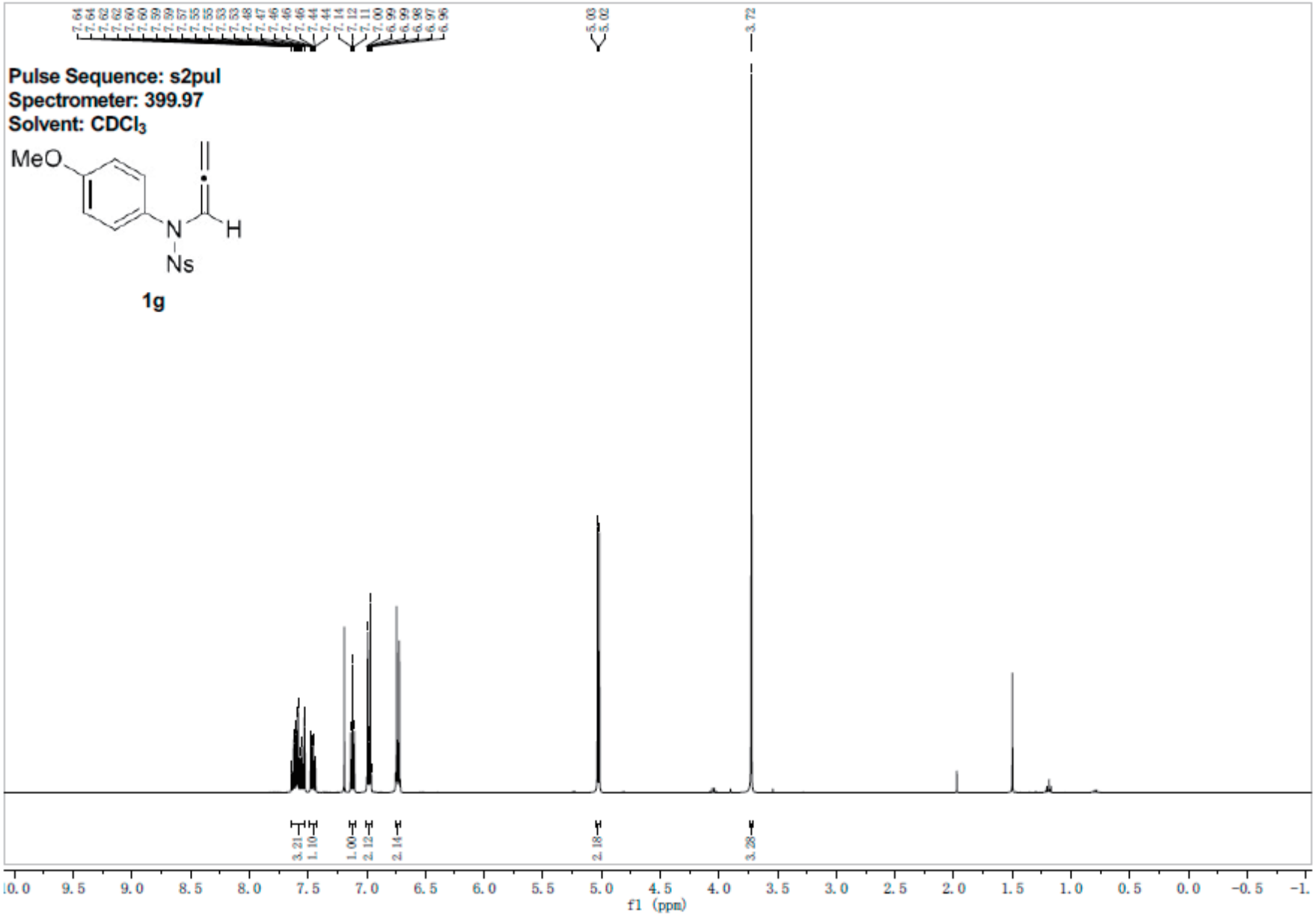

201.30
144.22
140.36
139.92
136.10
130.34
130.26
129.76
128.59
127.96
101.96
87.76
21.70
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
I
N
H
Ts
1d
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30
f1 (ppm)

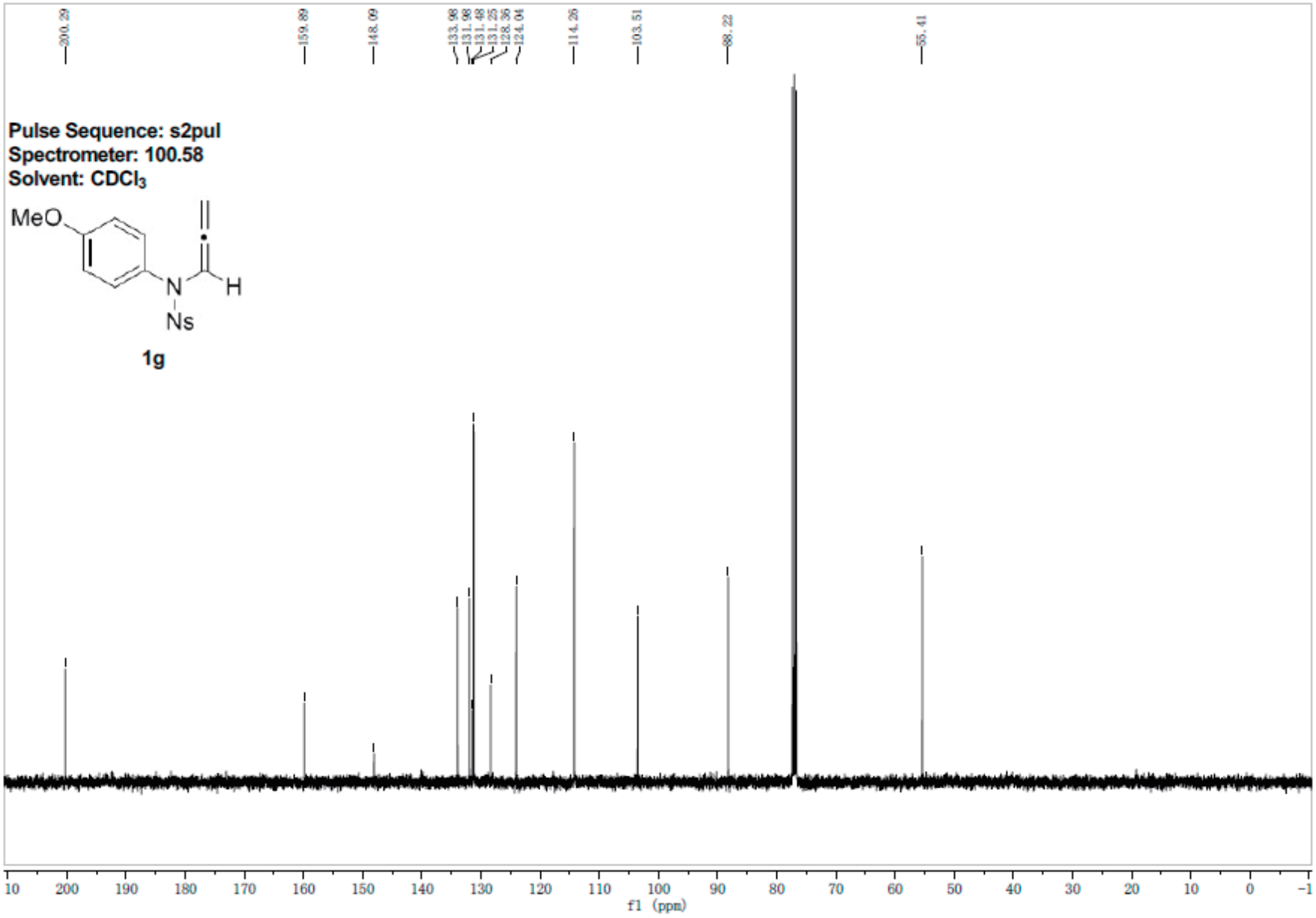

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
F3C
N
H
Ts
1e
7.59
7.58
7.57
7.57
7.33
7.31
7.19
7.17
7.11
7.10
7.09
5.09
5.08
2.47
4.02
2.00
2.00
2.00
1.00
2.00
3.04
f1 (ppm)

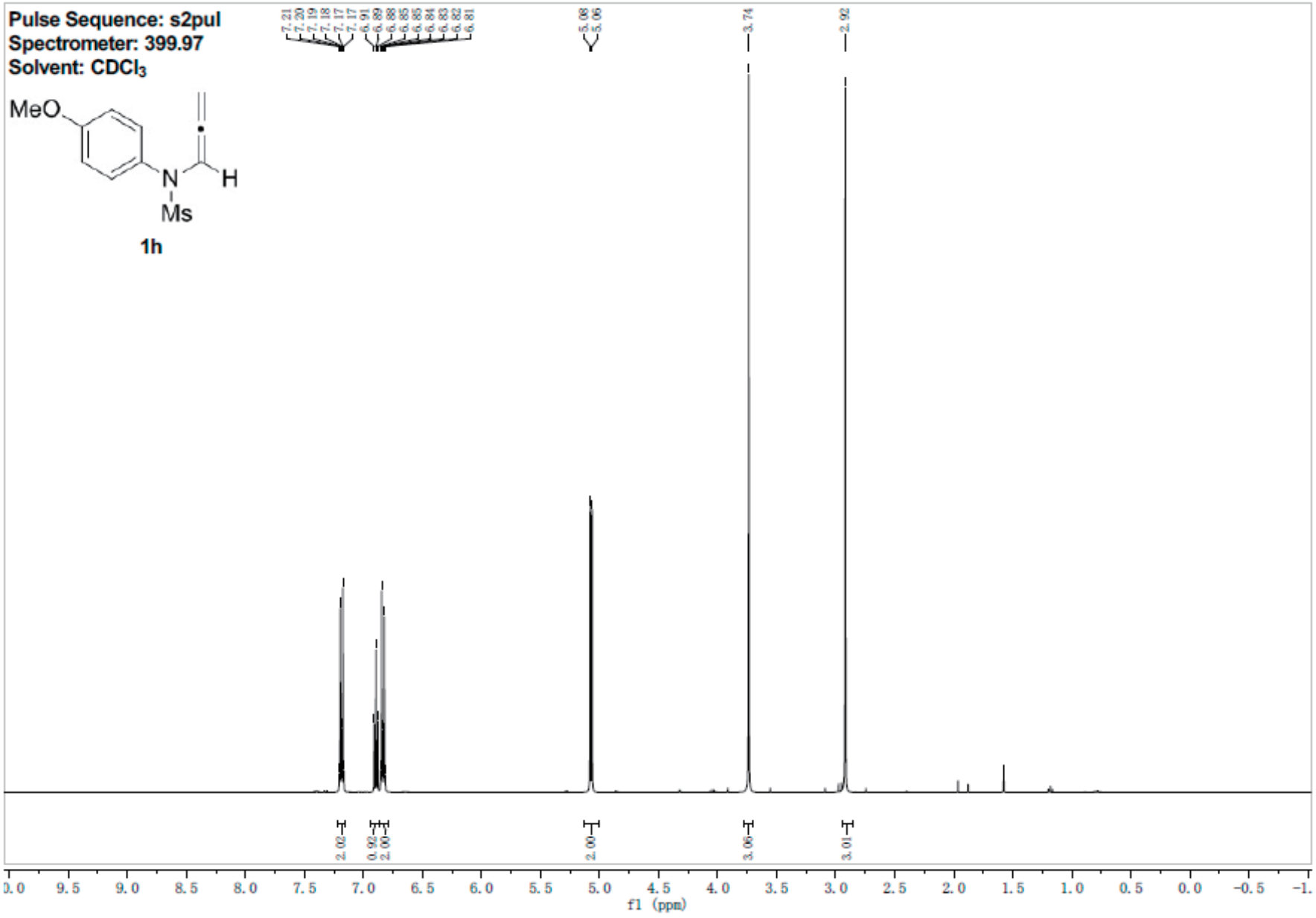

200.94
144.41
140.62
134.91
129.84
129.77
127.66
125.94
125.92
101.88
88.02
21.63
Pulse Sequence: s2pul
Spectrometer:150.91
Solvent: CDCl3
F3C
N
H
Ts
1e
f1 (ppm)

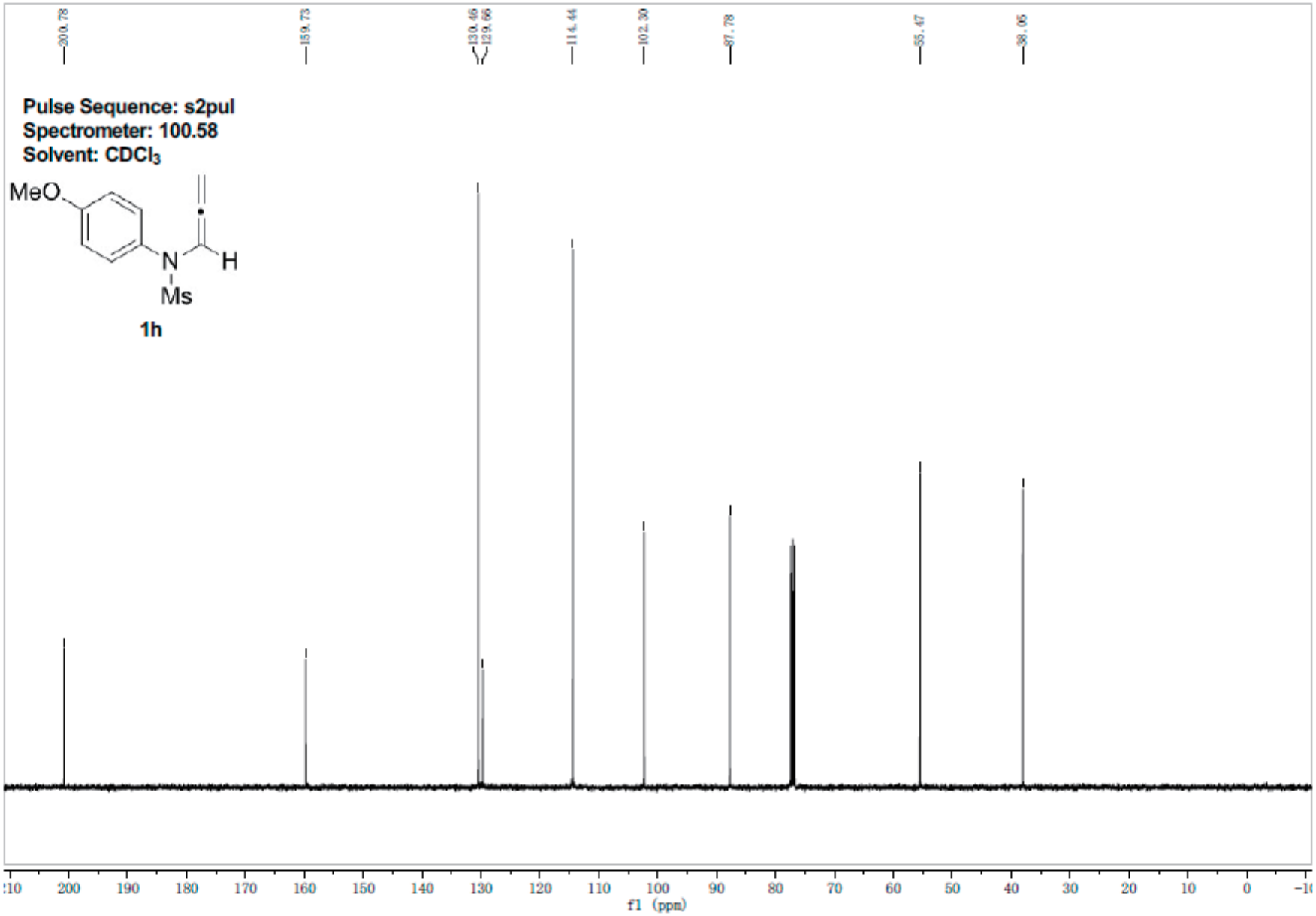

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
MeO
N
H
Ts
1f
7.58
7.55
7.29
7.27
7.15
7.14
7.12
6.92
6.90
6.80
6.78
5.04
5.02
3.77
2.44
2.05
2.08
1.00
2.00
2.00
2.00
3.04
3.01
f1 (ppm)

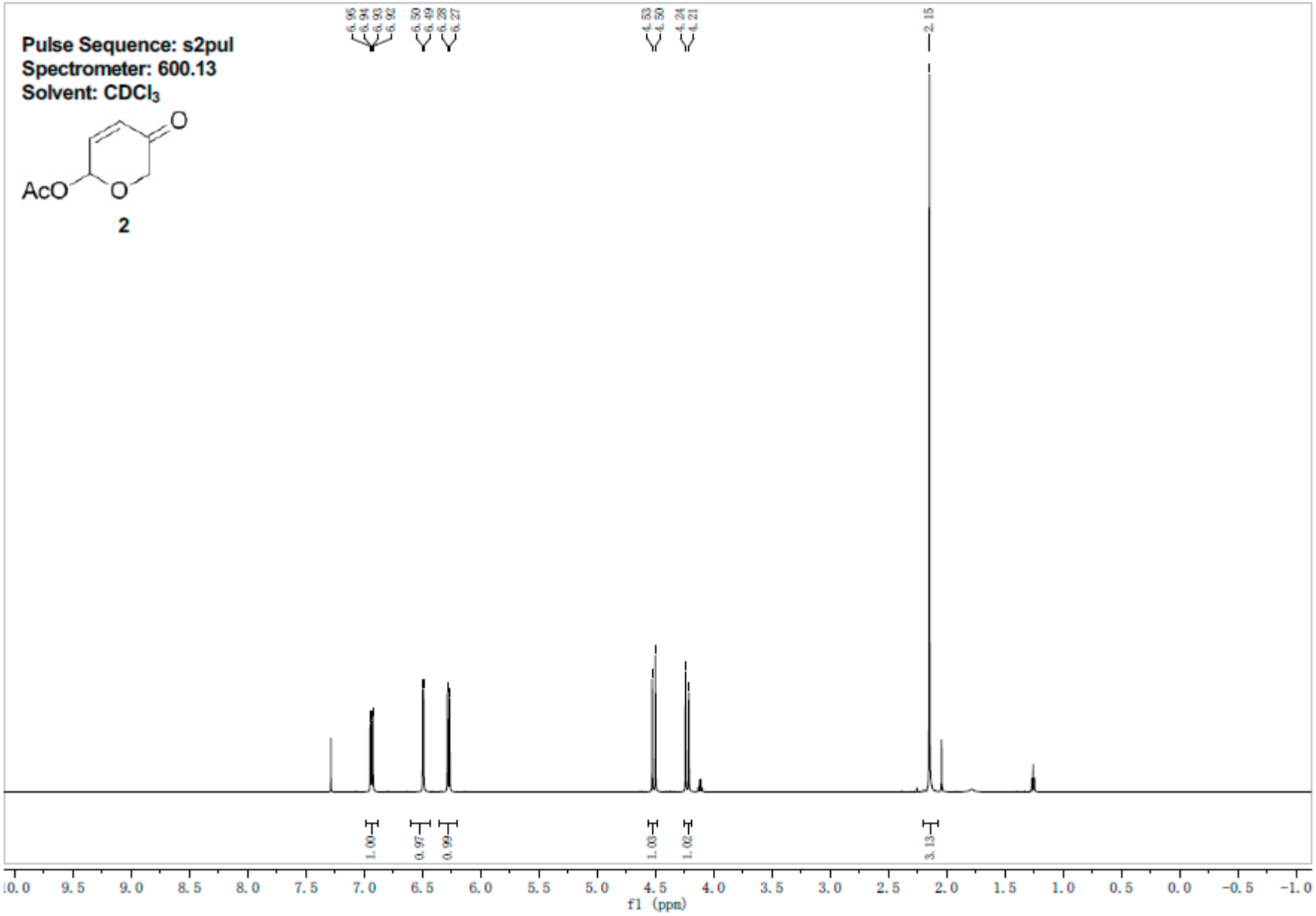

201.02
159.57
143.93
135.28
130.73
129.61
129.56
127.71
113.95
102.79
87.50
55.35
21.59
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
MeO
N
H
Ts
1f
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

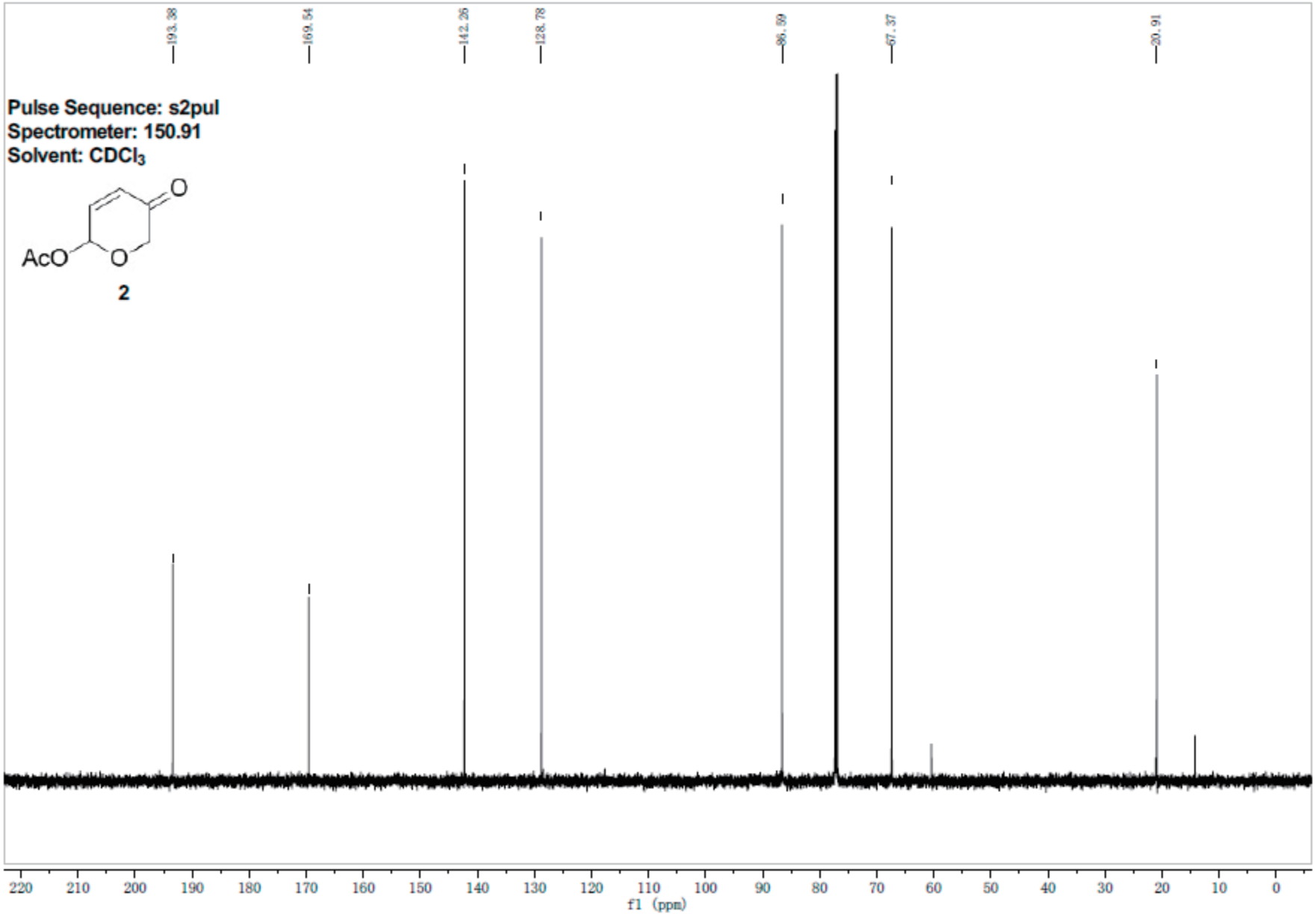

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
MeO
N
H
Ns
1g
f1 (ppm)

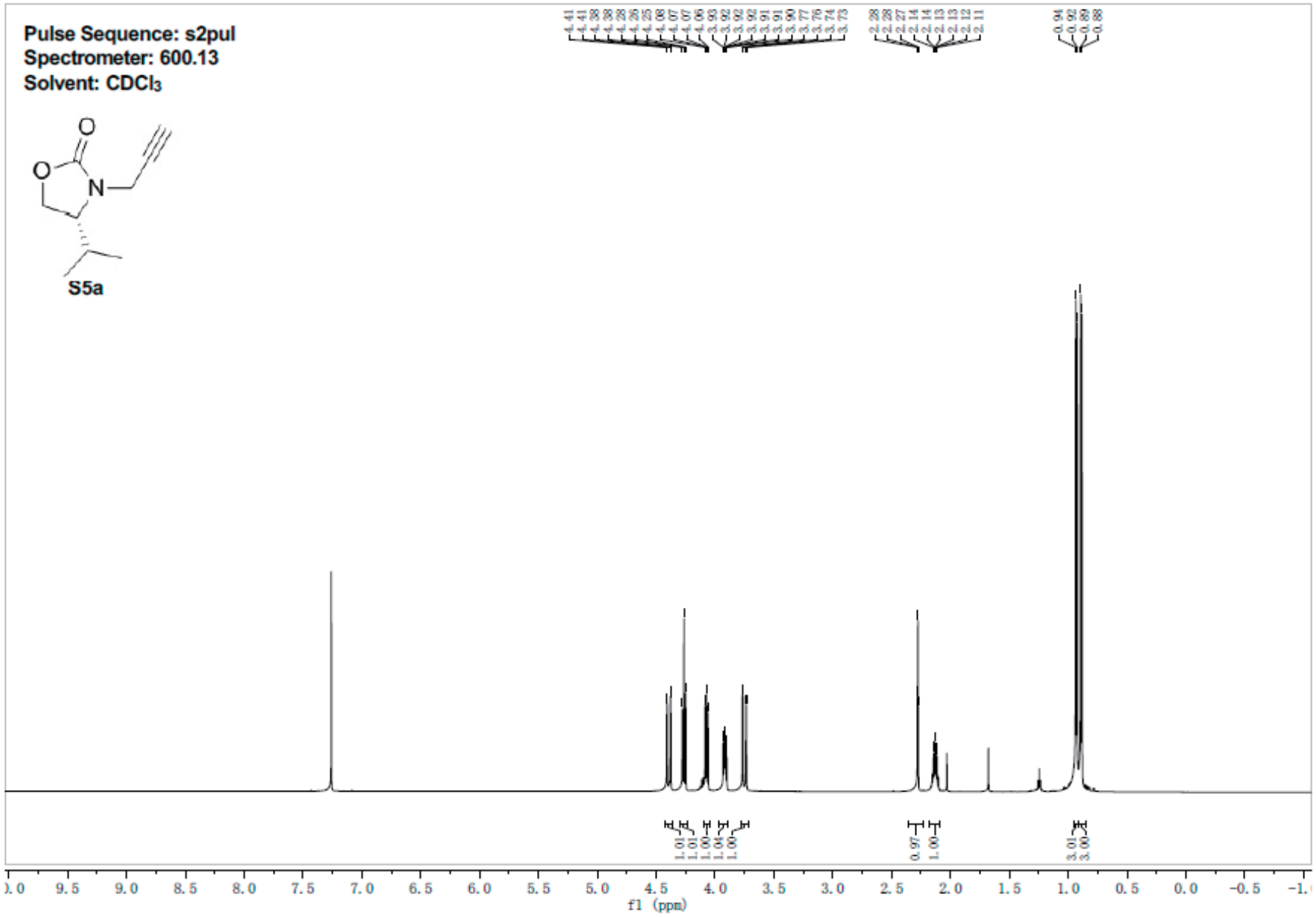

200.29
159.89
148.09
133.98
131.98
131.48
131.25
128.36
124.04
114.26
103.51
68.22
55.41
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
MeO
N
H
Ns
1g
f1 (ppm)

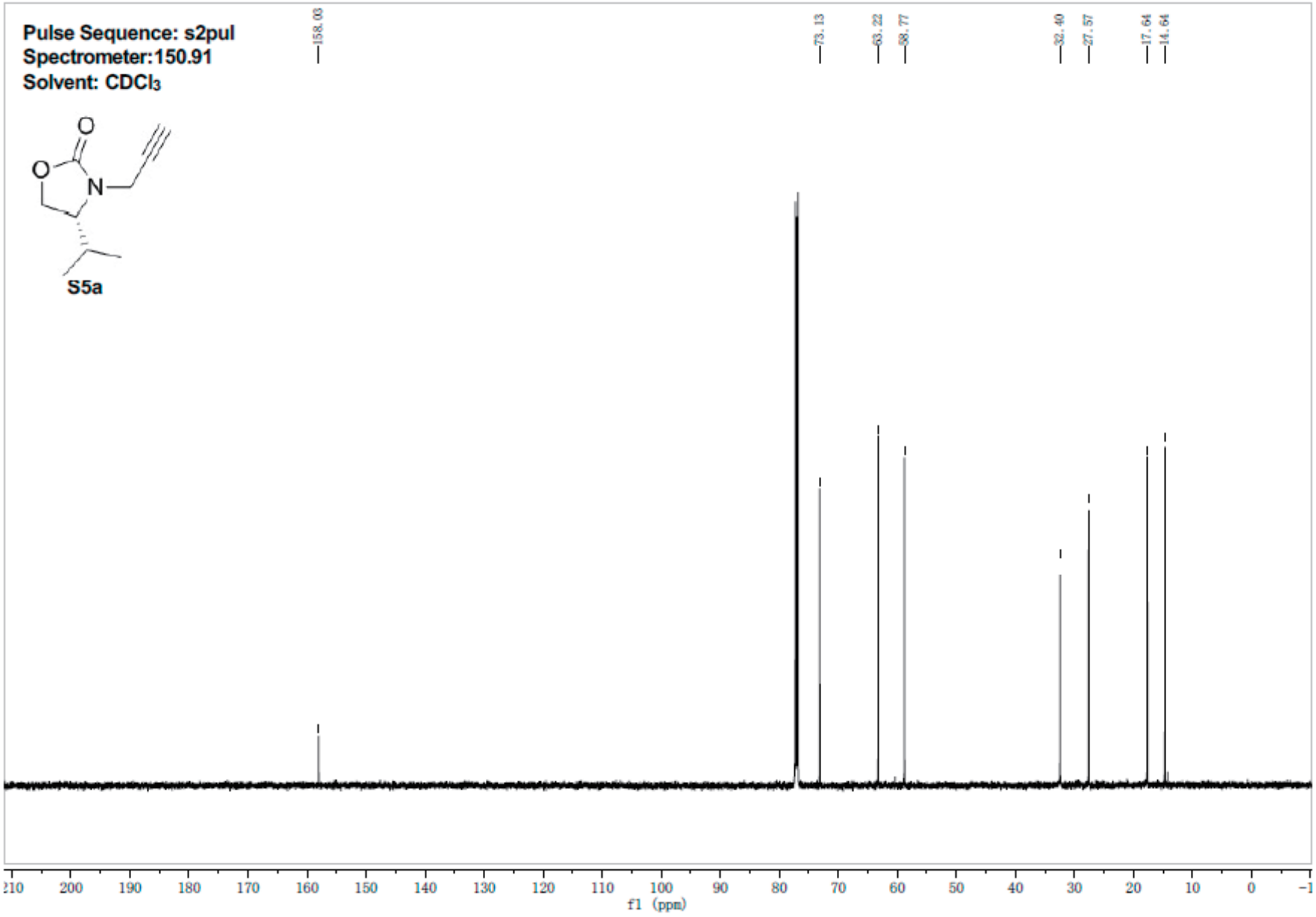

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
MeO
N
H
Ms
1h
7.21
7.20
7.19
7.18
7.17
7.17
6.91
6.89
6.88
6.85
6.85
6.84
6.83
6.82
6.81
5.08
5.06
3.74
2.92
2.02
0.92
2.00
2.00
3.06
3.01
f1 (ppm)

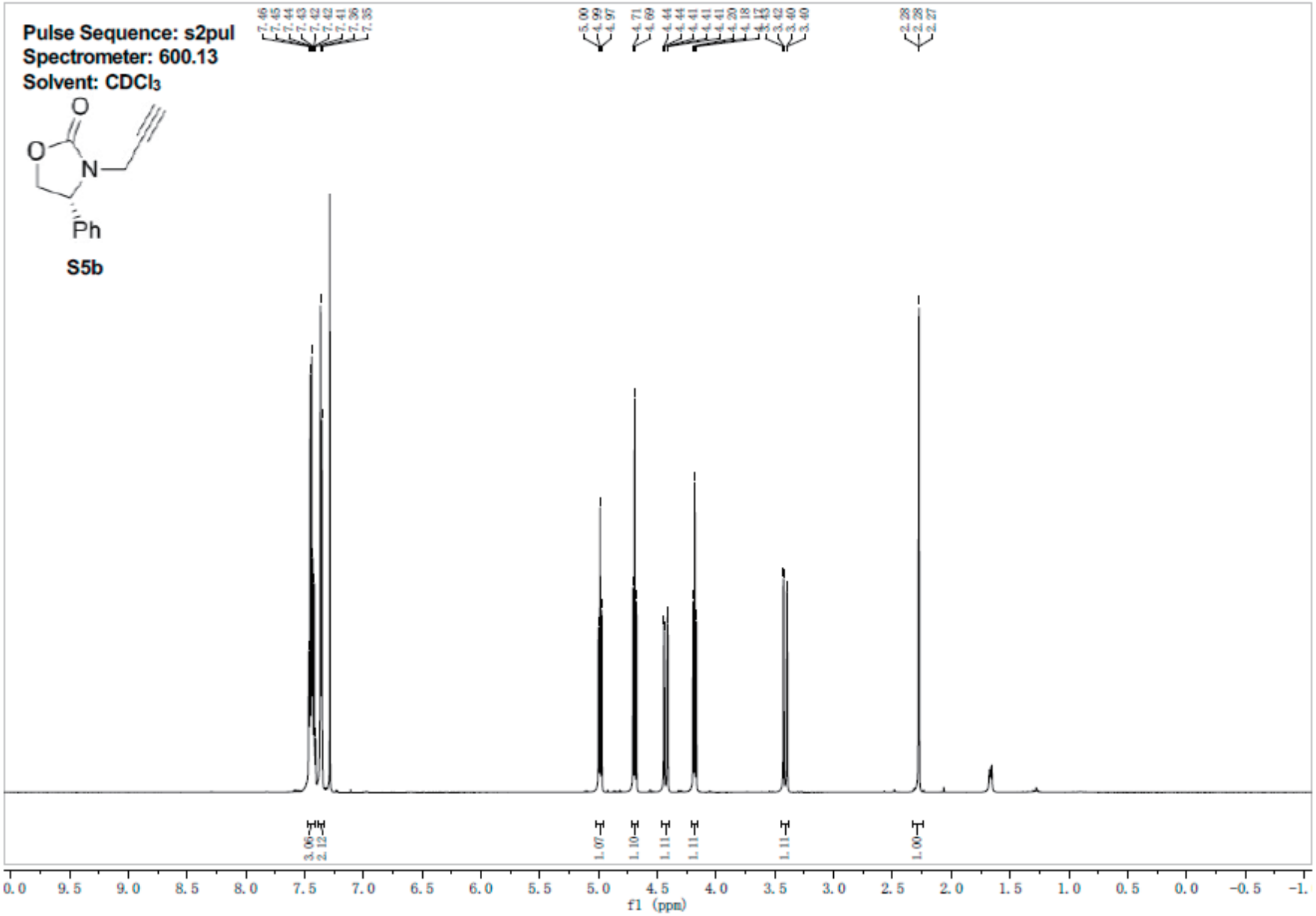

200.78
159.73
130.46
129.66
114.44
102.30
87.78
55.47
38.05
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
MeO
N
H
Ms
1h
f1 (ppm)

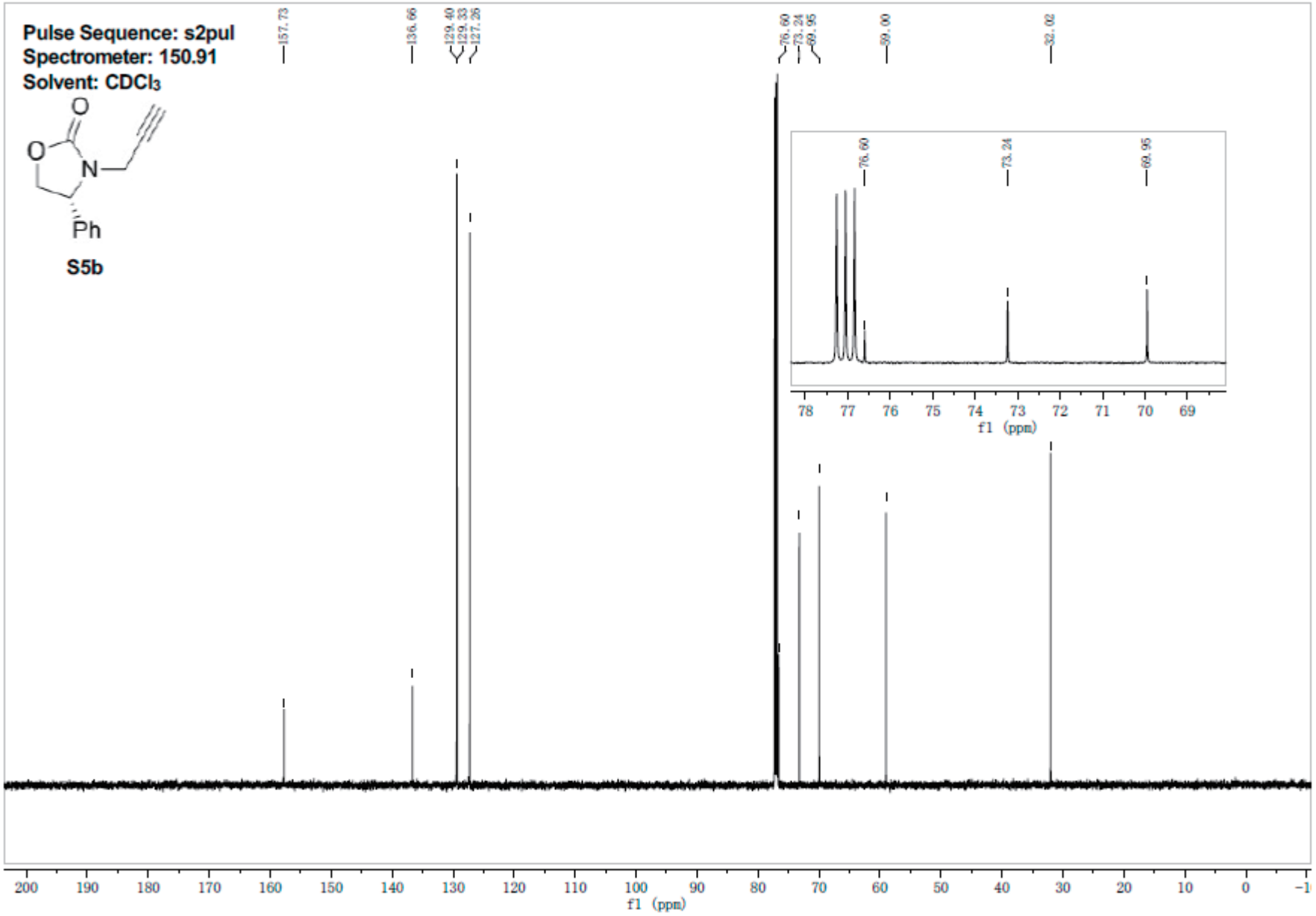

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
AcO
O
O
2
6.95
6.94
6.93
6.92
6.50
6.49
6.28
6.27
4.53
4.50
4.24
4.21
2.15
1.00
0.97
0.99
1.03
1.02
3.13
f1 (ppm)

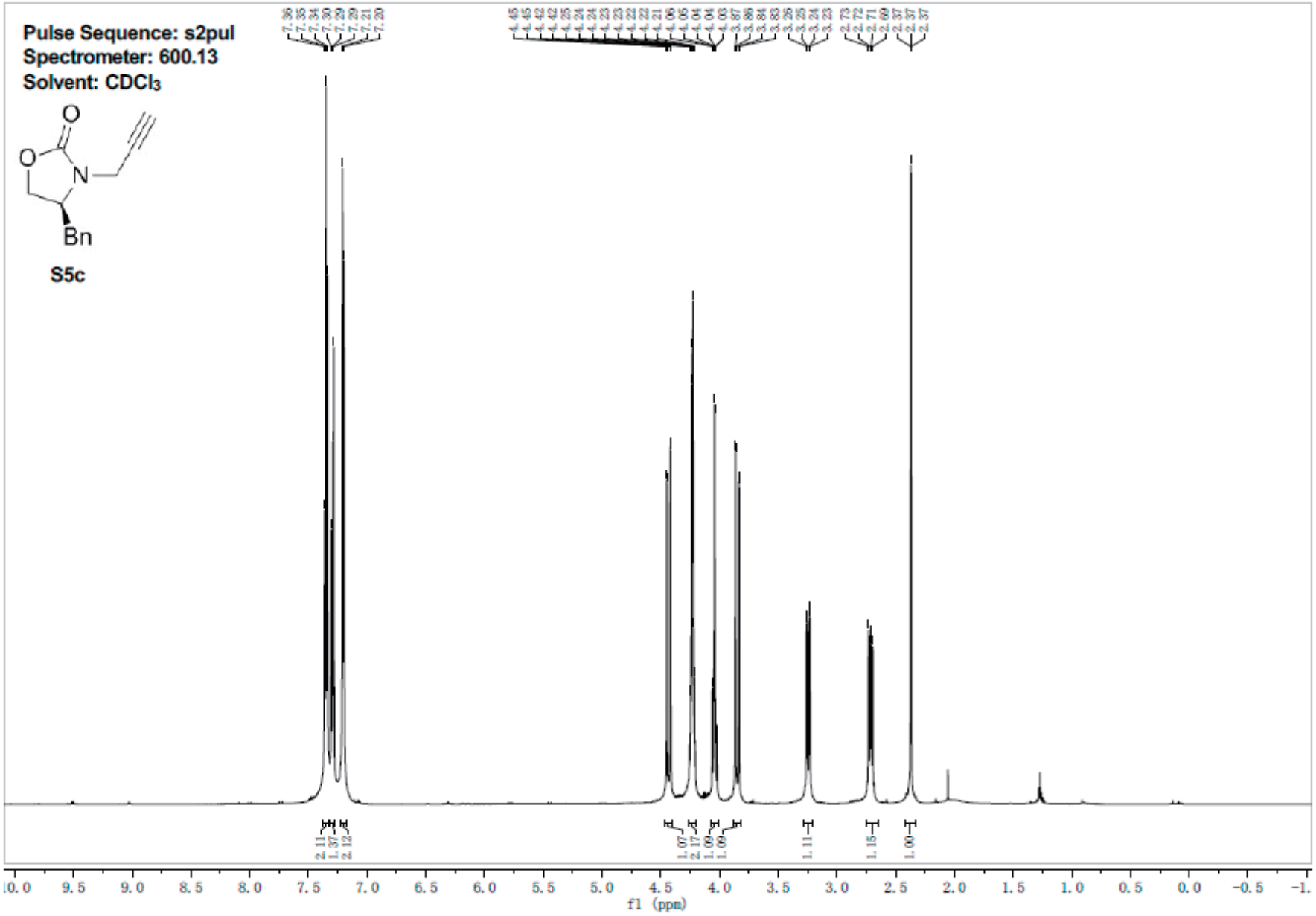

193.38
169.54
142.26
128.78
96.99
67.37
20.91
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
AcO
O
O
2
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

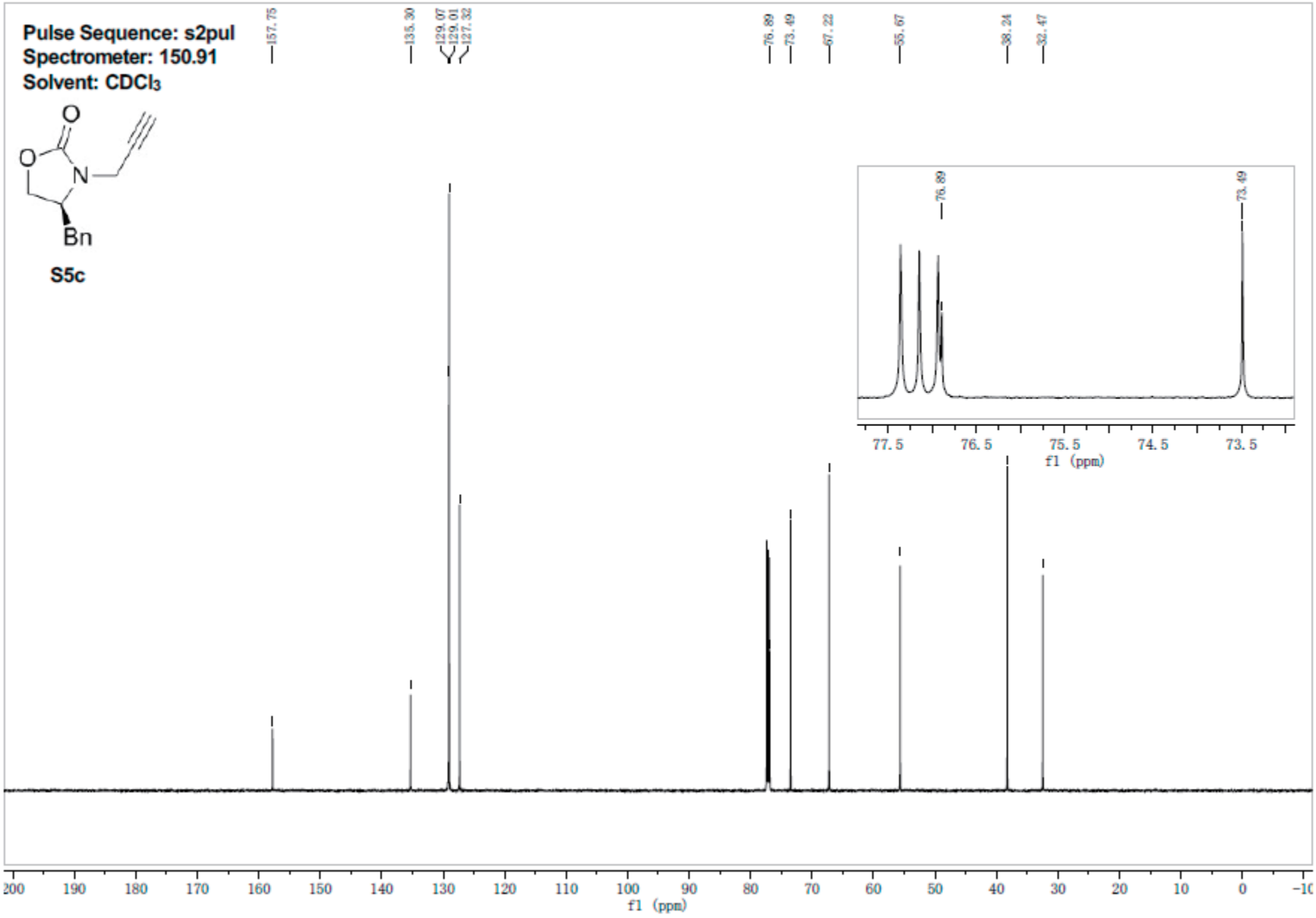

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
O
O
N
S5a
f1 (ppm)

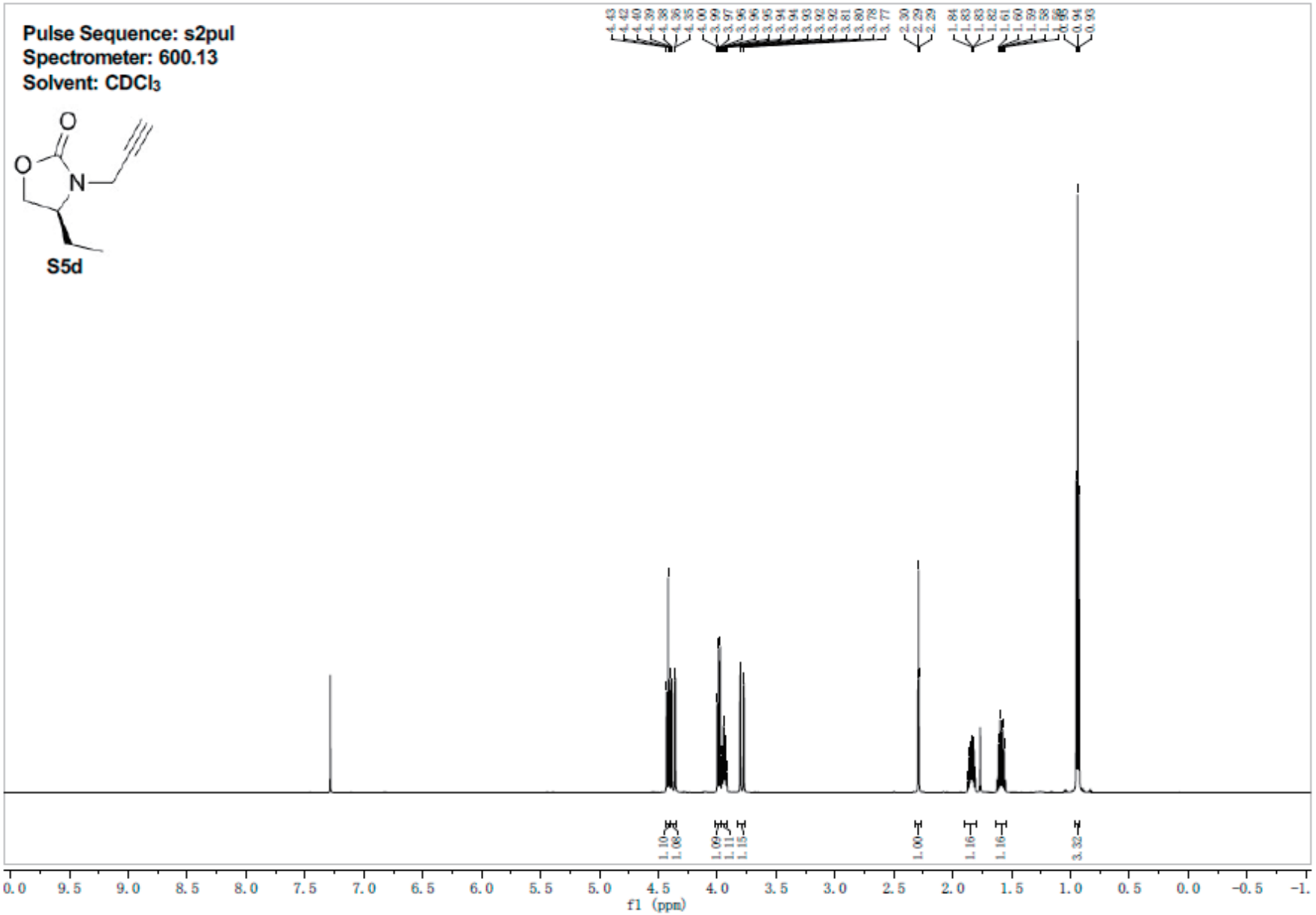

Pulse Sequence: s2pul
Spectrometer:150.91
Solvent: CDCl3
158.08
73.13
63.22
58.77
32.40
27.57
17.64
14.64
S5a
f1 (ppm)

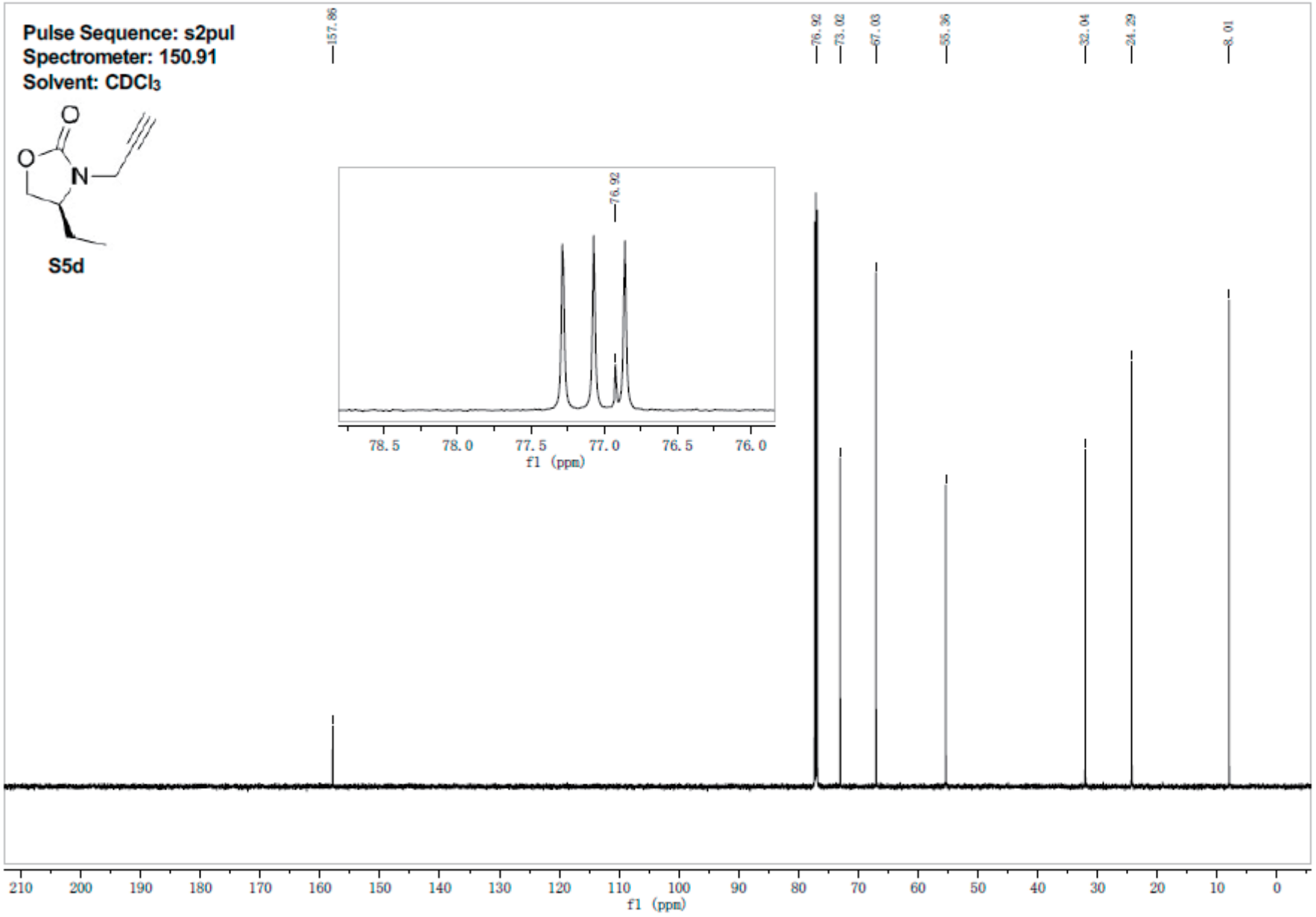

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
O
O
N
Ph
S5b
7.46
7.45
7.44
7.43
7.42
7.42
7.41
7.36
7.35
5.00
4.99
4.97
4.71
4.69
4.44
4.44
4.41
4.41
4.41
4.20
4.18
4.17
3.43
3.42
3.40
3.40
2.28
2.28
2.27
3.06
2.12
1.07
1.10
1.11
1.11
1.11
1.00
0.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.
f1 (ppm)

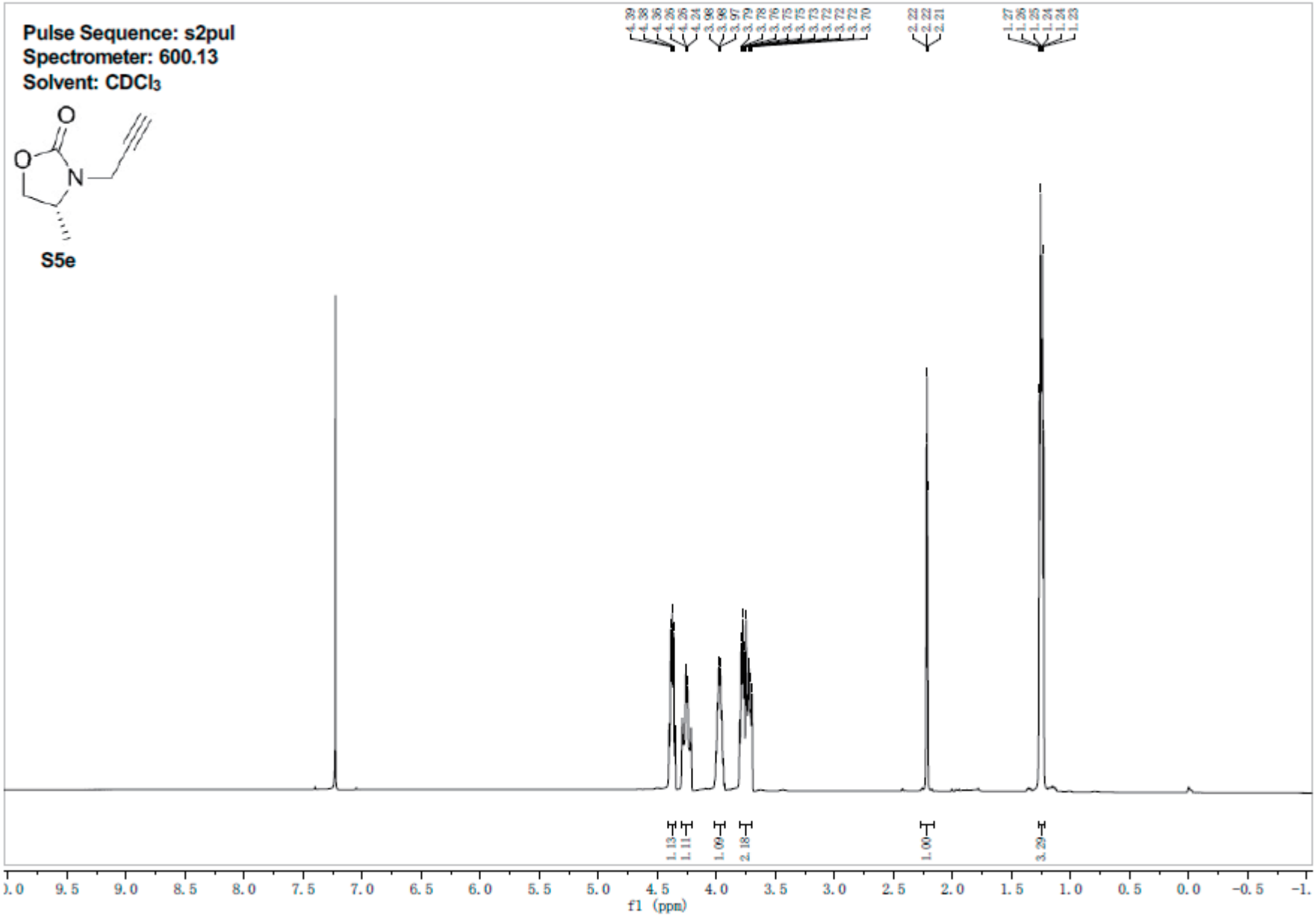

Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
S5b
157.73
136.66
129.40
129.33
127.26
76.60
73.24
69.95
69.00
32.02
f1 (ppm)

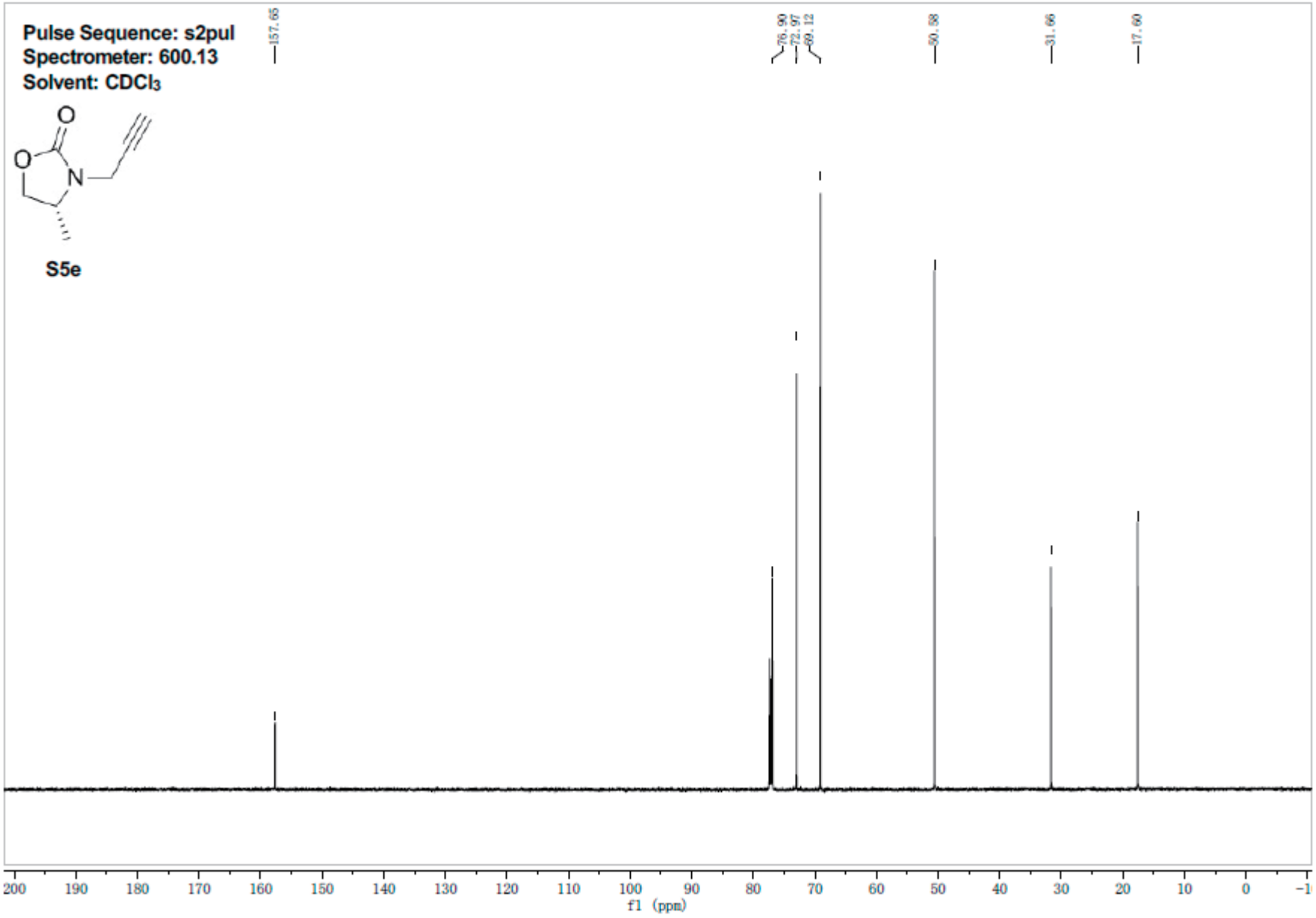

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
O
O
N
Bn
S5c
7.36
7.35
7.34
7.30
7.29
7.29
7.21
7.20
4.45
4.45
4.42
4.42
4.25
4.24
4.24
4.23
4.23
4.22
4.22
4.21
4.06
4.05
4.04
4.04
4.03
3.87
3.86
3.84
3.83
3.26
3.25
3.24
3.23
2.73
2.72
2.71
2.69
2.37
2.37
2.37
2.11
1.97
2.12
1.07
2.17
1.09
1.09
1.11
1.15
1.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.
f1 (ppm)

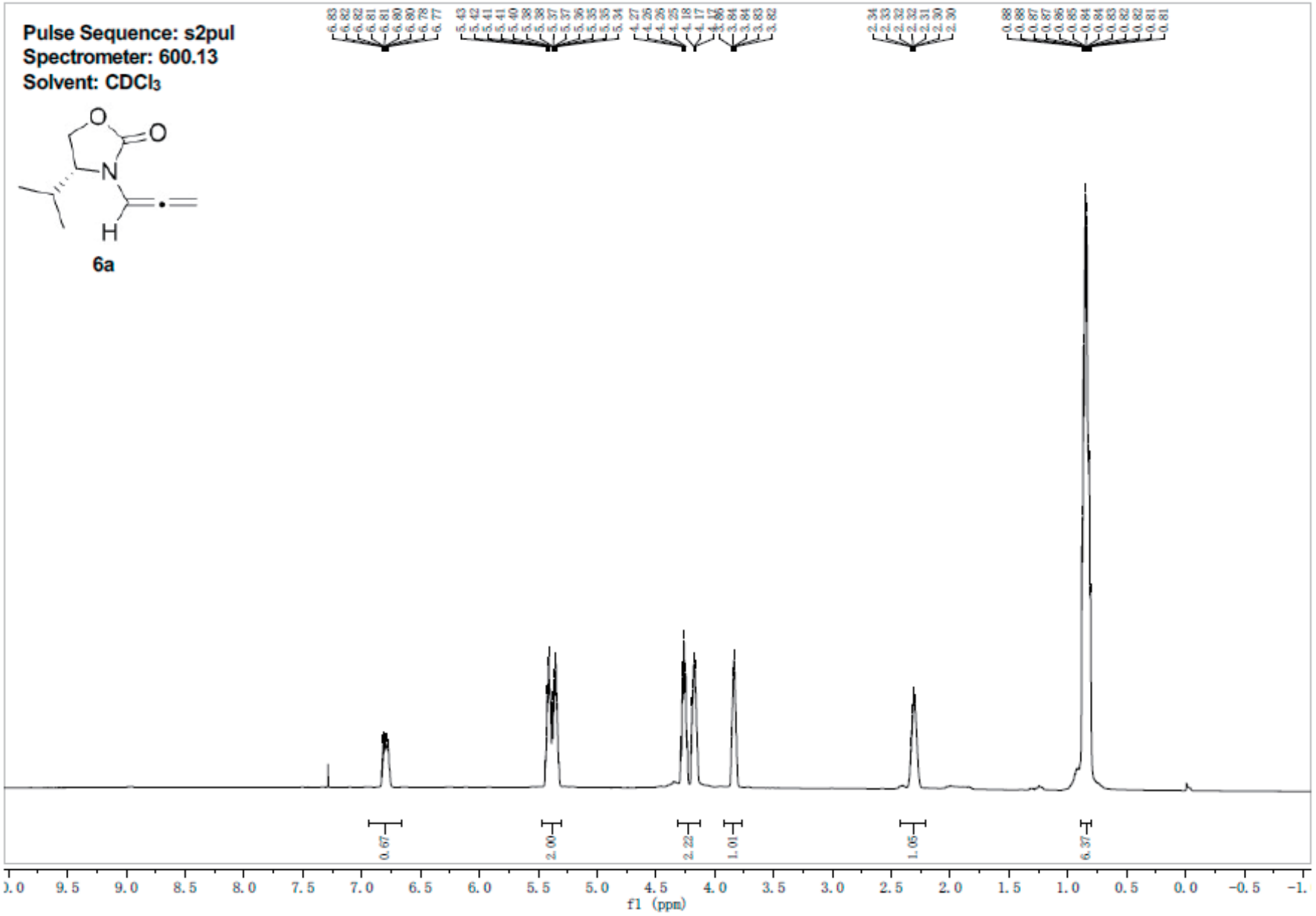

Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
157.75
135.30
129.07
129.01
127.32
76.89
73.49
67.22
55.67
38.24
32.47
O
O
N
Bn
S5c
f1 (ppm)

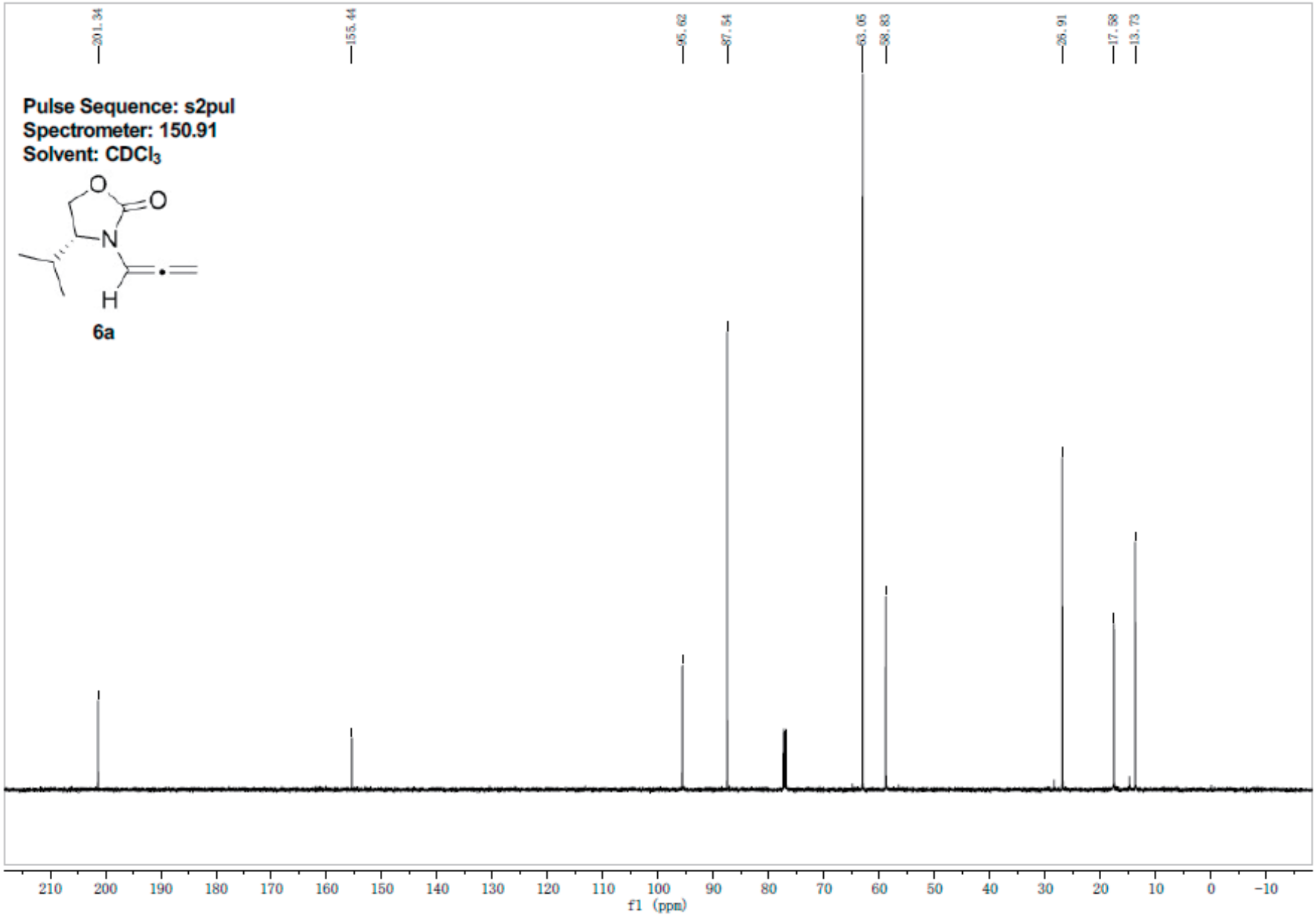

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
S5d
f1 (ppm)

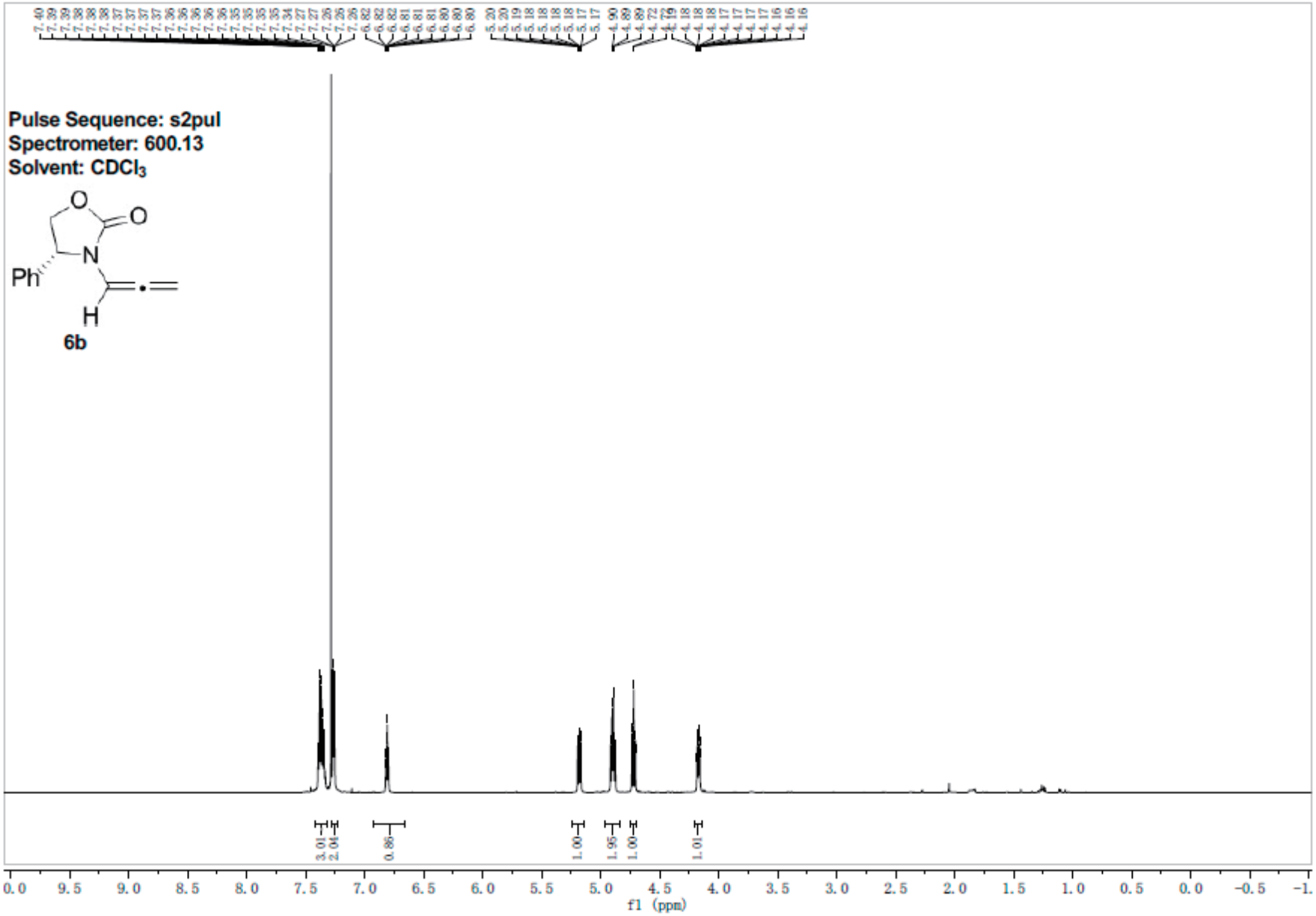

Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
S5d
157.86
76.92
73.02
67.03
55.36
32.04
24.29
8.01
78.5
78.0
77.5
77.0
76.5
76.0
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

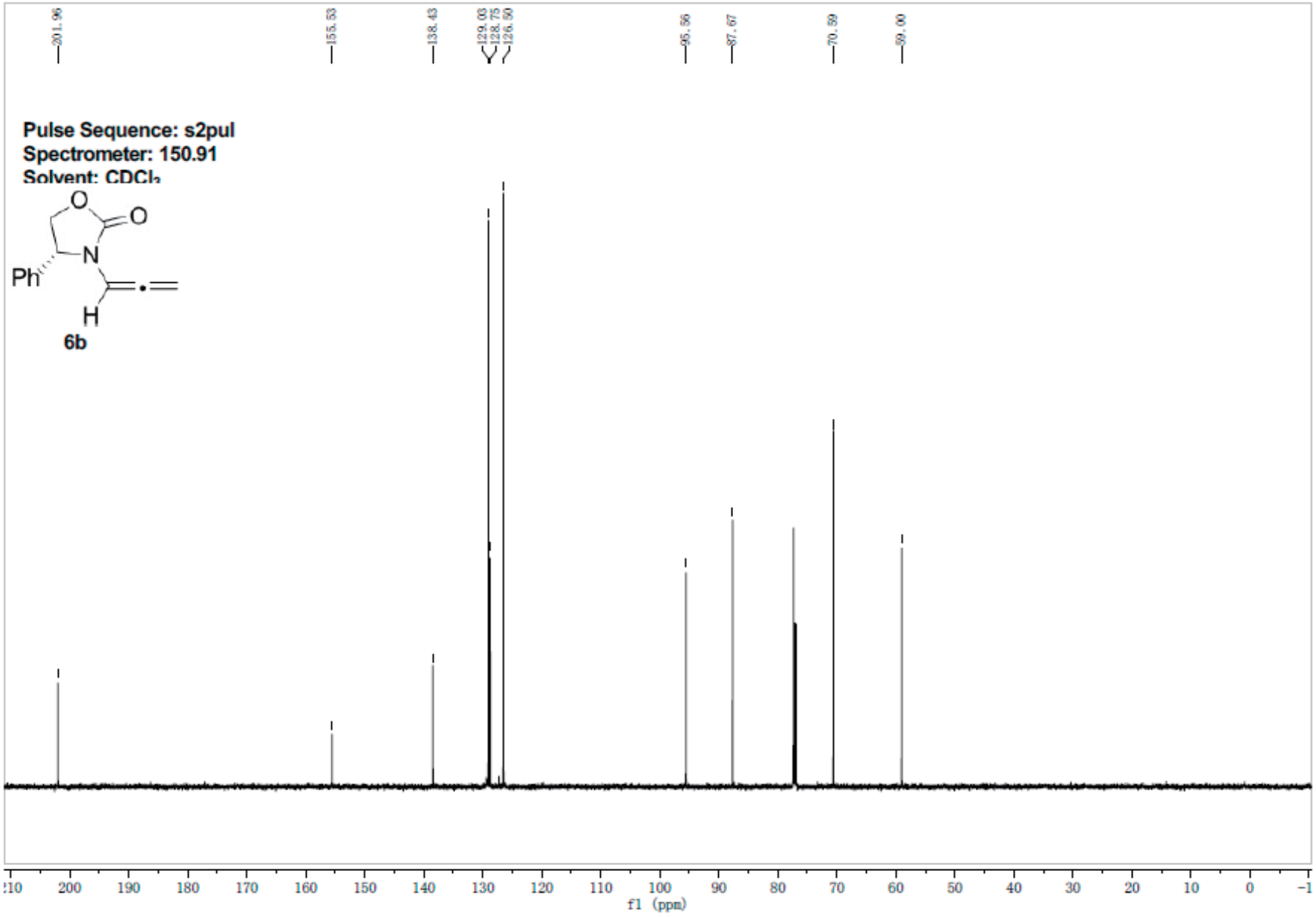

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
S5e
4.39
4.38
4.36
4.26
4.24
3.98
3.98
3.97
3.79
3.78
3.76
3.75
3.75
3.73
3.72
3.72
3.72
3.70
2.22
2.22
2.21
1.27
1.26
1.25
1.24
1.24
1.23
1.13
1.11
1.09
2.18
1.00
3.29
f1 (ppm)

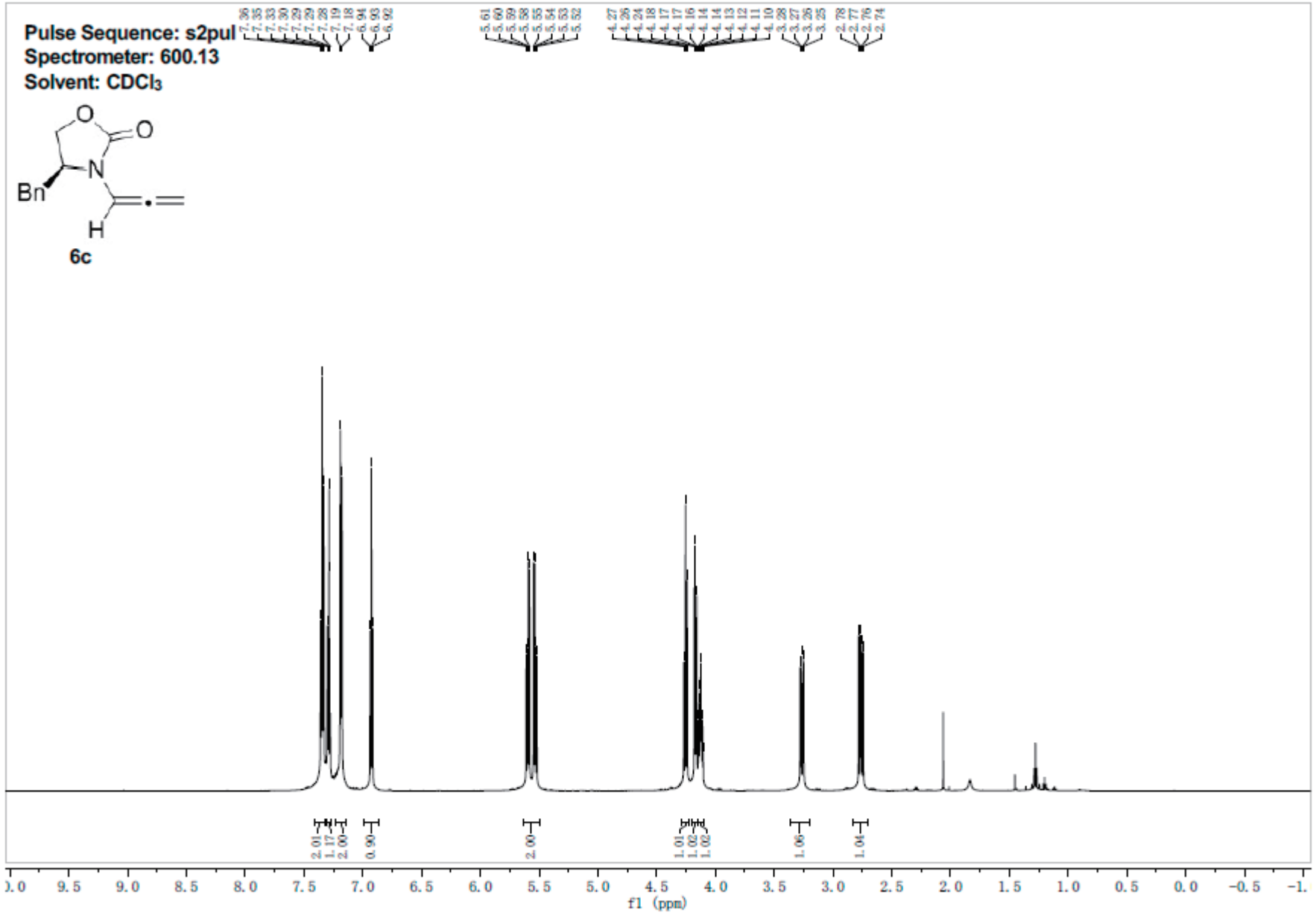

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
157.65
76.90
72.97
69.12
50.58
31.66
17.60
S5e
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−1
f1 (ppm)

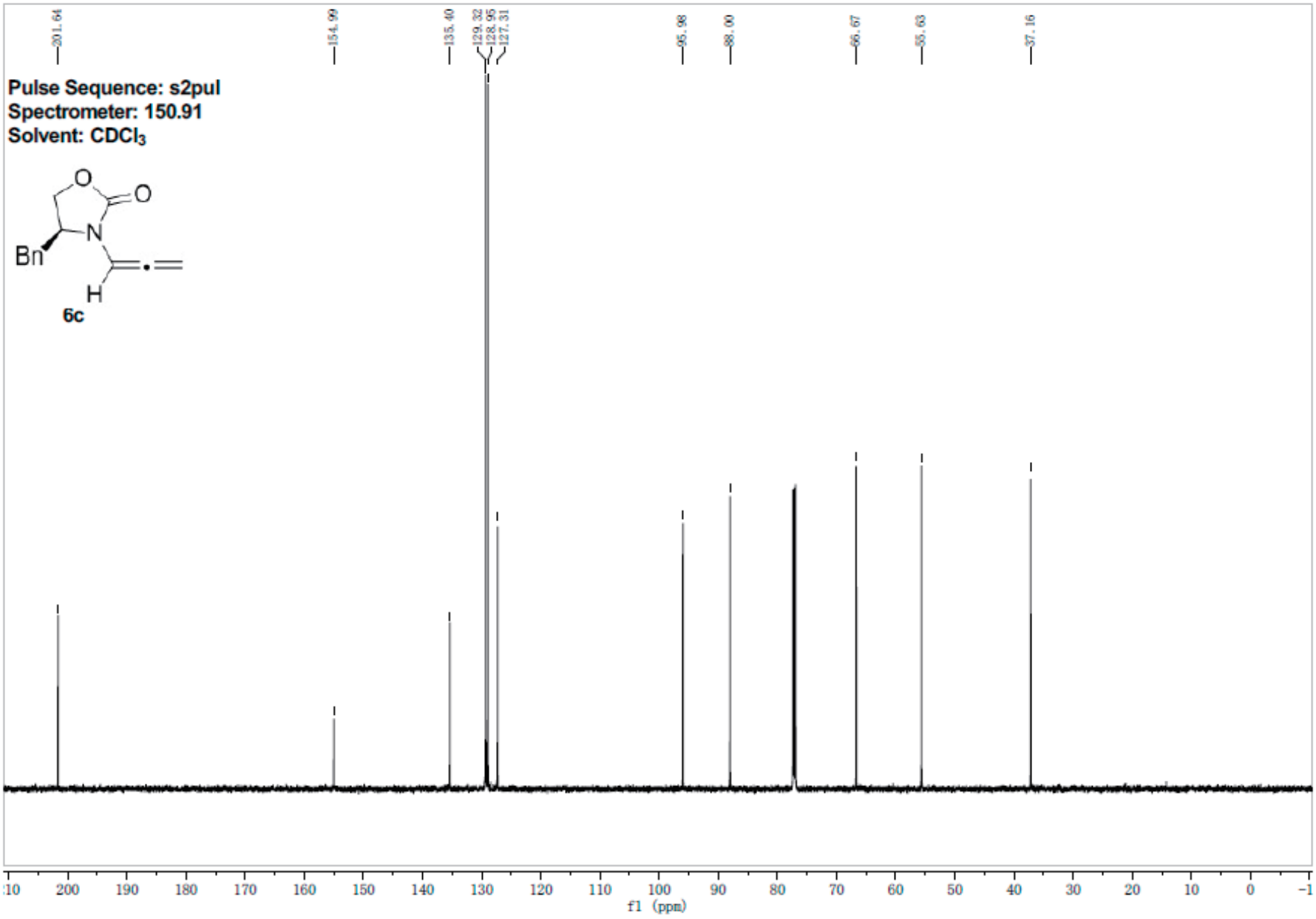

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
6a
f1 (ppm)

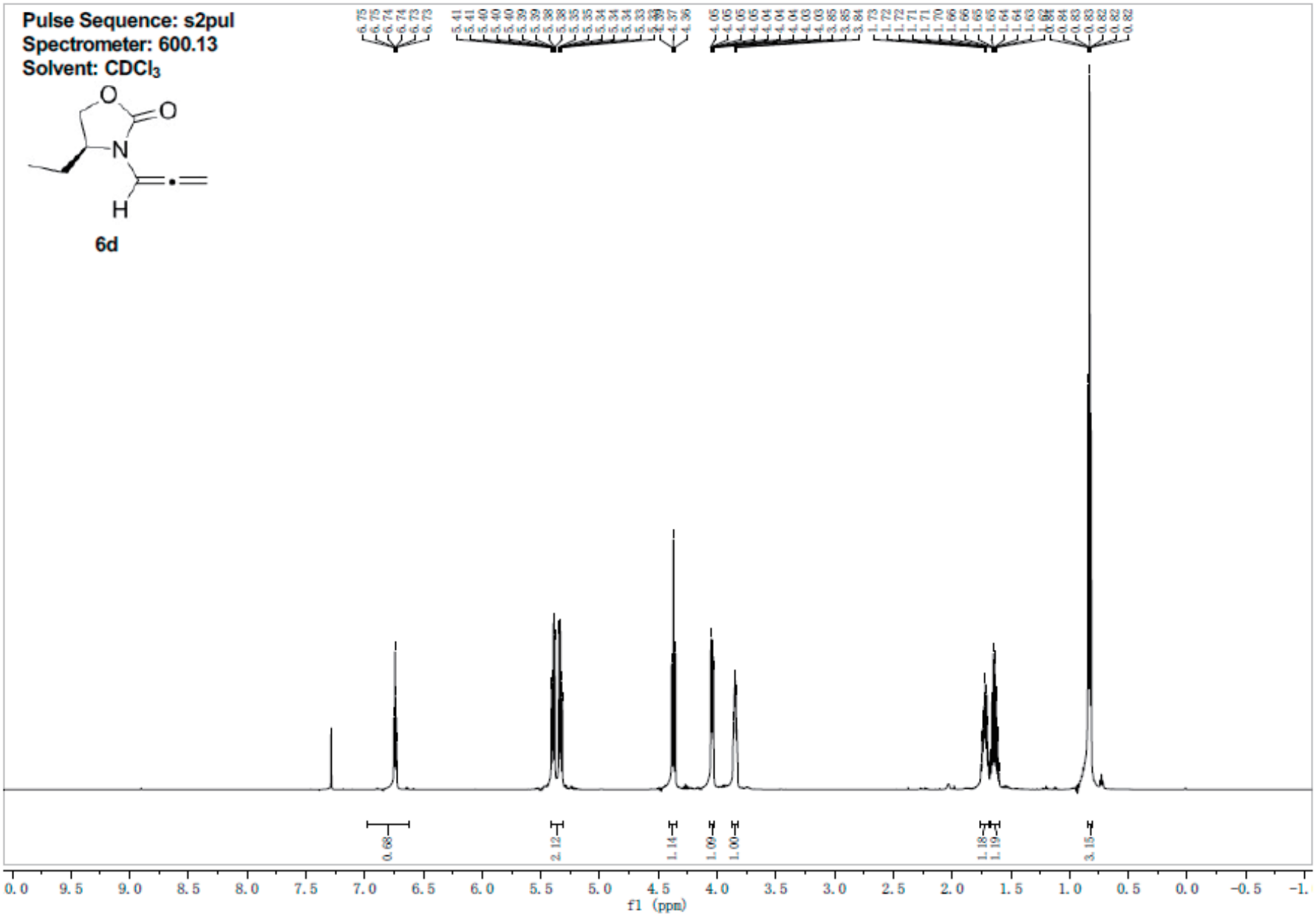

201.34
155.44
95.62
87.54
63.05
58.83
26.91
17.58
13.73
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
N
H
6a
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10
f1 (ppm)

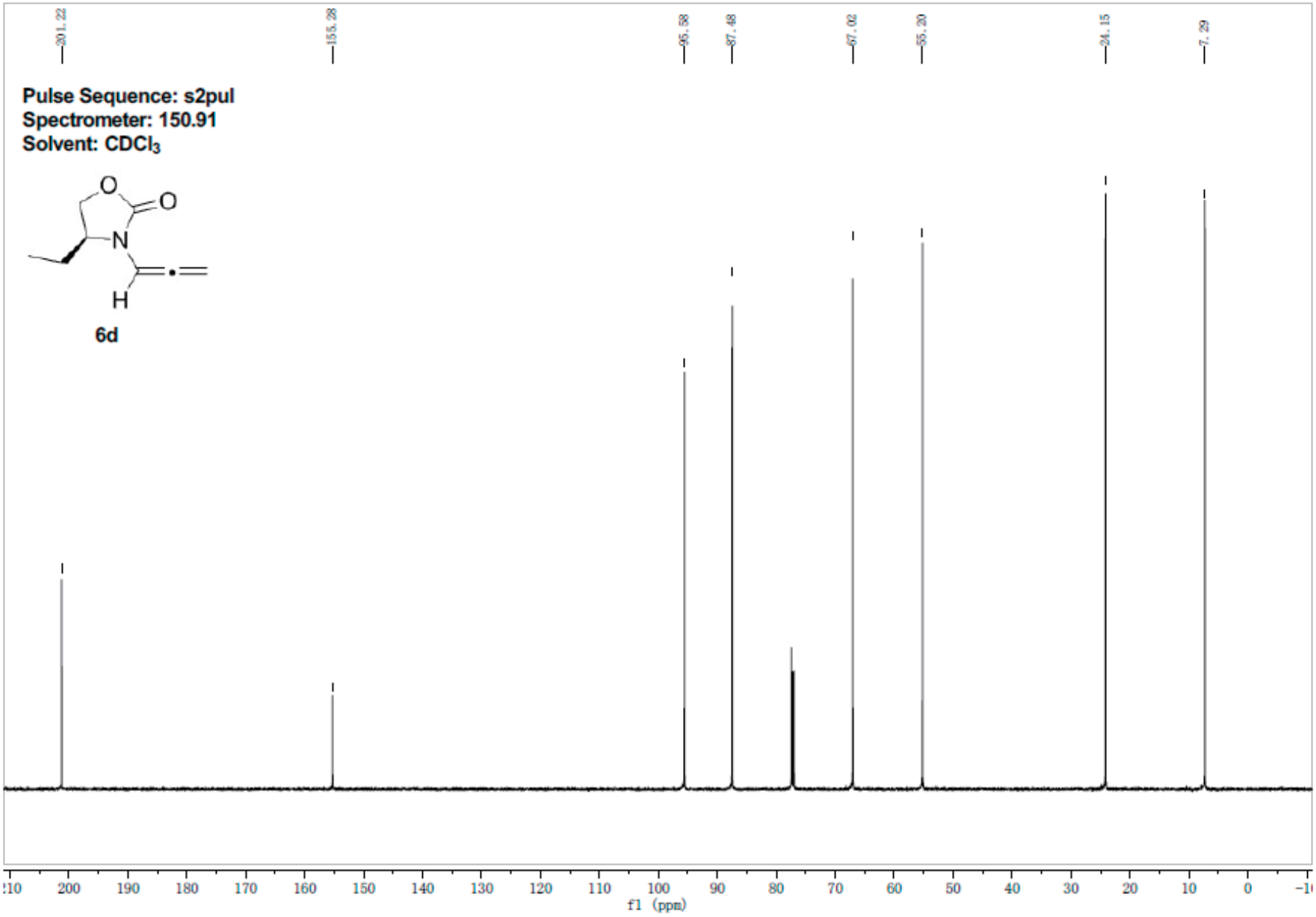

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
Ph
6b
3.01
2.04
0.86
1.00
1.95
1.00
1.01
f1 (ppm)

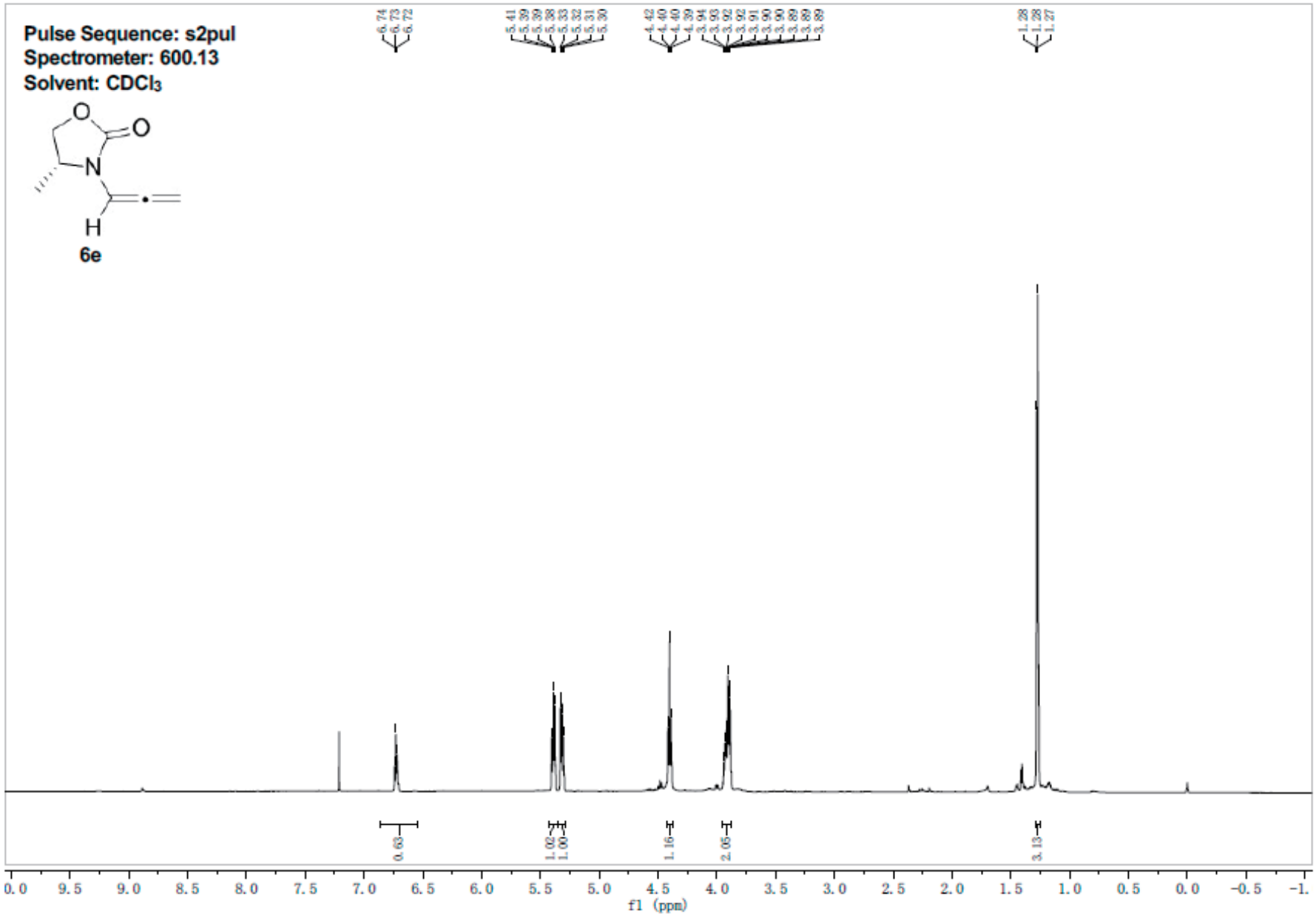

201.96
155.53
138.43
129.03
128.75
126.50
95.56
87.67
70.59
59.00
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
N
Ph
H
6b
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)

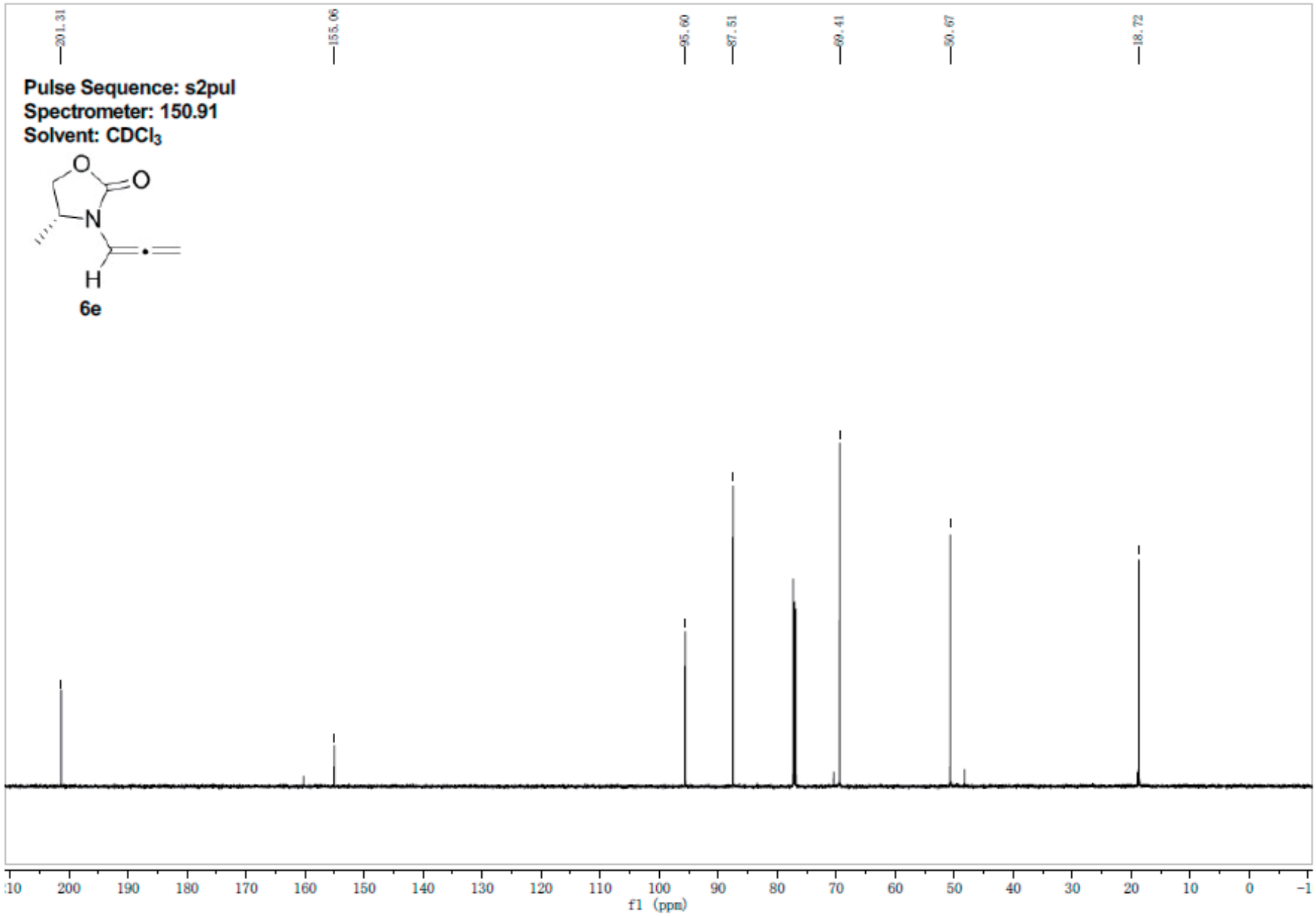

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
Bn
6c
f1 (ppm)

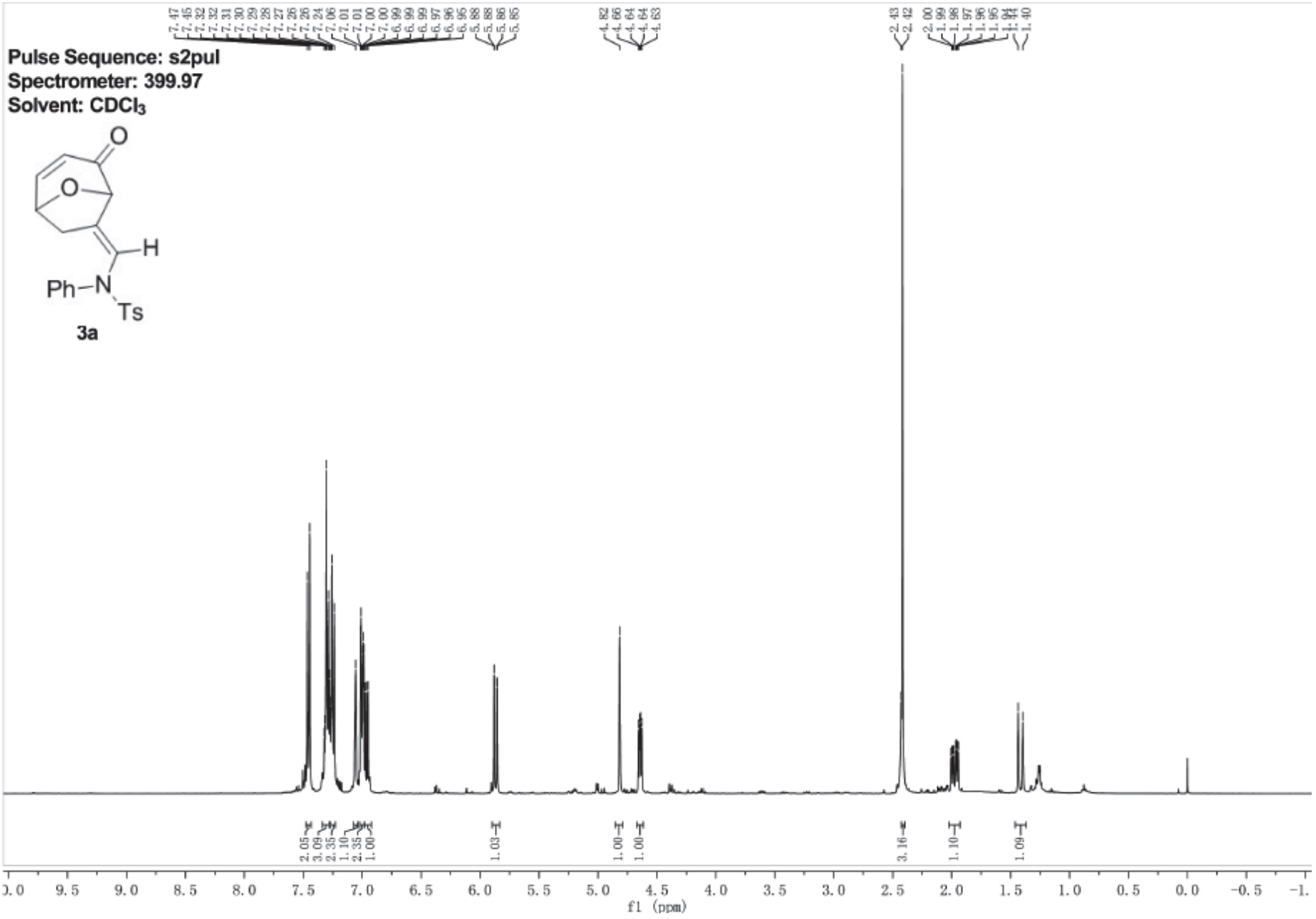

201.64
154.99
135.40
129.32
128.95
127.31
95.98
88.00
66.67
55.63
37.16
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
N
Bn
H
6c
f1 (ppm)

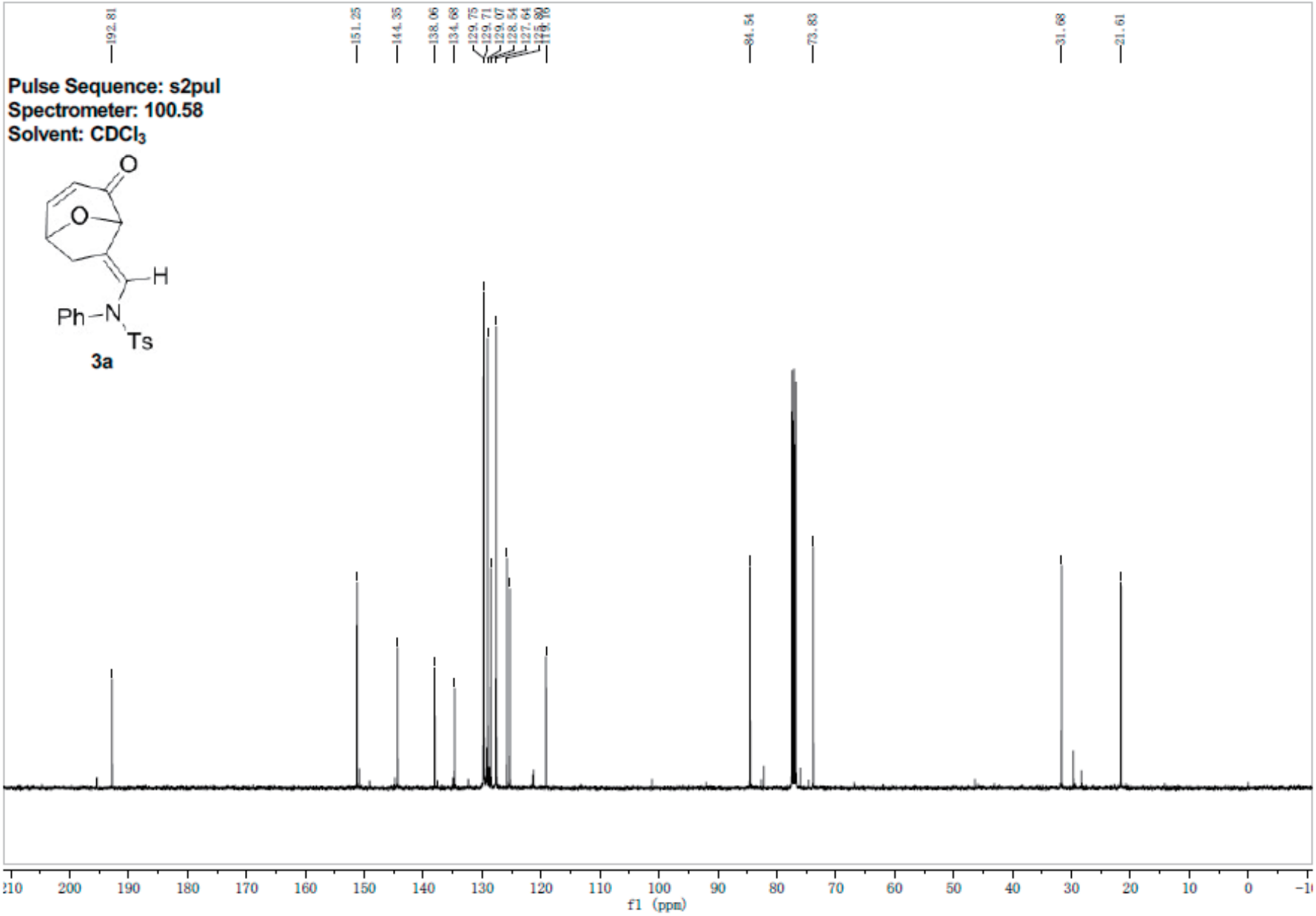

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
6d
f1 (ppm)

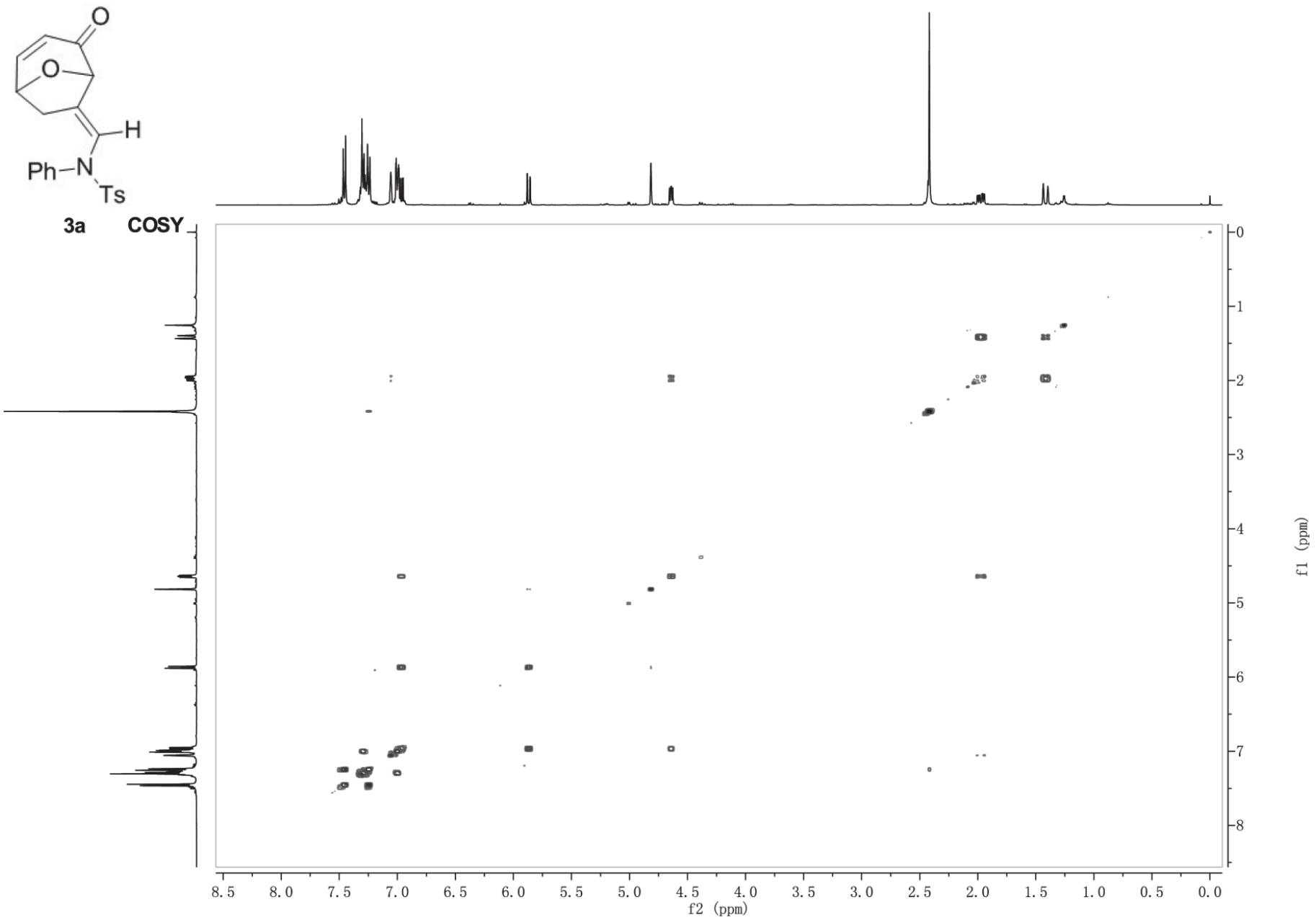

201.22
155.28
95.58
87.48
67.02
55.20
24.15
7.29
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
N
H
6d
f1 (ppm)

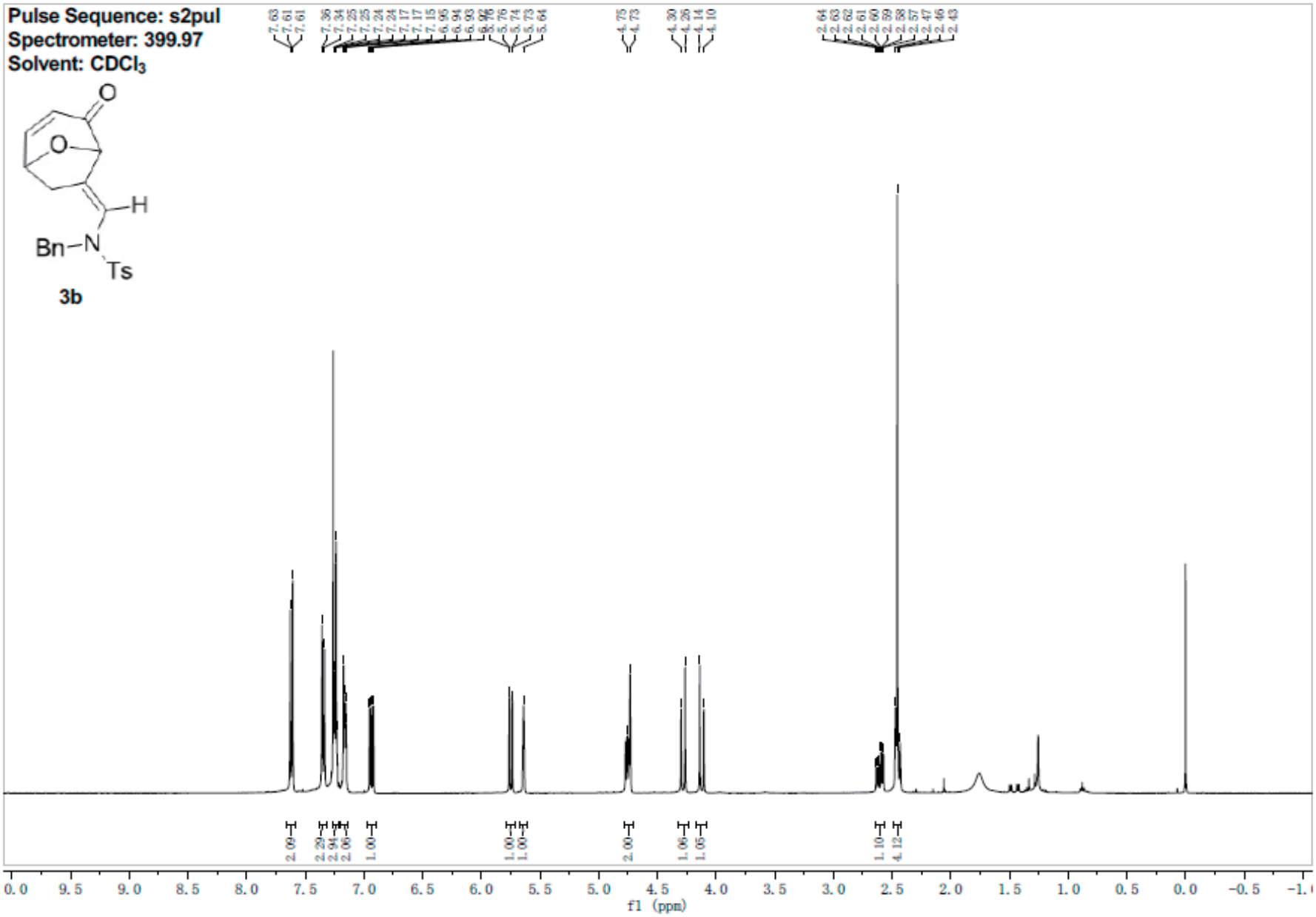

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
6e
6.74
6.73
6.72
5.41
5.39
5.39
5.38
5.33
5.32
5.31
5.30
4.42
4.40
4.40
4.39
3.94
3.93
3.92
3.92
3.91
3.90
3.90
3.89
3.89
3.89
1.28
1.28
1.27
0.63
1.02
1.00
1.16
2.05
3.13
f1 (ppm)

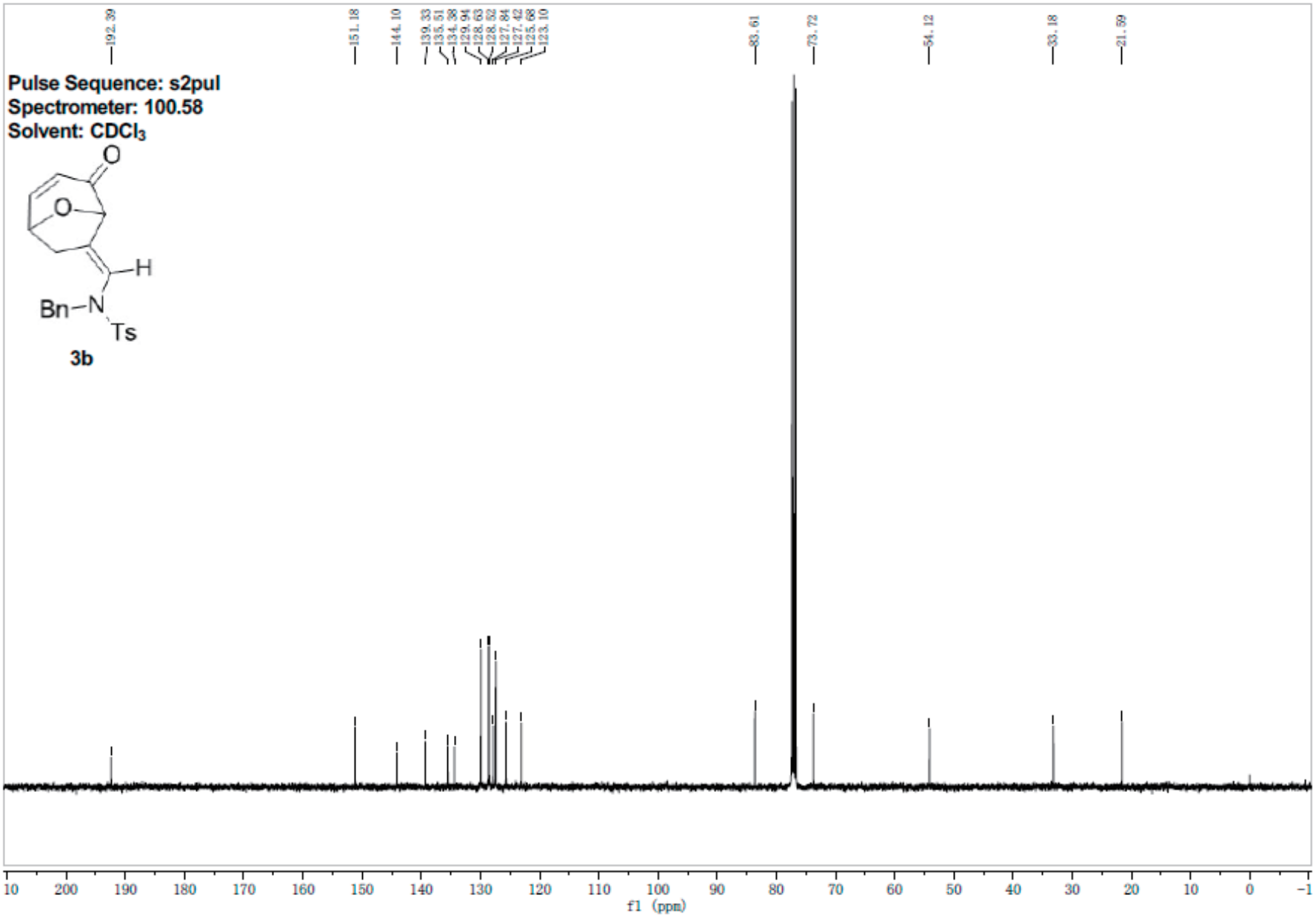

201.31
155.06
95.60
87.51
69.41
50.67
18.72
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
N
H
6e
f1 (ppm)

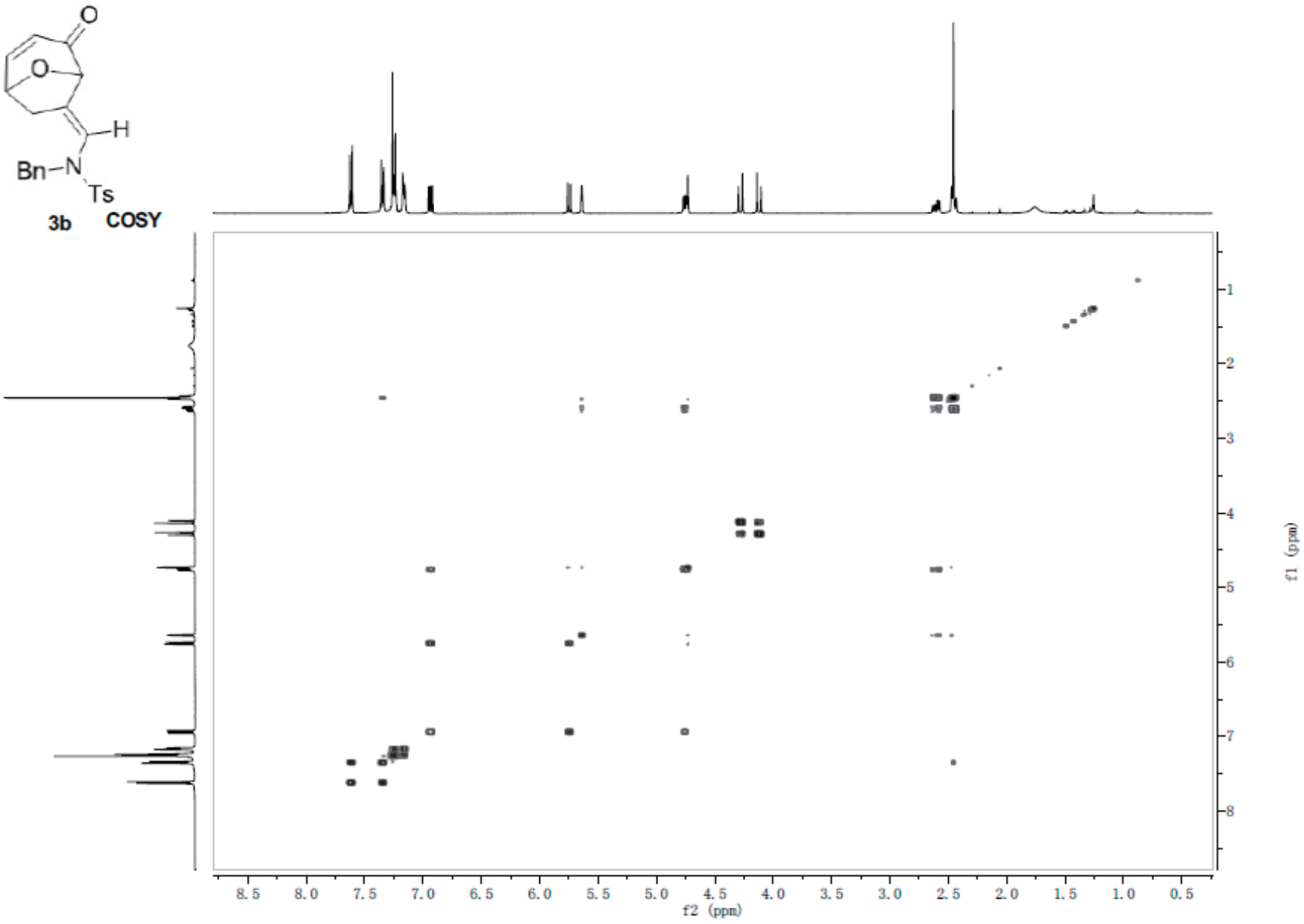

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
O
O
H
Ph–N
Ts
3a
f1 (ppm)

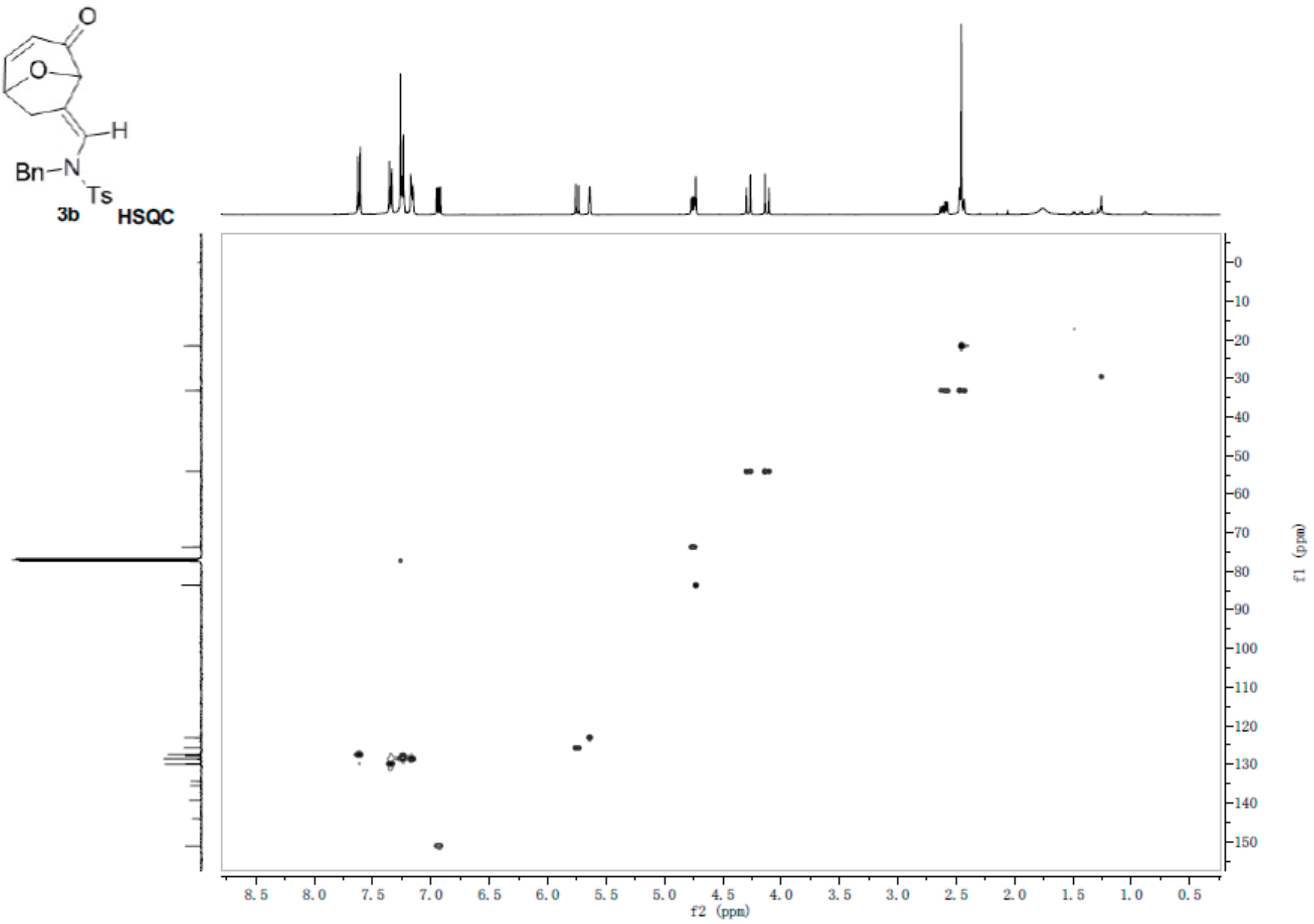

192.81
151.25
144.35
138.06
134.68
129.75
129.71
129.07
128.54
127.64
84.54
73.83
31.68
21.61
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
O
O
H
Ph–N
Ts
3a
f1 (ppm)

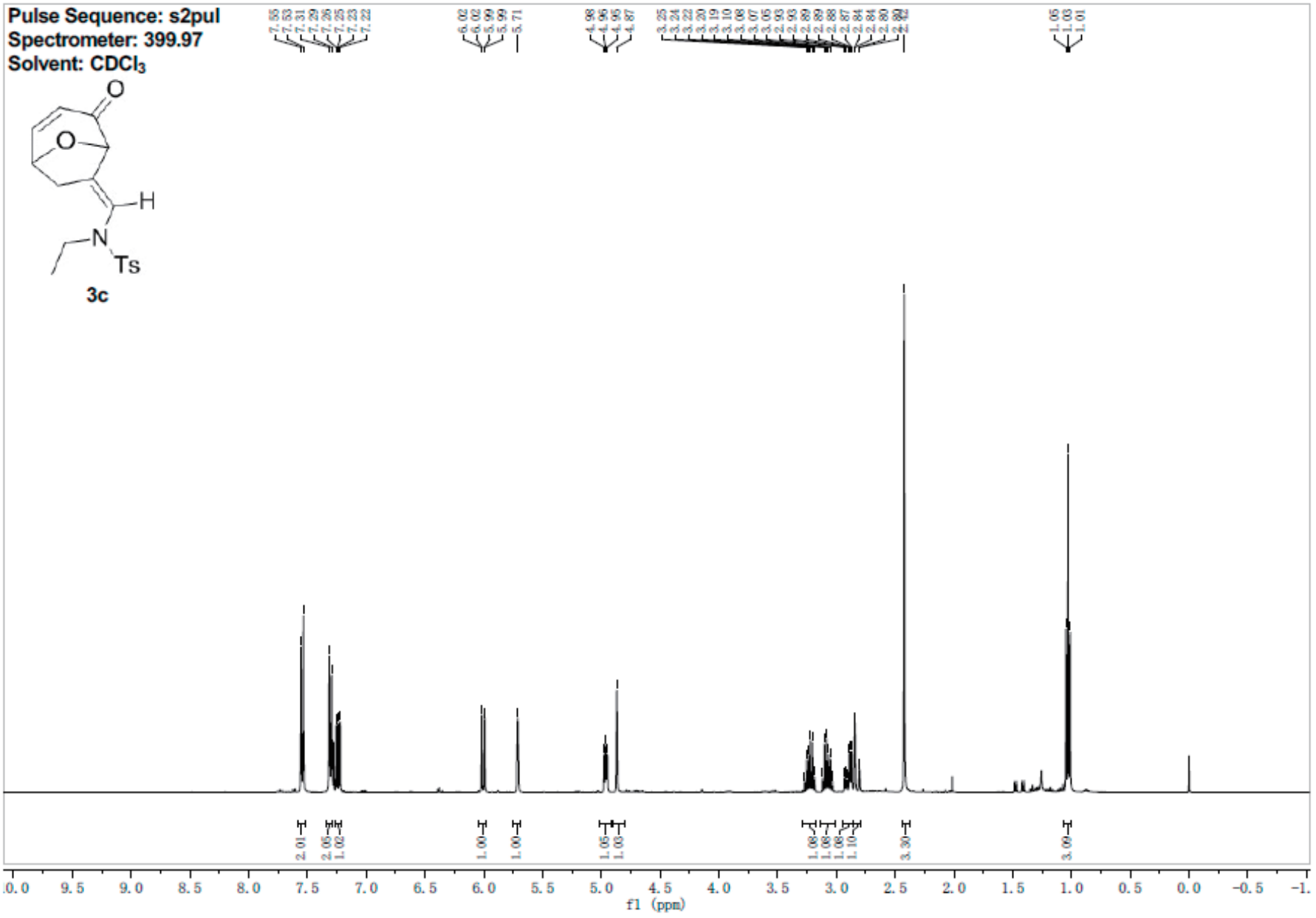

O
O
H
Ph–N
Ts
3a COSY
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f2 (ppm)
0 1 2 3 4 5 6 7 8
f1 (ppm)

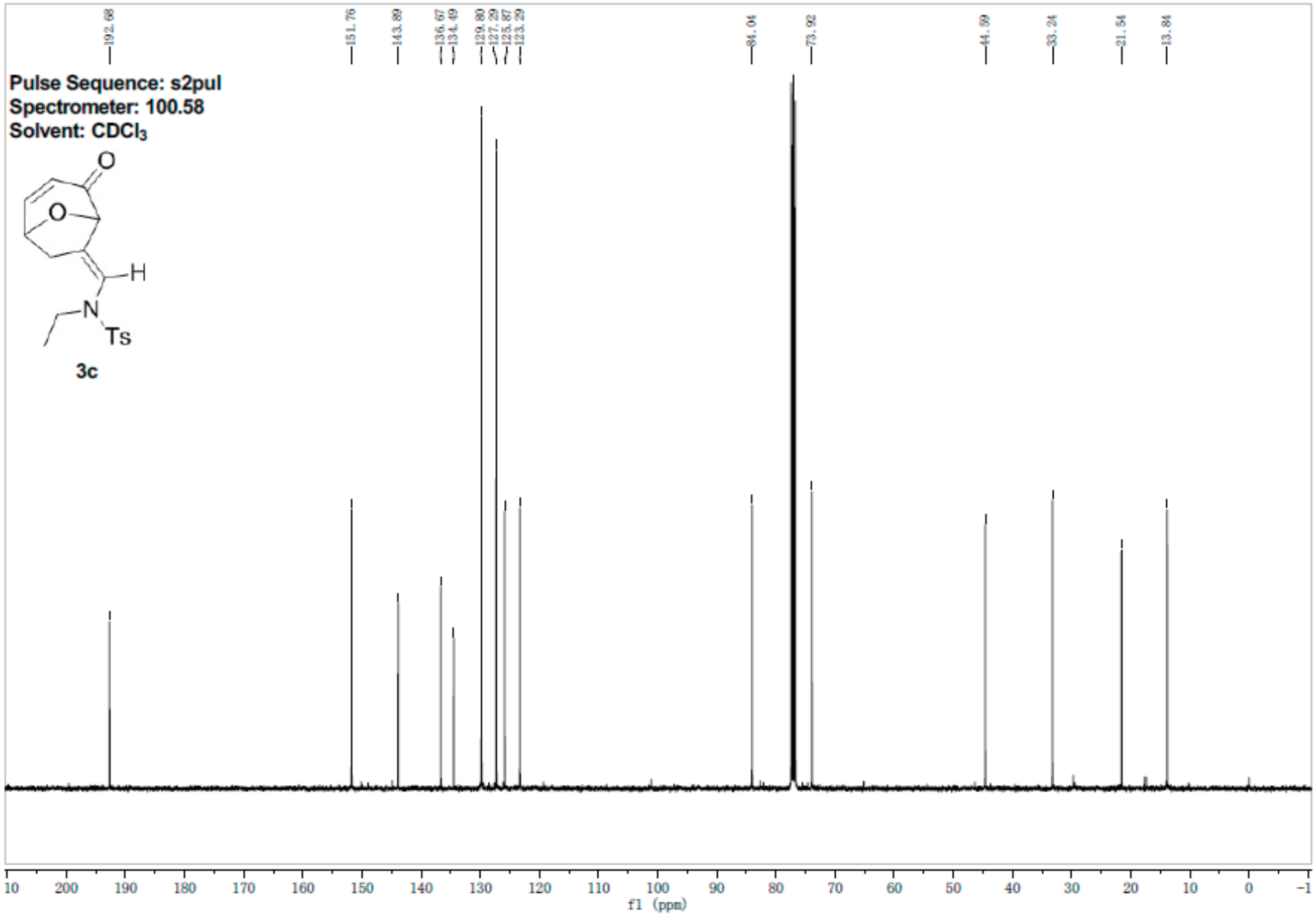

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
O
O
H
Bn–N
Ts
3b
f1 (ppm)

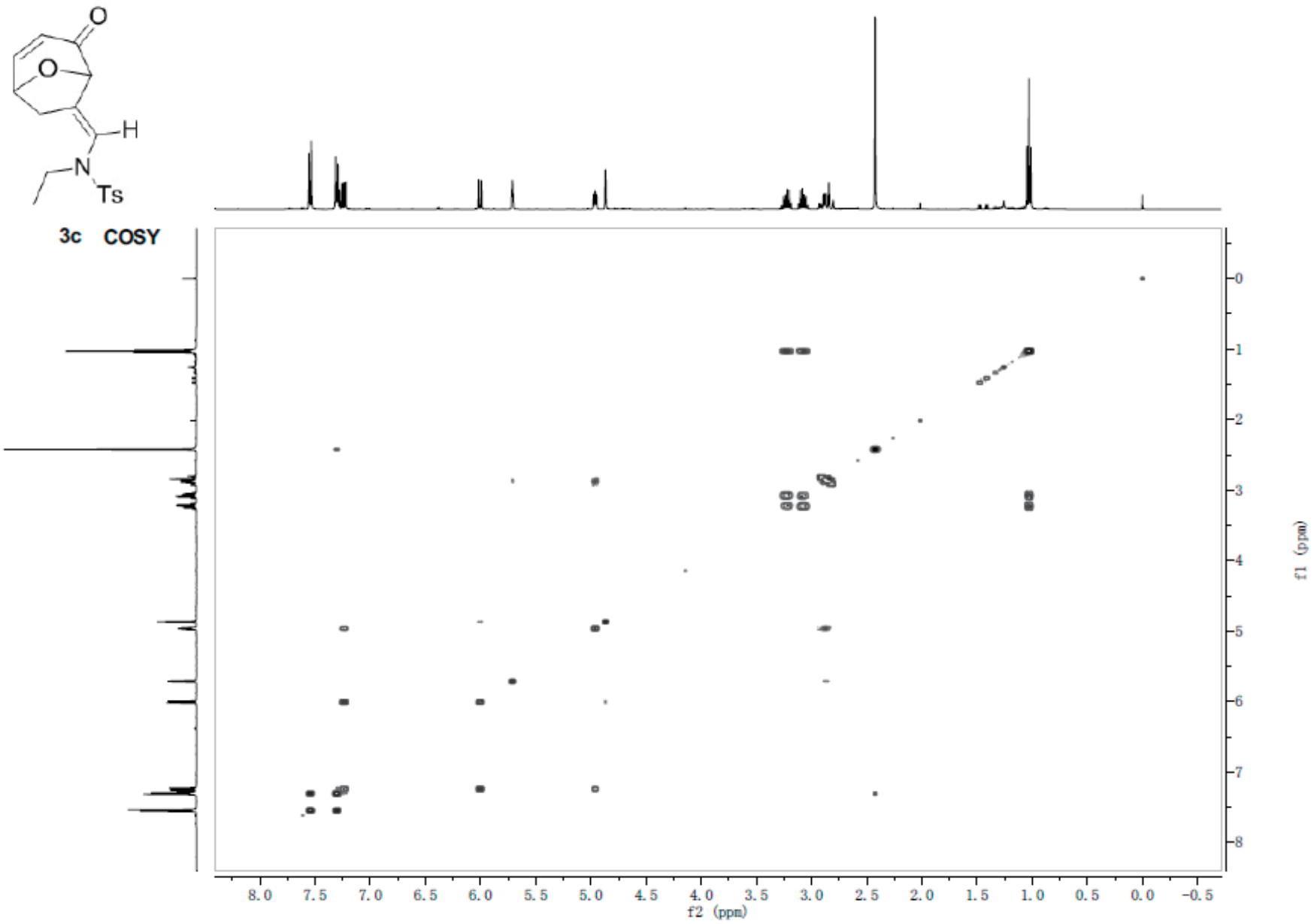

192.39
151.18
144.10
139.33
135.51
134.38
129.94
128.63
128.52
127.84
127.42
125.68
123.10
83.61
73.72
54.12
33.18
21.89
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
O
O
H
Bn–N
Ts
3b
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−1
f1 (ppm)

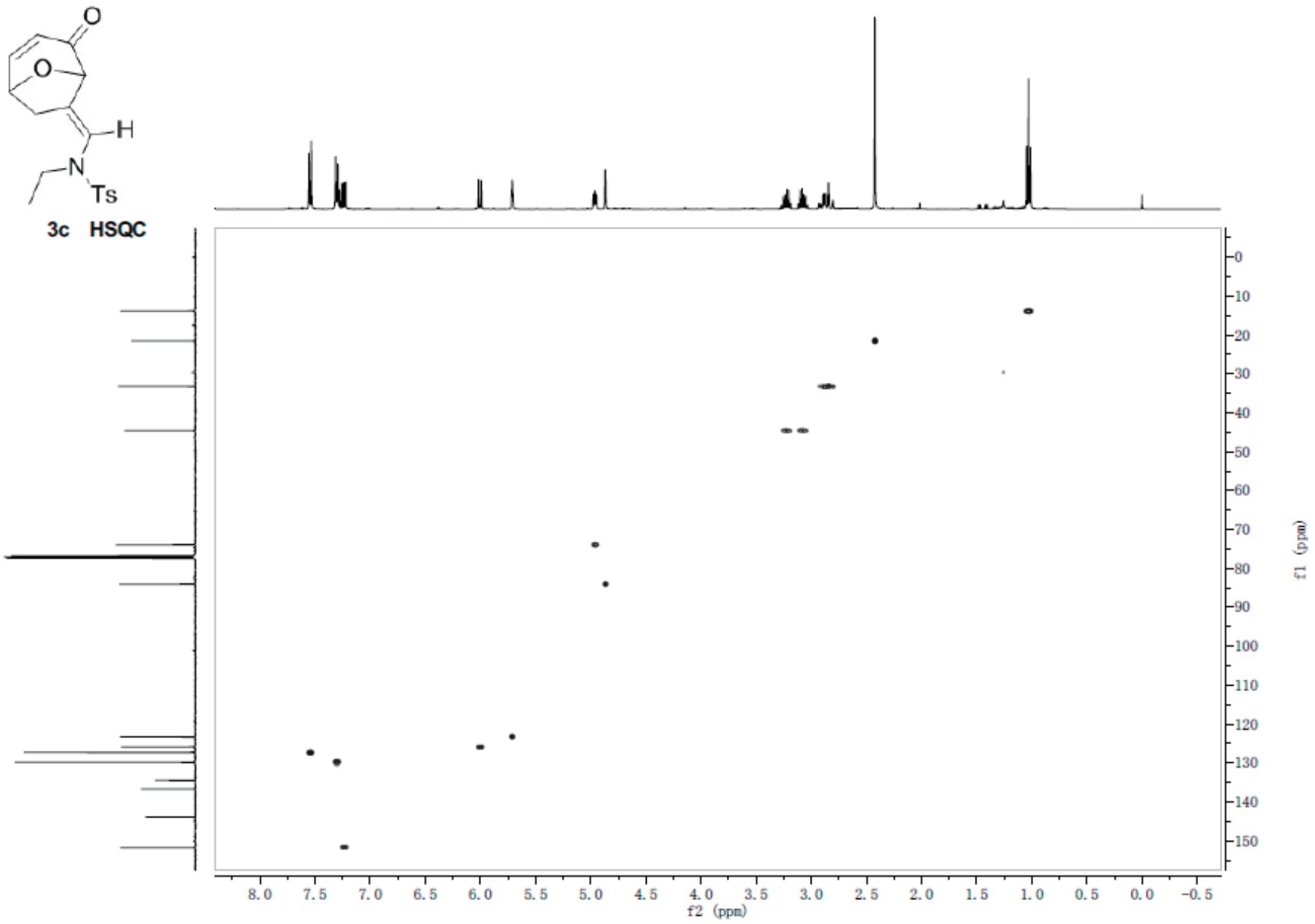

O
O
H
Bn–N
Ts
3b COSY
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f2 (ppm)
1 2 3 4 5 6 7 8
f1 (ppm)

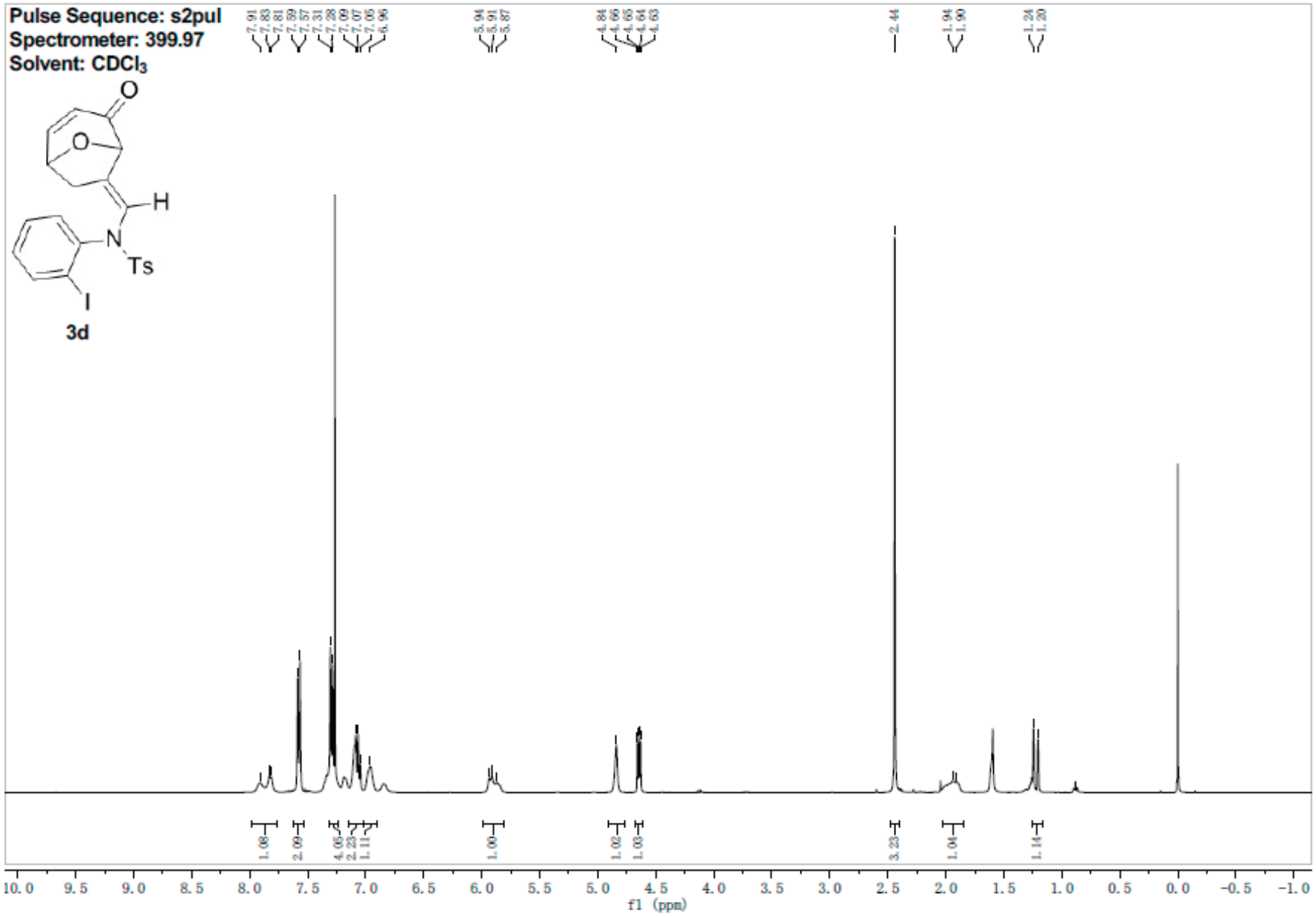

O
O
H
Bn–N
Ts
3b
HSQC
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
f1 (ppm)

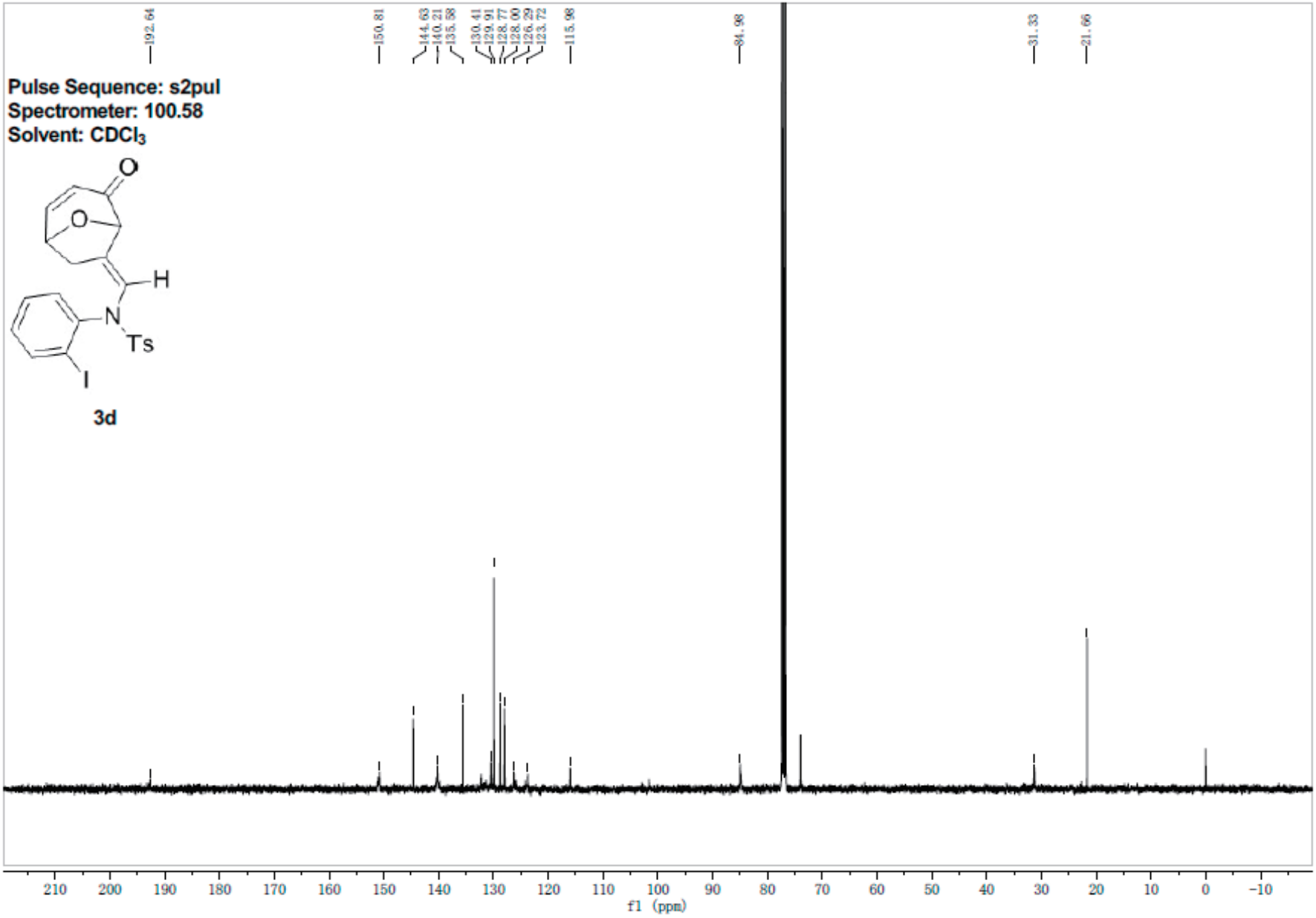

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
O
O
H
N
Ts
3c
f1 (ppm)

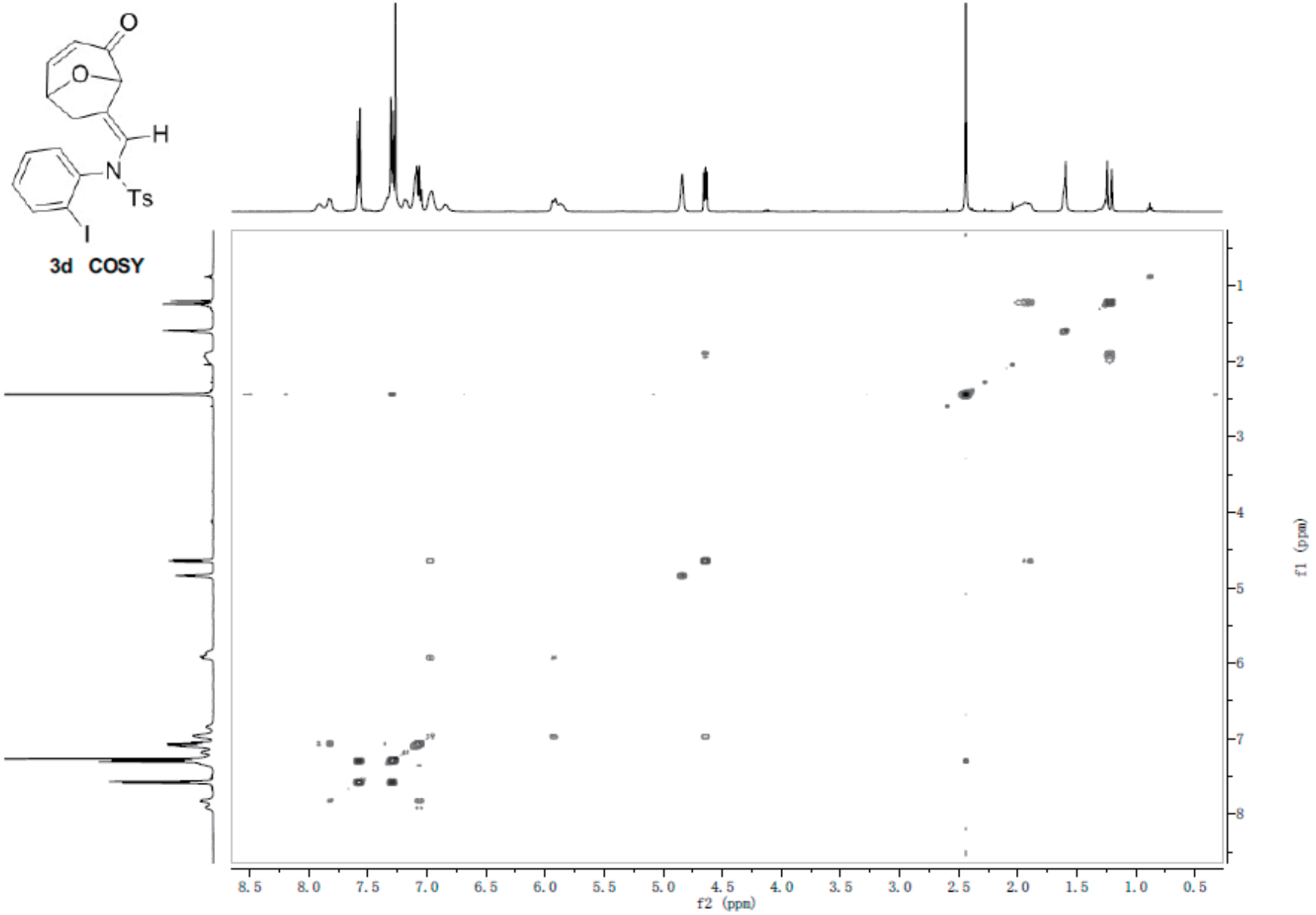

192.68
151.76
143.89
136.67
134.49
129.80
127.29
125.87
123.29
84.04
73.92
44.59
33.24
21.54
13.84
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
O
O
H
N
Ts
3c
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −1
f1 (ppm)

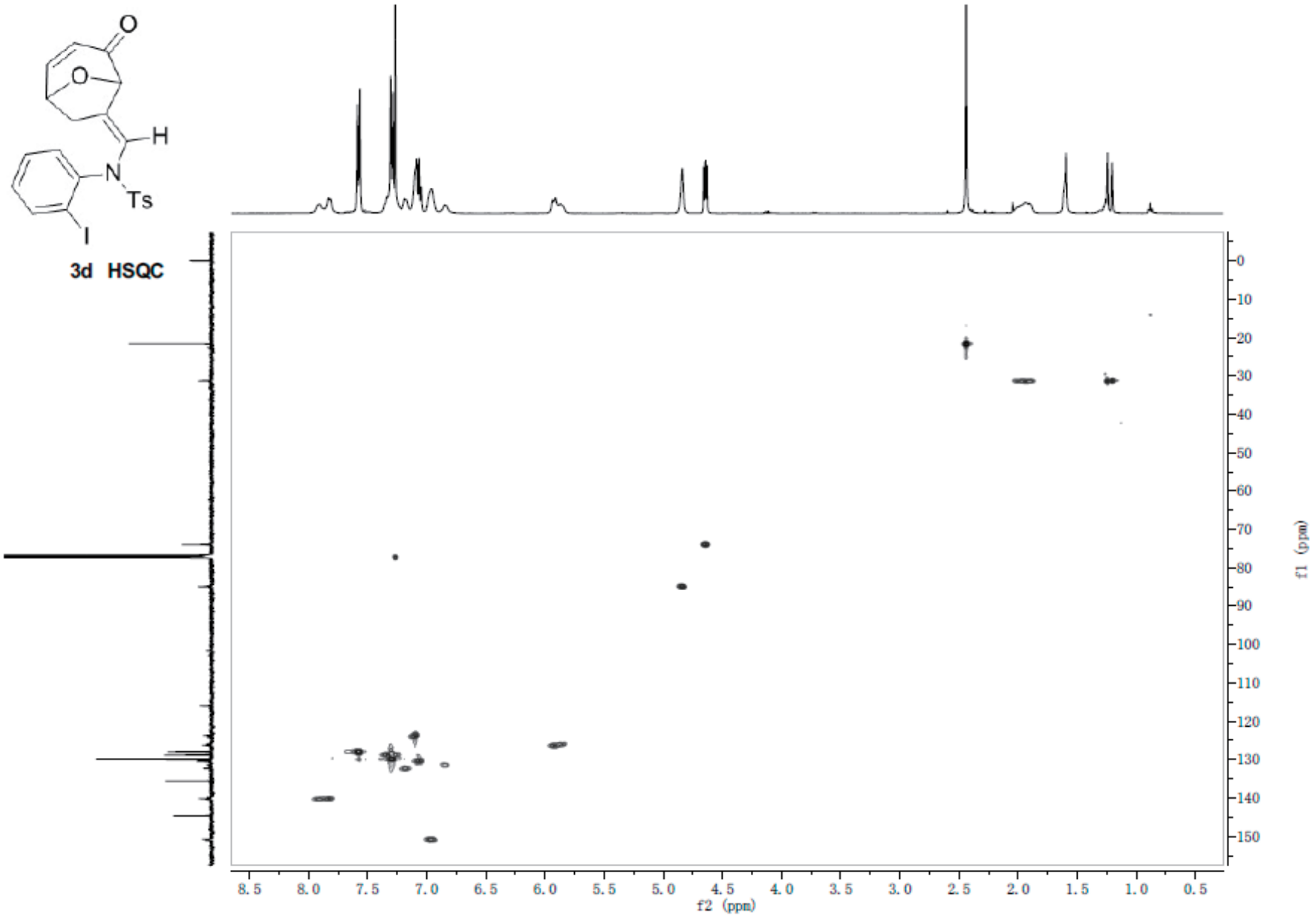

O
O
H
N
Ts
3c COSY
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f2 (ppm)
0
1
2
3
4
5
6
7
8
f1 (ppm)

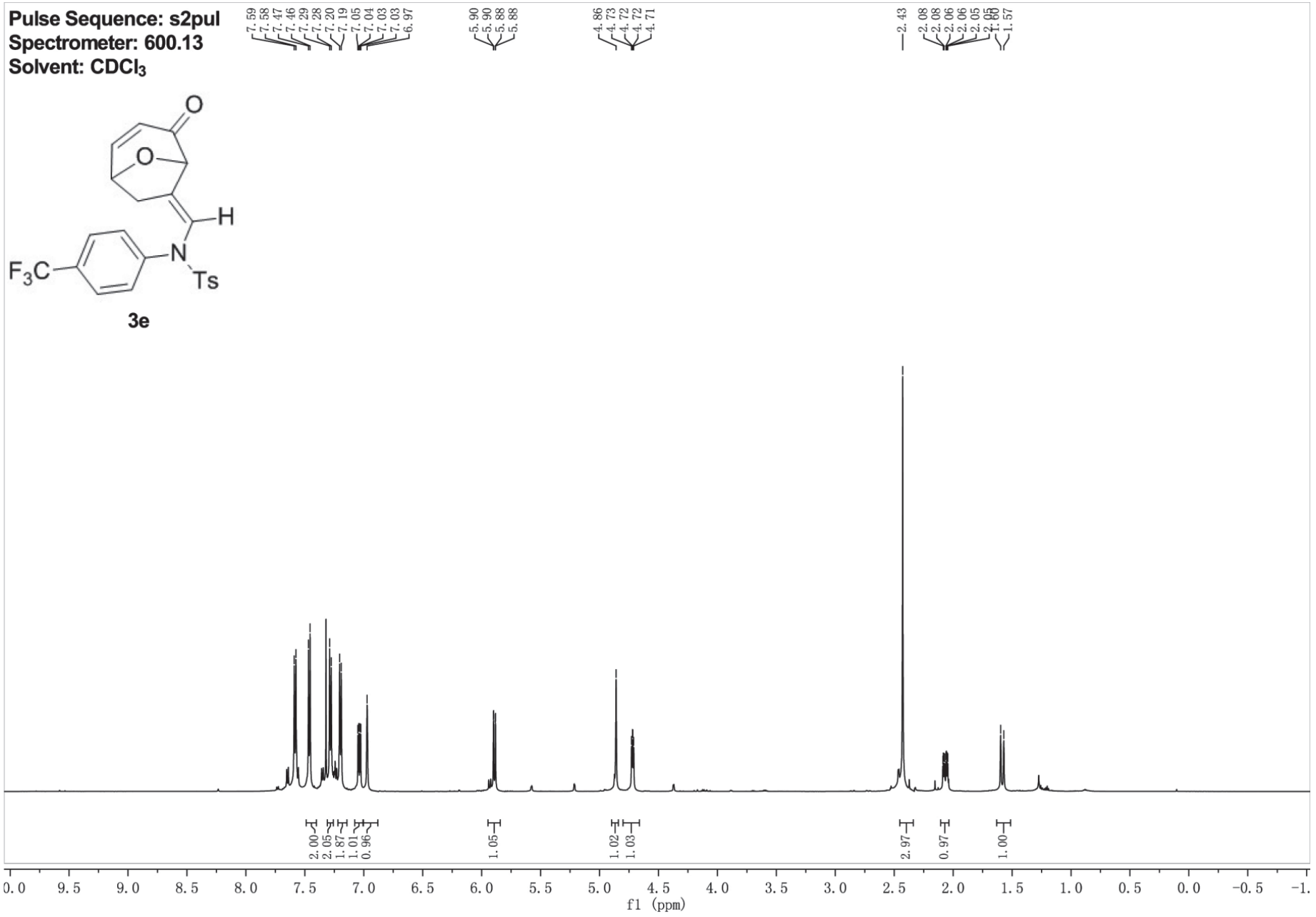

O
O
H
N
Ts
3c HSQC
f2 (ppm)
f1 (ppm)

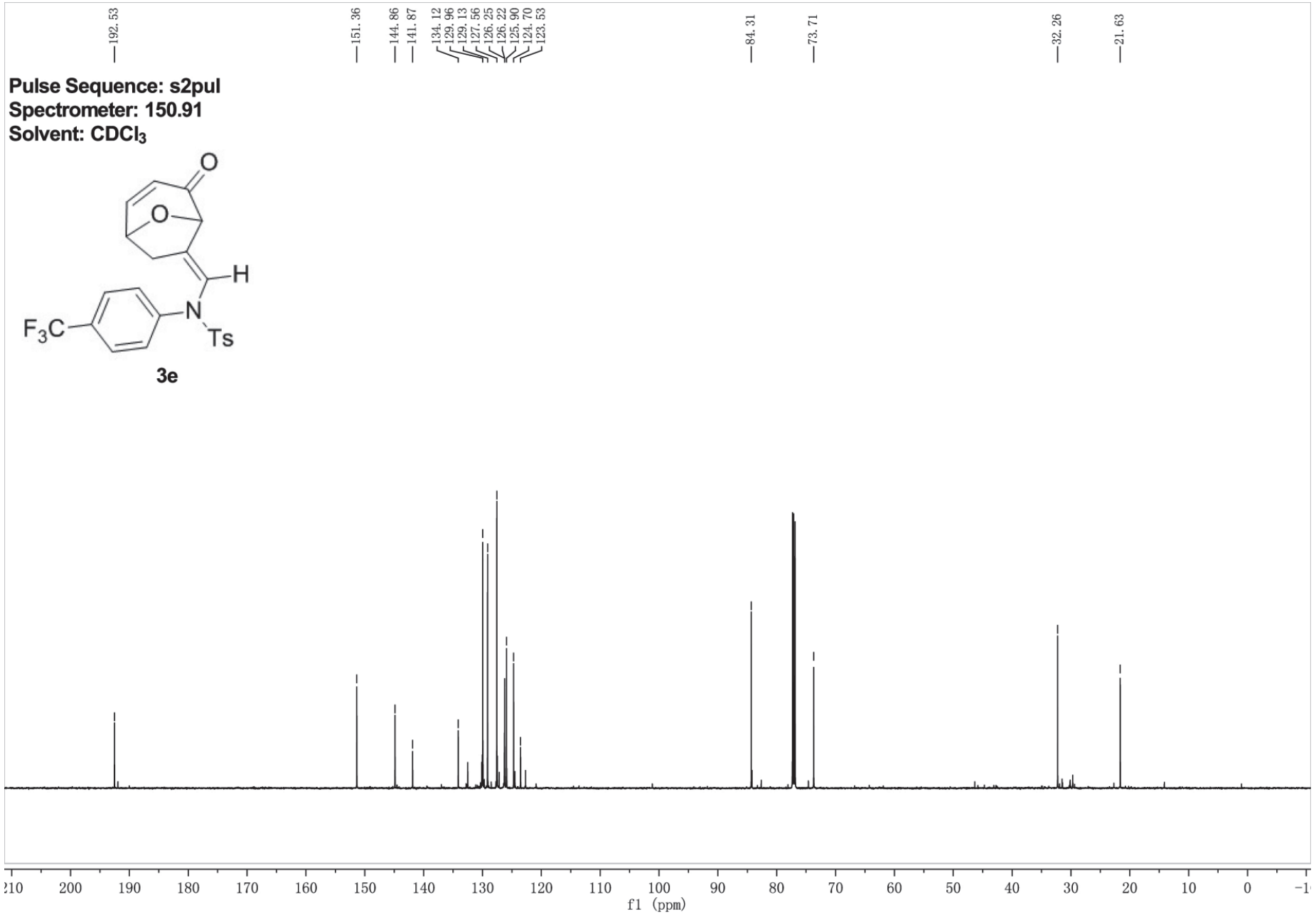

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
3d
f1 (ppm)

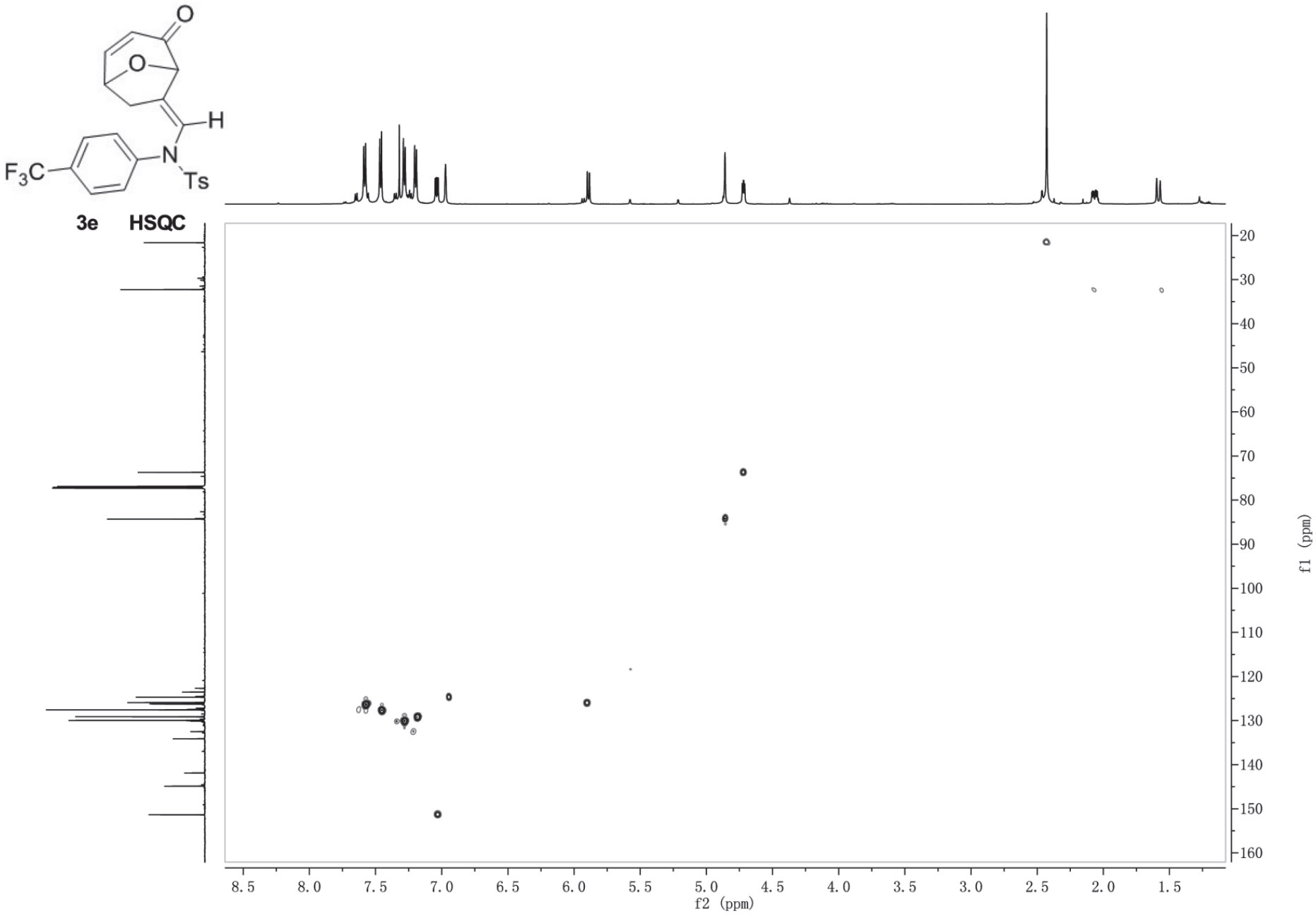

192.64
150.81
144.63
140.21
135.58
130.41
129.91
128.77
128.00
126.29
123.72
115.98
84.98
31.33
21.66
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
O
O
H
N
Ts
I
3d
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10
f1 (ppm)

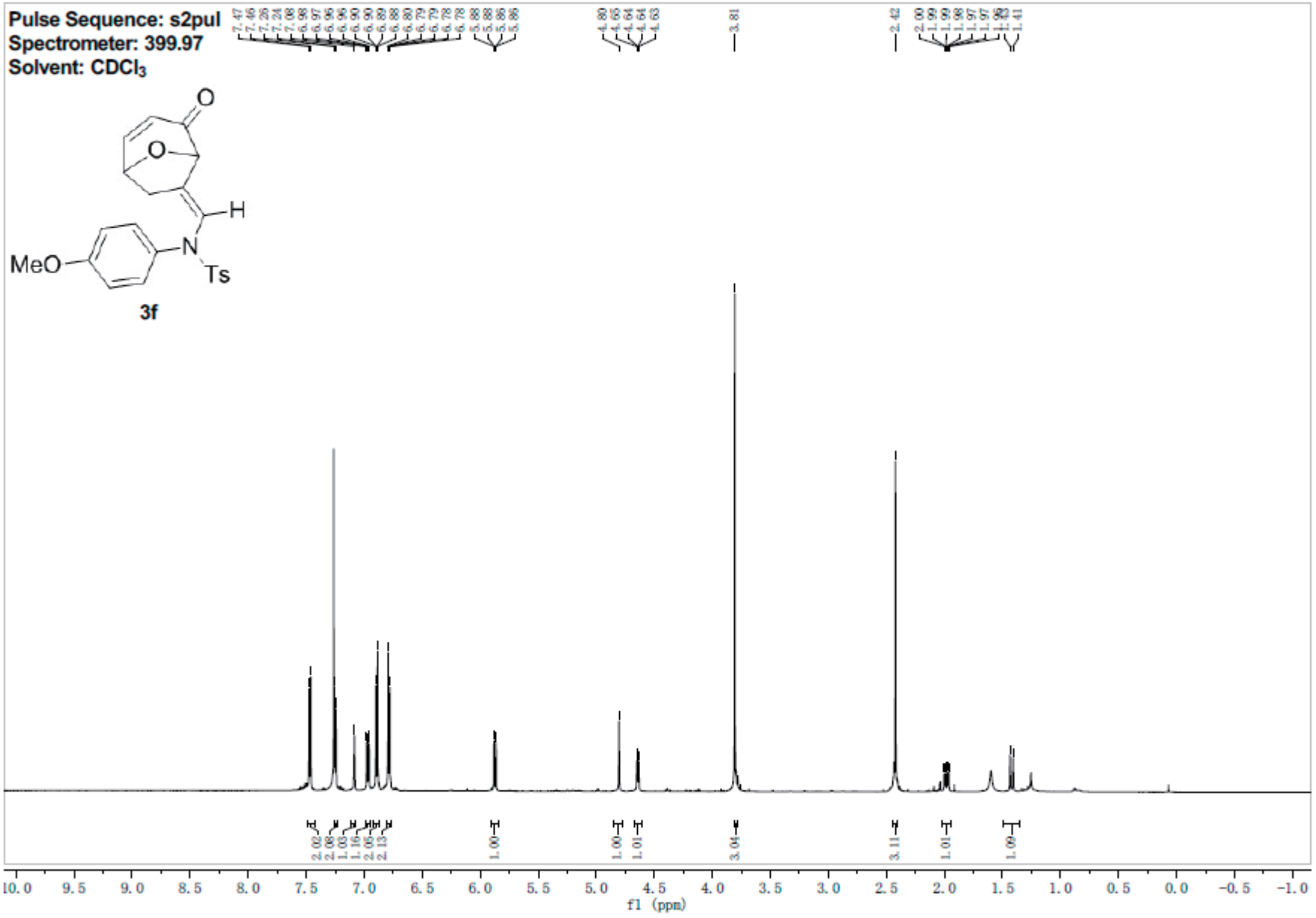

O
O
H
N
Ts
I
3d COSY
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)
f1 (ppm)

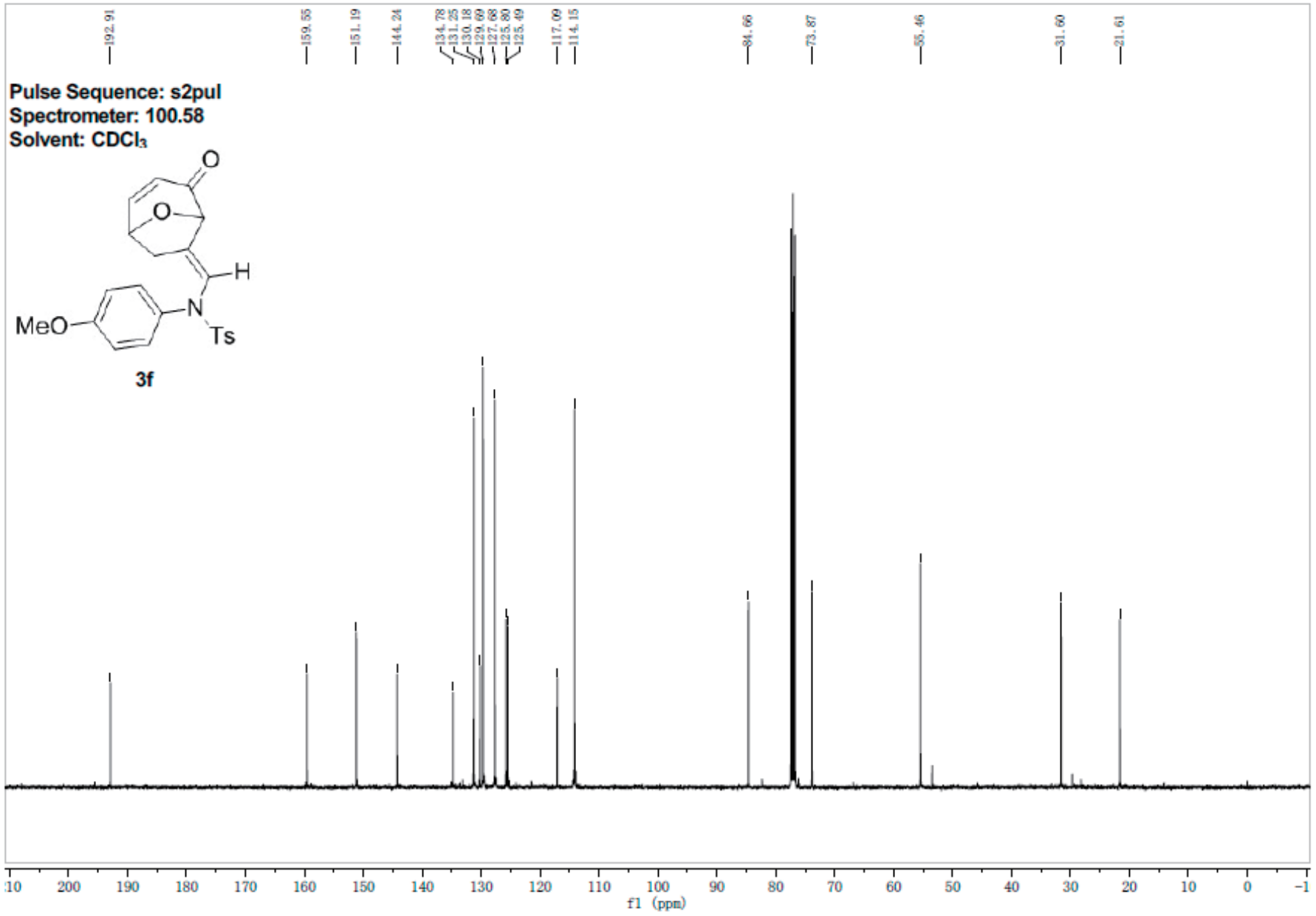

O
O
H
N
Ts
I
3d HSQC
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
f1 (ppm)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)

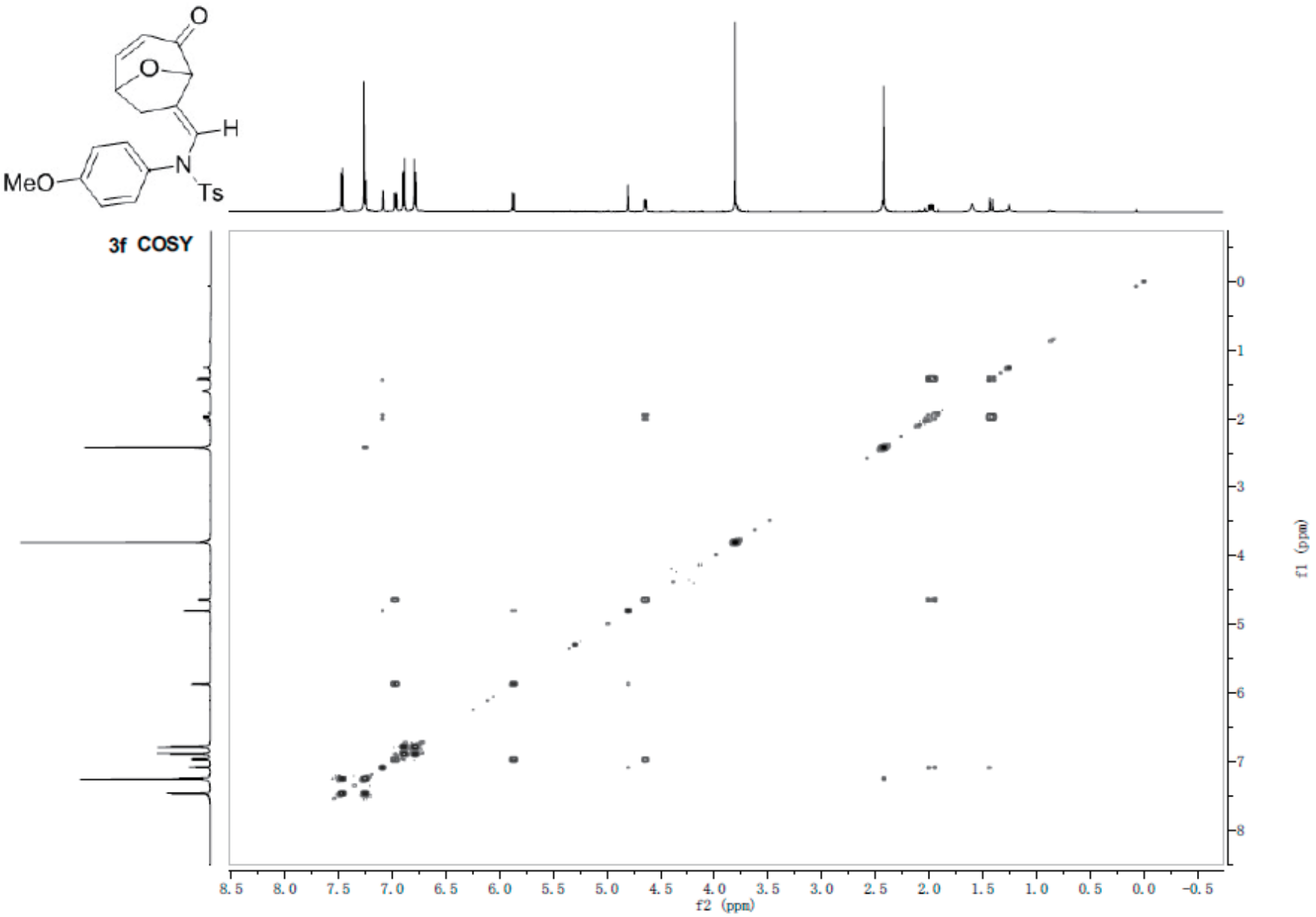

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
O
O
H
N
Ts
F3C
3e
7.59
7.58
7.47
7.46
7.29
7.28
7.20
7.19
7.05
7.04
7.03
7.03
6.97
5.90
5.90
5.88
5.88
4.86
4.73
4.72
4.72
4.71
2.43
2.08
2.08
2.06
2.06
2.05
1.57
2.00
2.05
1.87
1.01
0.96
1.05
1.02
1.03
2.97
0.97
1.00
f1 (ppm)

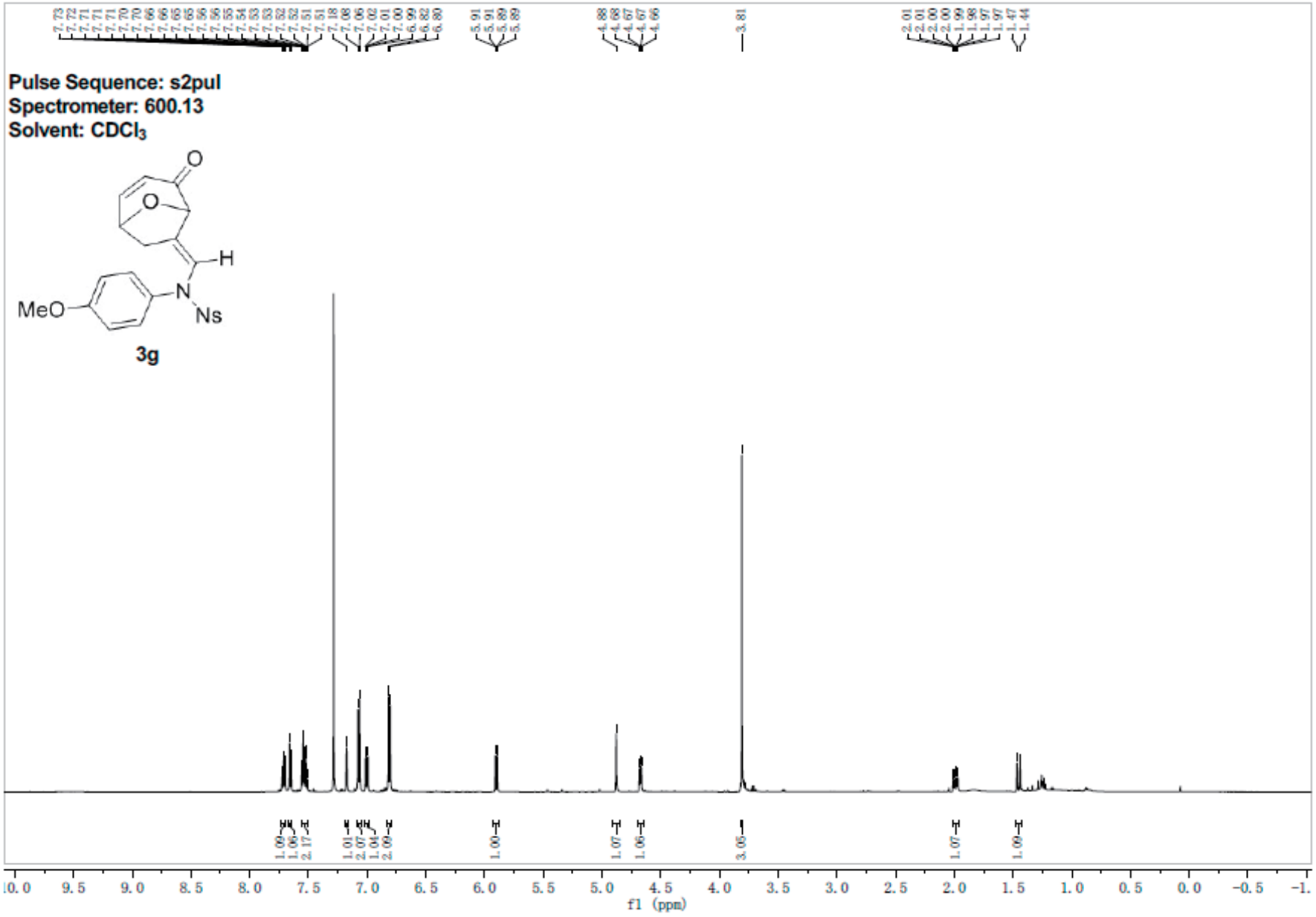

192.53
151.36
144.86
141.87
134.12
129.96
129.13
127.56
126.25
126.22
125.90
124.70
123.53
84.31
73.71
32.26
21.63
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
H
N
Ts
F3C
3e
f1 (ppm)

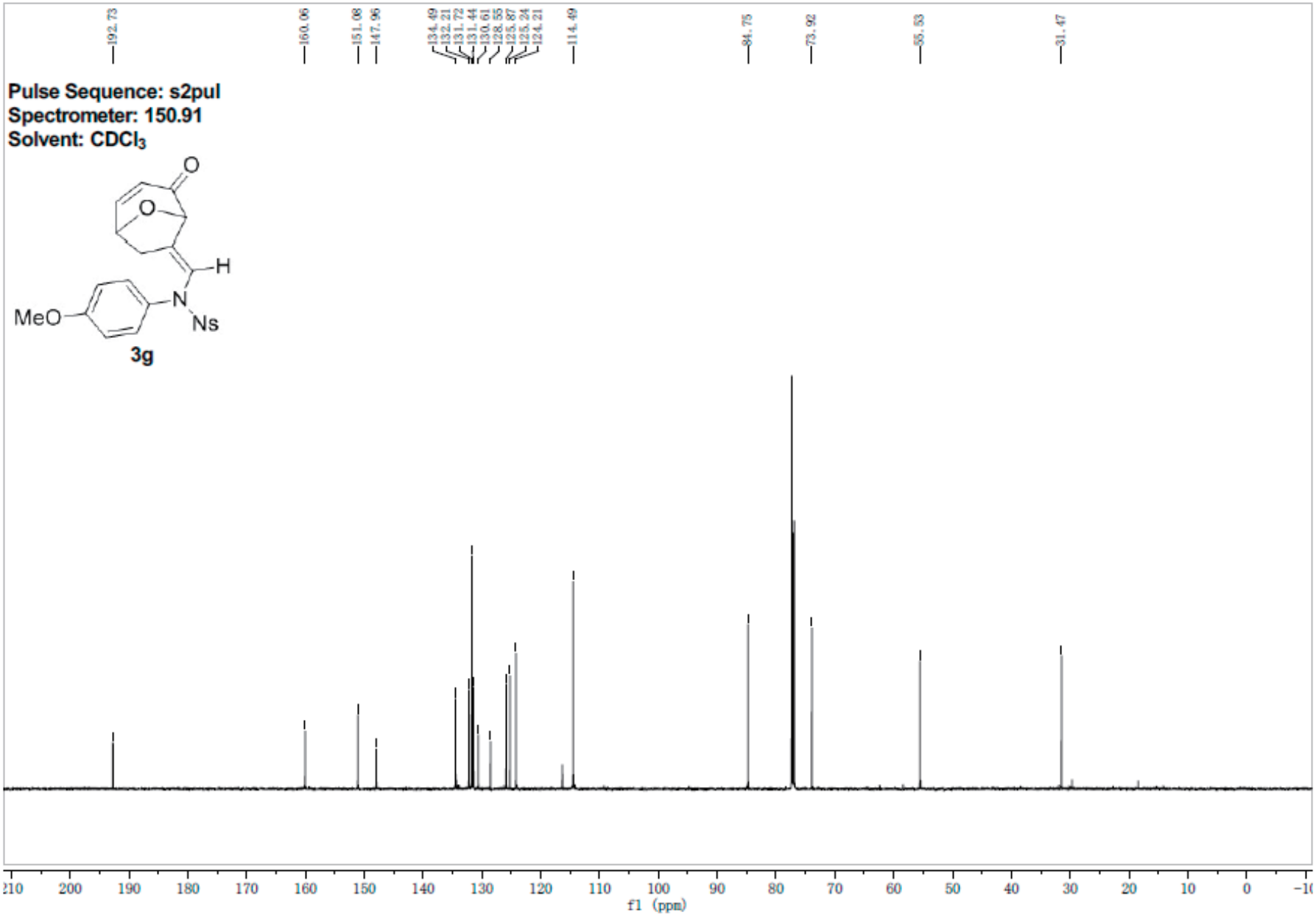

O
O
H
N
Ts
F3C
3e HSQC
f2 (ppm)
f1 (ppm)

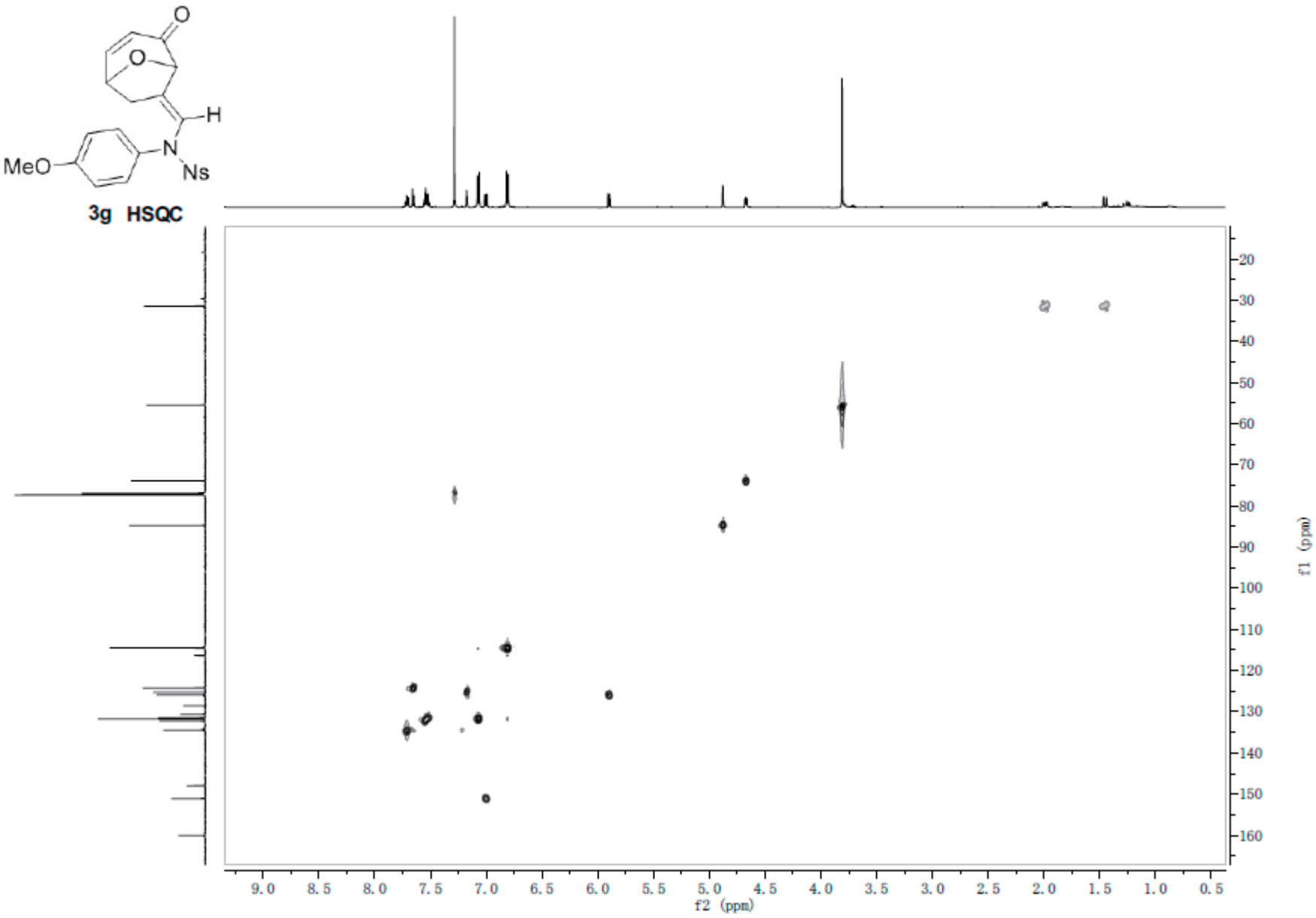

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
O
O
H
N
MeO
Ts
3f
f1 (ppm)

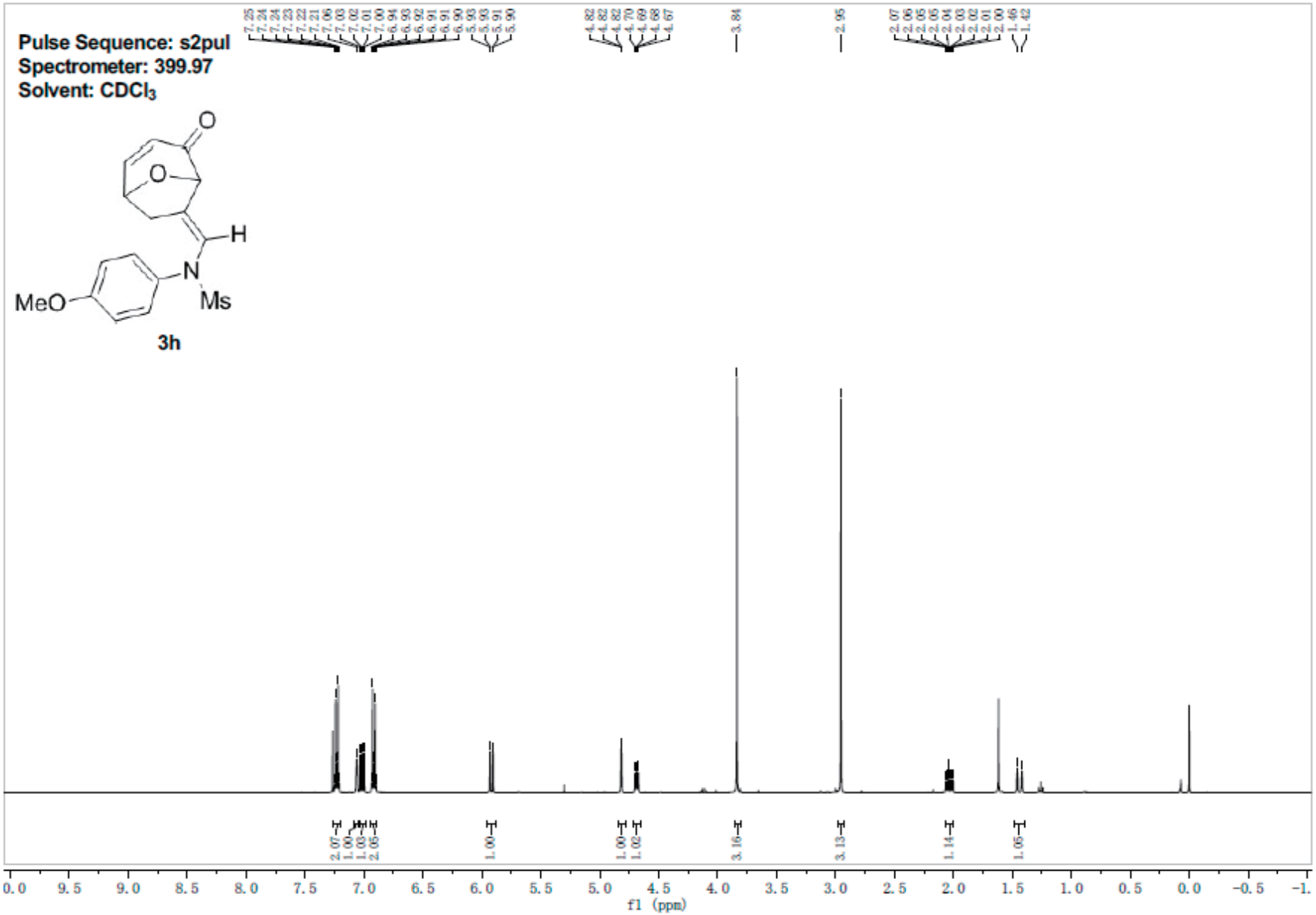

192.91
159.55
151.19
144.24
134.78
131.25
130.18
129.69
127.68
125.80
125.49
117.09
114.15
84.66
73.87
55.46
31.60
21.61
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
O
O
H
N
MeO
Ts
3f
f1 (ppm)

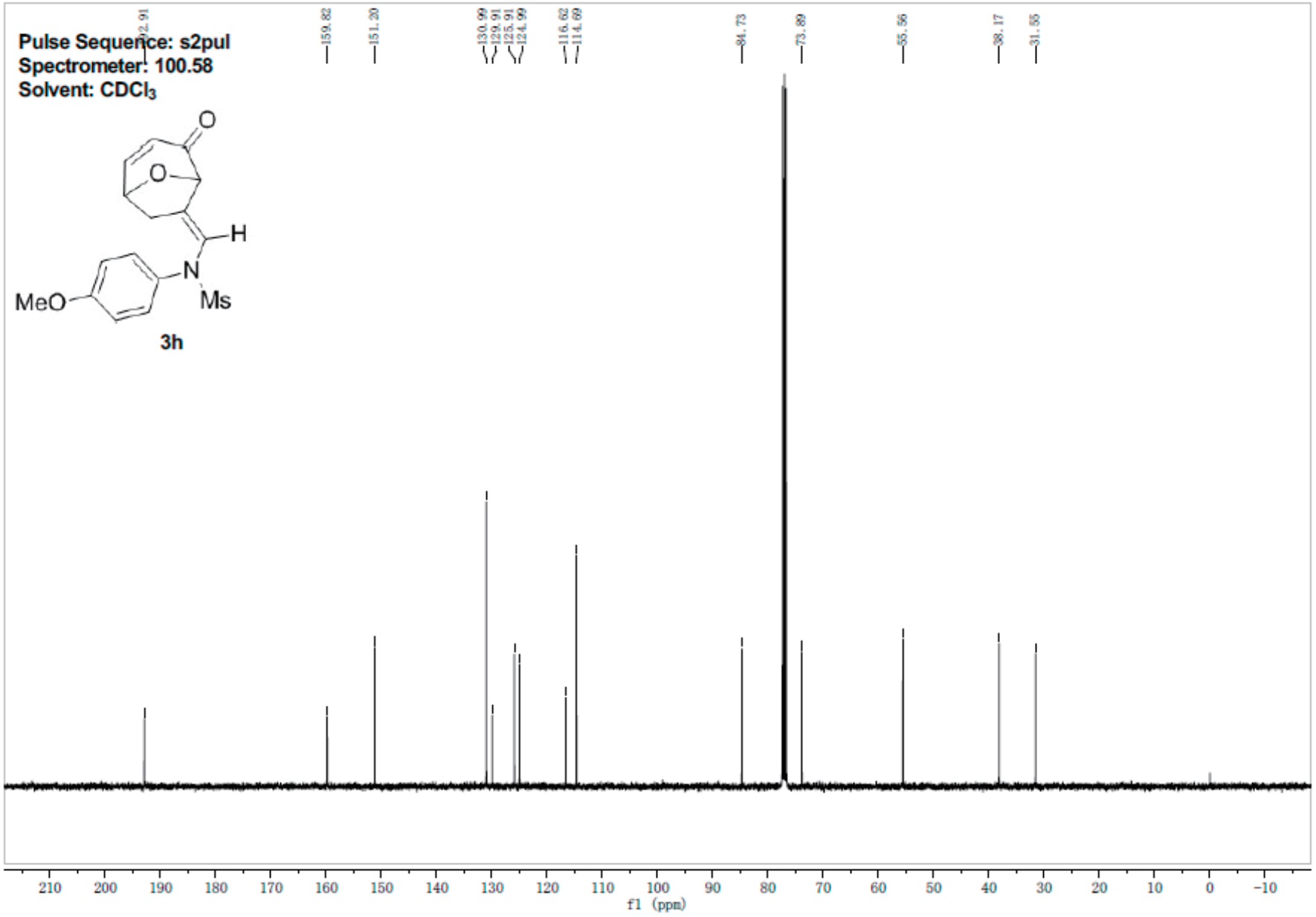

3f COSY
O
O
H
N
Ts
MeO
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f2 (ppm)
0
1
2
3
4
5
6
7
8
f1 (ppm)

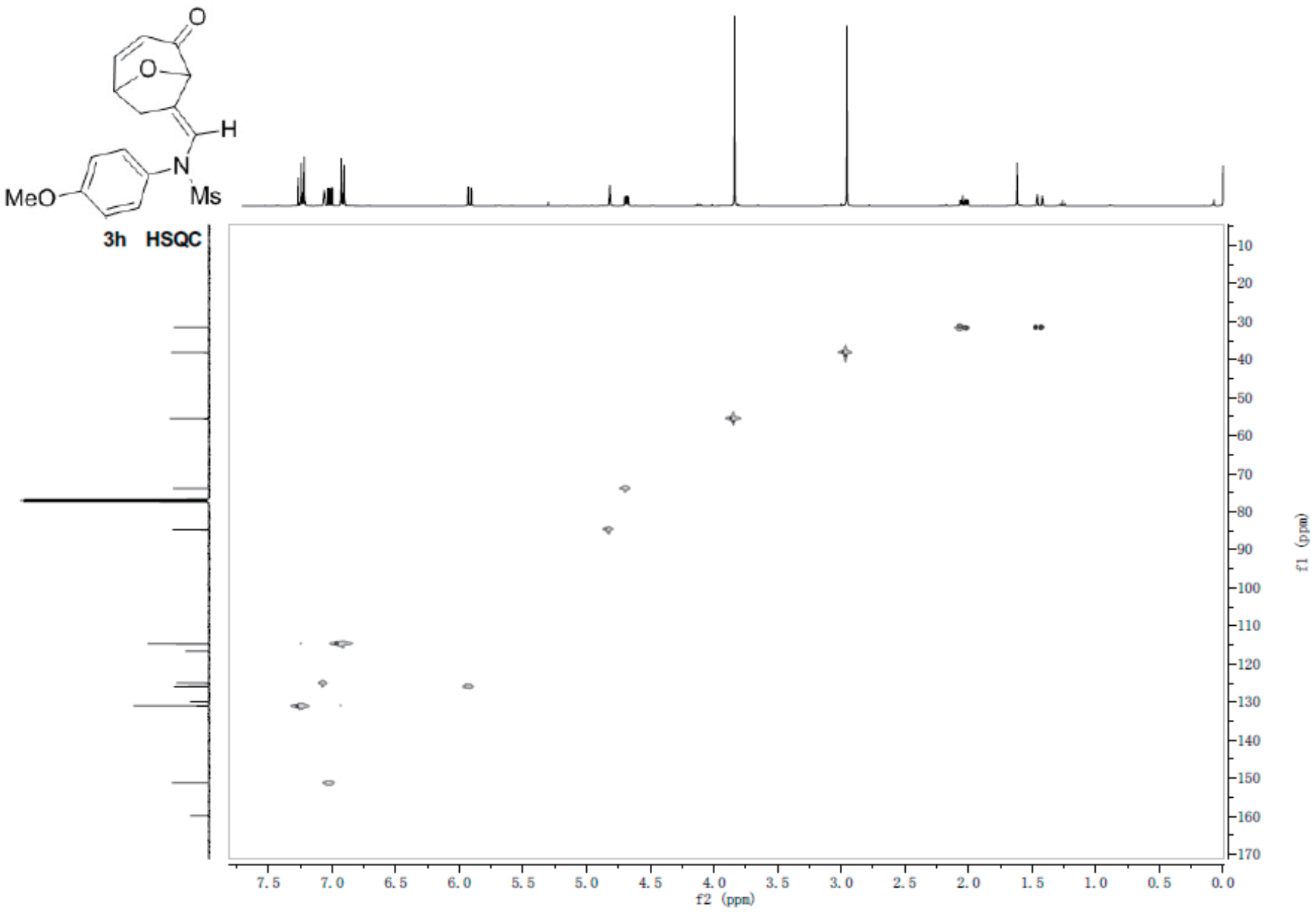

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
MeO
N
Ns
H
O
3g
f1 (ppm)

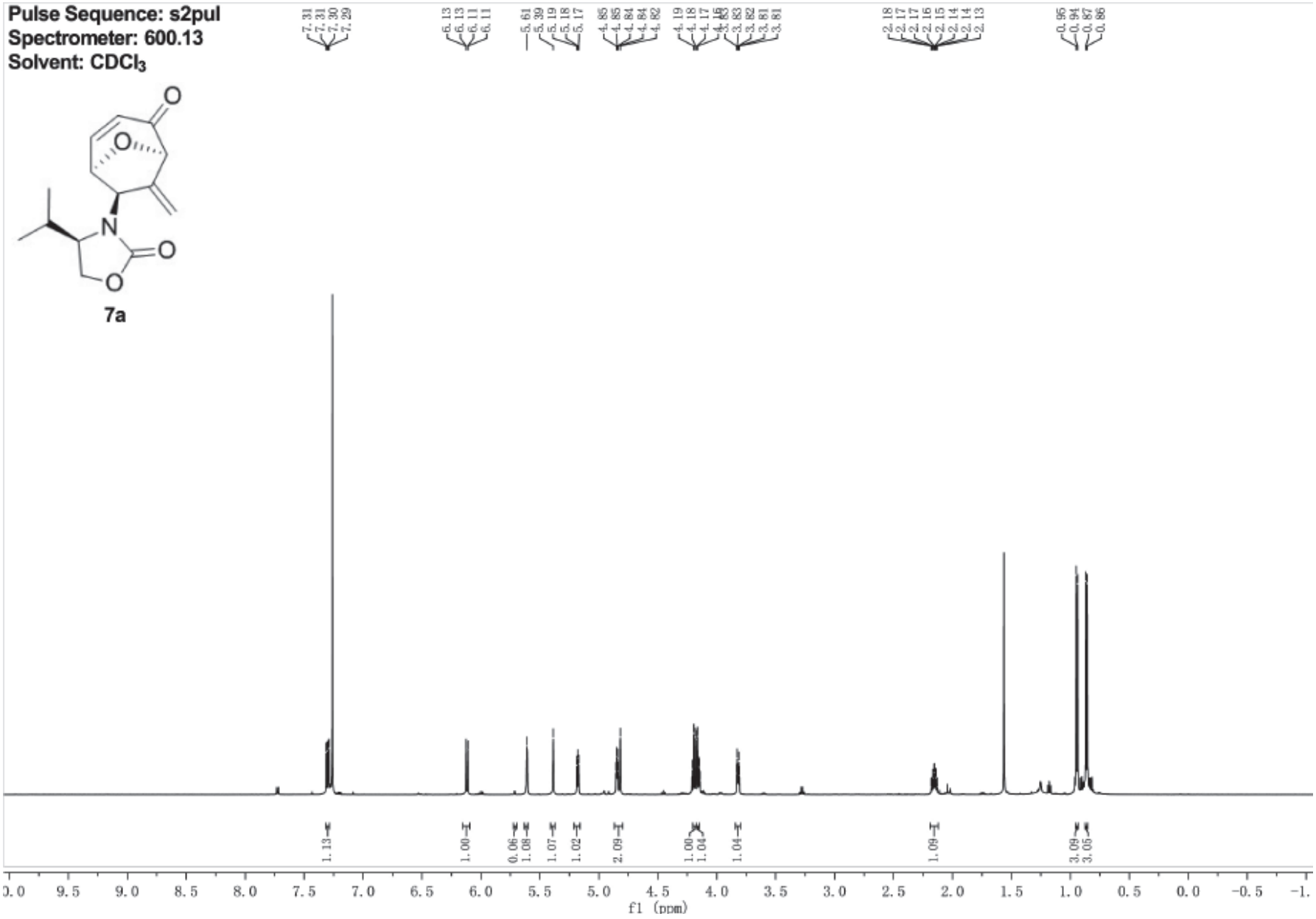

192.73
160.06
151.08
147.96
134.49
132.21
131.72
131.44
130.61
128.55
125.87
125.24
124.21
114.49
84.75
73.92
55.53
31.47
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
H
N
MeO
Ns
3g
f1 (ppm)

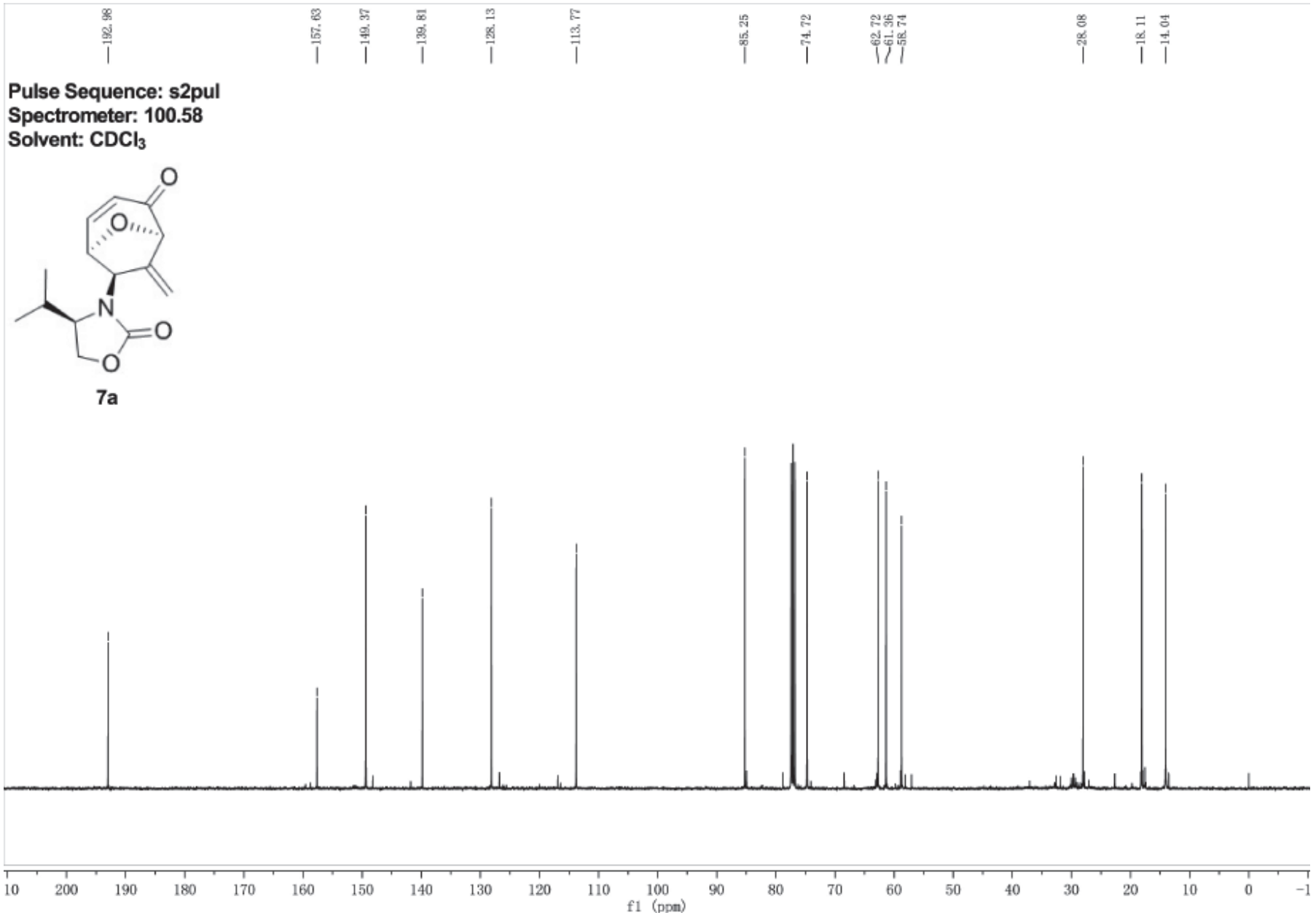

O
O
H
N
Ns
MeO
3g HSQC
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
f1 (ppm)

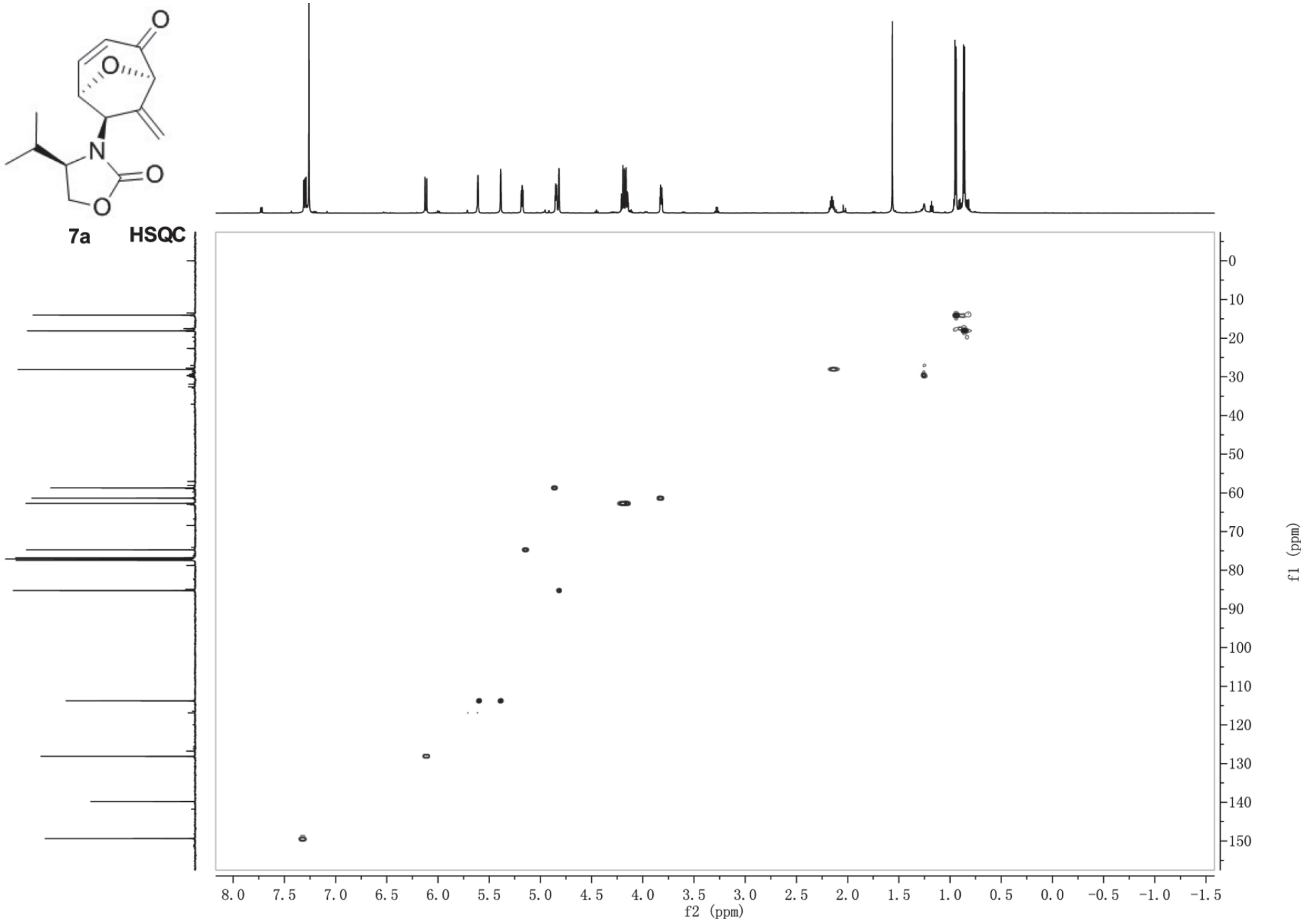

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
O
O
H
N
MeO
Ms
3h
f1 (ppm)

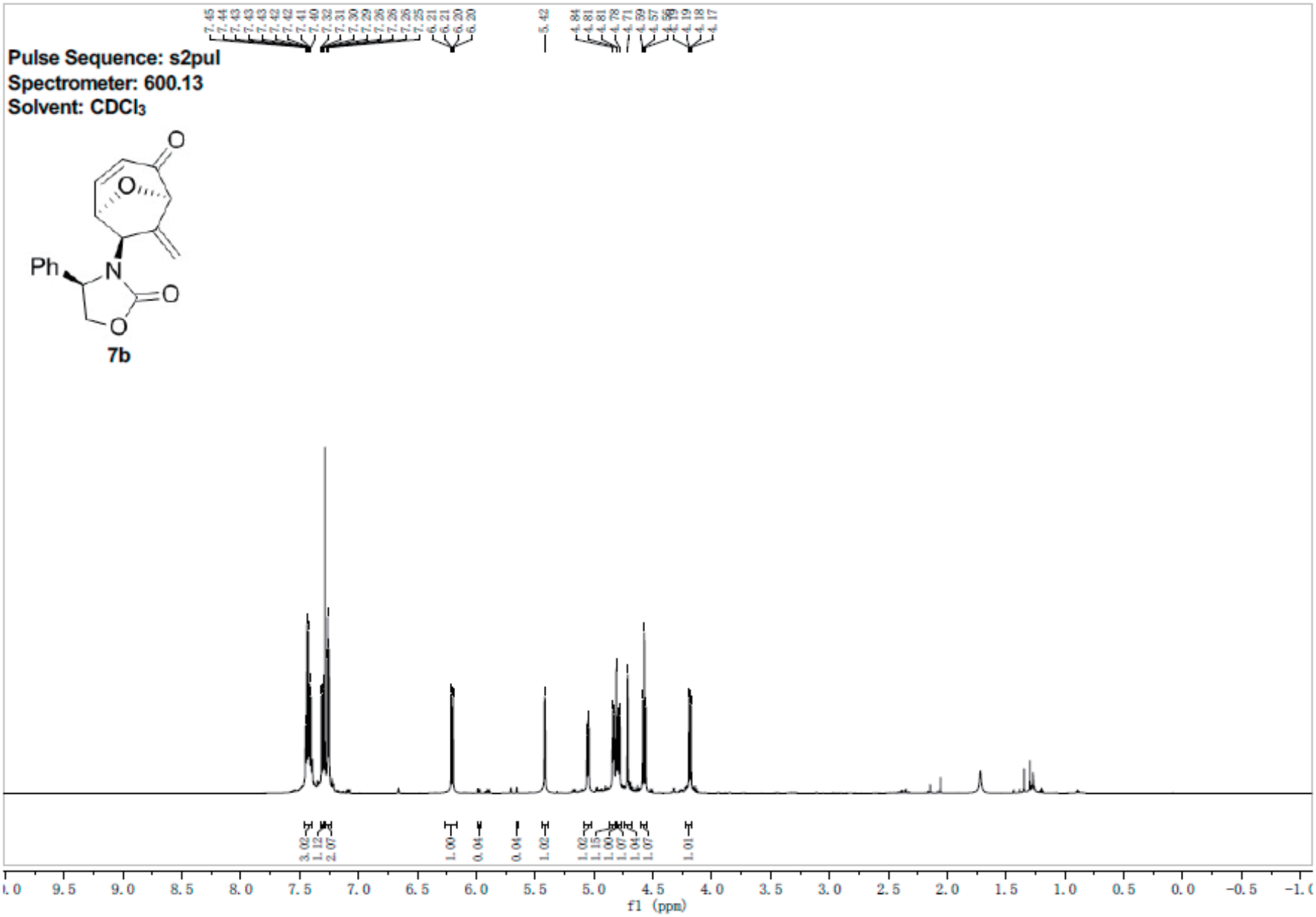

Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
O
O
H
N
MeO
Ms
3h
159.82
151.20
130.99
129.91
125.91
124.99
116.62
114.69
84.73
73.89
55.56
38.17
31.55
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

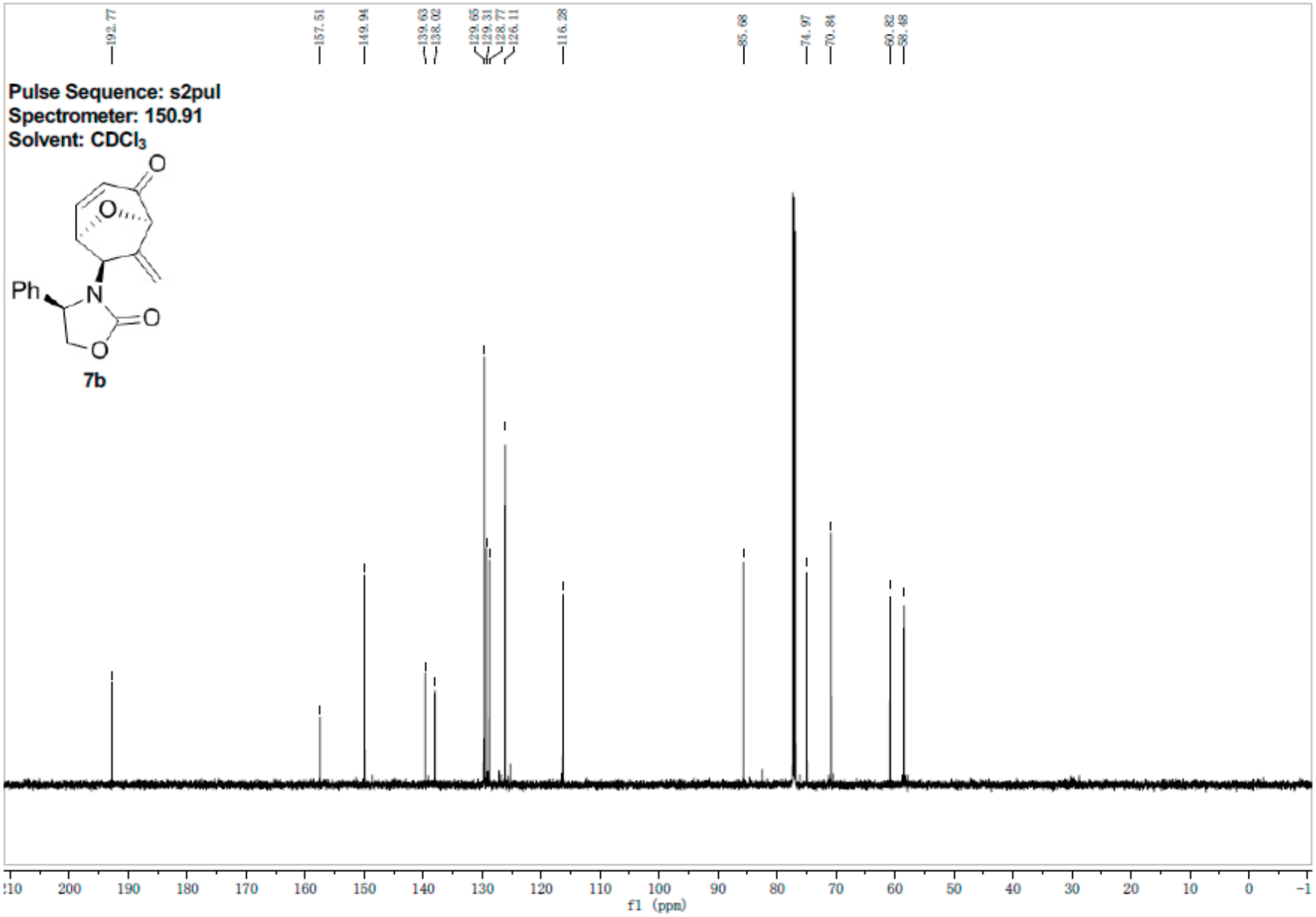

O
O
H
N
MeO
Ms
3h HSQC
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f2 (ppm)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
f1 (ppm)

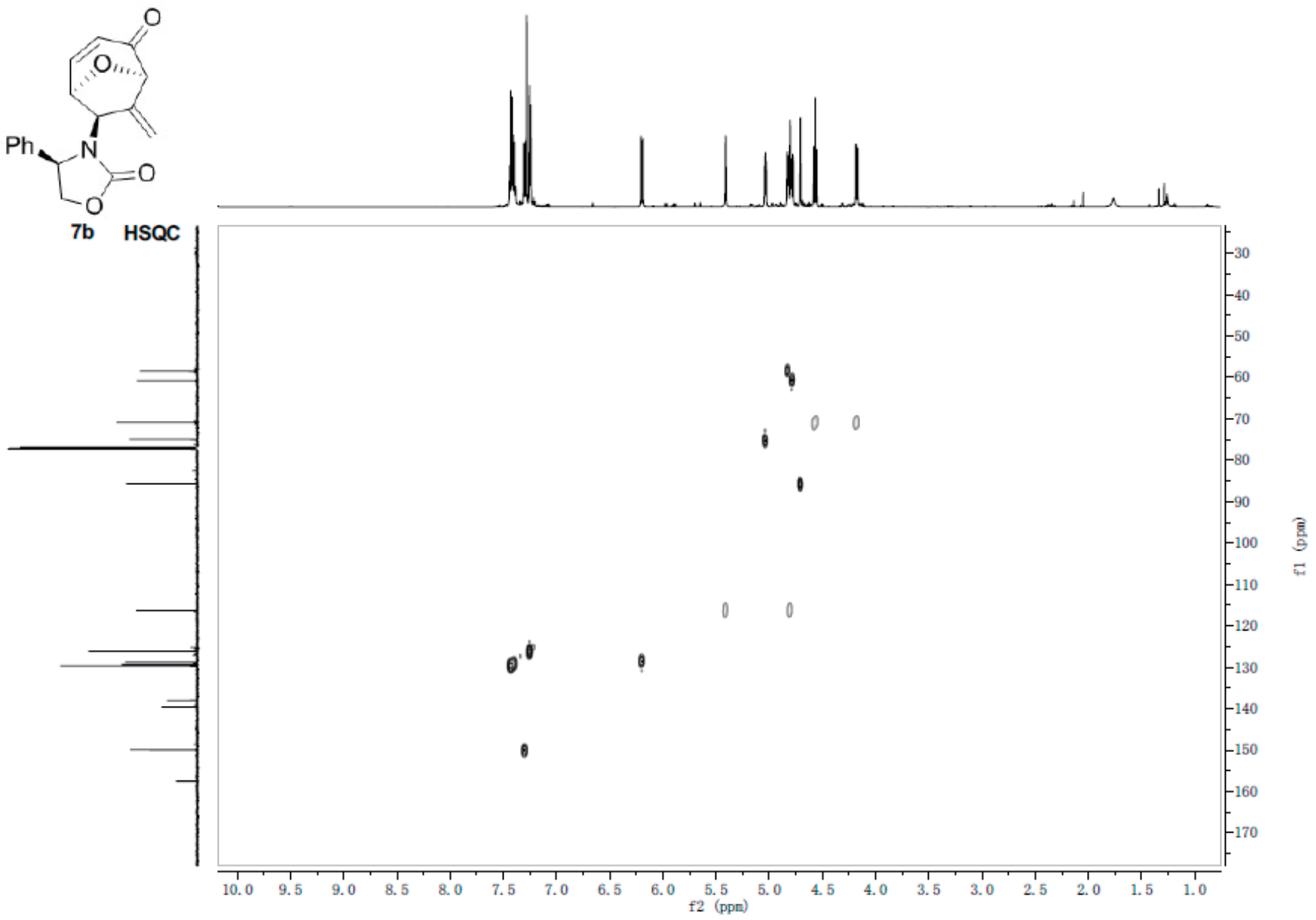

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
7a
f1 (ppm)

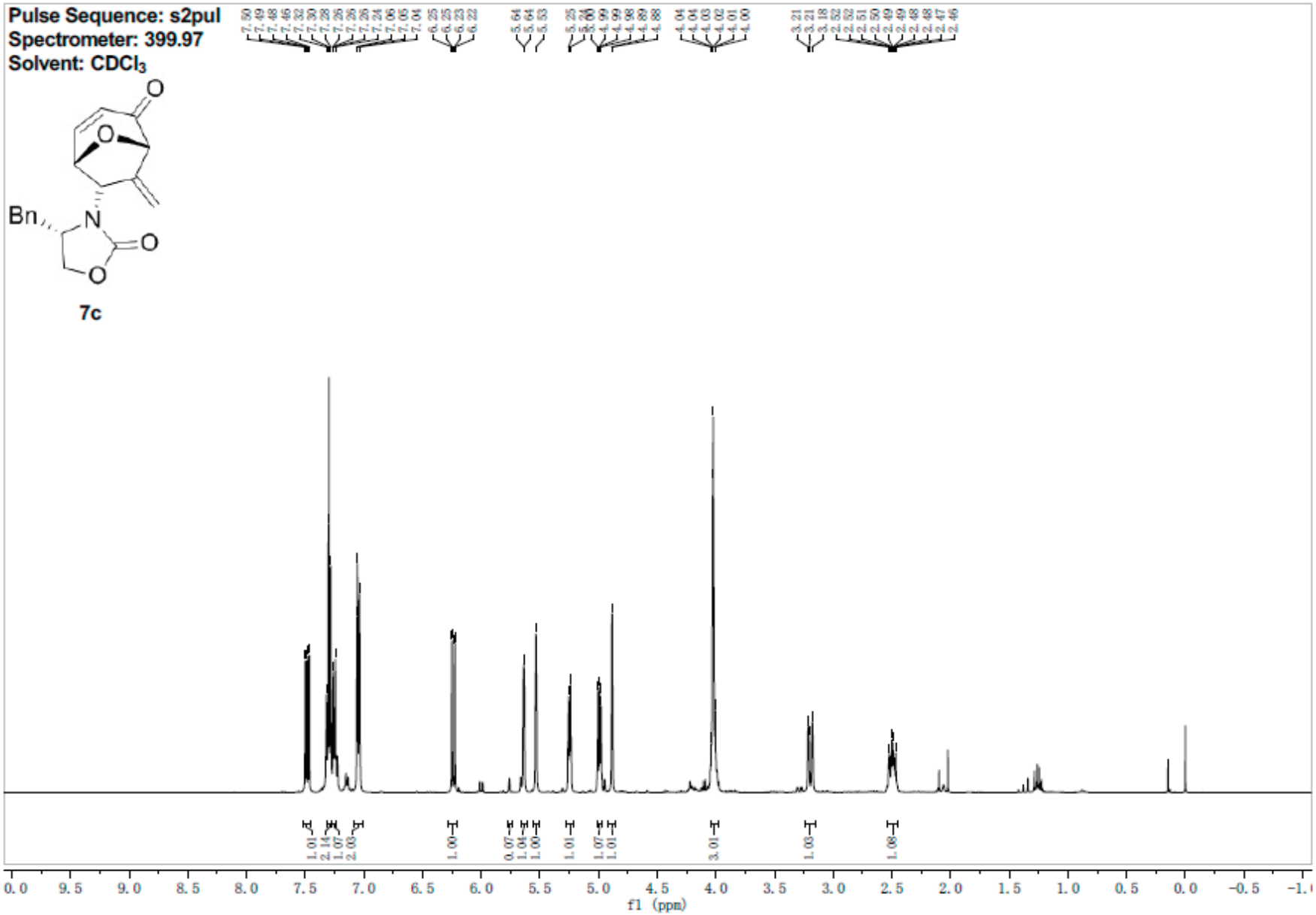

192.98
157.63
149.37
139.81
128.13
113.77
85.25
74.72
62.72
61.36
58.74
28.08
18.11
14.04
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
O
O
N
O
O
7a
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−1
f1 (ppm)

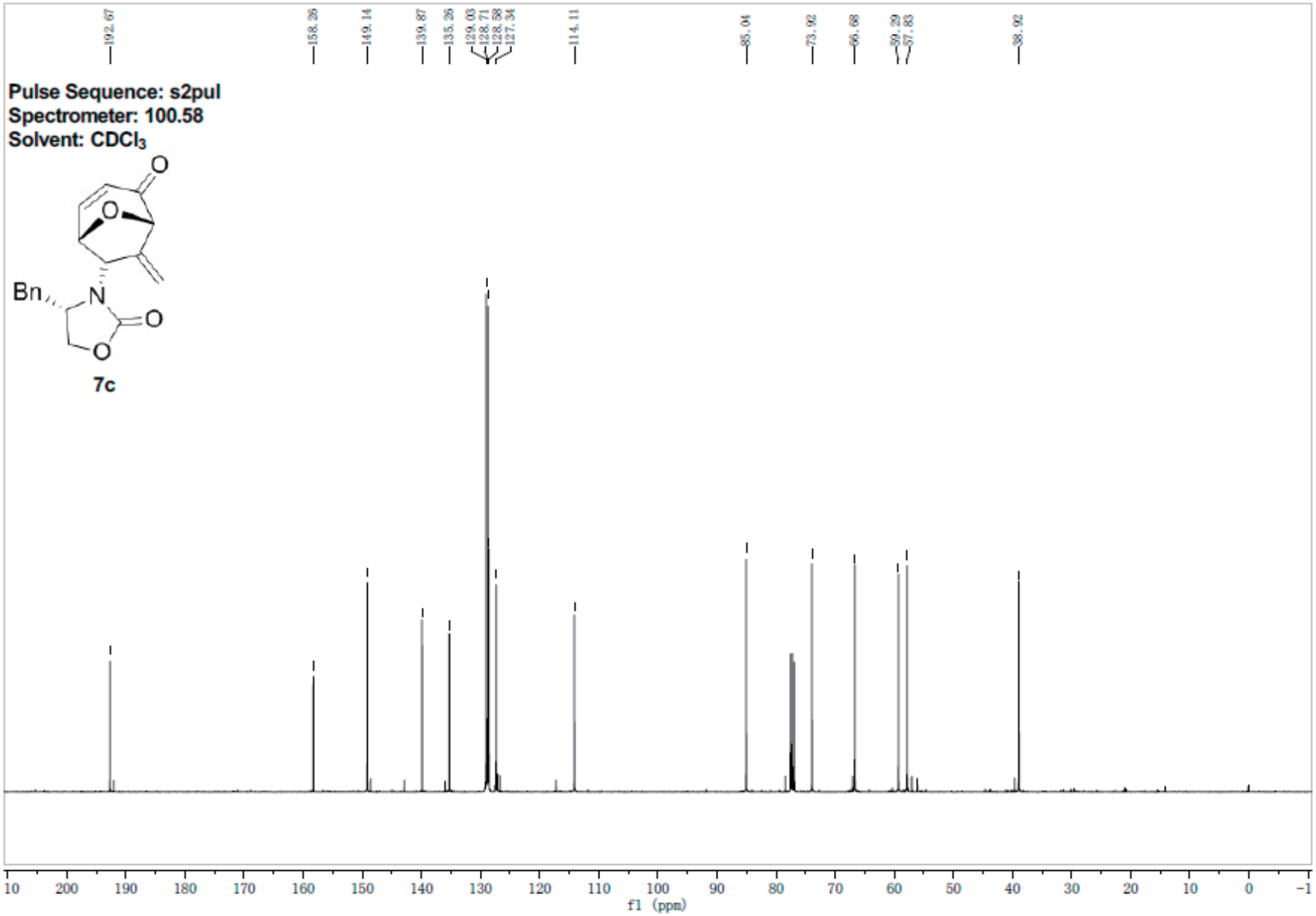

7a
HSQC
f2 (ppm)
f1 (ppm)

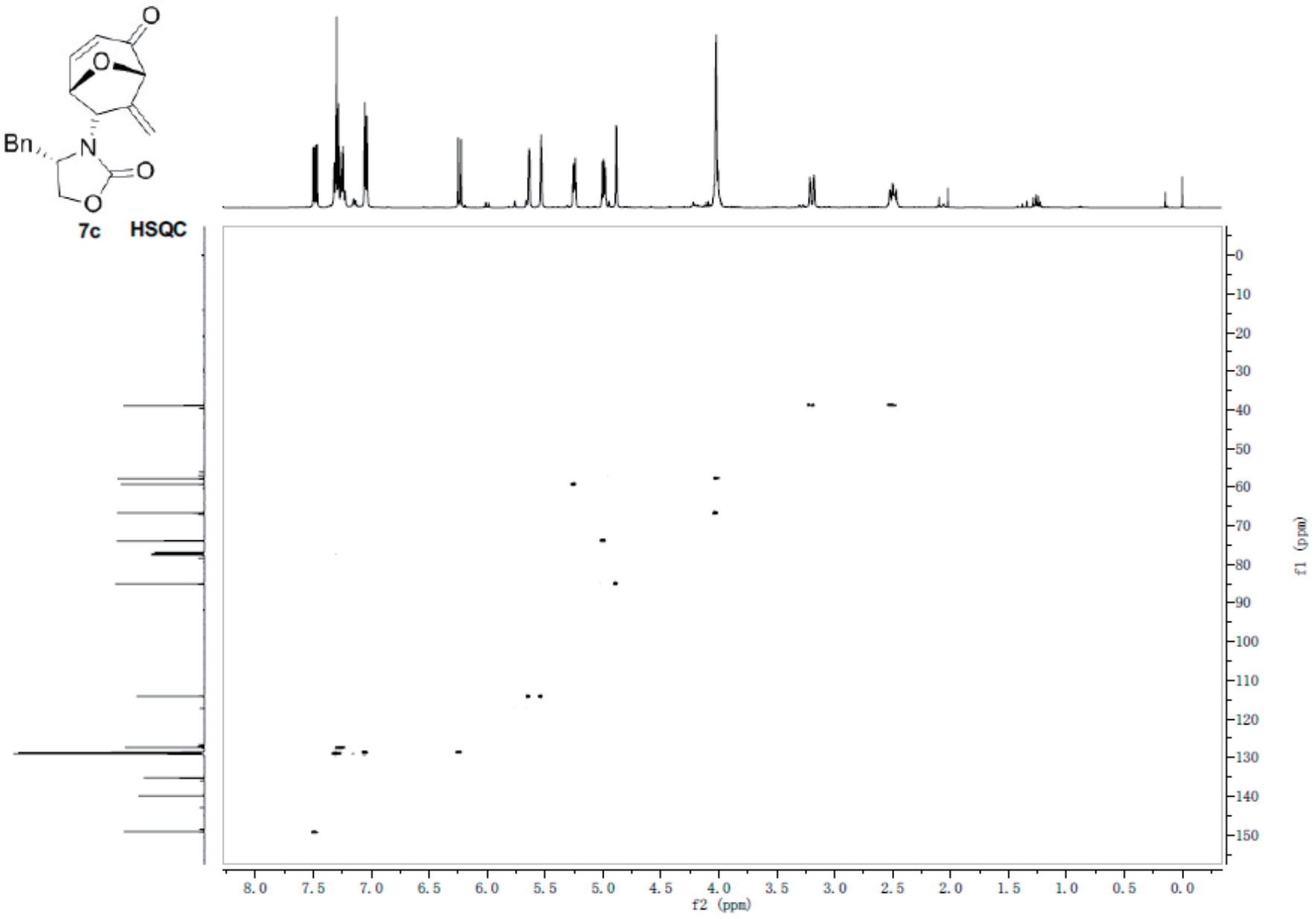

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
Ph
N
O
O
O
O
7b
f1 (ppm)

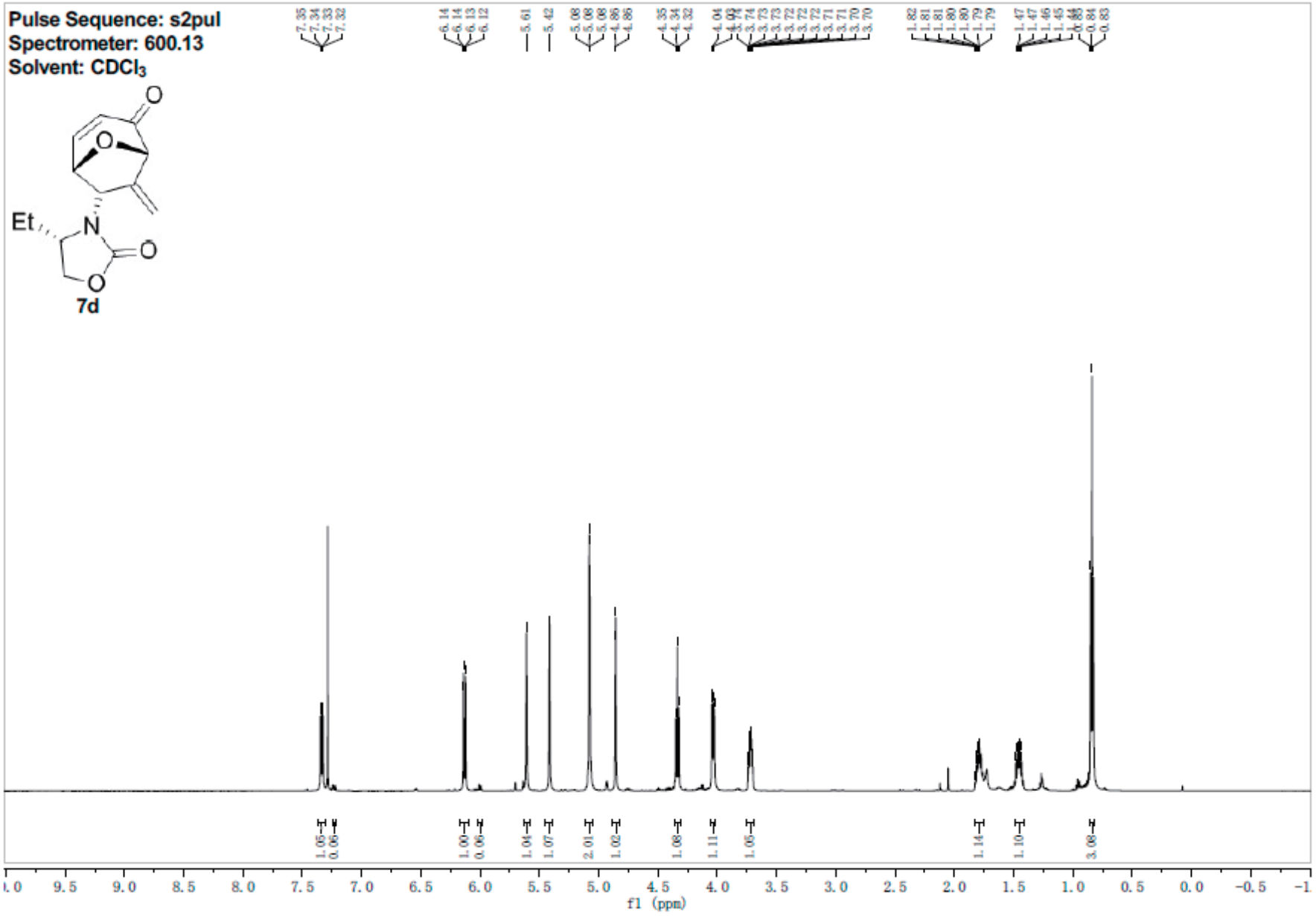

192.77
157.51
149.94
139.63
138.02
129.65
129.31
128.77
126.11
116.28
85.68
74.97
70.84
60.82
58.48
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
Ph
N
O
O
O
O
7b
f1 (ppm)

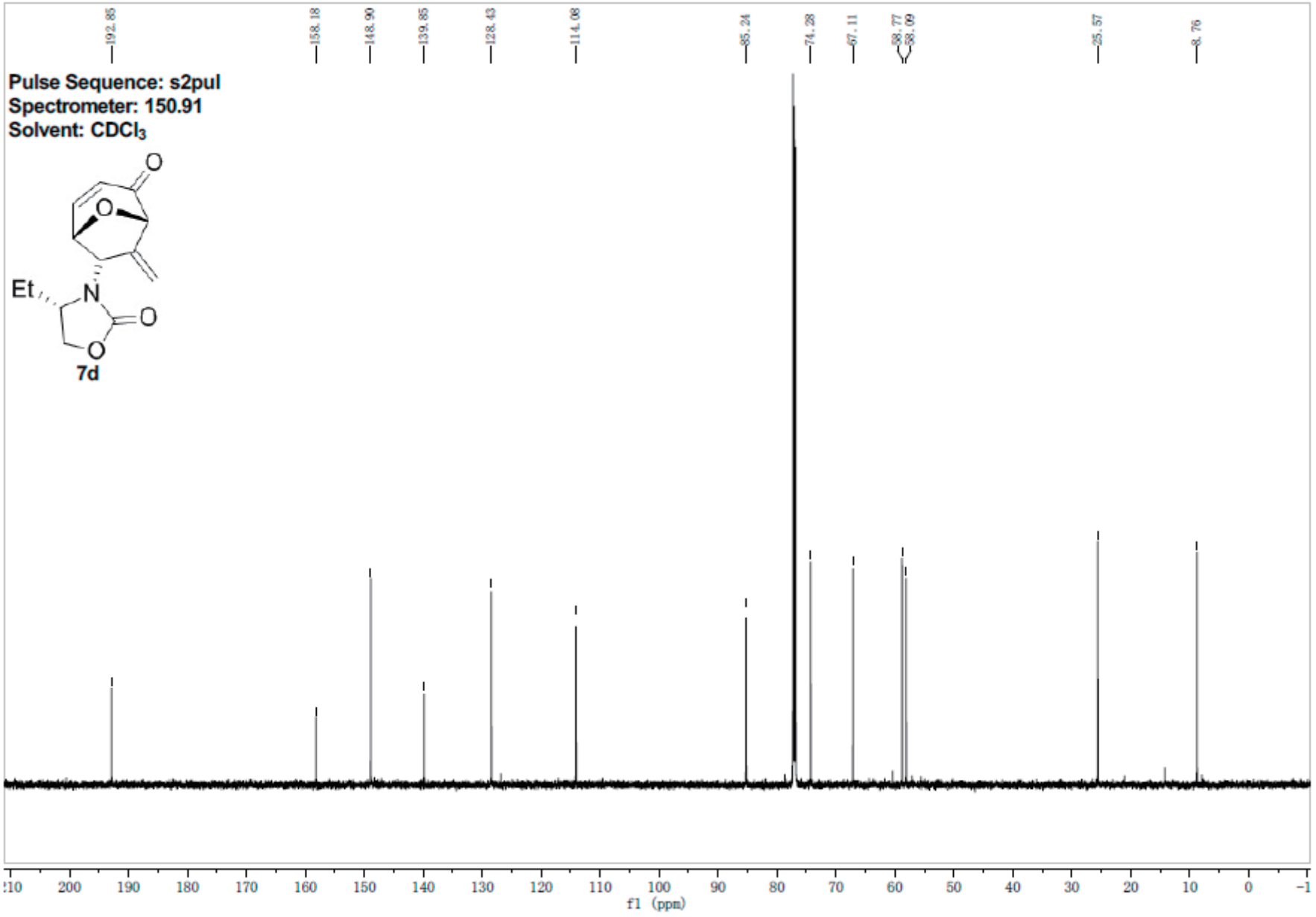

O
O
Ph
N
O
O
7b HSQC
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
f2 (ppm)
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
f1 (ppm)

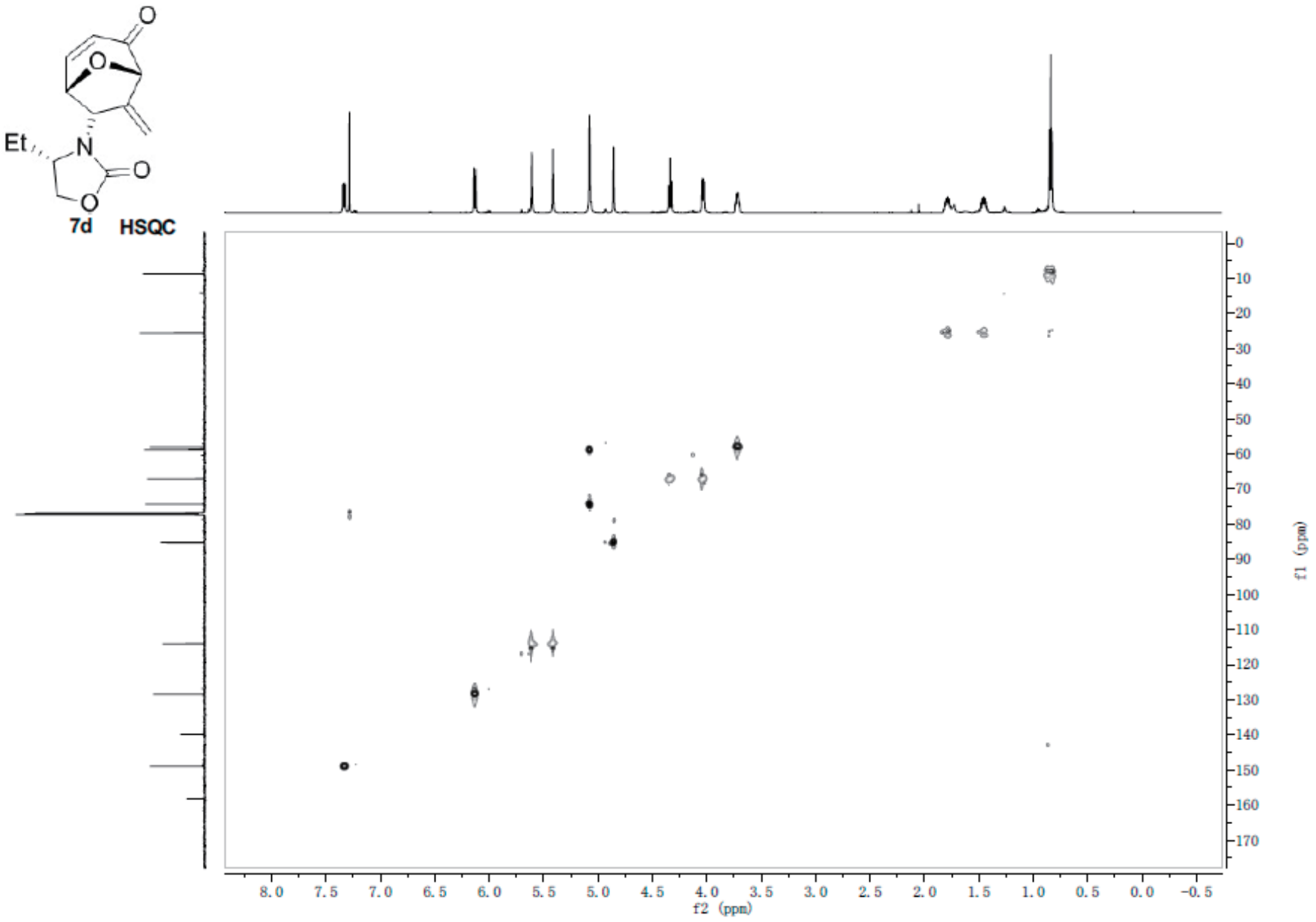

Pulse Sequence: s2pul
Spectrometer: 399.97
Solvent: CDCl3
Bn
N
O
O
O
O
7c
f1 (ppm)

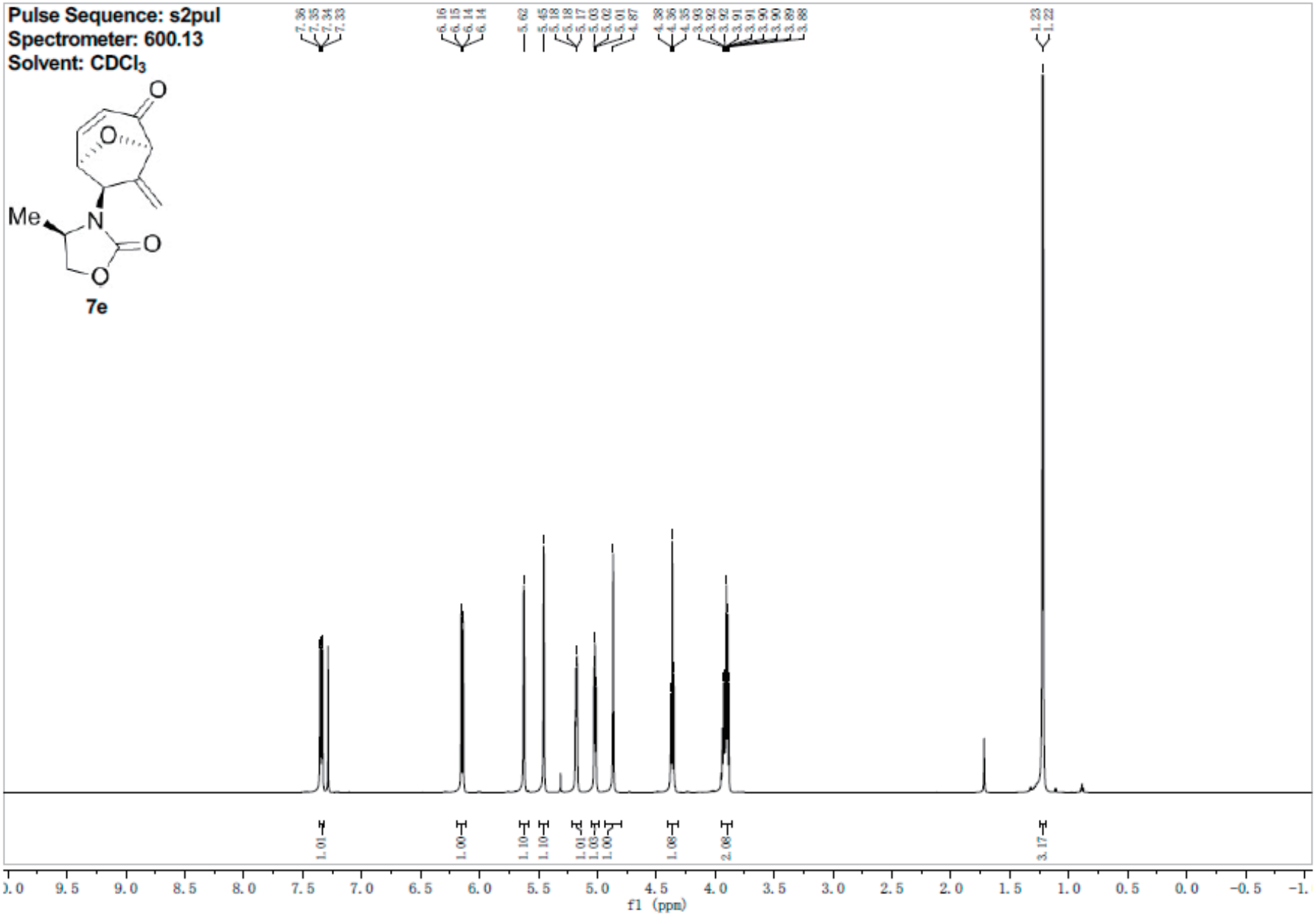

192.67
158.26
149.14
139.87
135.26
129.05
128.71
128.58
127.34
114.11
85.04
73.92
66.68
59.29
57.83
38.92
Pulse Sequence: s2pul
Spectrometer: 100.58
Solvent: CDCl3
Bn
N
O
O
O
O
7c
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−1
f1 (ppm)

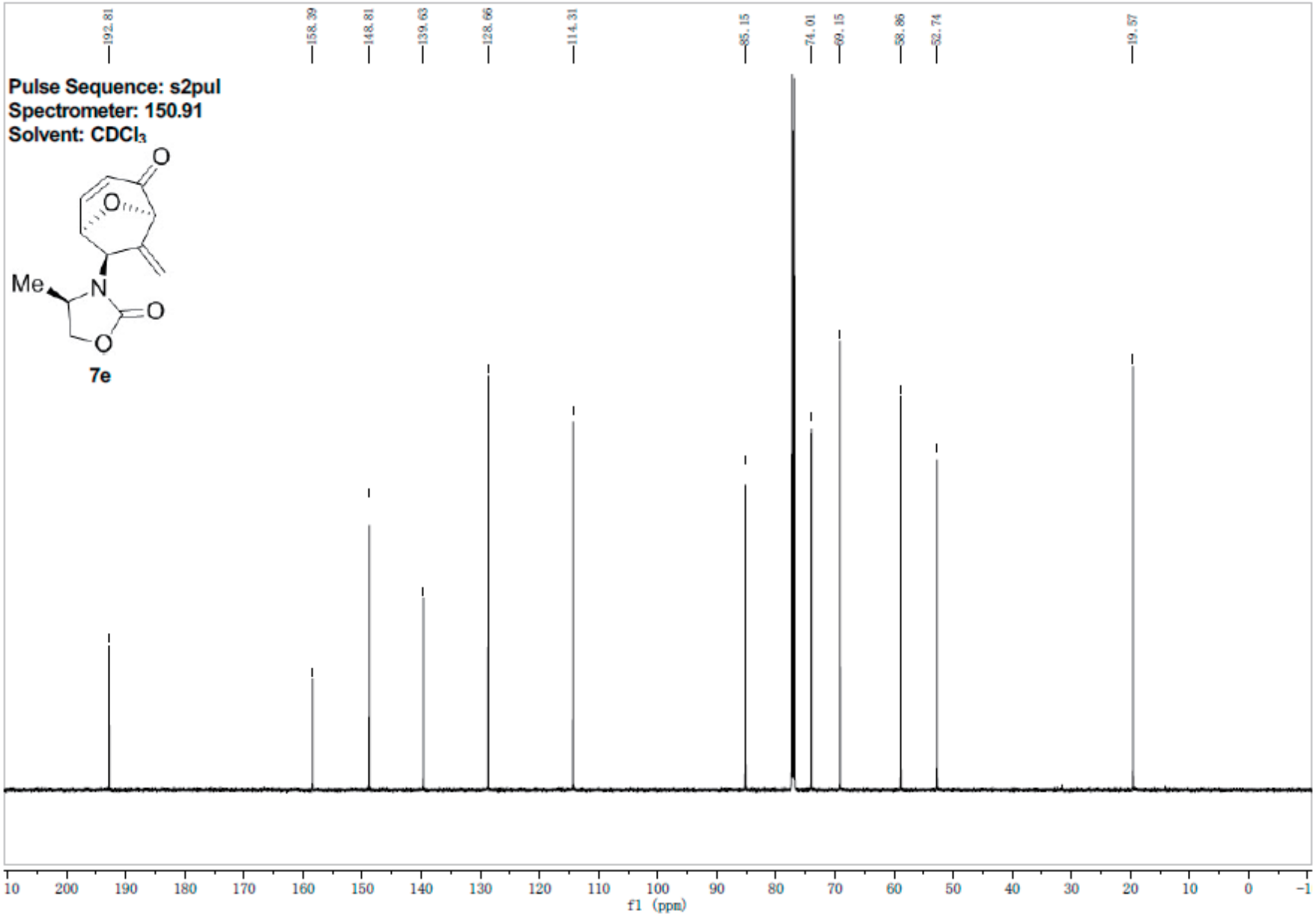

Bn
N
O
O
O
O
7c
HSQC
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f2 (ppm)
f1 (ppm)

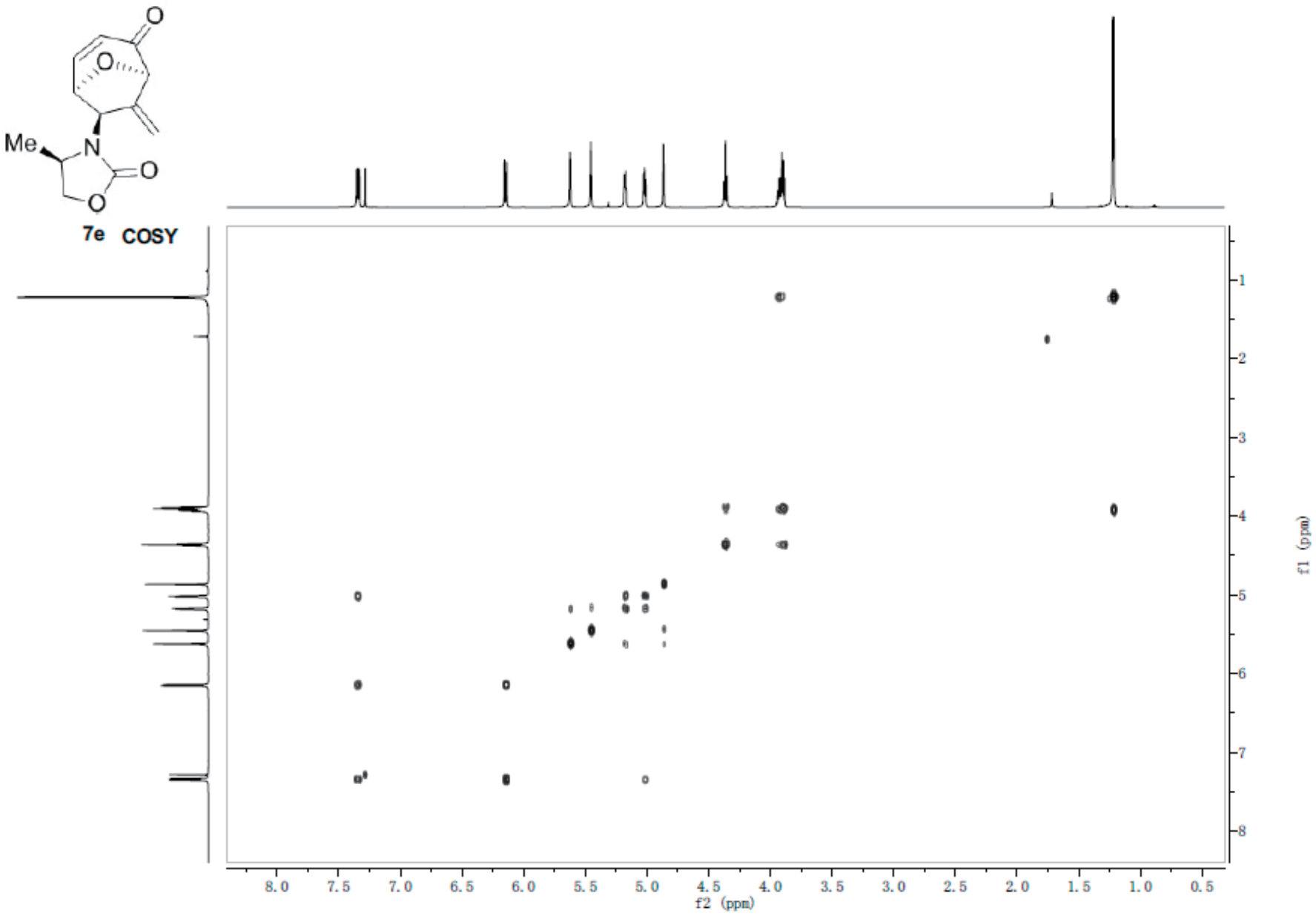

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
Et
N
O
O
O
7d
f1 (ppm)

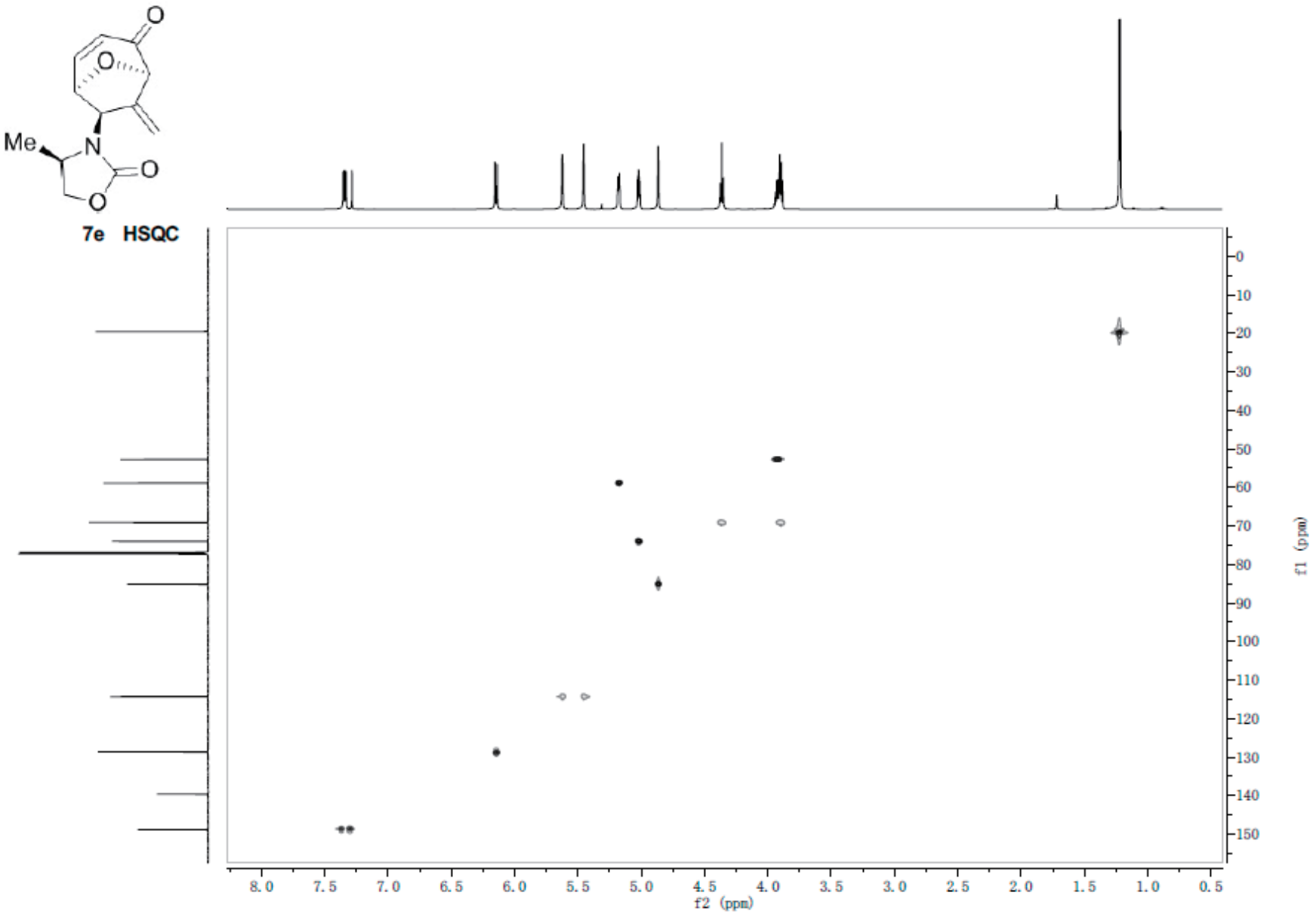

192.85
158.18
148.90
139.85
128.43
114.08
85.24
74.28
67.11
58.77
58.09
25.57
8.76
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
Et
N
O
O
O
O
7d
f1 (ppm)

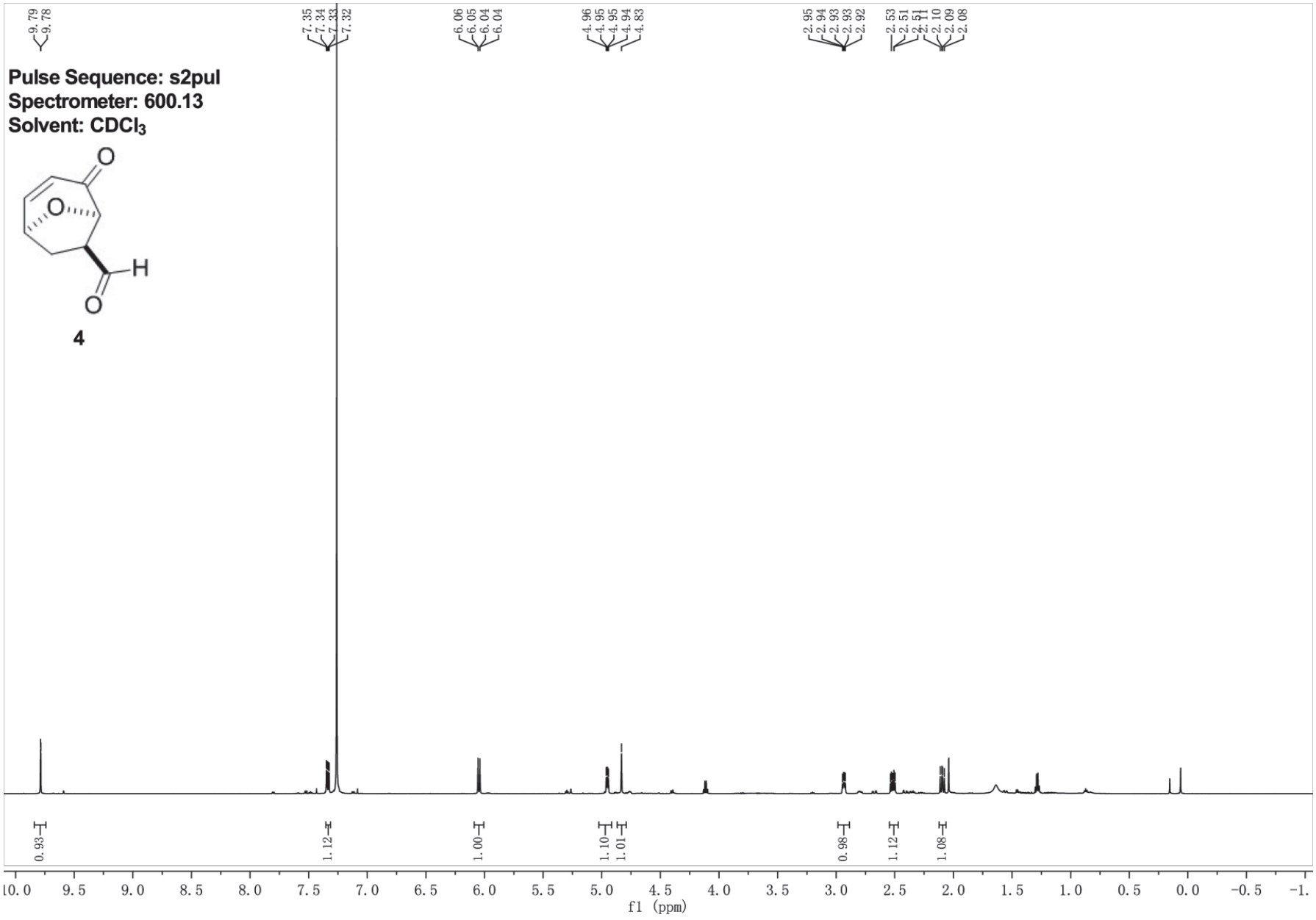

O
O
Et
N
O
O
7d
HSQC
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f2 (ppm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
f1 (ppm)

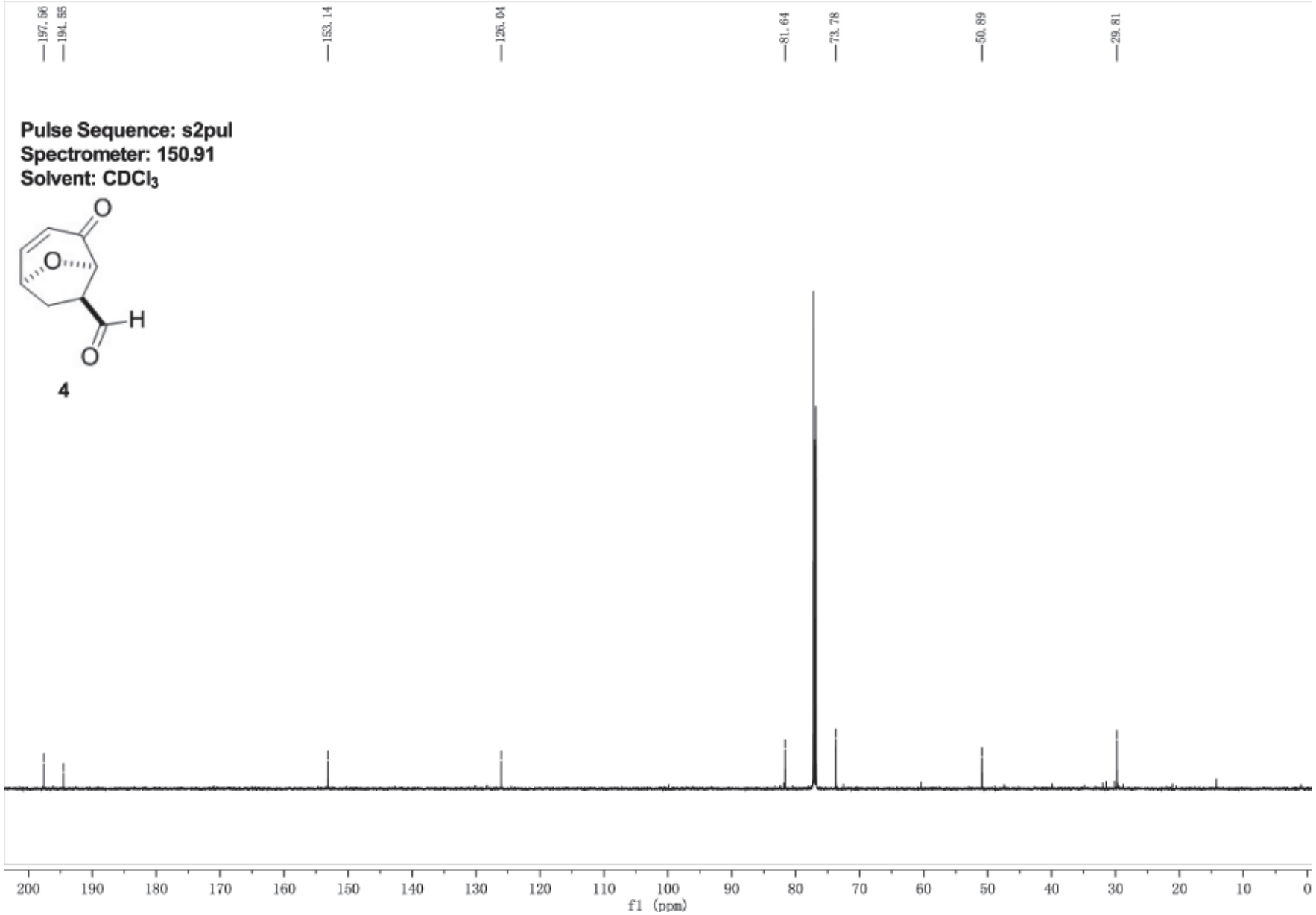

Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
Me
N
O
O
O
O
7e
f1 (ppm)

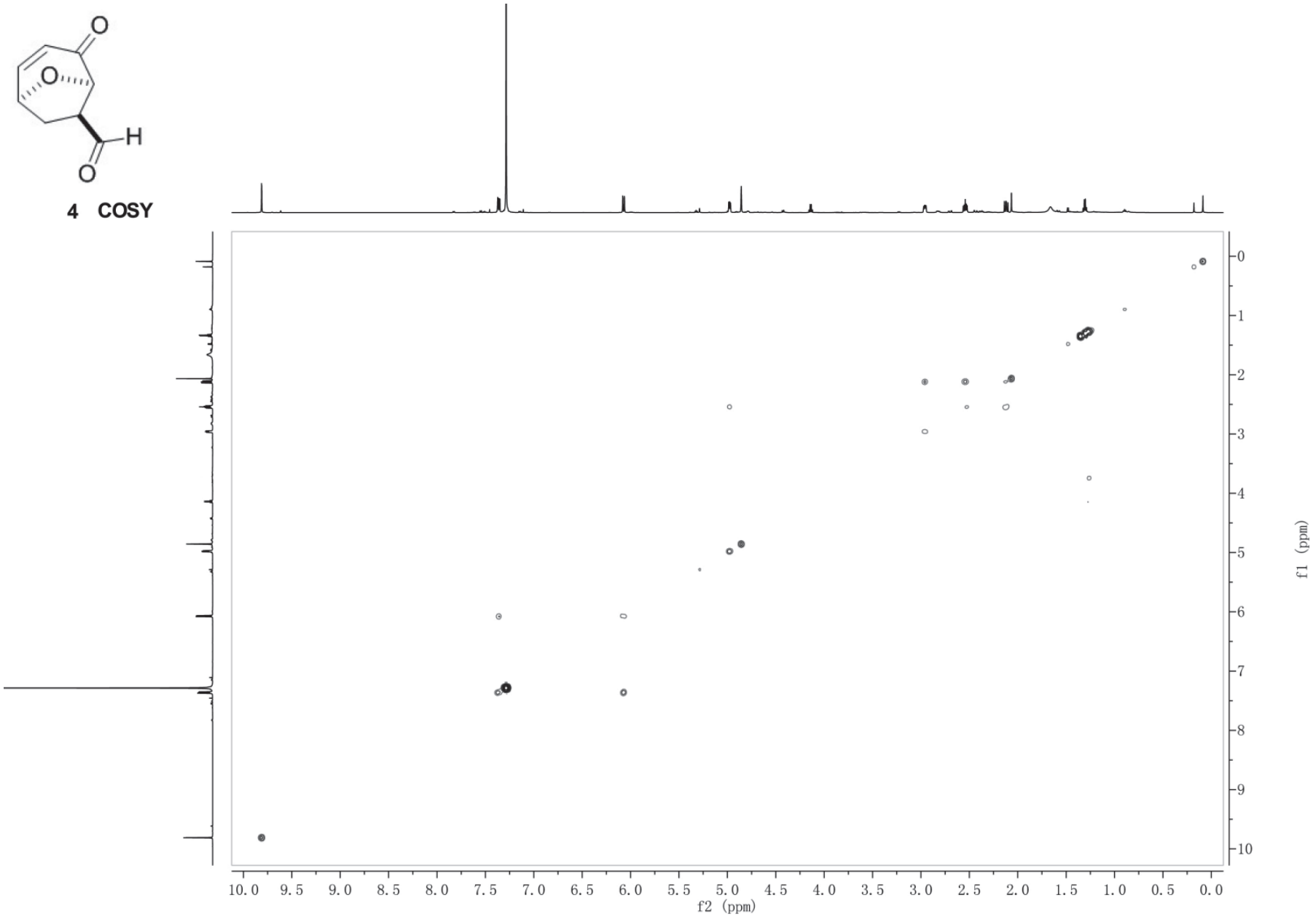

192.81
158.39
148.81
139.63
128.66
114.31
85.15
74.01
69.15
58.86
52.74
19.57
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
Me
N
O
O
7e
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−1
f1 (ppm)

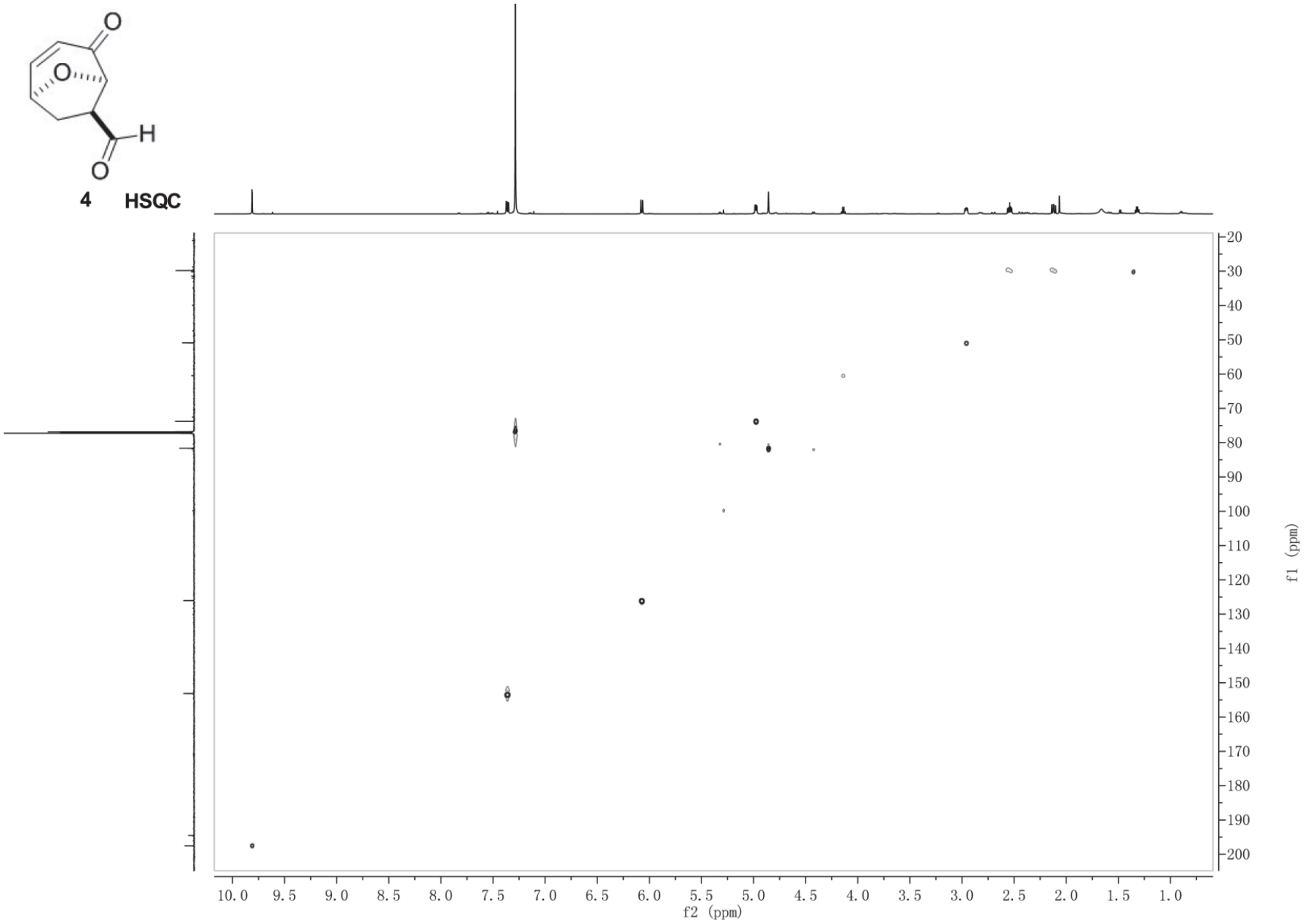

Me
N
O
O
O
O
7e COSY
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)
f1 (ppm)

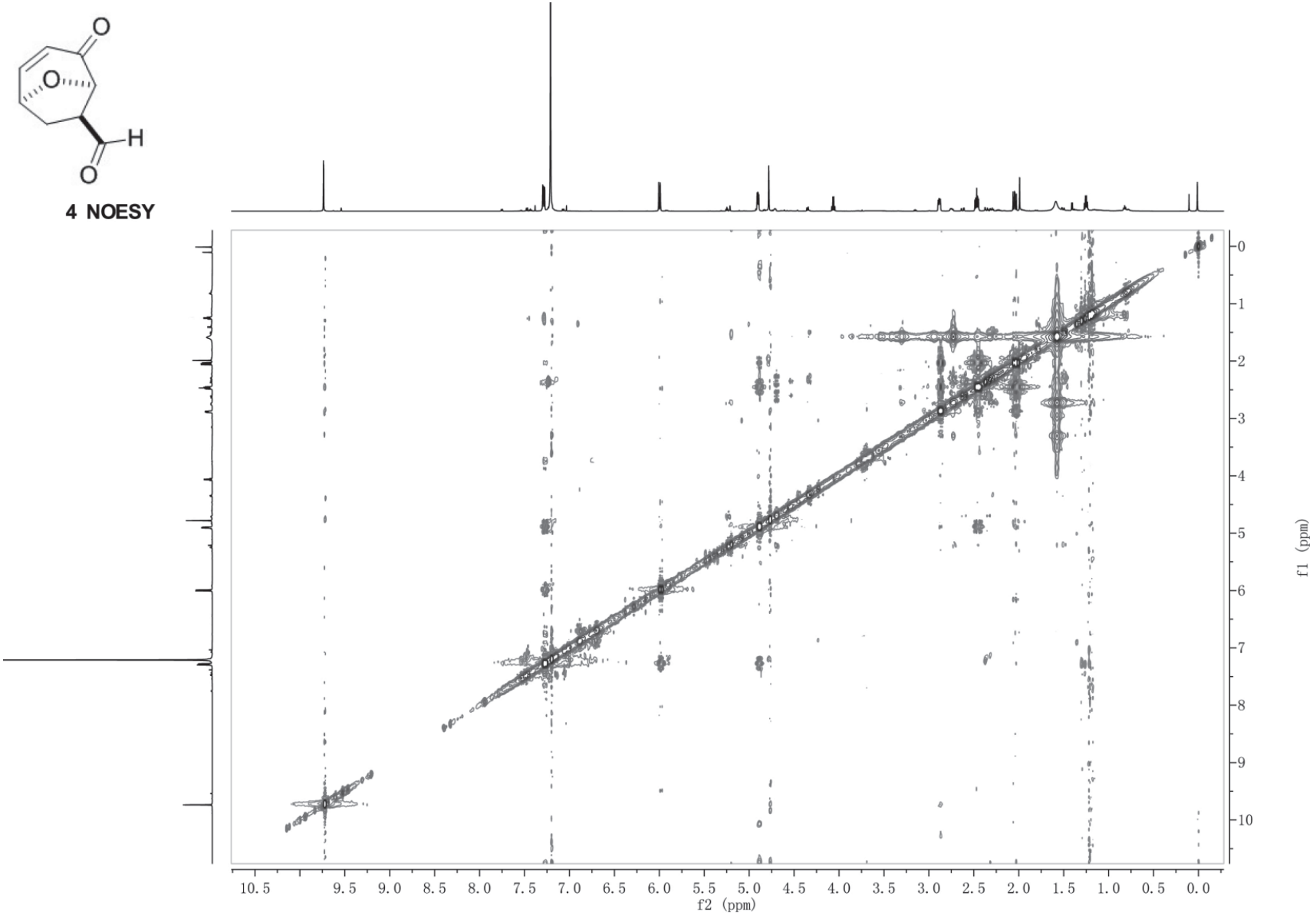

Me
N
O
O
O
7e HSQC
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
f1 (ppm)


9.79
9.78
7.35
7.34
7.33
7.32
6.06
6.05
6.04
6.04
4.96
4.95
4.95
4.94
4.83
2.95
2.94
2.93
2.92
2.53
2.51
2.10
2.09
2.08
Pulse Sequence: s2pul
Spectrometer: 600.13
Solvent: CDCl3
O
O
H
O
4
0.93
1.12
1.00
1.10
1.01
0.98
1.12
1.08
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.
f1 (ppm)


197.56
194.55
153.14
126.04
81.64
73.78
50.89
29.81
Pulse Sequence: s2pul
Spectrometer: 150.91
Solvent: CDCl3
O
O
H
O
4
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
O
H
O
4 COSY
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f2 (ppm)
0 1 2 3 4 5 6 7 8 9 10
f1 (ppm)


O
O
H
O
4 HSQC
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
f2 (ppm)
20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
f1 (ppm)


O
O
H
O
4 NOESY
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f2 (ppm)
0
1
2
3
4
5
6
7
8
9
10
f1 (ppm)