Electronic Supporting Information

Chemical Emulation of the Biosynthesis of (±)-Arnebidin

Zhilong Feng,[†,1] Tao Zhang,[†,2] Nan Wang,[2] Shoufeng Wang,[*,1] Jun Deng[*,2]

1 School of Chemistry and Chemical Engineering, University of Jinan, 336 West Road of Nan Xinzhuang, Jinan, 250022, People's Republic of China

2 State Key Laboratory and Institute of Elemento-Organic Chemistry, Frontiers Science Center for New Organic Matter, College of Chemistry, Nankai University, Tianjin 300071, China

[†] These authors contributed equally.

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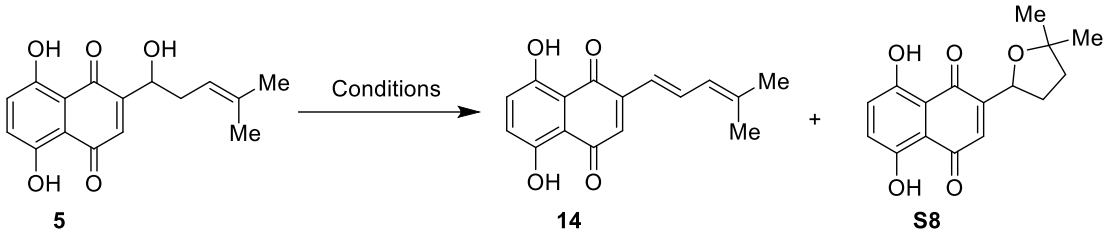
I General Information.

All reactions were carried out under an argon atmosphere with dry solvents under anhydrous conditions, unless otherwise noted. Tetrahydrofuran (THF) and 1,4-dioxane were distilled immediately before use from sodium-benzophenoneketyl. Methanol (MeOH) was distilled from magnesium stored under an argon atmosphere. Methylene chloride (CH_2Cl_2), triethylamine (Et_3N) and Pyridine were distilled from calcium hydride and stored under an argon atmosphere. Reagents were purchased at the highest commercial quality and used without further purification, unless otherwise stated. Solvents for chromatography were used as supplied by Titan chemical. Reactions were monitored by thin layer chromatography (TLC) carried out on 0.2 mm Qingdao gel plates (60F-254) using UV light as visualizing agent and aqueous ammonium cerium nitrate/ammonium molybdate or basic aqueous potassium permanganate as developing agent. Huang hai silica gel (60, particle size 0.040–0.063 mm) was used for flash column chromatography.

NMR spectra were recorded on Bruker AV III 400 and 600. The spectra were calibrated by using residual undeuterated solvents (for ^{1}H NMR) and deuterated solvents (for ^{13}C NMR) as internal references: undeuterated chloroform (δ_H = 7.26 ppm) and $CDCl_3$ (δ_C = 77.16 ppm); The following abbreviations are used to designate multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, quint = quintet, br = broad. IR spectra were recorded on a BRUKER Tensor-27 FT-IR spectrometer. High-resolution mass spectra (HRMS) were recorded on Agilent G6230 ESI-FT.

II Tables of optimization of the reaction conditions

Table S1. Optimization of the reaction conditions for synthesis of compound 14.



Entry	Conditions	Result
1	Ar, Burgess, DCE, 70 ℃	Decomposed
2	Ar, MsCl, Et_3N, DCM, 0 ℃	No reaction
3	Ar, PPTS, DCE, 80 ℃	No reaction
4	Ar, Ts_2O, DCM, 0 to 60 ℃	No reaction
5	Ar, $TsOH·H_2O$, DCM, 0 ℃	**S8** (90%)
6	Ar, $BF_3·Et_2O$, DCM, 0 ℃	**S8** (90%)
7	Ar, TFA, DCE, 0 ℃ to r.t.	**S8** (80%)
8	Ar, TFAA, Py, DCM, -20 ℃, wait 2 days	**14** (46%)
9	Ar, TFAA, Py, DCM, 0 ℃	**14** (10%)
10	Ar, Tf_2O, DCM, -78 to -30 ℃	**14** (10%)

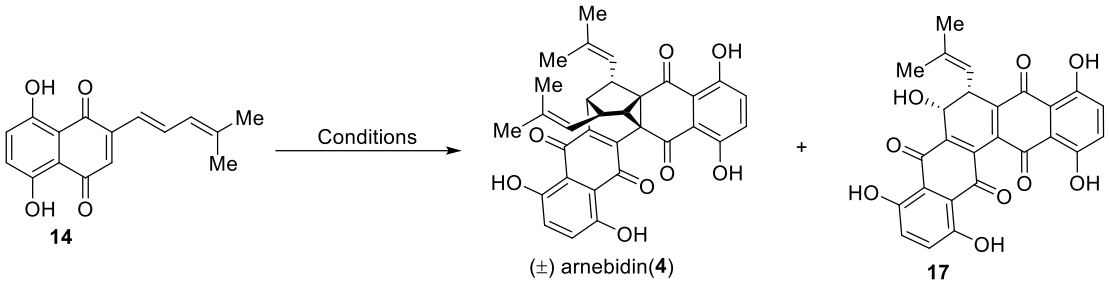
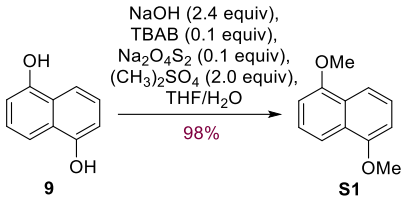


Table S2. Optimization of the reaction conditions for synthesis of compound 4.

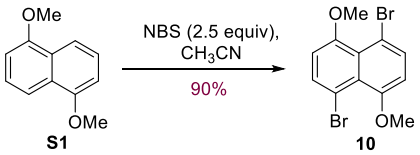
Entry	Conditions	Result
1	Air, neat, 2 days	No reaction
2	Air, 1,4-Dioxane, 2 days	No reaction
3	Air, Toluene, 130 ℃	No reaction
4	Air, *o*-DCB, 170 ℃	No reaction
5	Ar, Et_2AlCl, Toluene, -78 to 50 ℃	No reaction
6	Ar, BF_3•Et_2O, DCM, 50 ℃	No reaction
7	Ar, $Yb(OTf)_3$, 0 to 50 ℃	No reaction
8	O_2, Et_2O, 2 days, 35 ℃	No reaction
9	MnO_2, degassed DCM, 2 days, 30 ℃	No reaction
10	Air, neat, 100 ℃	Decomposed
11	Ar, $Eu(Fod)_3$, *o*-DCB, 150 ℃	Decomposed
12	Degassed 5% H_2O_2, degassed DMSO, 2 days, 35 ℃	Decomposed
13	DDQ, degassed THF, 2 days, 40 ℃	Decomposed
14	Air, THF, 2 days, 35 ℃	**4** (15%) + **17** (25%)
15	Air, DCM, 4 days, 35 ℃	**4** (15%) + **17** (25%)
16	O_2, DMF, 2 days, 35 ℃	**4** (10%) + **17** (5%)
17	Air, $CHCl_3$, 2 days, 35 ℃	**4** (5%) + **17** (10%)
18	Air, EA, 2 days, 35 ℃	**4** (10%) + **17** (10%)
19	$CuBr_2$, I_2, degassed THF, 40 ℃	**4** (18%)
20	Degassed THF, 2 days, 40 ℃	**4** (35%)

III Experimental Procedures and Spectroscopic Data of Compounds



To a stirred solution of **9** (8.0 g, 50.0 mmol, 1.00 equiv) in THF-H_2O (150 ml, 2:1) was added Tetrabutylammonium bromide (1.6 g, 5.0 mmol), sodium dithionite (1.0 g, 5.0 mmol) and sodium hydroxide (4.8 g, 120.0 mmol) under argon. Then dimethyl sulfate (9.5 ml, 100.0 mmol) was added dropwise to the solution. The reaction mixture was allowed to stir below 30 °C for 2 h. After 2 h, the solid was collected by filtration to give **S1** (9.2 g, 98% yield) as a yellow solid.

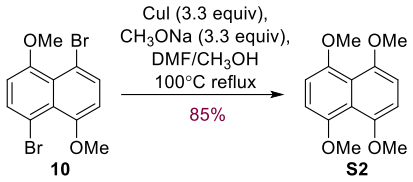
S1: yellow solid, R_f = 0.8 (silica, PE: EtOAc = 5 : 1); IR(film): ν_{max} = 3073, 2960, 2936, 2830, 1593, 1510, 1469, 1452, 1404, 1340, 1269, 1083, 865, 775; ^{1}H NMR (400 MHz, Chloroform-*d*) δ = 7.84 (d, *J* = 8.5 Hz, 2H), 7.38 (t, *J* = 8.0 Hz, 2H), 6.85 (d, *J* = 7.7 Hz, 2H), 4.00 (s, 6H) ppm; ^{13}C NMR (101 MHz, $CDCl_3$) δ 155.4, 126.7, 125.3, 114.3, 104.7, 55.7; HRMS (*m/z*): $[M+H]^+$ calcd for $C_{12}H_{13}O_2^+$ 189.0910 found 189.0914.



To a stirred solution of **S1** (10.0 g, 53.1 mmol, 1.00 equiv) in acetonitrile (106 ml) was added *N*-bromosuccinimide (23.6 g, 132.8 mmol) in acetonitrile (166 ml) at -20 °C under argon. The reaction mixture was allowed to stir at 10 °C for 1.5 h. After 1.5 h, the solid was collected by filtration, washed with methanol and petroleum to give **10** (16.5 g, 90% yield) as a greenish solid.

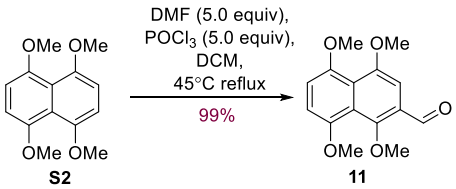
10: greenish solid, R_f = 0.7 (silica, PE: EtOAc = 5 : 1); IR(film): ν_{max} = 3351, 3335, 2953, 2916, 2848, 1731, 1589, 1458, 1366, 1304, 1252, 1058, 811; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.71 (d, *J* = 8.5 Hz, 2H), 6.74 (d, *J* = 8.5 Hz, 2H), 3.92 (s, 6H). ^{13}C

NMR (101 MHz, $CDCl_3$) δ 155.3, 133.8, 126.4, 108.5, 107.2, 55.9; HRMS (*m/z*): [$M^{+\cdot}$] calcd for $C_{12}H_{10}Br_2O_2^{+\cdot}$ 343.9042 found 343.9047.



A mixture of **10** (12.0 g, 34.7 mmol, 1.00 equiv), sodium methoxide (6.2 g, 114.4 mmol) and copper (I) iodide, *N, N*-dimethylformamide (85 ml) and methanol (85 ml) was allowed to reflux at 100 °C for 36 h. After 36 h, the mixture was filtered when it was hot. The filtrate was poured into ice water and the resulting precipitate was filtered. The residue was recrystallized from ethyl acetate to give **S2** (7.3 g, 85% yield) as a pink solid.

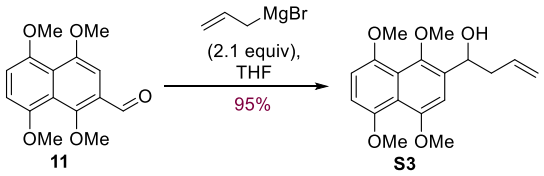
S2: pink solid, R_f = 0.4 (silica, PE: EtOAc = 5 : 1); IR(film): ν_{max} = 2951, 2923, 1733, 1660, 1613, 1587, 1433, 1455, 1284, 1260, 1181, 1061, 816, 714 cm; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.85 (d, *J* = 2.8 Hz, 4H), 3.90 (d, *J* = 2.9 Hz, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 151.4, 121.1, 108.8, 57.9; HRMS (*m/z*): [M+H]$^+$ calcd for $C_{14}H_{17}O_4^+$ 249.1121 found 249.1123.



To a mixture of phosphoryl chloride (18.0 ml, 193.3 mmol, 1.00 equiv) and *N, N*-dimethylformamide (15.0 ml, 193.3 mmol) was added a solution of **S2** (8.0 g, 32.2 mmol) in dichloromethane (54 ml) under argon and the mixture was allowed to reflux at 45 ℃ for 5 h. After 5 h, the resultant mixture was quenched with ice water (100 ml)

and extracted with EtOAc (80 mL×3). The combined organic phases were washed with brine (100 mL), dried over anhydrous Na_2SO_4. The solvent was evaporated under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 5 : 1) to give **11** (8.8 g, 99%) as a yellow solid.

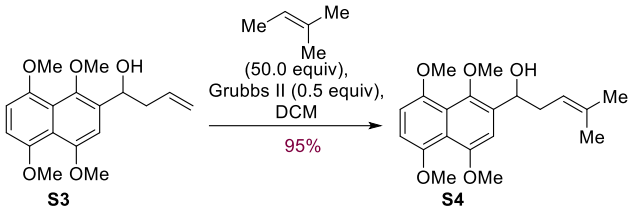
11: yellow solid, R_f = 0.5 (silica, PE: EtOAc = 3 : 1); IR(film): ν_{max} = 2951, 2925, 2916, 1675, 1599, 1586, 1520, 1472, 1364, 1258, 1189, 1072, 986, 763 ; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 10.55 (s, 1H), 7.18 (s, 1H), 7.02 (d, *J* = 8.7 Hz, 1H), 6.91 (d, *J* = 8.7 Hz, 1H), 3.98 (s, 3H), 3.97 (s, 3H), 3.90 (s, 3H), 3.89 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.3, 157.2, 153.8, 151.7, 151.6, 126.2, 124.0, 122.5, 112.9, 108.5, 101.6, 65.6, 58.3, 57.0, 56.7; HRMS (*m/z*): [$M^{-\cdot}$] calcd for $C_{15}H_{16}O_5^{-\cdot}$ 276.1003 found 276.0999.



To a stirred solution of **11** (8.0. g, 29.0 mmol, 1.00 equiv) in tetrahydrofuran (290 ml) was added allylmagnesium bromide (60.8 ml, 60.8 mmol, 1.0 M in tetrahydrofuran) at 0 °C under argon. The reaction mixture was allowed to stir at 0 °C for 1 h. After 1 h, the resultant mixture was quenched with saturated aq. NH_4Cl (200 ml) and extracted with EtOAc (200 mL×3). The combined organic phases were washed with brine (100 mL), dried over anhydrous Na_2SO_4. The solvent was evaporated under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 3 : 1) to give **S3** (8.8 g, 95%) as a brown syrup.

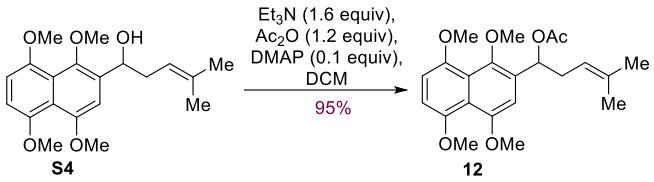
S3: brown syrup, R_f = 0.3 (silica, PE: EtOAc = 3 : 1); IR(film): ν_{max} = 2954, 2924, 2850, 1740, 1600, 1457, 1362, 1254, 1148, 1072, 1059, 1017, 819, 799 ; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.01 (s, 1H), 6.82 (d, *J* = 1.1 Hz, 2H), 5.91 (ddt, *J* = 17.1, 10.1, 7.2 Hz, 1H), 5.45 – 5.06 (m, 3H), 3.95 (s, 3H), 3.94 (s, 3H), 3.89 (s, 3H), 3.77 (s, 3H), 2.72 –

2.44 (m, 2H), 2.36 (d, J = 3.1 Hz, 1H). ^{13}C NMR (101 MHz, CDCl3) δ 153.6, 151.6, 150.4, 146.5, 135.1, 133.7, 122.7, 120.3, 118.3, 108.3, 107.7, 105.8, 68.0, 63.0, 57.9, 57.2, 57.0, 43.1; HRMS (*m/z*): [$M^{-\cdot}$] calcd for $C_{18}H_{22}O_5^{-\cdot}$ 318.1473 found 318.1470.



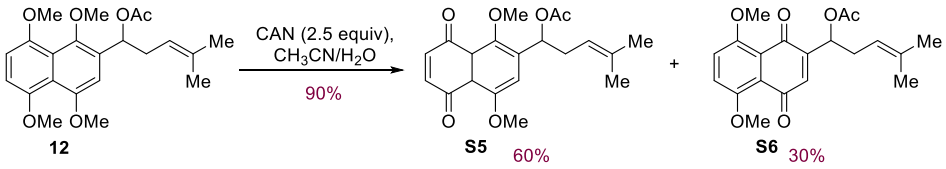
To a mixture of **S3** (9.0 g, 28.3 mmol, 1.00 equiv) in dichloromethane (141 ml) and 2-Methyl-2-butene (150.0ml, 1.4 mol) was added Grubbs 2nd (1.2 g, 1.4 mmol) at room temperature under argon. The reaction mixture was allowed to stir at 40 °C for 2 h. After 2 h, the resultant mixture was quenched with saturated aq. $NaHCO_3$ (300 ml) and extracted with EtOAc (300 mL×3). The combined organic phases were washed with brine (300 mL), dried over anhydrous Na_2SO_4. The solvent was evaporated under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 4 : 1) to give **S4** (9.3 g, 95%) as a yellow syrup.

S4: yellow syrup, R_f = 0.4 (silica, PE: EtOAc = 2 : 1); IR(film): ν_{max} = 2954, 2923, 2851, 1737, 1601, 1459, 1376, 1363, 1255, 1078, 1071, 1018, 820, 729; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.02 (s, 1H), 6.82 (d, J = 1.7 Hz, 2H), 5.31 – 5.18 (m, 2H), 3.95 (s, 3H), 3.94 (s, 3H), 3.90 (s, 3H), 3.77 (s, 3H), 2.53 (t, J = 7.1 Hz, 2H), 2.31 (s, 1H), 1.73 (d, J = 1.4 Hz, 3H), 1.66 (d, J = 1.3 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.5, 151.6, 150.4, 146.7, 135.5, 134.1, 122.7, 120.4, 120.3, 108.3, 107.8, 106.1, 68.8, 63.0, 57.9, 57.3, 57.1, 37.3, 26.1, 18.2; HRMS (*m/z*): [$M^{+\cdot}$] calcd for $C_{20}H_{26}O_5^{+\cdot}$ 346.1775 found 346.1776.



To a stirred solution of **S4** (8.0 g, 23.1 mmol, 1.00 equiv) in dichloromethane (46 ml) was added DMAP (0.28 g, 2.3 mmol), Et_3N (5.1 ml, 36.9 mmol) and Ac_2O (2.6 ml, 27.7 mmol) at 0 °C under argon. The reaction mixture was allowed to stir at room temperature for 0.5 h. After 0.5 h, the resultant mixture was quenched with MeOH (50 ml). The solvent was evaporated under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 5 : 1) to give **12** (8.5 g, 95%) as a colorless oil.

12: colorless oil, R_f = 0.7 (silica, PE: EtOAc = 2 : 1); IR(film): ν_{max} = 2990, 2954, 2931, 1738, 1601, 1517, 1451, 1365, 1317, 1257, 1236, 1076, 996, 936, 826, ; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.88 (s, 1H), 6.83 (s, 2H), 6.35 (dd, *J* = 7.5, 5.6 Hz, 1H), 5.14 (t, *J* = 7.2 Hz, 1H), 3.93 (s, 6H), 3.89 (s, 3H), 3.83 (s, 3H), 2.57 (h, *J* = 8.2, 7.7 Hz, 2H), 2.10 (s, 3H), 1.66 (s, 3H), 1.56 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.4, 153.4, 151.5, 150.6, 147.0, 134.8, 130.8, 122.8, 120.7, 119.3, 108.7, 107.9, 106.3, 71.0, 62.7, 58.0, 57.5, 57.1, 34.7, 25.9, 21.5, 18.1; HRMS (*m/z*): [$M^{+\cdot}$] calcd for $C_{22}H_{28}O_6^{+\cdot}$ 388.1880 found 388.1884.

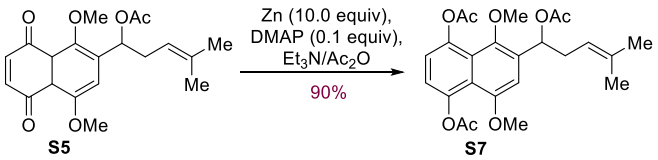


To a stirred solution of **12** (8.9 g, 22.9 mmol, 1.00 equiv) in acetonitrile (229 ml) was added dropwise ammonium cerium (IV) nitrate (30.3 g, 57.2 mmol) in water (72 ml) under argon. The reaction mixture was allowed to stir at room temperature for 0.5 h. After 0.5 h, the resultant mixture was diluted with water (80 ml) and extracted with EtOAc (300 mL×3). The combined organic phases were washed with brine (300 mL), dried over anhydrous Na_2SO_4. The solvent was evaporated under vacuum, and the

residue was purified by flash column chromatography (silica gel, PE: EtOAc = 5 : 1) to give first fraction **S5** (4.9 g, 60%) as a yellow oil and second fraction **S6** (2.5 g, 30%) as a orange oil.

S5: yellow oil, R_f = 0.7 (silica, PE: EtOAc = 1 : 1); IR(film): ν_{max} = 2956, 2923, 2850, 1742, 1659, 1551, 1465, 1343, 1246, 1236, 1058, 1049, 866; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.26 (s, 1H), 6.78 (d, *J* = 2.0 Hz, 2H), 6.14 (dd, *J* = 7.5, 4.8 Hz, 1H), 5.17 – 5.06 (m, 1H), 3.97 (s, 3H), 3.91 (s, 3H), 2.62 – 2.39 (m, 2H), 2.13 (s, 3H), 1.68 (d, *J* = 1.4 Hz, 3H), 1.53 (d, *J* = 1.4 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 184.9, 184.5, 170.1, 156.2, 150.9, 144.7, 139.1, 138.0, 135.9, 125.4, 120.4, 118.2, 117.0, 70.7, 62.3, 56.9, 34.2, 25.9, 21.3, 18.0; HRMS (*m/z*): $[M+H]^+$ calcd for $C_{20}H_{22}NaO_6^+$ 381.1309 found 381.1311.

S6: orange oil, R_f = 0.4 (silica, PE: EtOAc = 1 : 1); IR(film): ν_{max} = 2953, 2917, 2838, 1731, 1713, 1657, 1587, 1568, 1464, 1448, 1284, 1212, 1049, 976, 838, 756,; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.28 (s, 2H), 6.61 (s, 1H), 5.70 (td, *J* = 8.6, 5.0 Hz, 1H), 5.13 (dt, *J* = 8.9, 1.4 Hz, 1H), 3.94 (s, 3H), 3.93 (s, 3H), 3.01 – 2.50 (m, 2H), 1.94 (s, 3H), 1.72 (d, *J* = 1.3 Hz, 3H), 1.69 (d, *J* = 1.4 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 184.8, 184.6, 170.3, 153.9, 153.6, 146.2, 138.2, 136.7, 122.9, 121.5, 121.2, 120.3, 120.1,70.0, 57.0, 56.9, 35.3, 25.8, 21.2, 18.7; HRMS (*m/z*): $[M+H]^+$ calcd for $C_{20}H_{23}O_6^+$ 359.1489 found 359.1495.

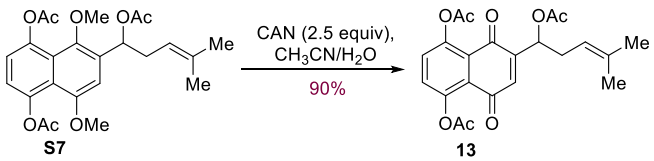


S5 **S7**

To a stirred mixture of **S5** (5.0 g, 13.9 mmol, 1.00 equiv), Et_3N (55.5 ml), Ac_2O (222 ml), DMAP (0.17 g, 1.4 mmol) was added Zn powder (9.1 g, 138.7 mmol) at 0 °C under argon. The reaction mixture was allowed to stir at room temperature for 2 h. After 2 h, the resultant mixture was poured into ice water (300 ml) and extracted with EtOAc (300 mL×3). The combined organic phases were washed with saturated aq. $NaHCO_3$ (300 ml×3) and brine (300 mL), dried over anhydrous Na_2SO_4. The solvent was evaporated

under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 5 : 1) to give **S7** (5.6 g, 90%) as a light yellow oil.

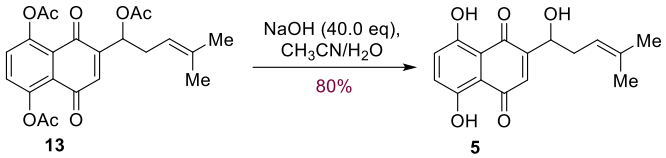
S7: colorless oil, R_f = 0.6 (silica, PE: EtOAc = 1 : 1); IR(film): ν_{max} = 2969, 2936, 2847, 1767, 1739, 1608, 1464, 1448, 1365, 1217, 1201, 1150, 1046, 919, 851; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.09 (d, *J* = 8.1 Hz, 1H), 7.03 (d, *J* = 8.1 Hz, 1H), 6.82 (s, 1H), 6.25 (dd, *J* = 7.7, 5.8 Hz, 1H), 5.09 (t, *J* = 7.3 Hz, 1H), 3.91 (s, 3H), 3.82 (s, 3H), 2.62 – 2.40 (m, 2H), 2.36 (s, 3H), 2.35 (s, 3H), 2.09 (s, 3H), 1.66 (d, *J* = 1.4 Hz, 3H), 1.53 (d, *J* = 1.4 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.3, 170.3, 169.5, 152.2, 145.5, 144.9, 143.9, 135.2, 131.7, 123.8, 121.4, 120.6, 119.7, 118.8, 105.2, 70.6, 62.8, 56.7, 34.8, 25.9, 21.4, 21.1, 20.9, 18.0; HRMS (*m/z*): $[M+Na]^+$ calcd for $C_{24}H_{28}NaO_8^+$ 467.1676 found 467.1676.



To a stirred solution of **S7** (5.0 g, 11.2 mmol, 1.00 equiv) in acetonitrile (112 ml) was added dropwise ammonium cerium (IV) nitrate (14.9 g, 28.1 mmol) in water (35 ml) under argon. The reaction mixture was allowed to stir at room temperature for 0.5 h. After 0.5 h, the resultant mixture was diluted with water (50 ml) and extracted with EtOAc (100 mL×3). The combined organic phases were washed with brine (100 mL), dried over anhydrous Na_2SO_4. The solvent was evaporated under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 3 : 1) to give **13** (4.2 g, 90%) as a yellow oil.

13: yellow oil, R_f = 0.7 (silica, PE: EtOAc = 1 : 1); IR(film): ν_{max} = 2974, 2933, 1774, 1747, 1666, 1638, 1586, 1463, 1413, 1369, 1329, 1230, 1183, 1045, 1014, 937, 916, 733; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.36 (s, 2H), 6.65 (d, *J* = 1.3 Hz, 1H), 5.87 (ddd, *J* = 7.1, 4.5, 1.3 Hz, 1H), 5.07 (t, *J* = 7.3 Hz, 1H), 2.60 – 2.31 (m, 2H), 2.42 (s, 3H), 2.41 (s, 3H), 2.08 (s, 3H), 1.67 (d, *J* = 1.4 Hz, 3H), 1.55 (d, *J* = 1.4 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 183.3, 182.1, 169.7, 169.3, 169.3, 149.0, 147.8, 147.4, 136.2,

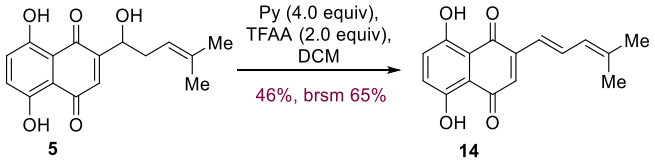
133.5, 131.1, 131.0, 124.6, 124.3, 117.8, 69.4, 32.8, 25.9, 21.1, 21.0, 18.0; HRMS (*m/z*): $[M+Na]^+$ calcd for $C_{22}H_{22}NaO_8^+$ 437.1207 found 437.1215.



13 **5**

To a stirred solution of Sodium hydroxide (5.8 g, 144.8 mmol) in water (145ml) was added a solution of **13** (3.0 g, 7.2 mmol) in acetonitrile (18 ml) at 0 °C. The reaction mixture was allowed to stir at room temperature for 2 h. After 2 h, the resultant mixture was quenched with Acetic acid until the system changes from deep blue to red. Then the resultant mixture was extracted with EtOAc (100 mL×3). The combined organic phases were washed with brine (100 mL), dried over anhydrous Na_2SO_4. The solvent was evaporated under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 5 : 1 with 1‰ formic acid) to give **5** (1.68 g, 80%) as a dark red solid.

5: dark red solid, R_f = 0.3 (silica, PE: EtOAc = 10 : 1 with a drop of formic acid); IR(film): ν_{max} = 2962, 2952, 1611, 1569, 1449, 1428, 1397, 1339, 1222, 1199, 1112, 1080, 1070, 857, 778, 727; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 12.59 (s, 1H), 12.49 (s, 1H), 7.19 (d, *J* = 2.4 Hz, 2H), 7.16 (s, 1H), 5.20 (ddt, *J* = 8.3, 6.7, 1.6 Hz, 1H), 4.95 – 4.87 (m, 1H), 2.73 – 2.60 (m, 1H), 2.42 – 2.29 (m, 2H), 1.76 (s, 3H), 1.65 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 180.7, 179.9, 165.7, 165.1, 151.6, 137.5, 132.5, 132.4, 132.0, 118.6, 112.2, 111.7, 68.5, 35.8, 26.1, 18.2; HRMS (*m/z*): $[M-H]^-$ calcd for $C_{16}H_{15}O_5^-$ 287.0925 found 287.0925.

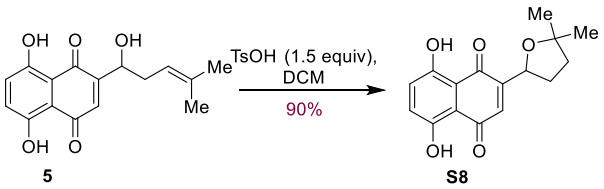


5 **14**

To a stirred solution of **5** (100 mg, 0.35 mmol, 1.00 equiv) in dichloromethane (3.5 ml) was added Pyridine (0.11 ml, 1.4 mmol) and trifluoroacetic anhydride (0.1 ml, 0.69

mmol) at -20 °C under argon. The reaction mixture was allowed to stir at -20 °C for 20 minutes. After 20 minutes, the resultant mixture was quenched with water (10 ml) and was extracted with EtOAc (10 mL×3). The combined organic phases were washed with brine (10 mL), dried over anhydrous Na_2SO_4. Let the dried organic phase stand for two days. The solvent was evaporated under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 10 : 1 with 1‰ formic acid) to give **14** (43 mg, 46%) as a red solid.

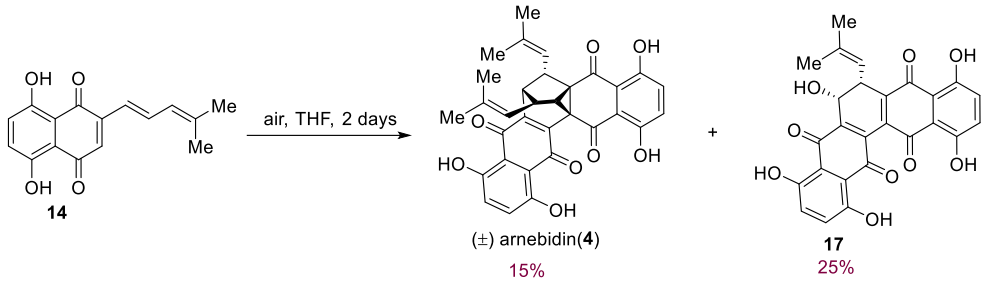
14: red solid, R_f = 0.7 (silica, PE: EtOAc = 10 : 1 with a drop of formic acid); IR(film): ν_{max} = 3307, 3275, 2943, 2915, 1844, 1653, 1624, 1507, 1457, 1447, 1313, 1039, 895, 787; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 12.72 (s, 1H), 12.68 (s, 1H), 7.50 (dd, *J* = 15.6, 11.2 Hz, 1H), 7.23 (d, *J* = 9.5 Hz, 1H), 7.19 (d, *J* = 9.4 Hz, 1H), 7.06 (s, 1H), 6.65 (d, *J* = 15.5 Hz, 1H), 6.14 (d, *J* = 11.3 Hz, 1H), 1.94 (s, 3H), 1.92 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 183.5, 183.4, 162.7, 161.6, 145.1, 144.8, 135.5, 131.3, 130.5, 128.2, 126.5, 120.2, 112.3, 112.1, 26.8, 19.3; $[M-H]^-$ calcd for $C_{16}H_{13}O_4^-$ 269.0819 found 269.0820.



To a stirred solution of **5** (20 mg, 0.07 mmol, 1.00 equiv) in dichloromethane (0.35 ml) was added TsOH·H_2O (20 mg, 0.01 mmol) at 0 °C under argon. The reaction mixture was allowed to stir at 0 °C for 20 minutes. After 20 minutes, the resultant mixture was quenched with water (2 ml) and was extracted with EtOAc (2 mL×3). The combined organic phases were washed with brine (5 mL), dried over anhydrous Na_2SO_4. The solvent was evaporated under vacuum, and the residue was purified by flash column chromatography (silica gel, PE: EtOAc = 30 : 1 with 1‰ formic acid) to give **S8** (17 mg, 90%) as a red solid.

S8: red solid, R_f = 0.8 (silica, PE: EtOAc = 10 : 1 with a drop of formic acid); ^{1}H NMR (Chloroform-*d*) δ 1.35 (3H, d, J = 1.0Hz). 1.38 (3H. s). 1.80 (1H, m), 1.82 (1H, m), 1.90 (1H, m), 2.63 (1H, m), 5.15 (1H, dd, J = 7.5, 1.5 Hz), 7.18 (1H, d, J= 9.0 Hz), 7.20

(1H. d, J = 9.0 Hz), 7.21 (1H, d, J = 1.5 Hz). 12.51 (1H. s),12.53 (1H, s). ^{13}C NMR (CDCl3) δ 27.8, 28.7, 33.4, 38.4, 74.4, 82,1, 111.6, 112.1, 131.2, 131.3, 131.7, 153.0, 163.4, 163.9, 181.5, 182.4. This compound was identified as anhydroalkannin by comparison of the spectral data with the published ones.[1]

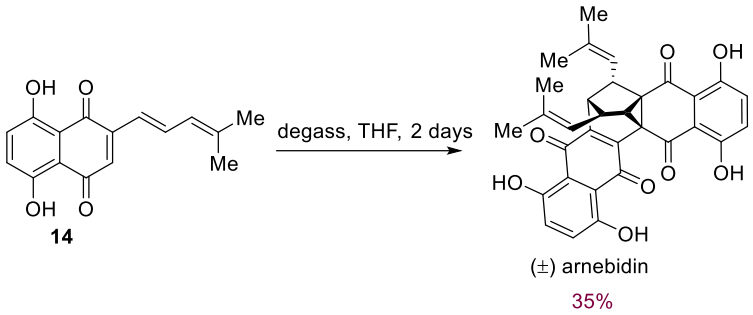


Compound **14** (20 mg, 0.074 mmol, 1.00 equiv) was completely dissolved in dry tetrahydrofuran. After standing at 35 ℃ for two days, the residue was purified by flash column chromatography to afford fraction arnebidin (**4**) (3 mg, 15%) as a red solid, followed by fraction **17** (4.4 mg, 25%) as a purple solid.

Arnebidin (**4**): red solid, R_f = 0.6 (silica, PE: EtOAc = 5 : 1 with a drop of formic acid); IR(film): ν_{max} = 2970, 2918, 1615, 1575, 1455, 1393, 1331, 1258, 1232, 1208, 1135, 1078, 1050, 926, 839, 786, 732, 700; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 12.50 (s, 1H), 12.39 (s, 1H), 12.30 (s, 1H), 12.09 (s, 1H), 7.29 (s, 1H), 7.28 (s, 1H),7.26 (s, 1H), 7.25 (s, 1H), 4.62 (d, *J* = 9.0 Hz, 1H), 4.38 (d, *J* = 8.9 Hz, 1H), 3.88 (t, *J* = 4.8 Hz, 1H), 3.81 (dd, *J* = 9.0, 4.6 Hz, 1H), 3.38 – 3.33 (m, 1H), 2.68 (d, *J* = 2.4 Hz, 1H), 1.83 (d, *J* = 1.3 Hz, 3H), 1.72 (d, *J* = 1.4 Hz, 3H), 1.60 (d, *J* = 1.4 Hz, 3H), 1.54 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 195.6, 193.3, 182.8, 182.4, 159.1, 158.7, 157.5, 156.4, 144.4, 140.2, 138.8, 138.0, 130.1, 129.4, 129.2, 129.1, 117.5, 116.9, 112.8, 112.6, 111.8, 111.6, 49.4, 45.4, 40.8, 38.5, 38.2, 37.7, 26.1, 25.9, 18.8, 18.8; HRMS (*m/z*): $[M+Na]^+$ calcd for $C_{32}H_{26}NaO_8^+$ 561.1520 found 561.1522.

17: purple solid, R_f = 0.6 (silica, PE: EtOAc = 5 : 1 with a drop of formic acid); IR(film): ν_{max} = 2917, 2850, 1609, 1569, 1455, 1400, 1336, 1246, 1198, 856, 775, 765, 733, 723; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 12.45 (s, 1H), 12.39 (s, 1H), 12.23 (s, 1H), 12.21 (s, 1H), 7.29 (s, 1H), 7.27 (s, 1H), 7.26 (s, 1H), 7.25 (s, 1H), 5.06 (s, 1H), 4.55 (dd, J =

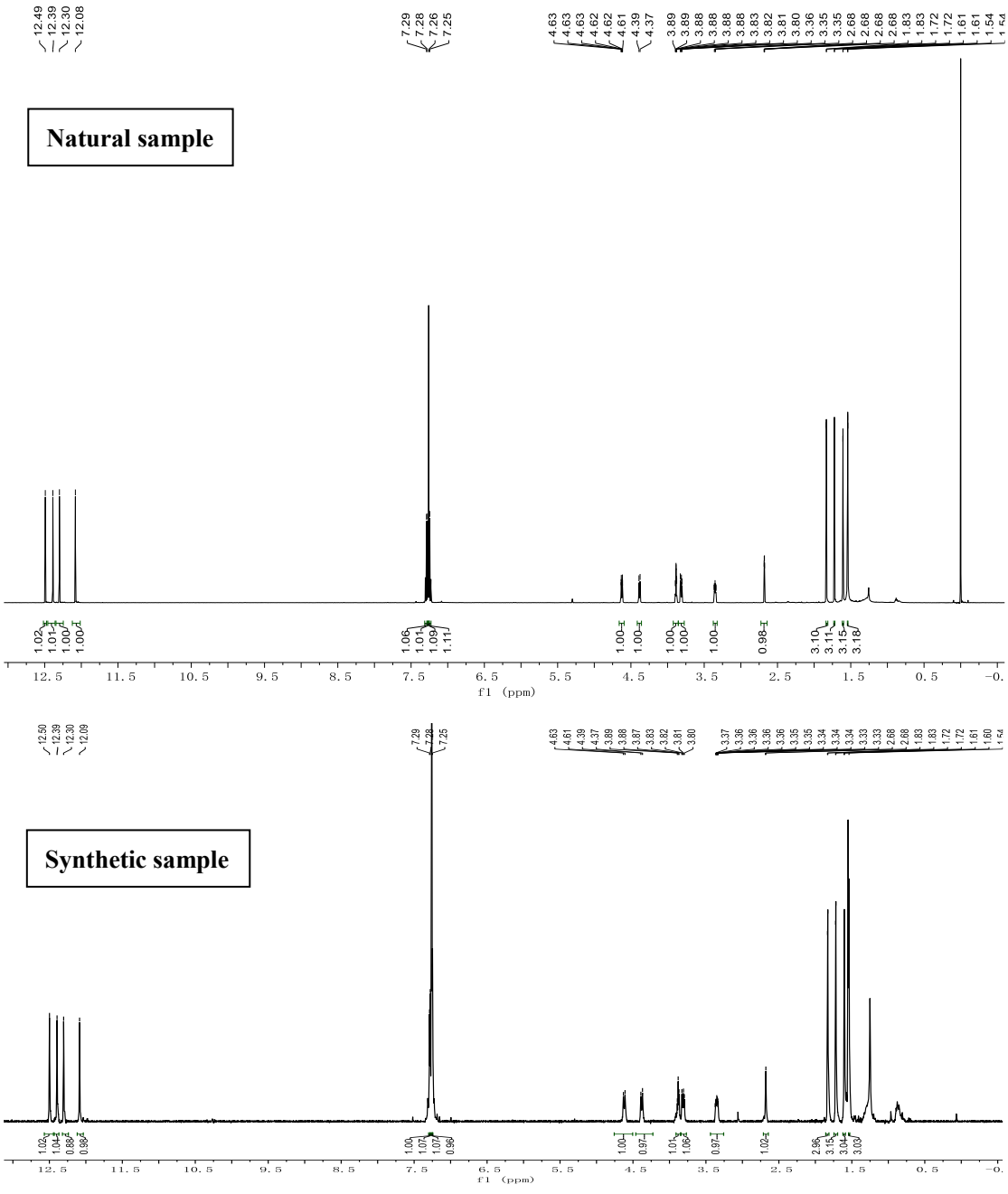
9.7, 1.6 Hz, 1H), 4.49 (d, J = 9.8 Hz, 1H), 1.98 (d, J = 1.3 Hz, 3H), 1.65 (d, J = 1.3 Hz, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 182.2, 180.7, 180.1, 179.1, 163.8, 163.4, 161.5, 160.9, 149.5, 143.4, 140.3, 137.8, 135.7, 132.3, 131.4, 131.3, 130.3, 116.3, 112.7, 112.6, 112.5, 112.2, 64.2, 39.0, 26.2, 18.9; HRMS (*m/z*): $[M-H]^-$ calcd for $C_{26}H_{17}O_9^-$ 473.0878 found 473.0880.

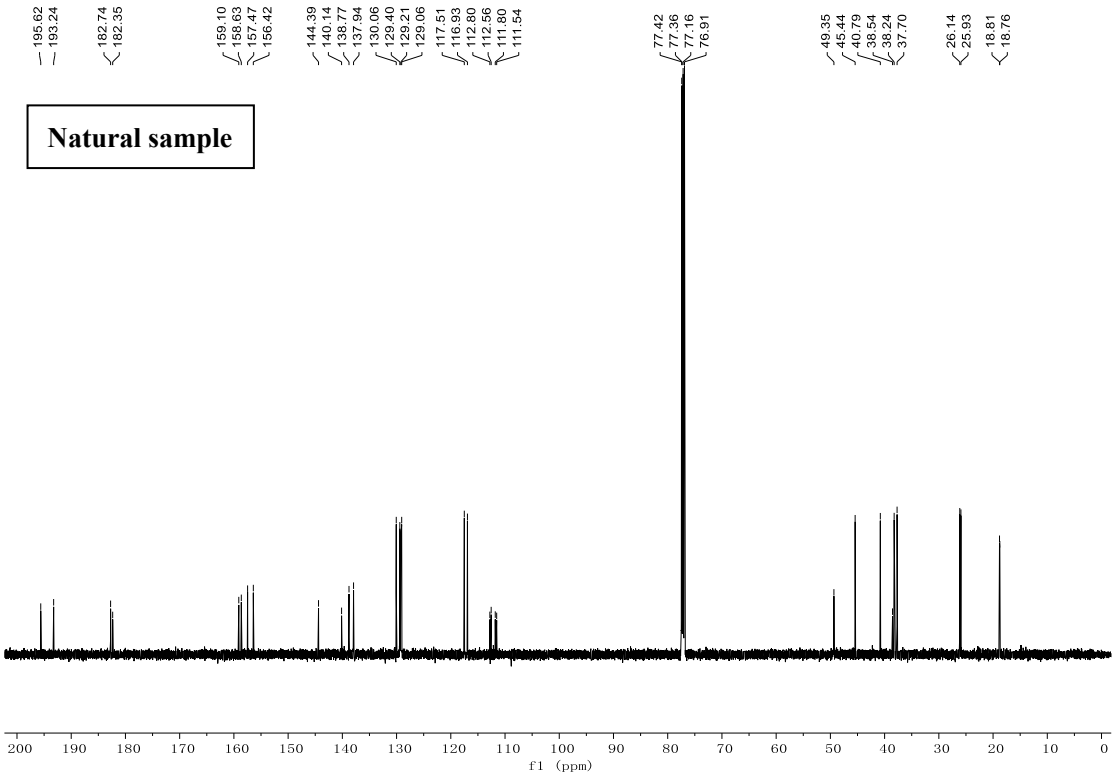


Compound **14** (10 mg, 0.037 mmol, 1.00 equiv) was completely dissolved in dry tetrahydrofuran, and the mixture was degassed. After standing at 40 ℃ for two days, the residue was purified by flash column chromatography to afford arnebidin (**4**) (3.5 mg, 35%) as a red solid.

IV Comparison of the spectra and data of natural[2] and synthetic arnebidin

Figure S1. Comparison of the spectra and data ($CDCl_3$) of natural and synthetic Arnebidin.




195.62
193.24
182.74
182.35
159.10
158.63
157.47
156.42
144.39
140.14
138.77
137.94
130.06
129.40
129.21
129.06
117.51
116.93
112.80
112.56
111.80
111.54
77.42
77.36
77.16
76.91
49.35
45.44
40.79
38.54
38.24
37.70
26.14
25.93
18.81
18.76
Natural sample
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

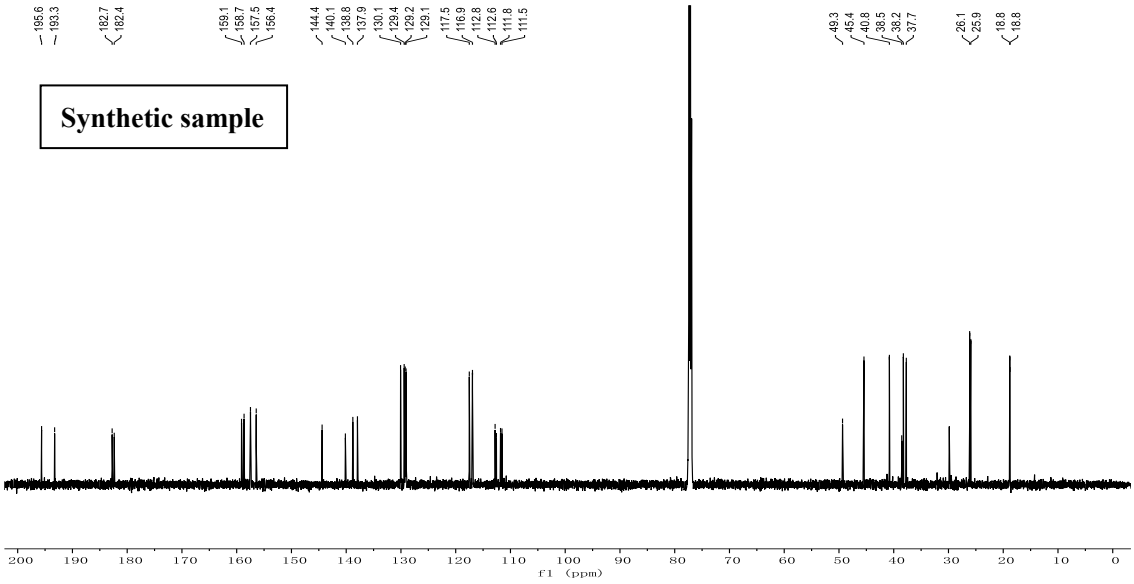
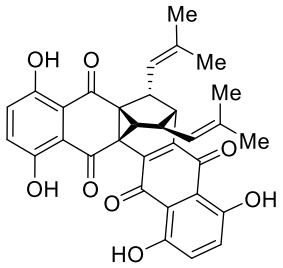

195.6
193.3
182.7
182.4
159.1
158.7
157.5
156.4
144.4
140.1
138.8
137.9
130.1
129.4
129.2
129.1
117.5
116.9
112.8
112.6
111.8
111.5
49.3
45.4
40.8
38.5
38.2
37.7
26.1
25.9
18.8
18.8
Synthetic sample
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Table S3 Comparison of the ^{1}H NMR spectroscopic data ($CDCl_3$) of natural and synthetic Arnebidin.



(±)-Arnebidin

Natural δ_H [ppm, mult, *J* (Hz)] 600 MHz		**Synthetic** δ_H [ppm, mult, *J* (Hz)] 400 MHz		**Err** (Natural–Synthetic) $\Delta\delta_H$ (ppm)
12.49	1 H, s	12.50	1 H, s	−0.01
12.39	1 H, s	12.39	1 H, s	0
12.30	1 H, s	12.30	1 H, s	0
12.08	1 H, s	12.09	1 H, s	−0.01
7.30	1 H, d, 8.1	7.29	1 H, s	0.01
7.27	1 H, d, 8.1	7.28	1 H, s	−0.01
7.26	1 H, d,8.1	7.26	1 H, s	0
7.24	1 H, d, 8.1	7.25	1 H, s	−0.01
4.62	1 H, dt, 9.0, 1.4	4.62	1 H, d, 9.0	0
4.38	1 H, dt, 9.0, 1.4	4.38	1 H, d, 8.9	0
3.88	1 H, td, 4.5, 1.1	3.88	1 H, t, 4.5	0
3.81	1 H, dd, 9.0, 4.5	3.81	1 H, d, 9.0, 4.6	0
3.35	1 H, ddd, 9.0, 4.5, 2.7	3.38-3.33	1 H, m,	0
2.68	1 H, d, 2.7	2.68	1 H, d, 2.4	0
1.83	3 H, d, 1.4	1.83	3 H, d, 1.3	0
1.72	3 H, d, 1.4	1.72	3 H, d, 1.4	0
1.61	3 H, d, 1.4	1.60	3 H, d, 1.4	0
1.54	3 H, d, 1.4	1.54	3 H, s	0

Calibrated by using $CDCl_3$ (δ_H = 7.26 ppm) as internal reference.

Table S4 Comparison of the ^{13}C NMR spectroscopic data ($CDCl_3$) of natural and synthetic Arnebidin.

Natural δ_C (ppm) 150 MHz	**Synthetic** δ_C (ppm) 150 MHz	**Err** (Natural–Synthetic) $\Delta\delta_C$ (ppm)
195.6	195.6	0
193.2	193.3	-0.1
182.7	182.7	0
182.4	182.4	0
159.1	159.1	0
158.6	158.7	-0.1
157.5	157.5	0
156.4	156.4	0
144.4	144.4	0
140.1	140.1	0
138.8	138.8	0
137.9	137.9	0
130.1	130.1	0
129.4	129.4	0
129.2	129.2	0
129.1	129.1	0
117.5	117.5	0
116.9	116.9	0
112.8	112.8	0
112.6	112.6	0
111.8	111.8	0
111.5	111.5	0
49.3	49.3	0
45.4	45.4	0
40.8	40.8	0
38.5	38.5	0
38.2	38.2	0

37.7	37.7	0
26.1	26.1	0
25.9	25.9	0
18.8	18.8	0
18.8	18.8	0

Calibrated by using $CDCl_3$ (δ_C = 77.16 ppm) as internal reference.

V DFT calculation

Geometry optimizations and frequency calculations of stationary points were carried out by using Gaussian 16 Rev. A.03.[3] Geometry optimizations and frequency calculations of stationary points were performed at ωB97X-D level of theory in gas phase with def2-SVP basis set for all atoms.[4] [5] Frequency calculations were conducted at the same level of theory to confirm the presence of local minima (no imaginary frequencies) and transition states (one imaginary frequency) on the PES. Subsequent single point energies were carried out by using ORCA quantum chemistry software package (version 6.1.1.). [6]Higher level of single point electronic energies for those structures were calculated at RI-ωB97M-V/def2-TZVPP level.[7] Solvent effect was modelled by employing the SMD model. [8] Auxiliary basis set def2/J was utilized to accelerate SCF calculations. [9]Intrinsic reaction coordinate (IRC) calculations were performed to verify that the saddle points found were true TSs connecting the reactants and the products.[10] The thermal correction to the Gibbs free energy was calculated at 298.15 K and 1 atm using unscaled harmonic frequencies. The calculation of ΔG_{gas} uses a reference state of 1 atm and the calculations of ΔG_s use a reference state of 1M. Based on the ΔG_{gas} reference state (24.46 L at 298.15 K) from 1 atm to 1M, the Gibbs free energy can be computed by using equation ΔG_{gas} (1M) = ΔG_{gas}(1 atm) + RTln(24.46) = ΔG_{gas}(1 atm) + 1.89 kcal/mol.[11] The cubic files for electrostatic potential maps were generated with Multiwfn program, and the results were visualized by the VMD program. [12] [13] The 3D diagrams of molecules were generated using CYLview 2.0. [14]错误!未找到引用源。

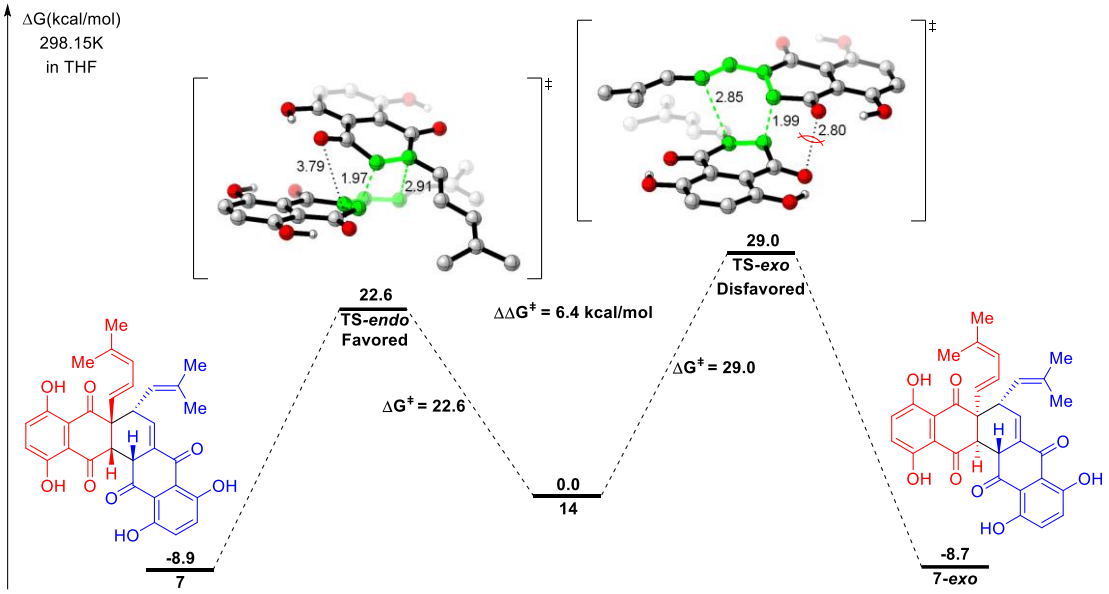


Figure S2. Calculated energy profiles for the formation of **7** and **7-*exo*** at the SMD-(THF)-RI-ωB97M-V/def2-TZVPP//ωB97X-D/def2-SVP level of theory.

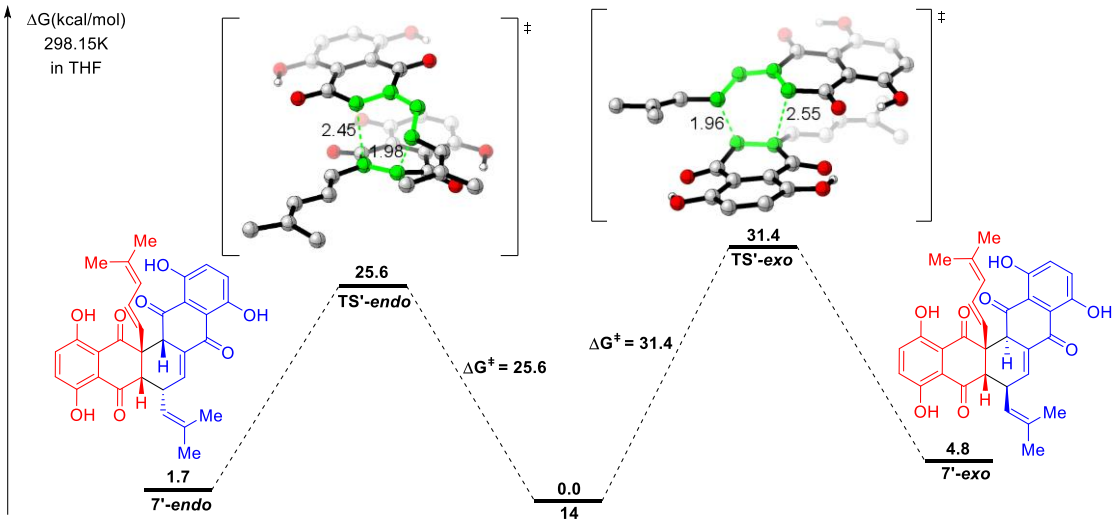


Figure S3. Calculated energy profiles for the formation of other putative regioisomers **7'-*endo*** and **7'-*exo*** at the SMD-(THF)-RI-ωB97M-V/def2-TZVPP//ωB97X-D/def2-SVP level of theory.

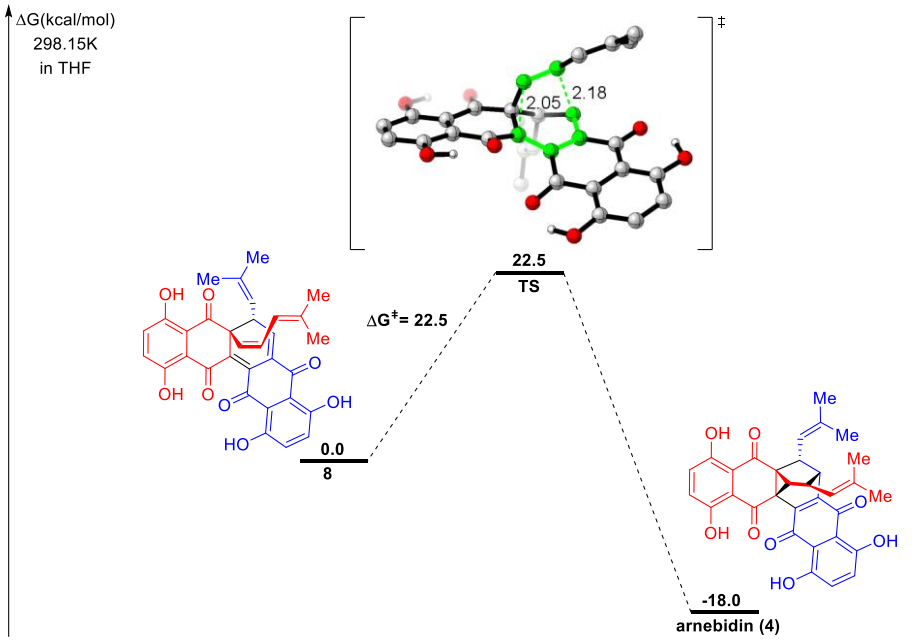


Figure S4. Calculated energy profiles for the formation of Arnebidin (**4**) at the SMD-(THF)-RI-ωB97M-V/def2-TZVPP//ωB97X-D/def2-SVP level of theory.

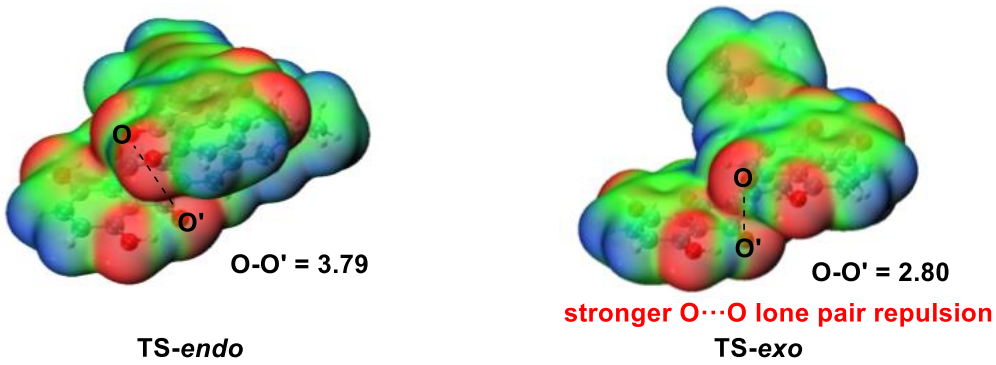


Figure S5. Electrostatic Potential Map for **TS-*endo*** and **TS-*exo***.

Cartesian Coordinates and Energies

14

Thermal correction to Gibbs Free Energy (Hartree): 0.220882
Single point energy (Hartree): -919.085538
Gibbs free energy (Hartree): -918.864656

C	-4.65971400	0.19775500	-0.00030300
C	-4.38664300	-1.14577700	-0.00028000
C	-3.04912700	-1.62283600	-0.00000300
C	-2.00200700	-0.68996800	0.00016200
C	-2.28964800	0.70506500	0.00012400
C	-3.61283200	1.15778300	-0.00005700
O	-3.93640100	2.44286100	0.00004100
O	-2.85588200	-2.93367100	0.00017100
C	-0.61885100	-1.16454300	0.00035100
C	0.49364300	-0.15278800	0.00011100
C	0.18113800	1.16628500	0.00004900
C	-1.19353700	1.67689100	0.00021800
O	-1.40500500	2.89365900	-0.00027500
O	-0.35151800	-2.36680600	-0.00037000
C	1.84553600	-0.70189200	-0.00005800
C	2.98741600	0.01738600	0.00007100
C	4.30493900	-0.58821000	-0.00011500
C	5.49207800	0.05614600	0.00002100
C	6.78126900	-0.71611800	-0.00019000
C	5.65529000	1.54977900	0.00040500
H	-5.68760200	0.56468300	-0.00045400
H	-5.18917200	-1.88529800	-0.00040800
H	-3.08746200	2.94979800	0.00039700
H	-1.88083800	-3.08062200	0.00056300
H	1.89646900	-1.79350100	-0.00025700
H	2.93086600	1.11012100	0.00035000
H	4.31833600	-1.68372200	-0.00039700
H	6.61499300	-1.80183000	-0.00053500
H	7.38850700	-0.45780200	-0.88385000
H	7.38845000	-0.45836100	0.88367500
H	4.70769200	2.10130700	0.00052400
H	6.23301400	1.86762800	0.88385400
H	6.23305700	1.86807900	-0.88285300
H	0.95044500	1.94142700	-0.00017600

TS-*endo*

Thermal correction to Gibbs Free Energy (Hartree): 0.472423

Single point energy (Hartree): -1838.162716
Gibbs free energy (Hartree): -1837.690293

C	-5.48115800	1.13271200	0.60263800
C	-5.10389900	2.36428000	0.13529600
C	-3.73386800	2.72605200	0.05460000
C	-2.76779300	1.79708000	0.46007400
C	-3.15968600	0.51712800	0.95824000
C	-4.51737000	0.17881300	1.02675200
O	-4.95530700	-0.98859200	1.47030100
O	-3.43204000	3.92851000	-0.41353300
C	-1.35811300	2.12627600	0.30756700
C	-0.34400300	1.07651000	0.60118400
C	-0.72389500	-0.08663600	1.31341500
C	-2.16141300	-0.45759000	1.40091400
O	-2.49311000	-1.55981700	1.84590300
C	0.21482600	-1.02866600	1.75334000
C	1.58669700	-0.87764400	1.67126600
C	2.46962100	-1.98554600	1.86976600
O	-0.97520800	3.23005800	-0.09546700
C	3.81908600	-1.97506900	1.71444000
C	-1.52837900	-4.07106000	-1.11981000
C	-0.25306900	-4.55382300	-0.93200400
C	0.87587400	-3.70264500	-0.97999000
C	0.67375600	-2.33519200	-1.19072700
C	-0.64427800	-1.83635900	-1.39060800
C	-1.74981800	-2.70097000	-1.37907800
O	-2.99513300	-2.27980300	-1.57671100
O	2.08339000	-4.24093400	-0.79960000
C	1.82883100	-1.41569700	-1.14443900
C	1.56843000	0.02331300	-1.09153400
C	0.24441400	0.51388900	-1.18779800
C	-0.86055200	-0.40592400	-1.57478400
O	-1.93904000	0.05866200	-1.94315900
O	2.98773100	-1.85928700	-1.12623500
C	4.59291200	-3.25640700	1.78608800
C	4.63850300	-0.74942700	1.45284200
H	-6.53345300	0.85012900	0.66411300
H	-5.84429100	3.09699200	-0.18988500
H	-4.15855400	-1.52045900	1.71145800
H	-2.44873900	4.00028500	-0.41218100
H	-0.19307400	-1.98814600	2.08398700
H	2.01131400	0.10826100	1.47439000
H	1.98802900	-2.95113600	2.05577800

H	-2.39393100	-4.73441300	-1.08709700
H	-0.07929700	-5.61544400	-0.74656200
H	-2.94720500	-1.32455400	-1.80724100
H	2.73063200	-3.50411000	-0.91217300
H	3.94172600	-4.12789800	1.93187400
H	5.33344000	-3.22214700	2.60248700
H	5.15942500	-3.40079300	0.85142600
H	4.06689100	0.18531200	1.49284900
H	5.09669300	-0.82670200	0.45393300
H	5.46167700	-0.68607000	2.18282100
H	0.12259200	1.51280700	-1.61658200
H	0.62739900	1.52426700	0.83804800
C	2.69216300	0.92192200	-0.98133300
H	3.67647000	0.45126500	-1.03769800
C	2.59624100	2.25846900	-0.76317200
H	1.60710300	2.72274600	-0.70368100
C	3.74089100	3.13029400	-0.60307000
H	4.72347900	2.65799500	-0.71640700
C	3.70044100	4.45317500	-0.32670400
C	4.96941400	5.24659900	-0.19372900
H	4.98315300	6.07978600	-0.91630500
H	5.86438400	4.63145100	-0.35962300
H	5.04111300	5.70151700	0.80853800
C	2.43673600	5.24380100	-0.13345500
H	1.51878000	4.64365000	-0.15723300
H	2.35571500	6.02167500	-0.91103600
H	2.46902000	5.77340400	0.83288800

7

Thermal correction to Gibbs Free Energy (Hartree): 0.475727
Single point energy (Hartree): -1838.216177
Gibbs free energy (Hartree): -1837.740450

C	-5.86052400	-1.91117800	0.14887200
C	-5.62399400	-1.64216700	-1.17533500
C	-4.40553200	-1.05615400	-1.59552900
C	-3.43314400	-0.75105000	-0.63116600
C	-3.67614300	-1.03570700	0.75206900
C	-4.89422600	-1.61660400	1.14158700
O	-5.19107900	-1.91474500	2.39941600
O	-4.24796700	-0.81750400	-2.89165800
C	-2.19256000	-0.10966800	-1.06779200
C	-1.20789900	0.36003800	-0.02118300
C	-1.34736500	-0.23910900	1.34891800

C	-2.66188900	-0.77579200	1.78294300
O	-2.87426300	-1.03605300	2.96896700
C	-0.31376000	-0.29440000	2.20164100
C	1.11109500	0.04812500	1.86780100
C	1.89541000	-1.25156800	1.87984700
O	-1.97823400	0.16552600	-2.24669100
C	3.16373400	-1.43575000	2.27453400
C	3.82656600	-2.63390300	-2.21639400
C	4.75600600	-1.68902200	-1.85787400
C	4.37873100	-0.51824400	-1.15541300
C	3.02432900	-0.31899900	-0.85592100
C	2.05844200	-1.29321600	-1.24938200
C	2.45599000	-2.46650700	-1.90018900
O	1.61215300	-3.43309900	-2.24301800
O	5.34051600	0.31938000	-0.78039200
C	2.64766400	0.80483800	0.00992700
C	1.20814900	0.89063700	0.53678200
C	0.23467800	0.31266600	-0.51504000
C	0.64104200	-1.08133800	-0.95009200
O	-0.19273500	-1.96974800	-1.09049600
O	3.47354800	1.64020700	0.36287400
C	3.80887400	-2.78736800	2.13342000
C	4.06944700	-0.35668700	2.79847600
H	-6.79871100	-2.36388700	0.47434400
H	-6.36809800	-1.87079600	-1.94022900
H	-4.40649500	-1.66117500	2.94392300
H	-3.35821700	-0.40645700	-3.00141800
H	-0.49680100	-0.72162800	3.19190500
H	1.50606800	0.69075800	2.66986700
H	1.35758500	-2.12197600	1.48876800
H	4.12088300	-3.54322000	-2.74316900
H	5.81441500	-1.82498200	-2.08680900
H	0.72498400	-3.18223900	-1.90246700
H	4.90173200	1.05971500	-0.29902000
H	3.10828900	-3.54184700	1.75029800
H	4.20928400	-3.13880900	3.09828300
H	4.66223600	-2.72620000	1.43702200
H	3.56223500	0.60043700	2.97131800
H	4.87868200	-0.16972200	2.07354600
H	4.54678400	-0.67699100	3.73814600
H	0.30585500	0.91002800	-1.43984300
H	-1.47447600	1.42892200	0.08156100
C	0.91541100	2.34520200	0.85332800
H	1.28745700	2.69398600	1.82171600

C	0.31706400	3.23130200	0.04502700
H	-0.03530600	2.90943900	-0.93984400
C	0.10632600	4.62937600	0.39943300
H	0.51275700	4.93471400	1.37018100
C	-0.52844800	5.56158700	-0.33818000
C	-0.66153100	6.97441500	0.15949800
H	-0.19870900	7.68186800	-0.54884900
H	-0.19044400	7.11389200	1.14210300
H	-1.72341700	7.26108200	0.24079800
C	-1.14848400	5.31100000	-1.68520500
H	-1.07979200	4.26936100	-2.02171100
H	-0.67009100	5.94593100	-2.44916600
H	-2.21495300	5.58954900	-1.66973600

TS-*exo*

Thermal correction to Gibbs Free Energy (Hartree): 0.471313
Single point energy (Hartree): -1838.151430
Gibbs free energy (Hartree): -1837.680117

C	5.51460400	2.47948600	-0.29498800
C	5.91109200	1.16739800	-0.35912900
C	5.03301500	0.11895700	0.01745400
C	3.73316300	0.44842900	0.41728000
C	3.31947500	1.81186100	0.49518100
C	4.21512000	2.83435200	0.14987700
O	3.90982700	4.12246800	0.22418200
O	5.48274300	-1.12696900	-0.03296000
C	2.79561800	-0.62114600	0.75122500
C	1.35973600	-0.25926300	0.90379700
C	1.03385600	1.06378900	1.29140100
C	1.98086800	2.16351000	0.98048700
O	1.63726700	3.34253500	1.11206300
C	-0.26320500	1.40459700	1.68461000
C	-1.28450600	0.48596000	1.85676900
C	-2.65393300	0.87464000	1.89850100
O	3.14832700	-1.79158400	0.87872900
C	-3.71058800	0.03698000	2.08804400
C	-0.46910500	-5.22150400	-0.39676600
C	-1.78185900	-4.90239600	-0.14455100
C	-2.25031600	-3.57067200	-0.25041000
C	-1.33374900	-2.55223300	-0.54724800
C	0.02007800	-2.89219600	-0.82607500
C	0.45599100	-4.22283600	-0.78377900
O	1.69346100	-4.59019200	-1.08970100

O	-3.55291300	-3.34722900	-0.08027500
C	-1.80729000	-1.15660200	-0.67146000
C	-0.82104100	-0.09469500	-0.89164300
C	0.56380300	-0.43486700	-0.91155500
C	0.96154300	-1.84046600	-1.20116300
O	2.06141900	-2.08026600	-1.68993000
O	-3.02781200	-0.92264800	-0.60720700
C	-5.11168000	0.53648900	1.91874800
C	-3.58664700	-1.39149800	2.51728600
H	6.19446800	3.28758200	-0.57031400
H	6.91586700	0.89726400	-0.68849400
H	2.98940700	4.17640800	0.57767500
H	4.75987300	-1.71057800	0.29387600
H	-0.49203300	2.47258300	1.73509200
H	-1.03987400	-0.57289800	1.96406000
H	-2.86520700	1.92306600	1.66299100
H	-0.11674000	-6.25259300	-0.33830200
H	-2.50755000	-5.67517500	0.11537000
H	2.17154200	-3.78604300	-1.39231200
H	-3.68587400	-2.38780300	-0.28687700
H	-5.14919000	1.61810300	1.73282900
H	-5.57908100	0.02204500	1.06227500
H	-5.72635300	0.30207000	2.80298700
H	-2.56353100	-1.78326200	2.46839200
H	-3.93158000	-1.48361800	3.56115300
H	-4.22771900	-2.04670600	1.91103700
H	1.22691700	0.27702500	-1.41323700
H	0.79721100	-1.08141500	1.35528400
C	-1.18890900	1.26777800	-1.21363000
H	-0.33676100	1.93327100	-1.39864300
C	-2.43149300	1.81103500	-1.27105900
H	-3.28490700	1.15780100	-1.09530500
C	-2.64977600	3.21885500	-1.52763600
H	-1.75281900	3.81494800	-1.73369700
C	-3.83931400	3.86130900	-1.51131700
C	-3.92161700	5.33755600	-1.77894400
H	-4.56978100	5.54033400	-2.64827700
H	-4.37348400	5.86595400	-0.92240400
H	-2.93490600	5.77906800	-1.97448300
C	-5.15622700	3.19501000	-1.22833400
H	-5.84632400	3.33557200	-2.07672800
H	-5.07118600	2.11903900	-1.03499200
H	-5.63919900	3.66333300	-0.35398600

7-*exo*

Thermal correction to Gibbs Free Energy (Hartree): 0.473950

Single point energy (Hartree): -1838.214116

Gibbs free energy (Hartree): -1837.740166

C	-6.51536000	-0.65044100	0.31298100
C	-6.34919700	0.12990700	-0.80351400
C	-5.05847700	0.42506200	-1.30621600
C	-3.93899300	-0.06977000	-0.61936500
C	-4.11218600	-0.89455800	0.53678000
C	-5.40217000	-1.19432600	0.99980800
O	-5.63691700	-1.97636400	2.04460600
O	-4.97664100	1.17111500	-2.40078400
C	-2.60232500	0.30757000	-1.08742200
C	-1.41892400	0.02999100	-0.17386500
C	-1.60522400	-1.21995400	0.65679800
C	-2.95769100	-1.51557400	1.19741900
O	-3.10375600	-2.29039800	2.14346900
C	-0.60481300	-2.06219200	0.94783600
C	0.79776800	-1.90641800	0.44838800
C	1.05857500	-2.90726600	-0.65387500
O	-2.43647300	0.91445000	-2.13851100
C	2.13179700	-3.70127700	-0.78624200
C	0.94357300	4.66960400	0.53155800
C	1.20635200	4.19706400	1.79457600
C	1.25496300	2.80693400	2.06277300
C	0.99498800	1.91293500	1.01505300
C	0.68438600	2.40940900	-0.28692400
C	0.70062300	3.78237900	-0.54612800
O	0.47975300	4.29594900	-1.75178300
O	1.56737300	2.41714800	3.29369200
C	1.15914900	0.47063600	1.23705500
C	1.07333000	-0.44623100	0.00975200
C	-0.06090000	0.07221300	-0.90969200
C	0.31653300	1.47482300	-1.36193400
O	0.32667600	1.80669800	-2.53655300
O	1.42330200	0.01705900	2.34655700
C	2.26342600	-4.61823900	-1.97246300
C	3.29390300	-3.73854000	0.16763300
H	-7.51093900	-0.88719000	0.69226600
H	-7.20768400	0.53812700	-1.33957800
H	-4.75884200	-2.29682300	2.36348900
H	-4.02192600	1.25632200	-2.62468000
H	-0.83683600	-2.93604000	1.56263600

H	1.47080400	-2.10487600	1.29361800
H	0.28446400	-2.96030100	-1.42861700
H	0.92564800	5.74109800	0.32468000
H	1.40581000	4.88131100	2.62100200
H	0.40647700	3.54294200	-2.37938300
H	1.56931900	1.43366500	3.29388300
H	1.40898700	-4.53475900	-2.65809800
H	3.18304300	-4.38955400	-2.53626200
H	2.34535500	-5.66842300	-1.64702800
H	3.54912700	-4.77910400	0.42422900
H	4.18391000	-3.29361600	-0.30842500
H	3.11250300	-3.19007800	1.09998800
H	-0.11586800	-0.55215200	-1.81304900
H	-1.46198200	0.88612700	0.53174500
C	2.40827800	-0.36159100	-0.71377100
H	2.36124700	-0.37077800	-1.80832100
C	3.60307300	-0.34337600	-0.10697800
H	3.63607100	-0.34774800	0.98734000
C	4.86727700	-0.34971400	-0.83065700
H	4.78326900	-0.30558100	-1.92254600
C	6.10328900	-0.41606900	-0.29689300
C	7.32174000	-0.42197500	-1.17814300
H	7.97734500	0.43257100	-0.94080900
H	7.92087900	-1.33272100	-1.01063400
H	7.06248500	-0.37059400	-2.24449800
C	6.39283900	-0.48913200	1.17662900
H	7.02587300	0.35985300	1.48293600
H	5.49452800	-0.48393700	1.80540400
H	6.96278600	-1.40430400	1.40743100

TS'-*endo*

Thermal correction to Gibbs Free Energy (Hartree): 0.472796

Single point energy (Hartree): -1838.158367

Gibbs free energy (Hartree): -1837.685571

C	5.03731600	-1.51748300	-0.83191800
C	4.49541700	-2.75269700	-0.58757100
C	3.09599000	-2.96354900	-0.66543600
C	2.26921700	-1.88351900	-0.99987800
C	2.83399300	-0.59991500	-1.27255000
C	4.21943500	-0.41319000	-1.17837500
O	4.80921800	0.75903900	-1.37909800
O	2.62811400	-4.17562200	-0.40541000
C	0.82120400	-2.08340300	-1.03585700

C	-0.02633900	-0.90261300	-1.23099000
C	0.50103100	0.34675000	-1.56097600
C	1.98274900	0.54599600	-1.59280100
O	2.45062700	1.65813000	-1.83854700
C	-0.31614700	1.46719100	-1.61406100
C	-1.67109000	1.41133700	-1.19826300
C	-2.49009300	2.62736700	-1.32269000
O	0.30368900	-3.19318300	-0.87425800
C	-3.83092900	2.68498300	-1.41329000
C	3.02162000	2.77018700	1.53271700
C	3.50009100	1.49250800	1.70663200
C	2.62580400	0.38234200	1.76174600
C	1.25827400	0.59653000	1.54148600
C	0.76458000	1.92017500	1.36999000
C	1.63619000	3.01665900	1.40499200
O	1.21820500	4.27510900	1.30705200
O	3.14740400	-0.81820600	1.99123700
C	0.34714200	-0.55585400	1.48518000
C	-1.01729500	-0.34430500	0.93771100
C	-1.49149700	0.98592000	0.72362400
C	-0.66598800	2.14446800	1.16363500
O	-1.17102800	3.26150400	1.26415700
O	0.71818800	-1.67254300	1.85657100
C	-4.53135200	4.00902600	-1.53444500
C	-4.74330100	1.49098100	-1.38932900
H	6.11321900	-1.34942400	-0.76161000
H	5.12446700	-3.60247600	-0.31775600
H	4.09807800	1.40317900	-1.60723100
H	1.64655100	-4.13261100	-0.51082300
H	0.15895800	2.43652300	-1.78757900
H	-2.20088800	0.47018600	-1.38083500
H	-1.93342000	3.56849400	-1.33082800
H	3.69822400	3.62591100	1.51127700
H	4.56866200	1.30433400	1.82157500
H	0.23500600	4.25133300	1.31351600
H	2.39415100	-1.45278200	2.03471600
H	-3.82641600	4.85083700	-1.53043800
H	-5.12426100	4.05355400	-2.46286500
H	-5.23841700	4.14784400	-0.69982400
H	-4.21989200	0.52674100	-1.37690700
H	-5.39803900	1.53644700	-0.50271600
H	-5.40940100	1.49935500	-2.26699500
H	-2.55684400	1.15627400	0.89700100
H	-1.07239400	-1.13796900	-1.41674200

C	-1.91423600	-1.49031900	0.96301000
H	-1.41463500	-2.45248800	1.10480300
C	-3.25148200	-1.45996500	0.77500400
H	-3.75876500	-0.49795900	0.65525600
C	-4.06597000	-2.66125500	0.73451400
H	-3.51211700	-3.60206700	0.82456700
C	-5.40611000	-2.73184700	0.58848500
C	-6.10402000	-4.06220600	0.54417100
H	-6.66757600	-4.17527400	-0.39731900
H	-5.40068000	-4.90173500	0.62735000
H	-6.83979900	-4.14419800	1.36180800
C	-6.31347100	-1.54096300	0.45669200
H	-5.79759400	-0.58014800	0.56855900
H	-6.81432400	-1.54673500	-0.52607400
H	-7.11160300	-1.58499500	1.21553600

7'-endo

Thermal correction to Gibbs Free Energy (Hartree): 0.477287
Single point energy (Hartree): -1838.200953
Gibbs free energy (Hartree): -1837.723666

C	5.01595600	-0.65409400	-1.00601000
C	4.61623900	-1.95634300	-0.84057500
C	3.26250900	-2.33143900	-1.01619100
C	2.32067900	-1.33123500	-1.29825400
C	2.73852700	0.02437600	-1.48454000
C	4.09241400	0.36073700	-1.36204400
O	4.55778600	1.58930400	-1.54841900
O	2.94489000	-3.61193800	-0.87814400
C	0.90615500	-1.69601500	-1.33586300
C	-0.12490000	-0.59950300	-1.17491000
C	0.33845700	0.77771500	-1.55449800
C	1.76816900	1.08544600	-1.78416700
O	2.13134700	2.21876400	-2.10040600
C	-0.55916300	1.77312100	-1.43976500
C	-1.83834300	1.45394600	-0.71489500
C	-2.79034800	2.59885400	-0.53359300
O	0.53611900	-2.86385500	-1.41379400
C	-4.07867100	2.62646900	-0.90912700
C	3.37314100	1.64196100	2.18342900
C	3.60804200	0.28966300	2.25674800
C	2.57033100	-0.64589400	2.04179100
C	1.30880400	-0.16640300	1.66567700
C	1.05755800	1.23287200	1.60340800

C	2.08277900	2.14624100	1.89920700
O	1.90634100	3.46064500	1.91710800
O	2.85846300	-1.93821300	2.16115500
C	0.27746600	-1.12033800	1.25843800
C	-0.81135400	-0.62670300	0.29885500
C	-1.30715300	0.79820300	0.62026700
C	-0.26870100	1.73259600	1.24185900
O	-0.55199000	2.91834200	1.39300700
O	0.35997000	-2.30689000	1.54774700
C	-4.91298700	3.85748200	-0.67057000
C	-4.81422100	1.50727100	-1.59906500
H	6.06209200	-0.36704200	-0.88592200
H	5.33069900	-2.73825000	-0.57906200
H	3.79197100	2.14594200	-1.82619700
H	1.98514800	-3.69774000	-1.07815600
H	-0.27708900	2.80271100	-1.67352300
H	-2.35973200	0.64208300	-1.24358600
H	-2.37211100	3.47944900	-0.03978500
H	4.17155000	2.36259300	2.36666800
H	4.59974100	-0.09697900	2.49696700
H	0.94941300	3.62364200	1.75728900
H	2.02633600	-2.44051100	2.02377000
H	-4.33543800	4.66067100	-0.19316900
H	-5.32079800	4.24163300	-1.62040700
H	-5.77807100	3.62417400	-0.02765700
H	-4.25443500	0.56479800	-1.65508000
H	-5.76292100	1.29821300	-1.07985500
H	-5.07983900	1.80528000	-2.62700300
H	-2.12754300	0.74004000	1.35086000
H	-0.95096600	-0.88250000	-1.84443300
C	-1.92658300	-1.64377600	0.24071600
H	-1.58668800	-2.65150500	-0.01391400
C	-3.23583200	-1.41655700	0.41990600
H	-3.58791300	-0.41191100	0.67059400
C	-4.24946200	-2.45715700	0.28720800
H	-3.87122400	-3.44738600	0.01003700
C	-5.57750700	-2.31864600	0.46771500
C	-6.50427700	-3.48925600	0.28660100
H	-7.25721600	-3.27497100	-0.49051400
H	-5.96549200	-4.40297900	0.00083100
H	-7.06181900	-3.69364100	1.21608900
C	-6.25840400	-1.03659200	0.86166300
H	-5.57140500	-0.19201600	0.99613500
H	-7.00406500	-0.75041900	0.10110800

H	-6.81153200	-1.17464000	1.80537000

TS'-*exo*

Thermal correction to Gibbs Free Energy (Hartree): 0.474122

Single point energy (Hartree): -1838.150435

Gibbs free energy (Hartree): -1837.676313

C	5.15377400	-0.36384200	-1.05333000
C	4.84416100	0.95494200	-1.27321100
C	3.50207700	1.36833700	-1.46446900
C	2.48750800	0.40119500	-1.42785600
C	2.81038800	-0.97036200	-1.20833700
C	4.14357800	-1.35659000	-1.01329600
O	4.51058800	-2.61029500	-0.77873700
O	3.26059400	2.65494000	-1.66542000
C	1.09659300	0.82567900	-1.60908200
C	0.05578300	-0.15887200	-1.38236600
C	0.33778300	-1.51425000	-1.16474600
C	1.75660000	-1.97912800	-1.10933400
O	2.01490000	-3.17065000	-0.92772000
C	-0.64720900	-2.39550300	-0.75401100
C	-1.96085300	-1.94037700	-0.45078300
C	-2.98550300	-2.94702400	-0.13455000
O	0.80736100	1.99919000	-1.88807600
C	-4.28789800	-2.88844900	-0.46608900
C	-4.64890400	2.83923200	-0.23667200
C	-3.54662100	3.60901500	-0.52585300
C	-2.23717600	3.18399400	-0.19066200
C	-2.07387900	1.91120600	0.37457900
C	-3.21514300	1.10805000	0.65111200
C	-4.50736800	1.58551100	0.39915100
O	-5.60554600	0.90602400	0.73131000
O	-1.23593900	4.02115800	-0.42205300
C	-0.72617900	1.45369000	0.76429600
C	-0.54436800	0.02032000	1.08872100
C	-1.69388500	-0.84525700	1.14858300
C	-3.04060600	-0.21759800	1.24654100
O	-3.97724400	-0.83302400	1.75072100
O	0.20664700	2.25974200	0.81351700
C	-5.22782600	-3.98820700	-0.06223000
C	-4.92667300	-1.76775700	-1.23599500
H	6.18704500	-0.68444800	-0.90837600
H	5.62179500	1.72000500	-1.30839700
H	3.68727700	-3.15424700	-0.79075200

H	2.28223100	2.73837200	-1.80847100
H	-0.35263900	-3.41877300	-0.50795400
H	-2.31210500	-1.11003800	-1.07051600
H	-2.63048300	-3.82017900	0.42370600
H	-5.65697400	3.19090100	-0.46271200
H	-3.65426400	4.59007800	-0.99176600
H	-5.30689100	0.12662300	1.25342200
H	-0.41810100	3.59551800	-0.08121700
H	-4.71259600	-4.80241200	0.46490800
H	-6.00990000	-3.58699000	0.60321700
H	-5.74187300	-4.40945100	-0.94144200
H	-4.22919900	-0.97434400	-1.53315300
H	-5.40011700	-2.15948300	-2.15073100
H	-5.72315800	-1.29681600	-0.64003600
H	-1.59851500	-1.68215800	1.84592700
H	-0.95120400	0.18493100	-1.62013100
C	0.69251600	-0.52191100	1.60258400
H	0.65231700	-1.58981600	1.84796600
C	1.88616800	0.11204100	1.75790100
H	1.93042600	1.17926100	1.54195700
C	3.08608600	-0.57985700	2.15866400
H	2.99383900	-1.65999900	2.32068400
C	4.31180800	-0.02204200	2.29490400
C	5.49684600	-0.86666300	2.66161700
H	6.25695300	-0.82209100	1.86417600
H	5.97836300	-0.48585800	3.57775700
H	5.22604900	-1.91924900	2.81783700
C	4.59874800	1.44192300	2.12522400
H	5.51987800	1.58391800	1.53970900
H	3.79384400	1.99723300	1.62868000
H	4.77517900	1.90413300	3.11133100

7'-*exo*

Thermal correction to Gibbs Free Energy (Hartree): 0.477318

Single point energy (Hartree): -1838.195903

Gibbs free energy (Hartree): -1837.718585

C	5.23287100	-0.78330700	-1.25460700
C	4.96234400	0.53687800	-1.51462100
C	3.63054700	1.00396400	-1.61306200
C	2.57948300	0.10022700	-1.39972100
C	2.86062500	-1.27657500	-1.14060300
C	4.18853700	-1.72402900	-1.08185600
O	4.52067900	-2.99096300	-0.87362500

O	3.44291100	2.29491000	-1.86856100
C	1.20600700	0.60583200	-1.41587300
C	0.08381400	-0.25959700	-0.88320800
C	0.39615700	-1.72475300	-0.82542800
C	1.77774000	-2.24386200	-0.93669300
O	2.00569600	-3.44790200	-0.80708800
C	-0.60990400	-2.53162200	-0.46363400
C	-1.93045200	-1.90761400	-0.13866200
C	-2.95244200	-2.91482600	0.29537900
O	0.93783000	1.72528200	-1.84431400
C	-4.21420800	-3.01854300	-0.14437200
C	-4.79295200	2.74262800	-0.54468000
C	-3.73802400	3.55404900	-0.90521200
C	-2.40889500	3.23535200	-0.54891300
C	-2.16966500	2.00414800	0.08032900
C	-3.25607900	1.16651900	0.43819000
C	-4.57734500	1.55752300	0.18783100
O	-5.63188200	0.85345000	0.60722500
O	-1.45410400	4.11665700	-0.82932200
C	-0.80062600	1.63914800	0.47693100
C	-0.43018500	0.14980300	0.58402000
C	-1.65716500	-0.76805600	0.93952300
C	-2.98582500	-0.07957300	1.15687500
O	-3.84885300	-0.62287800	1.83462100
O	0.04549100	2.50693800	0.61650500
C	-5.13644200	-4.06914100	0.40989100
C	-4.84628200	-2.09358600	-1.14945900
H	6.25975000	-1.14741900	-1.19171000
H	5.76610400	1.26021400	-1.66214900
H	3.67721300	-3.49952400	-0.80588800
H	2.47342000	2.43262400	-1.96790600
H	-0.44473500	-3.60484000	-0.34078700
H	-2.28986900	-1.38514700	-1.04141300
H	-2.61268200	-3.61632500	1.06616900
H	-5.82106400	3.02268800	-0.78059600
H	-3.91043000	4.49228700	-1.43536100
H	-5.29052400	0.17250900	1.22675300
H	-0.63057900	3.80407000	-0.40448600
H	-4.64249300	-4.69737700	1.16359900
H	-6.01494700	-3.59602600	0.87903200
H	-5.51704500	-4.72147400	-0.39316200
H	-4.12262300	-1.48469300	-1.70742900
H	-5.44220600	-2.66117100	-1.88084100
H	-5.53480400	-1.39712400	-0.64287100

H	-1.44089500	-1.28974600	1.88131000
H	-0.75742500	-0.07419600	-1.57258000
C	0.69980600	-0.12271200	1.56557600
H	0.58077700	-1.03062300	2.16602100
C	1.85709300	0.54996300	1.66805700
H	1.99604300	1.45497300	1.07745900
C	2.95947300	0.11340600	2.51162300
H	2.76860200	-0.76942600	3.13283500
C	4.18742000	0.66762300	2.56157600
C	5.25499600	0.08931700	3.44820400
H	6.11791600	-0.24355700	2.84717800
H	5.63504800	0.85052100	4.14995500
H	4.89132500	-0.76777600	4.03138300
C	4.61420400	1.87310500	1.77127100
H	5.53198800	1.64640400	1.20470800
H	3.86305900	2.23123600	1.05721800
H	4.86118100	2.70483700	2.45200900

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Thermal correction to Gibbs Free Energy (Hartree): 0.451286
Single point energy (Hartree): -1836.992952
Gibbs free energy (Hartree): -1836.541666

C	6.09349200	1.05523900	-0.12978300
C	5.58248600	2.29146800	-0.43793000
C	4.19484400	2.55702000	-0.33945200
C	3.33343100	1.51041700	0.02230700
C	3.86726700	0.22805400	0.36282000
C	5.25058800	0.00201700	0.30097300
O	5.81442100	-1.15108800	0.63690800
O	3.77669000	3.78748800	-0.60781000
C	1.88961600	1.77169500	0.05840000
C	0.98105000	0.59008500	0.19325900
C	1.53022300	-0.59263900	0.87088300
C	2.99423900	-0.84142700	0.85373100
O	3.44536000	-1.92189300	1.23601000
C	0.70322300	-1.47971500	1.45293300
C	-0.77256700	-1.21754600	1.47879700
C	-1.05006700	-0.30531000	2.65731100
O	1.44398100	2.91341600	0.03260900
C	-1.87929100	-0.53046400	3.68697600
C	-4.16109100	3.30492900	-1.66897000
C	-5.00395400	2.52174200	-0.91993300
C	-4.53333800	1.35726700	-0.26683900

C	-3.16871100	1.03723200	-0.35891300
C	-2.28910100	1.86713500	-1.12041300
C	-2.78997500	2.98037100	-1.81071000
O	-2.04107400	3.75911200	-2.58030300
O	-5.41275300	0.61576000	0.39360300
C	-2.68980300	-0.19648000	0.25933800
C	-1.20946000	-0.59476500	0.13031800
C	-0.30607500	0.57950500	-0.23363300
C	-0.85251300	1.58337800	-1.19291200
O	-0.13736500	2.11978500	-2.03276200
O	-3.45133100	-0.96288100	0.83948700
C	-1.13975500	-1.55601700	-1.04869400
C	-0.78045400	-2.84761400	-1.01334600
C	-0.70907000	-3.68627500	-2.20275300
C	-0.32836400	-4.97789200	-2.25743500
C	-2.02166600	0.49213700	4.78270600
C	-2.73360100	-1.75482100	3.85843700
C	-0.30272400	-5.71547500	-3.56750400
C	0.10096600	-5.79422700	-1.07026200
H	7.16518600	0.85753400	-0.18776300
H	6.23437200	3.10907800	-0.75033300
H	5.08987100	-1.74459600	0.94674300
H	2.80954200	3.81090700	-0.42434200
H	1.12624000	-2.34885100	1.96197200
H	-1.32374700	-2.15535800	1.60644700
H	-0.48475700	0.63380300	2.64945100
H	-4.52889300	4.19164900	-2.18817400
H	-6.06386000	2.76390700	-0.82582000
H	-1.14201100	3.35721600	-2.61016400
H	-4.92389400	-0.16657500	0.74096300
H	-1.39770000	-1.10859400	-2.01662200
H	-0.52558300	-3.30734400	-0.05591100
H	-0.99290300	-3.19733400	-3.14144000
H	-1.37544000	1.36576300	4.62141200
H	-1.77043800	0.05127600	5.76153800
H	-3.06510600	0.84129300	4.85164500
H	-2.47509200	-2.27213900	4.79697600
H	-2.65452900	-2.46746400	3.02995600
H	-3.79259400	-1.46129900	3.93756800
H	-0.62418700	-5.08274900	-4.40600800
H	-0.96049000	-6.59993600	-3.52947900
H	0.71240300	-6.08785800	-3.78460900
H	0.08649500	-5.24220800	-0.12290200
H	1.12440200	-6.17467700	-1.22191100

H	-0.54978200	-6.67717800	-0.95938300

TS

Thermal correction to Gibbs Free Energy (Hartree): 0.452975
Single point energy (Hartree): -1836.958859
Gibbs free energy (Hartree): -1836.505884

C	5.52394200	1.80152100	0.90278300
C	4.79682000	2.94875200	1.09915400
C	3.37910000	2.92632500	1.11224200
C	2.72472400	1.71157500	0.86788300
C	3.47993900	0.51544400	0.68855400
C	4.88061500	0.55373300	0.70963000
O	5.63797200	-0.52729700	0.56510200
O	2.73992400	4.06578900	1.34351500
C	1.25647600	1.69454300	0.81486800
C	0.59915500	0.43360200	0.36376600
C	1.32353900	-0.77407000	0.48114300
C	2.79796600	-0.77127600	0.53498300
O	3.43317800	-1.82672100	0.42427900
C	0.65050400	-1.97536400	0.29305900
C	-0.83715400	-2.02240100	0.58534200
C	-1.11329000	-1.83517100	2.05503400
O	0.59644900	2.65573200	1.19811400
C	-1.86012100	-2.61821300	2.84719700
C	-4.92577100	2.83399000	-0.98987400
C	-5.65594900	1.71066000	-0.69329100
C	-5.01749300	0.47612600	-0.42640400
C	-3.61433200	0.42534600	-0.43552900
C	-2.85130800	1.60237800	-0.72441100
C	-3.51005800	2.80213100	-1.03540900
O	-2.87751800	3.92218300	-1.35639200
O	-5.78282700	-0.58187900	-0.19032100
C	-2.95602200	-0.85879200	-0.21523400
C	-1.44747400	-0.92173700	-0.28669600
C	-0.69957300	0.38721300	-0.15055500
C	-1.38112800	1.59807100	-0.69953900
O	-0.73831000	2.54272200	-1.14740700
O	-3.58565500	-1.89421400	-0.01685700
C	-0.83583200	-1.00140100	-1.65353100
C	0.21840400	-1.89269300	-1.84148600
C	1.29865900	-1.60440800	-2.77699700
C	2.38906400	-2.37375000	-2.97080900
C	-2.03391500	-2.27894600	4.30380400

C	-2.58652700	-3.85766200	2.40397500
C	3.51632800	-1.90903500	-3.84599900
C	2.60943000	-3.68595600	-2.27169500
H	6.61515100	1.81720600	0.90664800
H	5.29042400	3.90815100	1.26354200
H	5.02164100	-1.29310700	0.47811500
H	1.77778300	3.85324500	1.37334300
H	1.23957700	-2.89070100	0.38380300
H	-1.25010300	-2.97908200	0.24166300
H	-0.64468900	-0.95092200	2.50101400
H	-5.41697200	3.78335000	-1.21022300
H	-6.74672300	1.73511900	-0.67191600
H	-1.91397700	3.71137100	-1.37976800
H	-5.18104700	-1.34982200	-0.05456700
H	-1.08066900	-0.24398400	-2.40182800
H	0.06985300	-2.93003100	-1.53617100
H	1.25210000	-0.62936000	-3.27381700
H	-1.48337800	-1.37130300	4.58662200
H	-1.68473900	-3.10841500	4.94079800
H	-3.09961400	-2.12554800	4.54107400
H	-2.23811200	-4.73070200	2.97991400
H	-2.47968200	-4.07440800	1.33534500
H	-3.66396200	-3.75075200	2.60799400
H	3.31805000	-0.92564700	-4.29338600
H	3.70729700	-2.63188300	-4.65613900
H	4.44658500	-1.84038900	-3.25714600
H	1.67390200	-4.19654500	-2.00502300
H	3.17219800	-3.50859500	-1.33932800
H	3.20108000	-4.37098600	-2.89656600

Arnebidin (4)

Thermal correction to Gibbs Free Energy (Hartree): 0.457069

Single point energy (Hartree): -1837.027382

Gibbs free energy (Hartree): -1836.570313

C	5.22762500	2.04289300	1.44355400
C	4.38940900	3.11410800	1.61386100
C	2.99896900	3.01105900	1.33959700
C	2.50066700	1.79984500	0.84667200
C	3.36872900	0.68047400	0.68805600
C	4.73157400	0.79307900	0.98718300
O	5.58277400	-0.21662200	0.87253500
O	2.24047900	4.07528200	1.56043400
C	1.07362000	1.69162300	0.52395100

C	0.61673200	0.43643600	-0.12144900
C	1.39822200	-0.66698700	-0.09507900
C	2.83261600	-0.60555500	0.24601500
O	3.54371800	-1.60699100	0.12406200
C	0.73907500	-1.95357900	-0.47335100
C	-0.54463600	-2.11761400	0.39185300
C	-0.35368500	-2.00061100	1.87549900
O	0.27475100	2.57384300	0.83203900
C	-0.79830000	-2.84138300	2.82100100
C	-5.21553700	2.48213800	-0.61842600
C	-5.79278700	1.37414500	-0.05431300
C	-5.03100600	0.21208800	0.22303900
C	-3.66045200	0.21023600	-0.07904900
C	-3.05350000	1.37578200	-0.65500000
C	-3.83594000	2.50498800	-0.94182900
O	-3.35091500	3.60904600	-1.49230900
O	-5.66374700	-0.82561300	0.75590000
C	-2.89180500	-1.01484400	0.17435200
C	-1.46070300	-1.05858000	-0.22060000
C	-0.76791500	0.24698400	-0.62214000
C	-1.61869900	1.43425200	-0.95770100
O	-1.11480900	2.38177600	-1.55047300
O	-3.40294500	-2.00807300	0.68988500
C	-1.00961000	-0.87203200	-1.64232400
C	0.17192500	-1.77945200	-1.90899300
C	1.14664000	-1.22524200	-2.91815400
C	2.22972200	-1.86338300	-3.38265400
C	-0.52725600	-2.56513400	4.27601600
C	-1.59176800	-4.09195000	2.56118800
C	3.18510900	-1.19181200	-4.32965000
C	2.60775300	-3.25833400	-2.96048700
H	6.29339800	2.11835900	1.66568000
H	4.76493600	4.07238600	1.97678300
H	5.06396800	-0.99701600	0.56455600
H	1.30982600	3.81284600	1.36980400
H	1.43420800	-2.79385100	-0.37586000
H	-0.98783800	-3.09046100	0.13800600
H	0.18975300	-1.10994700	2.21020400
H	-5.80170500	3.37663600	-0.83576500
H	-6.85553200	1.35416800	0.19297400
H	-2.39149700	3.45018900	-1.66138500
H	-4.99164100	-1.53534400	0.88773700
H	-1.72074800	-0.65713800	-2.44396100
H	-0.22111500	-2.75754300	-2.23748500

H	0.96542700	-0.19520500	-3.24466600
H	0.06459200	-1.65081200	4.42129500
H	0.01658200	-3.40582900	4.73786000
H	-1.47281200	-2.45700500	4.83280300
H	-1.04873100	-4.97530000	2.93581400
H	-1.83397400	-4.24844800	1.50421000
H	-2.54611500	-4.04729800	3.10979200
H	2.88272000	-0.16085900	-4.55965900
H	3.25816700	-1.75266500	-5.27610700
H	4.19956900	-1.16614400	-3.89805100
H	1.75215400	-3.83751800	-2.58575300
H	3.35700200	-3.21332000	-2.15238900
H	3.05623700	-3.81587800	-3.79686900

VI References

1 H. Inouye, H. Matsumura, M. Kawasaki, K. Inoue, M. Tsukada, M. Tabata, *Phytochemistry* **1981**, *20*, 1701–1705.

2 L. Wang, S. Wang, Q. Wang, Y. Wang, H. Liang, Q. Zhang, P. Tu, *J. Org. Chem.*, **2025**, *90*, 648–652.

3 M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, G. A. Petersson, H. Nakatsuji, X. Li, M. Caricato, A. V. Marenich, J. Bloino, B. G. Janesko, R. Gomperts, B. Mennucci, H. P. Hratchian, J. V. Ortiz, A. F. Izmaylov, J. L. Sonnenberg, D. Williams-Young, F. Ding, F. Lipparini, F. Egidi, J. Goings, B. Peng, A. Petrone, T. Henderson, D. Ranasinghe, V. G. Zakrzewski, J. Gao, N. Rega, G. Zheng, W. Liang, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, K. Throssell, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. J. Bearpark, J. J. Heyd, E. N. Brothers, K. N. Kudin, V. N. Staroverov, T. A. Keith, R. Kobayashi, J. Normand, K. Raghavachari, A. P. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, J. M. Millam, M. Klene, C. Adamo, R. Cammi, J. W. Ochterski, R. L. Martin, K. Morokuma, O. Farkas, J. B. Foresman, and D. J. Fox. Gaussian 16, Revision A.03, Gaussian, Inc., Wallingford CT, **2016**.

4 (a) J. D. Chai, H.-G. Martin, *Phys. Chem. Chem. Phys.* **2008**, *10*, 6615–6620. (b) J. D. Chai, H. G. Martin, *J. Chem. Phys.* **2008**, *128*, 084106.

5 F. Weigend, R. Ahlrichs, *Phys. Chem. Chem. Phys.* **2005**, *7*, 3297.

6 (a) F. Neese, *WIRES Comput. Mol. Sci.* **2012**, *2*, 73–78. (b) F. Neese, *WIRES Comput. Mol. Sci.* **2025**, *15*, *1*, e70019.

7 (a) N. Mardirossian, H. G. Martin, *J. Chem. Phys.* **2016**, *144*, 214110. (b) Vydrov, O. A.; Van Voorhis, T. *J. Chem. Phys.* **2010**, *133*, 244103. (c) Hujo, W.; Grimme, S. *J. Chem. Theory Comput.* **2011**, *7*, 3866.

8 A. V. Marenich, C. J. Cramer, D. G. Truhlar, *J. Phys. Chem. B.* **2009**, *113*, 6378–6396.

9 F. Weigend, *Phys. Chem. Chem. Phys.* **2006**, *8*, 1057.

10 (a) K. Fukui, *J. Phys. Chem.* **1970**, *74*, 4161–4163. (b) K. Fukui, *Acc. Chem. Res.* **1981**, *14*, 363–368.

11 M. D. Liptak, G. C. Shields, *J. Am. Chem. Soc.* **2001**, *123*, 7314–7319.

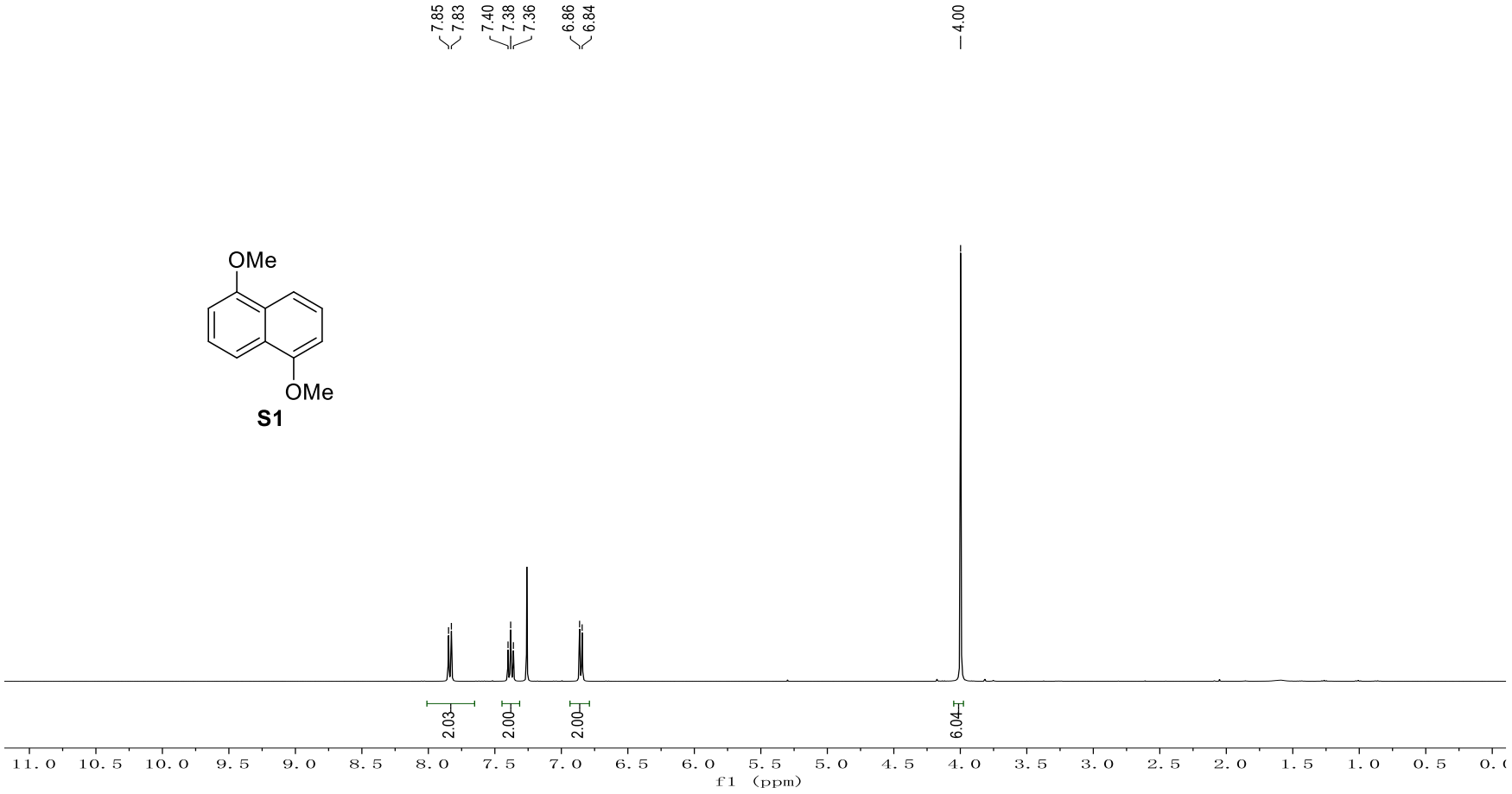
12 (a) T. Lu, F. Chen. *J. Comput. Chem.* **2012**, *33*, 580–592. (b) Tian Lu. *J. Chem. Phys.* **2024**, *161*, 082503.

13 W. Humphrey, A. Dalke, Schulten, K. *J. Mol. Graphics.* **1996**, *14*, 33−38.

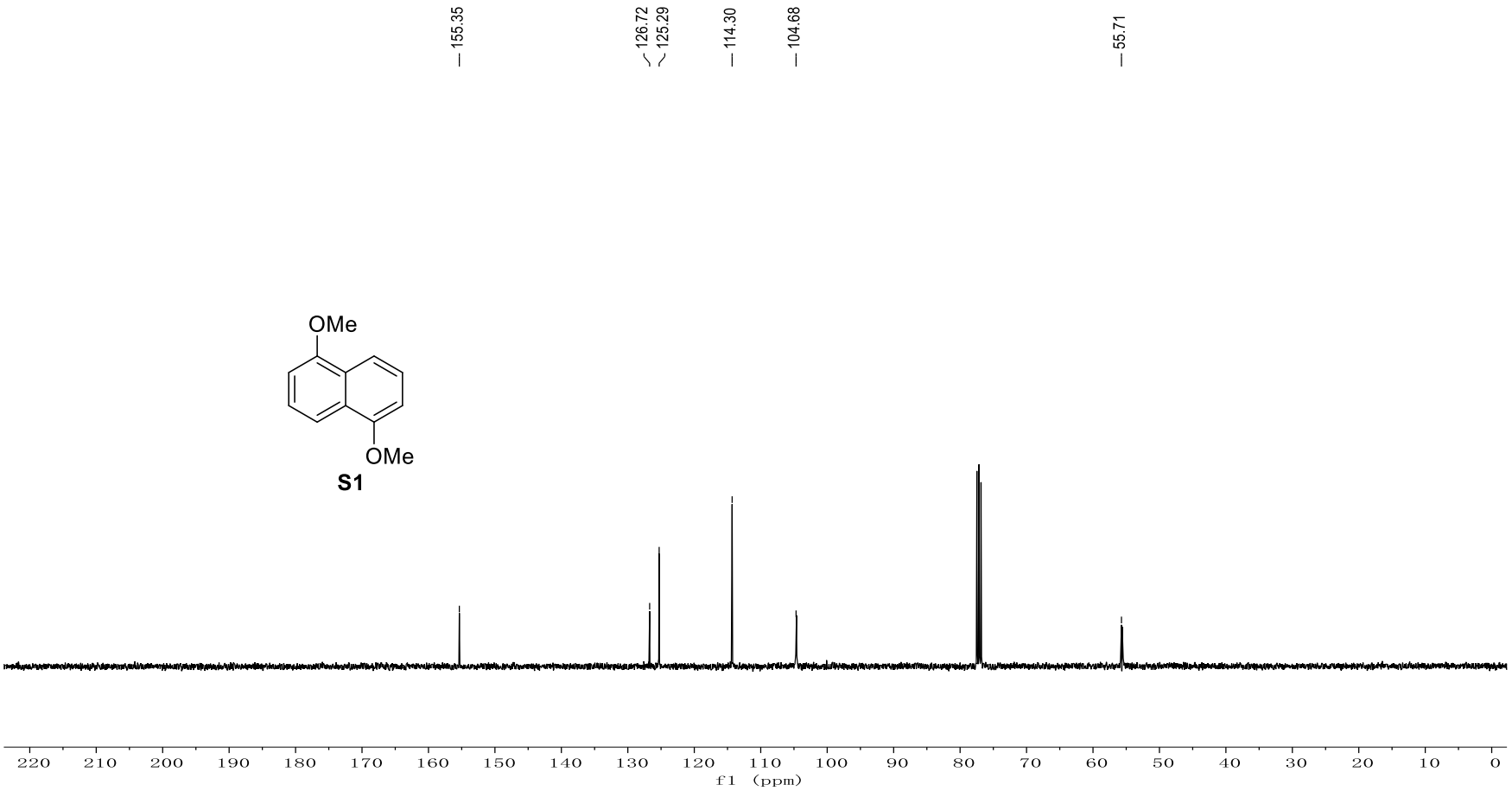
14 CYLview20; C. Y. Legault, Université de Sherbrooke, **2020** (http://www.cylview.org).

VII ^{1}H and ^{13}C NMR spectra of compounds

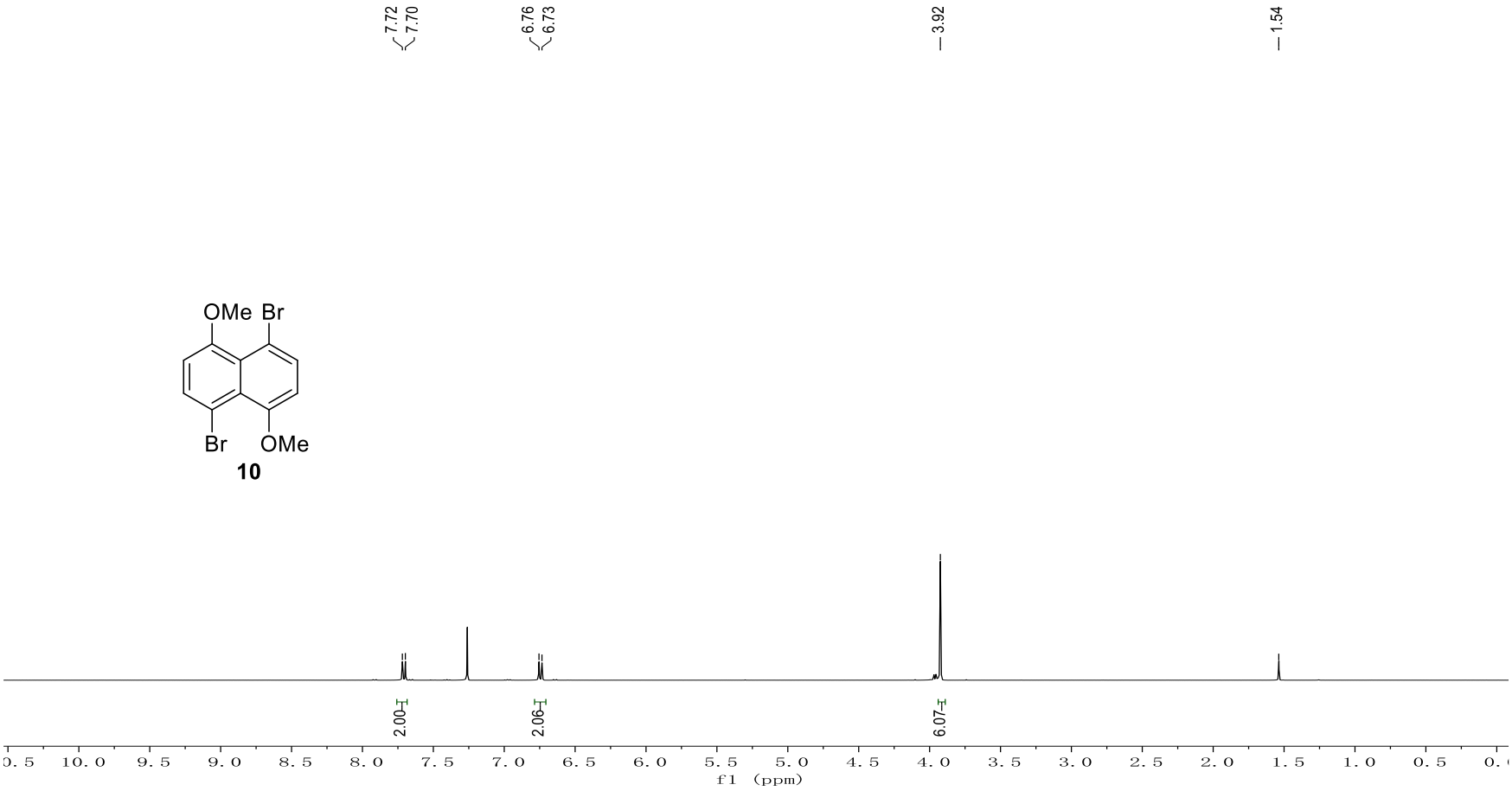
^{1}H NMR Spectrum of S1 (400 MHz, $CDCl_3$)



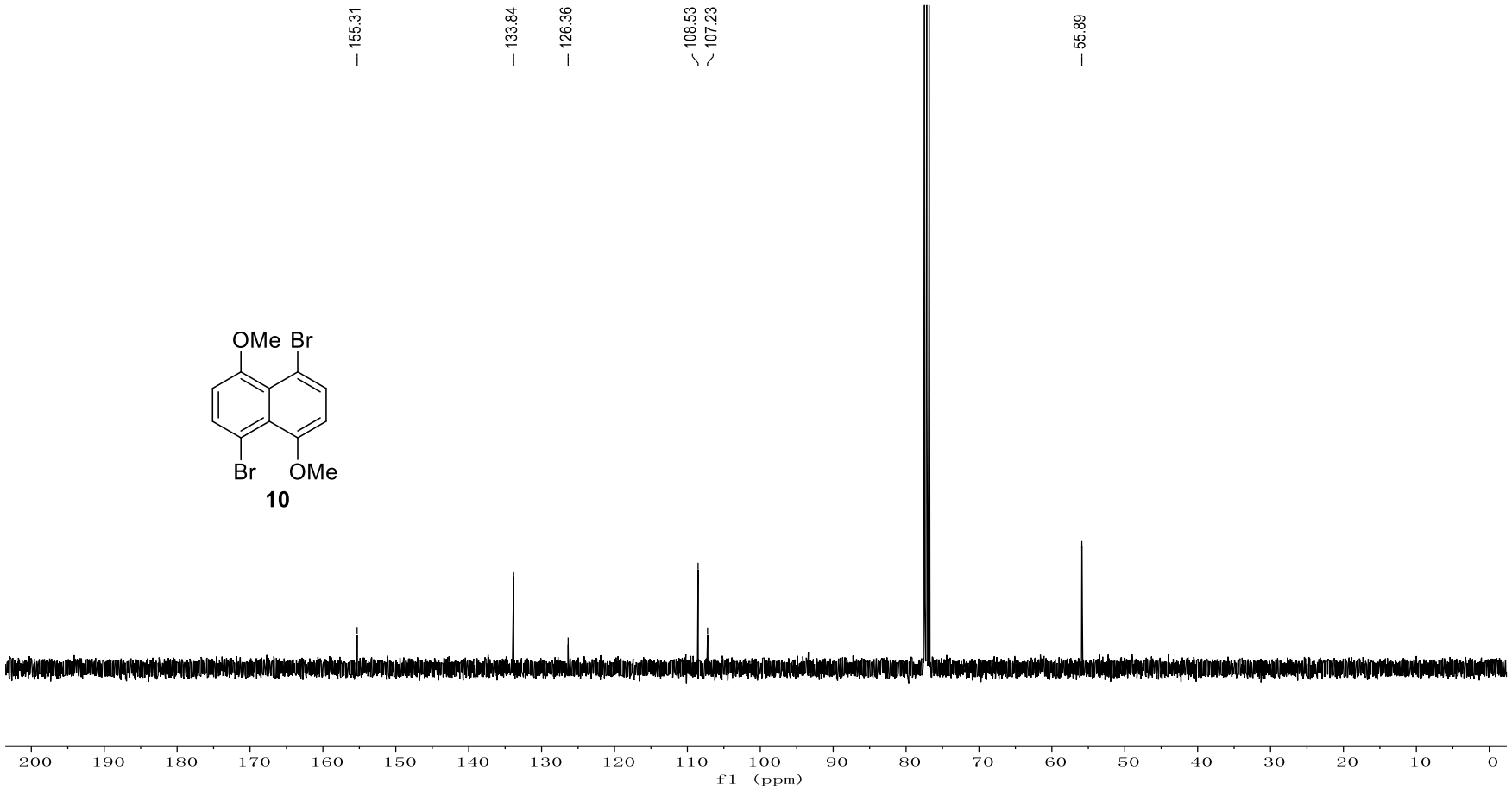
^{13}C NMR Spectrum of S1 (101 MHz, $CDCl_3$)



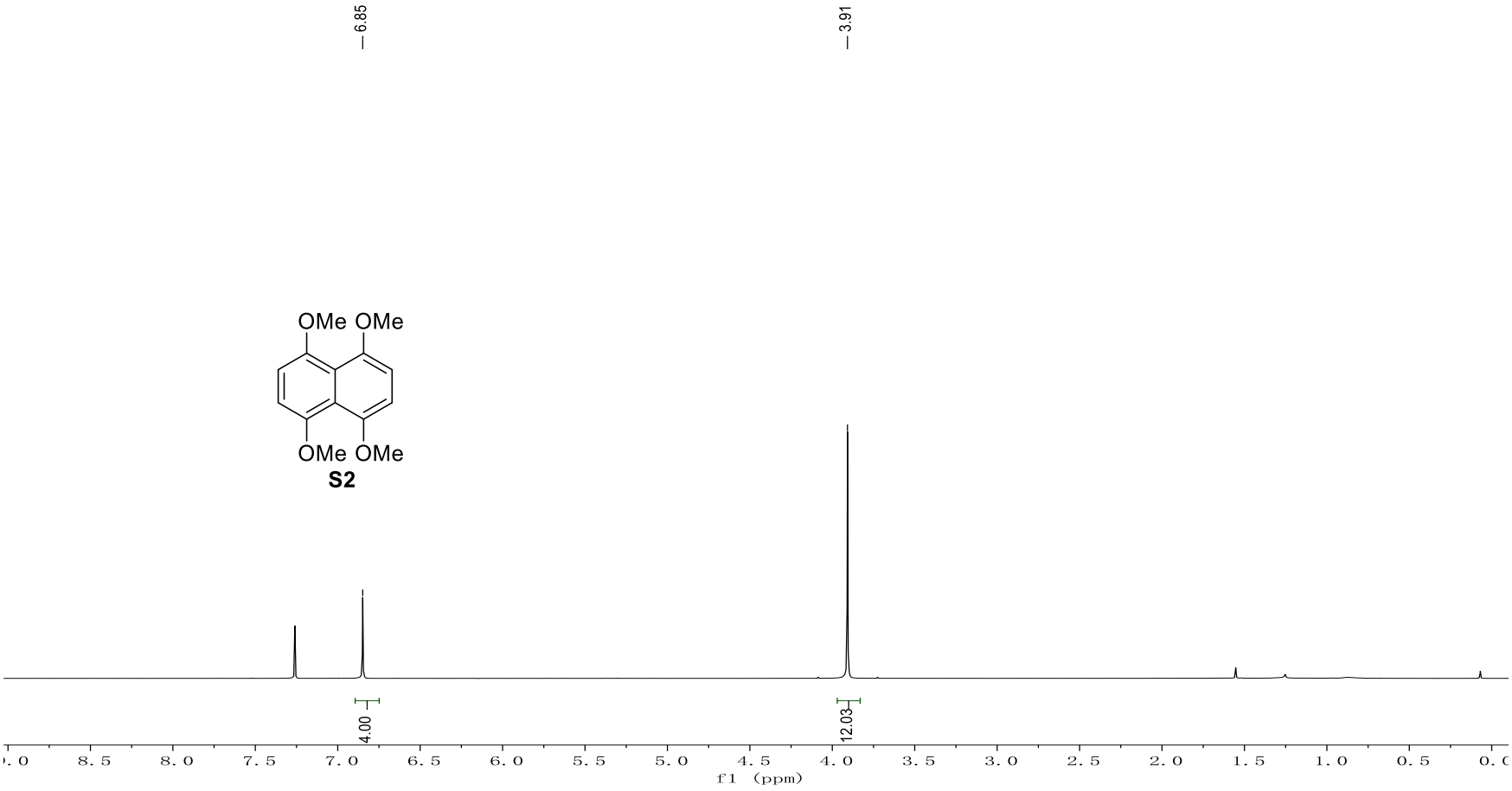
^{1}H NMR Spectrum of 10 (400 MHz, $CDCl_3$)



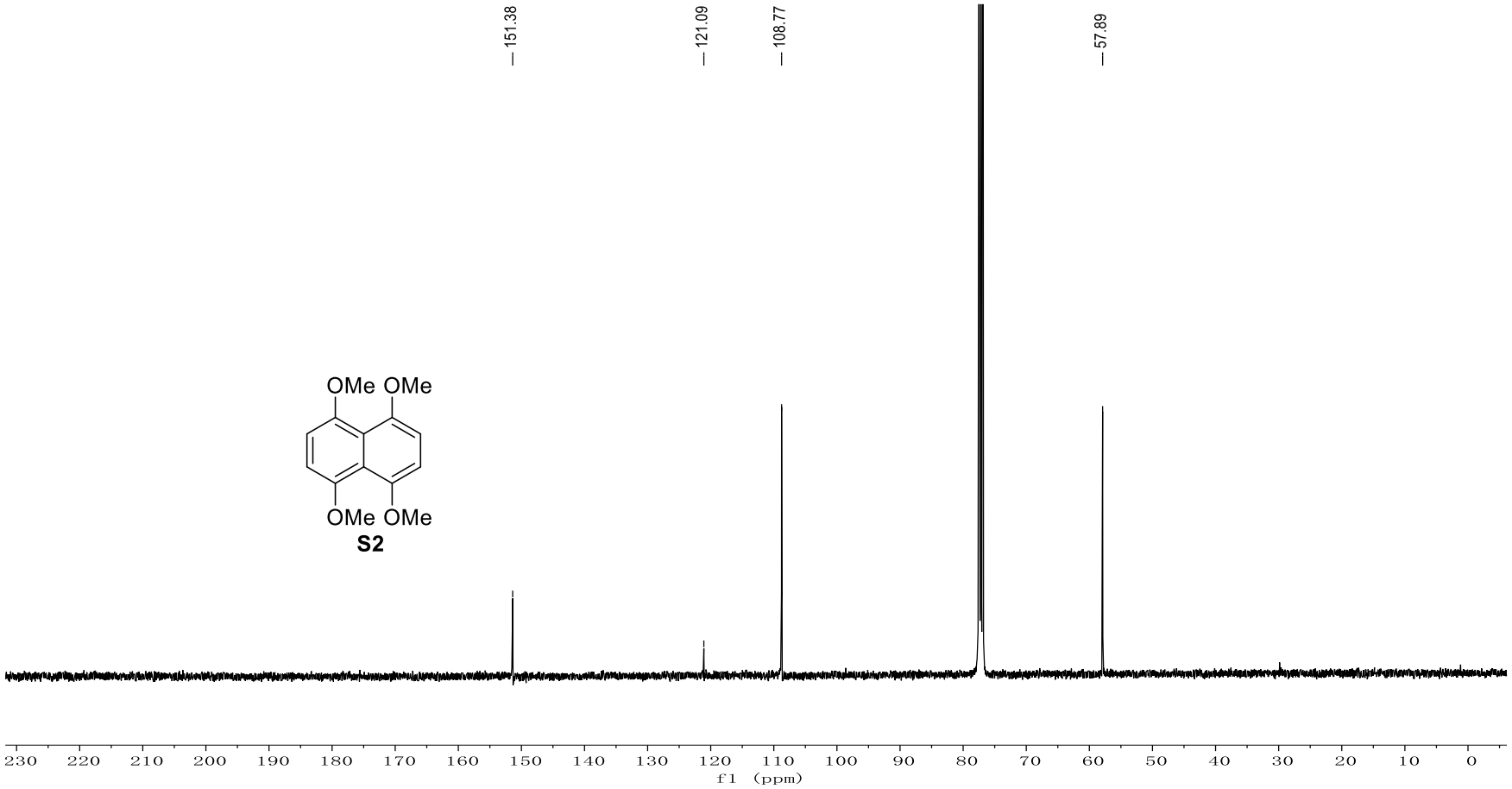
^{13}C NMR Spectrum of 10 (101 MHz, $CDCl_3$)



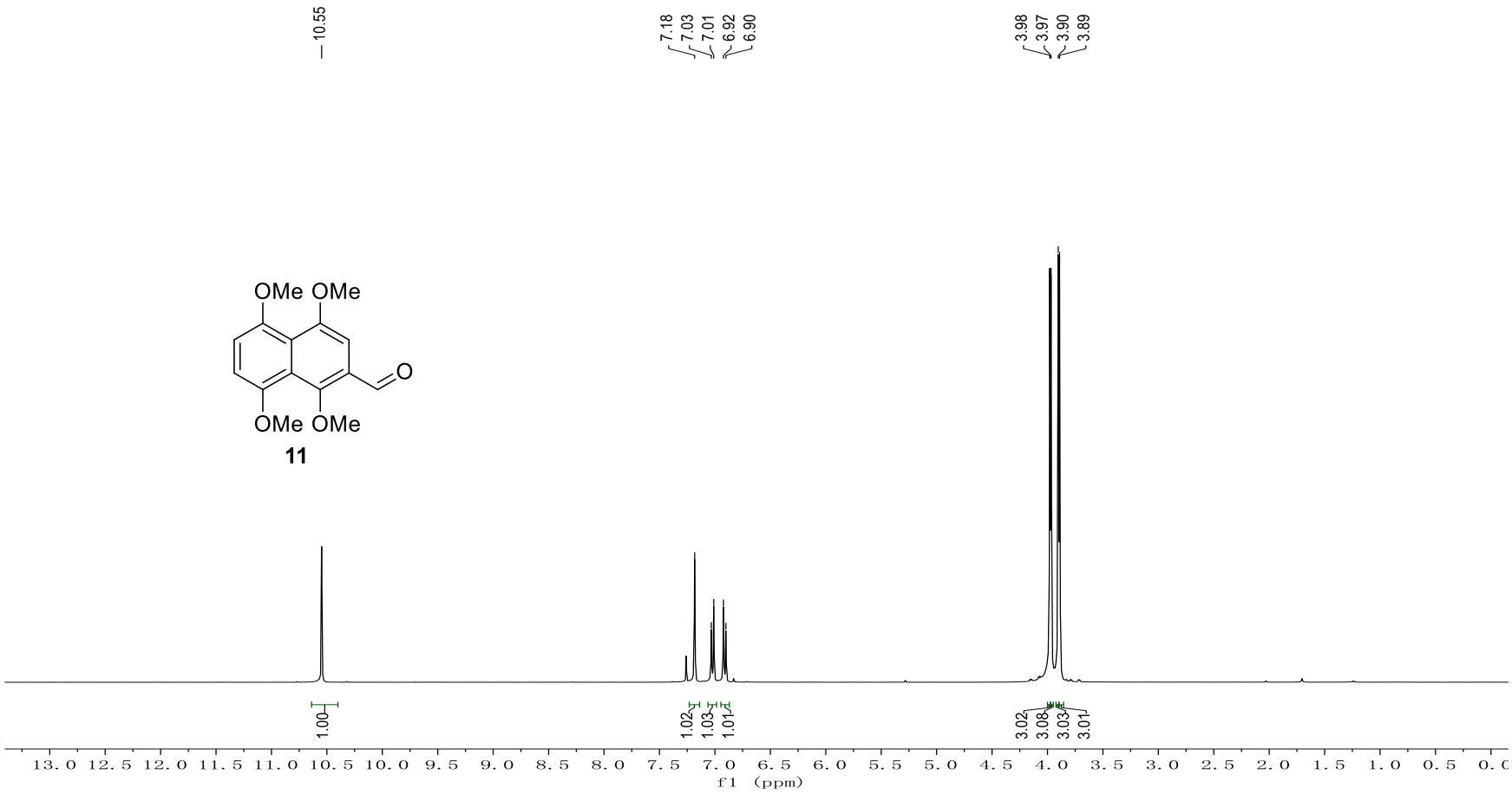
^{1}H NMR Spectrum of S2 (400 MHz, $CDCl_3$)



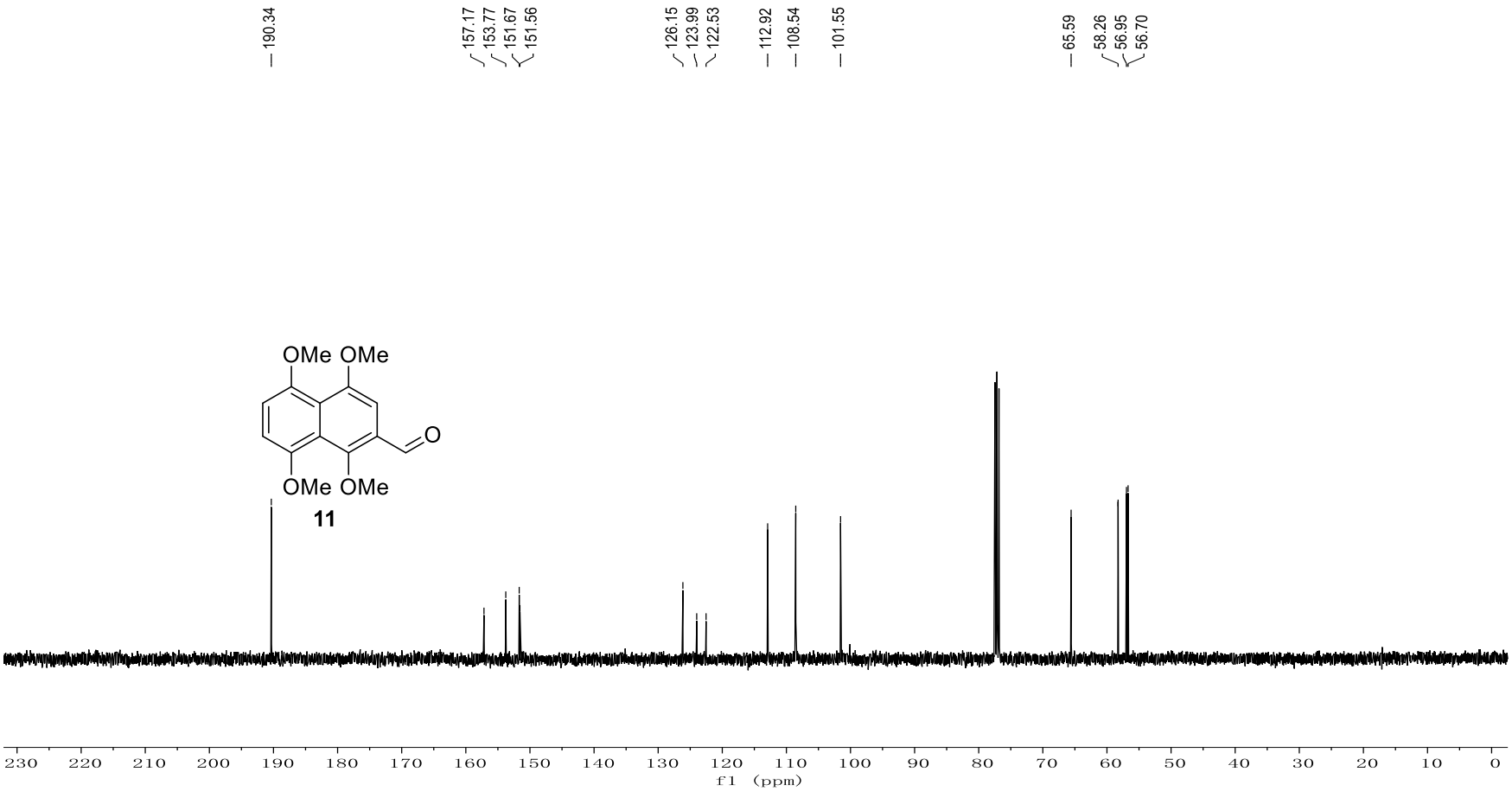
^{13}C NMR Spectrum of S2 (101 MHz, $CDCl_3$)



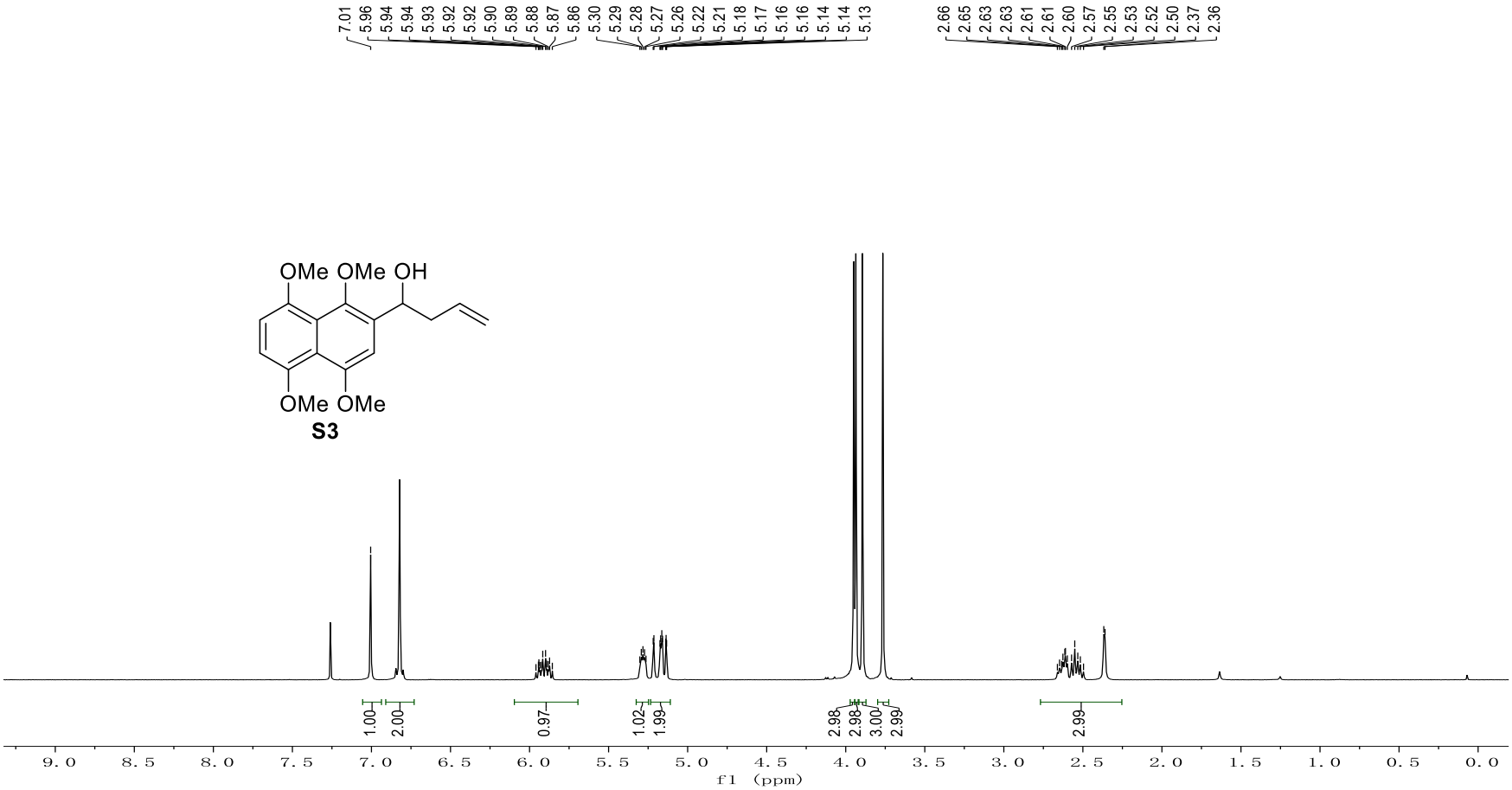
^{1}H NMR Spectrum of 11 (400 MHz, $CDCl_3$)



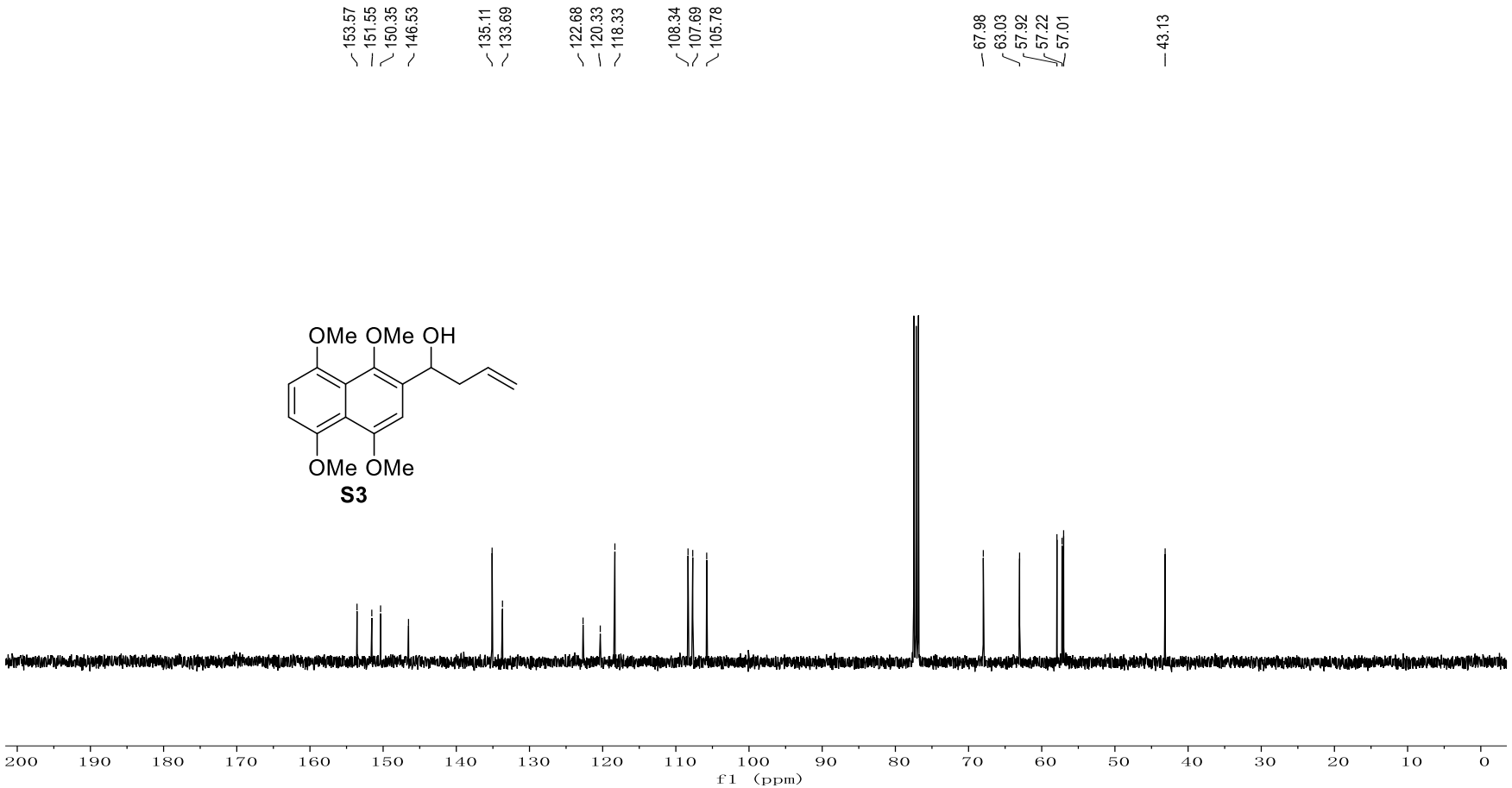
^{13}C NMR Spectrum of 11 (101 MHz, $CDCl_3$)



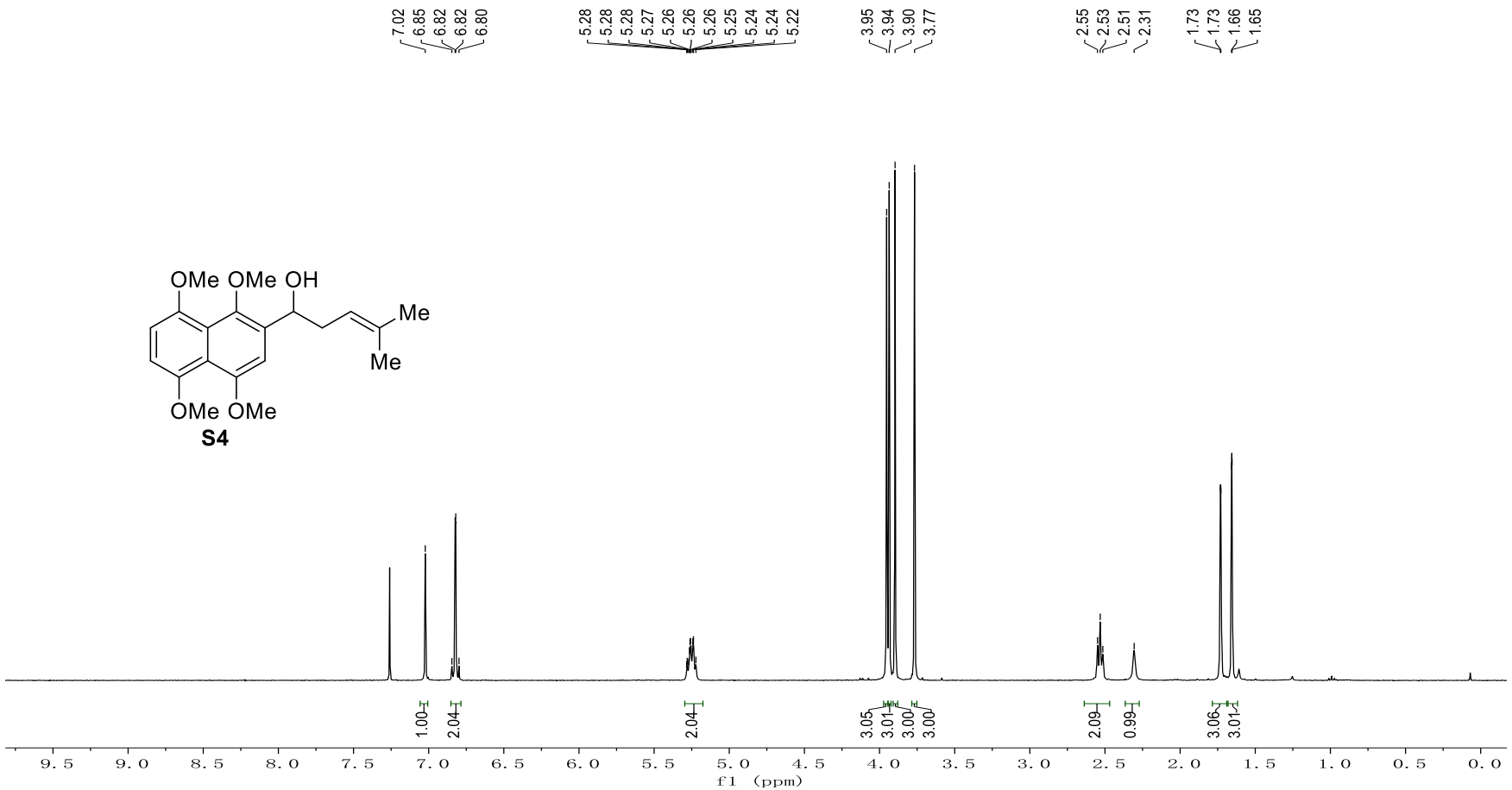
^{1}H NMR Spectrum of S3 (400 MHz, $CDCl_3$)



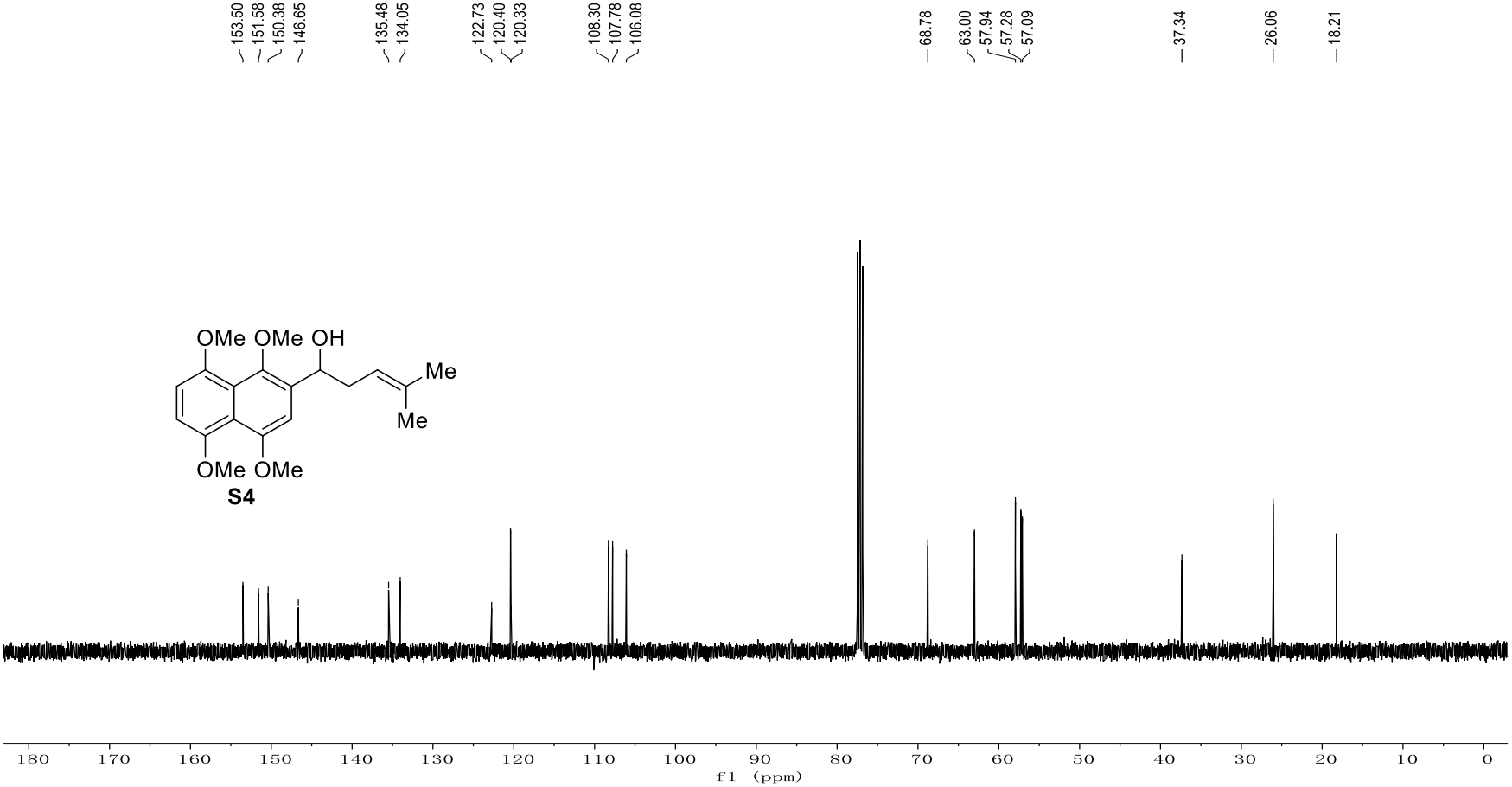
^{13}C NMR Spectrum of S3 (101 MHz, $CDCl_3$)



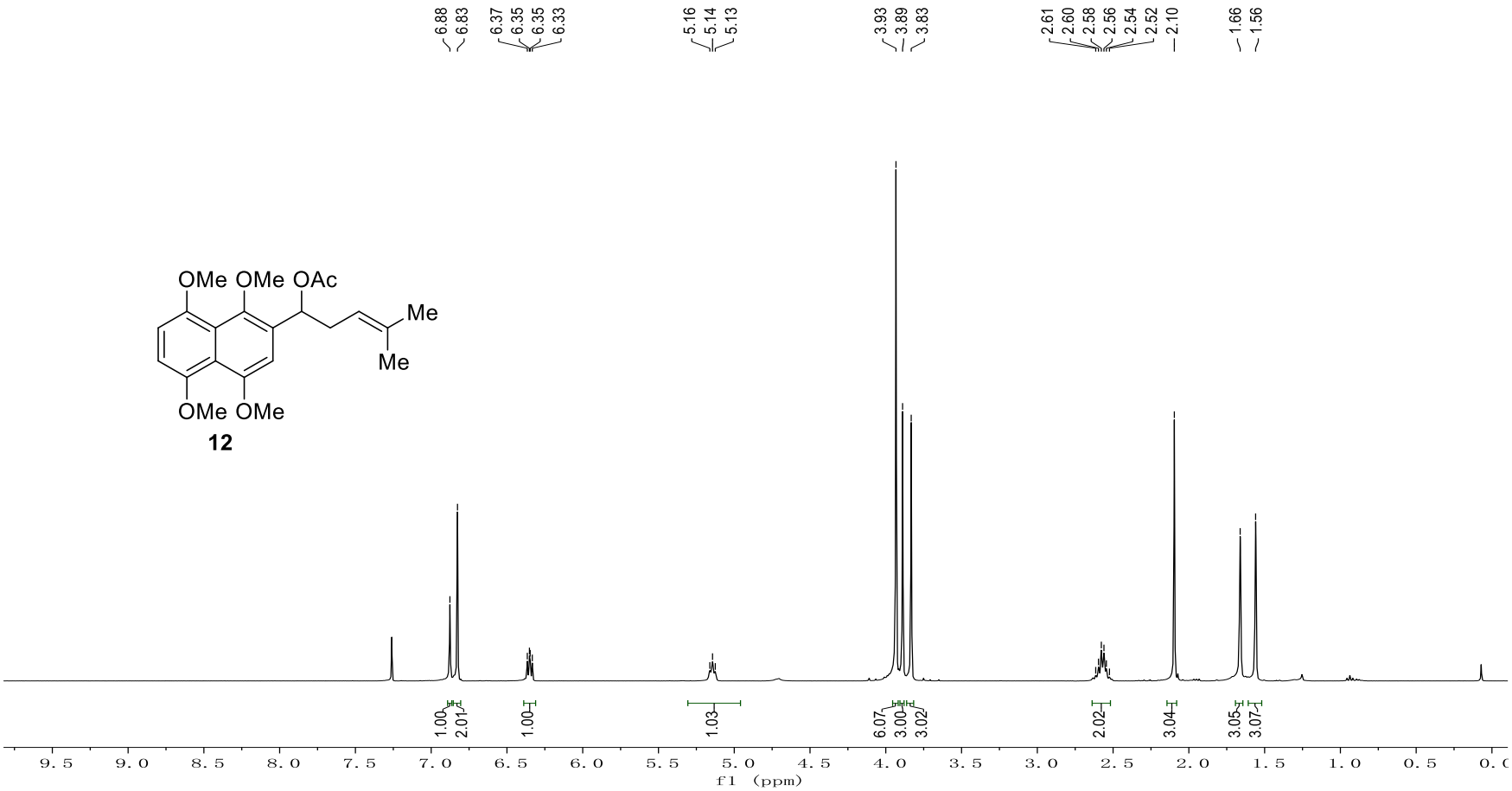
^{1}H NMR Spectrum of S4 (400 MHz, $CDCl_3$)



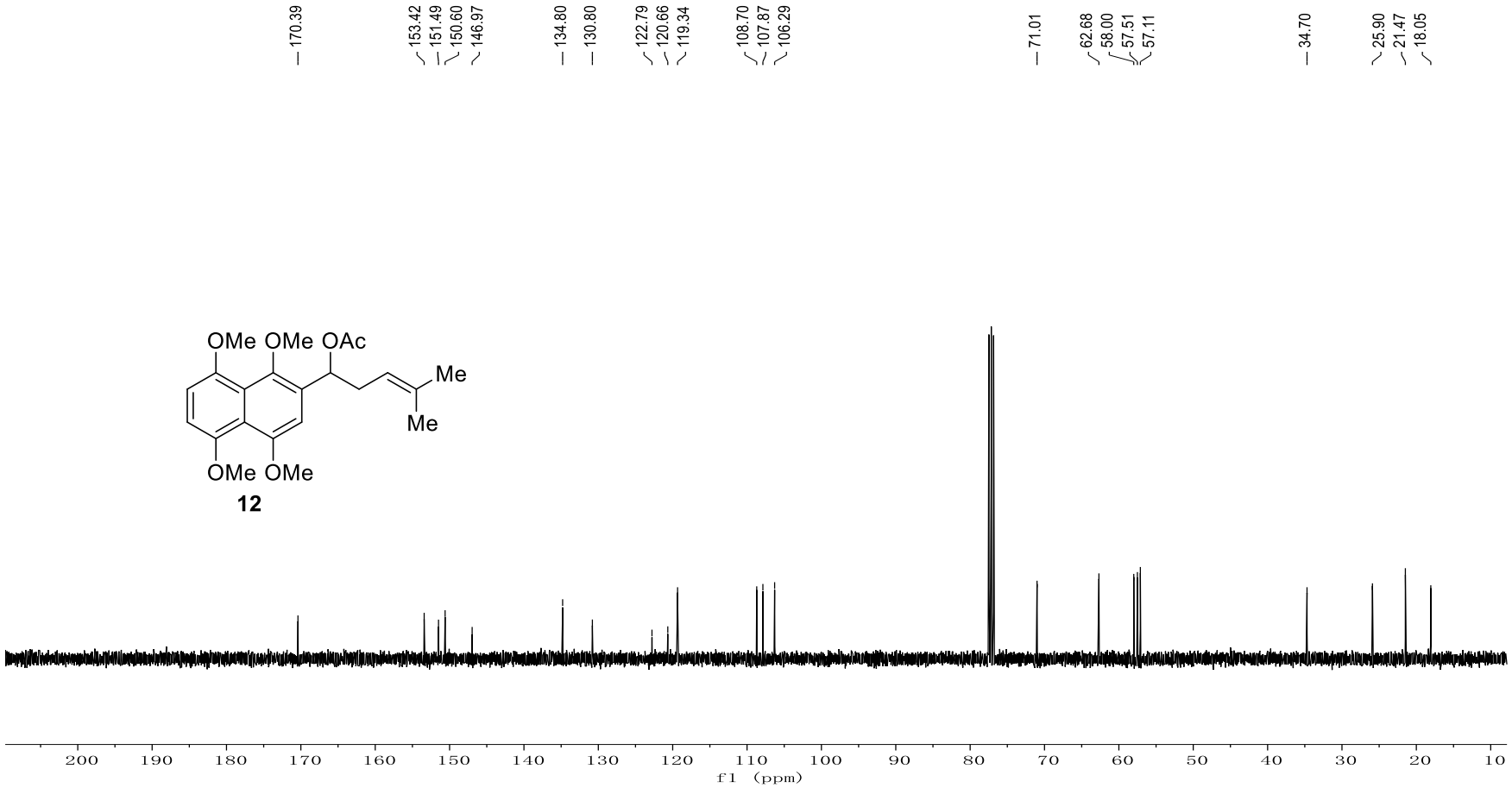
^{13}C NMR Spectrum of S4 (101 MHz, $CDCl_3$)



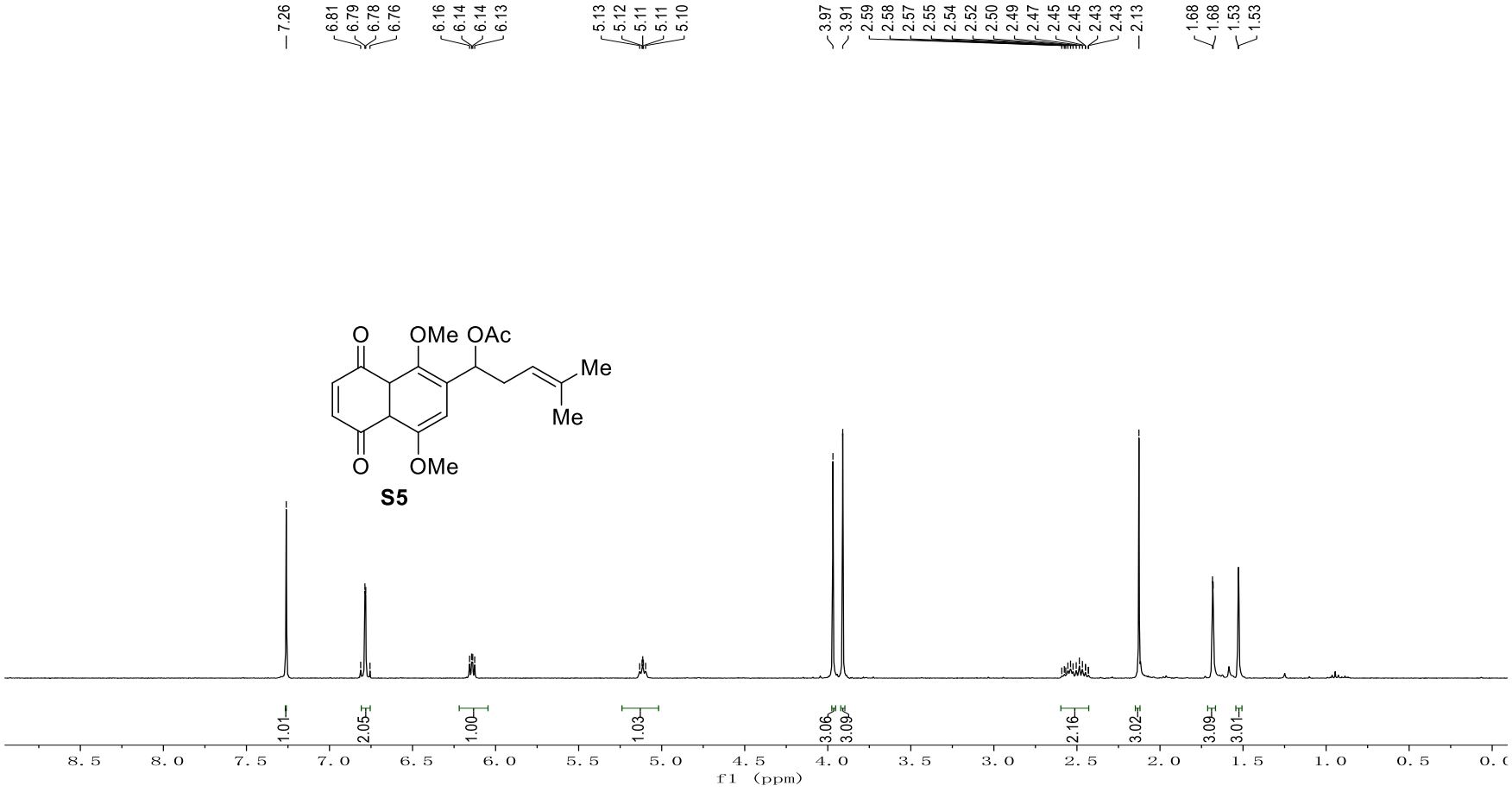
^{1}H NMR Spectrum of 12 (400 MHz, $CDCl_3$)



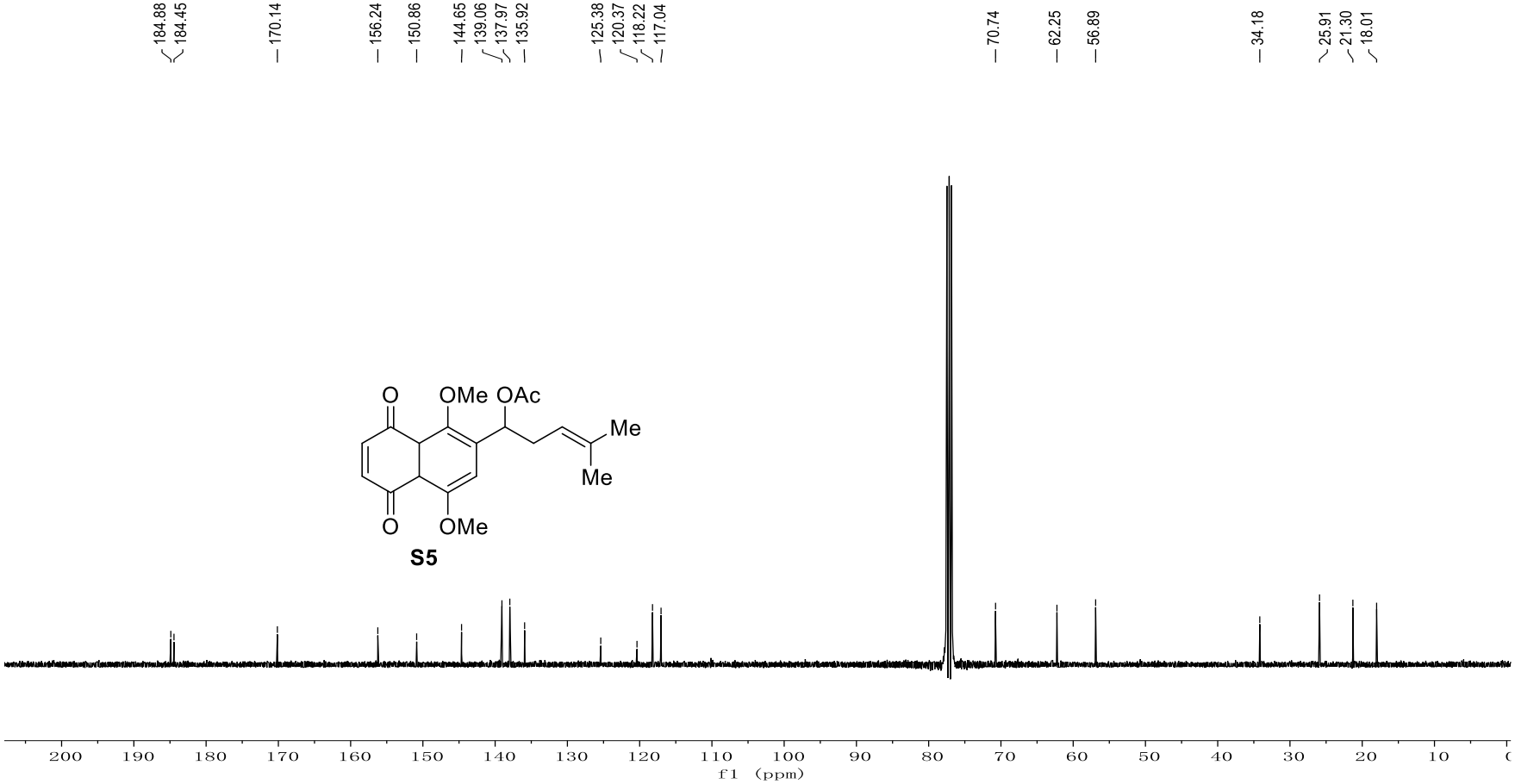
^{13}C NMR Spectrum of 12 (101 MHz, $CDCl_3$)



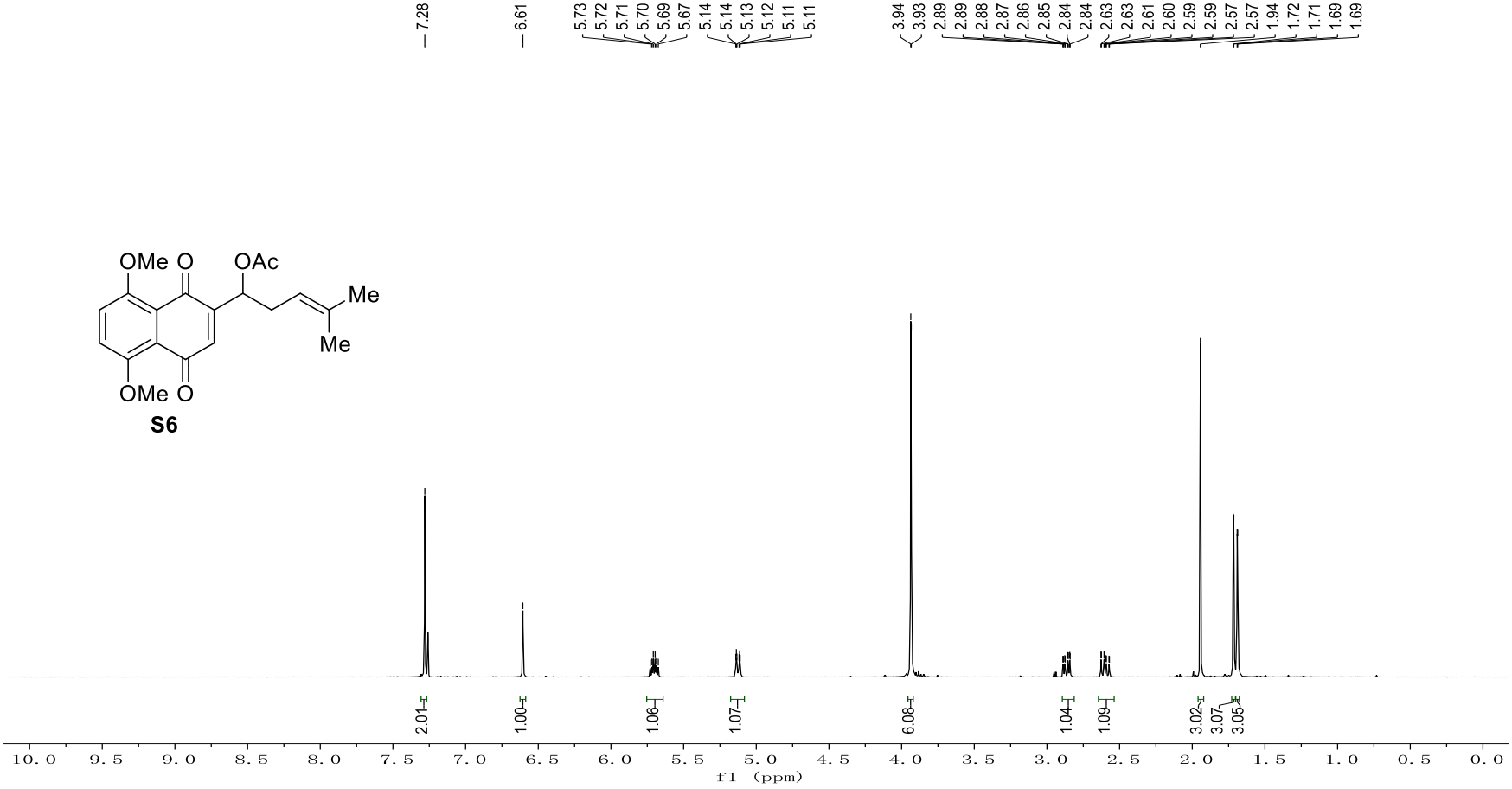
^{1}H NMR Spectrum of S5 (400 MHz, $CDCl_3$)



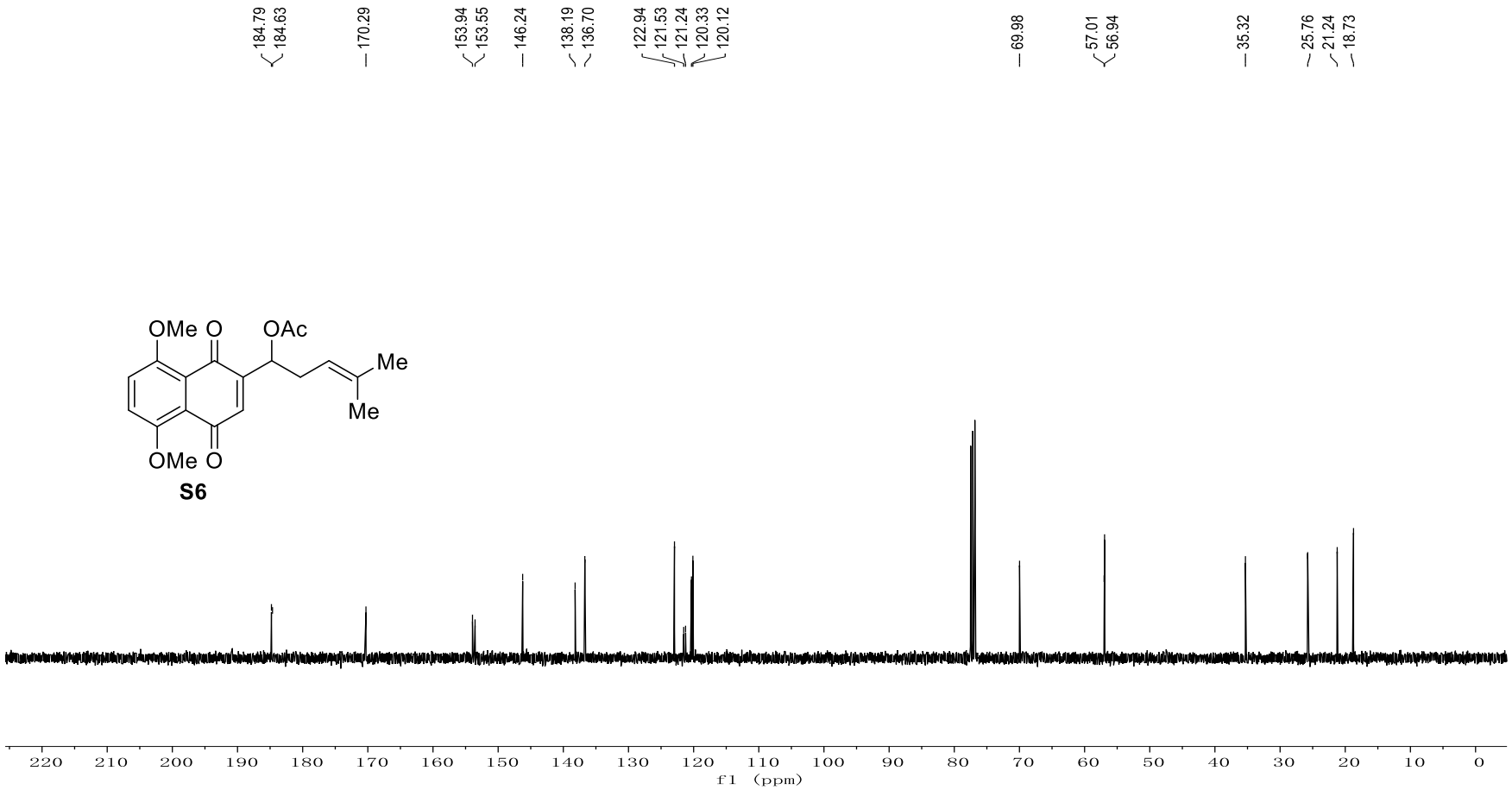
^{13}C NMR Spectrum of S5 (101 MHz, $CDCl_3$)



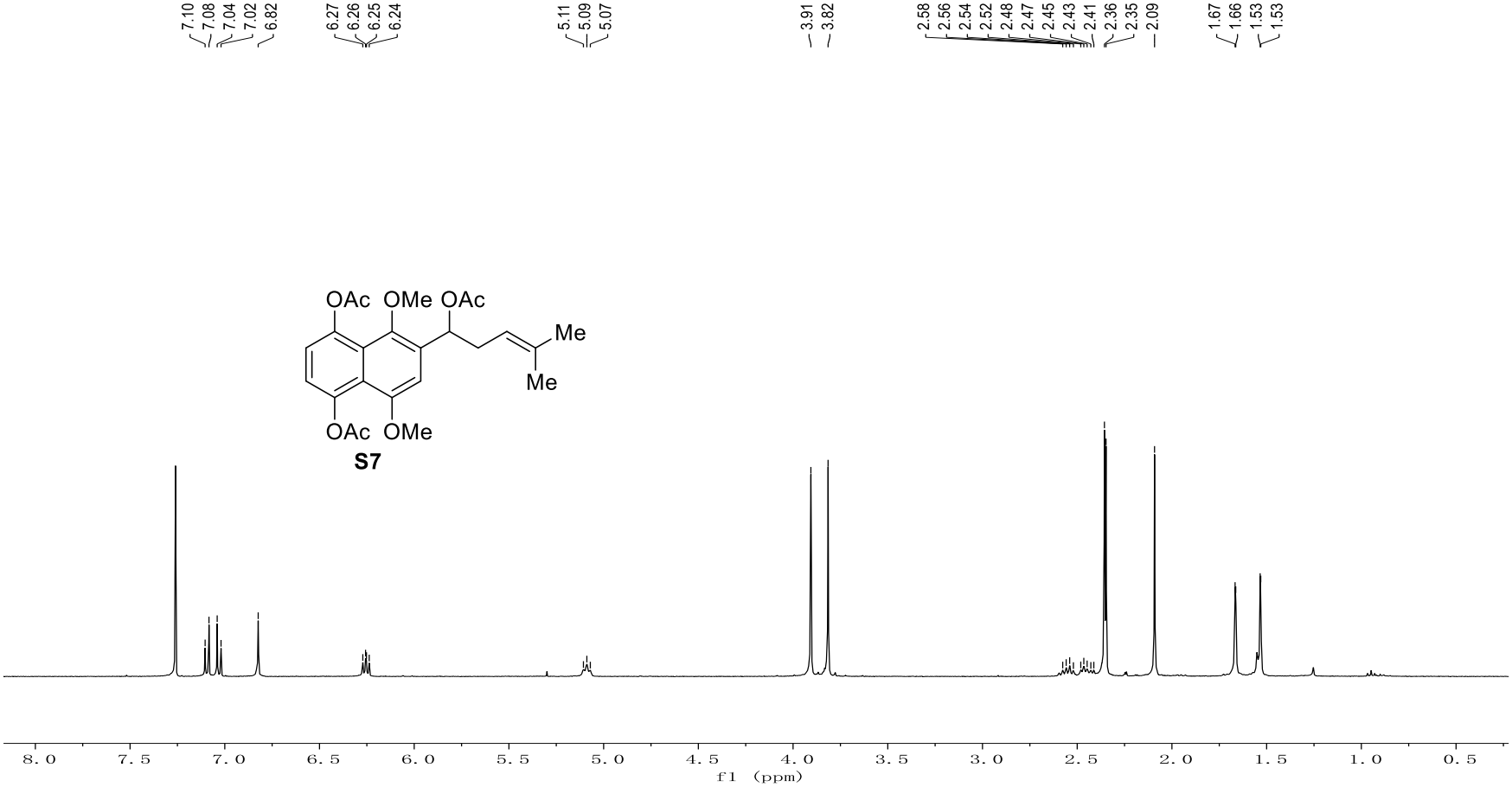
^{1}H NMR Spectrum of S6 (400 MHz, $CDCl_3$)



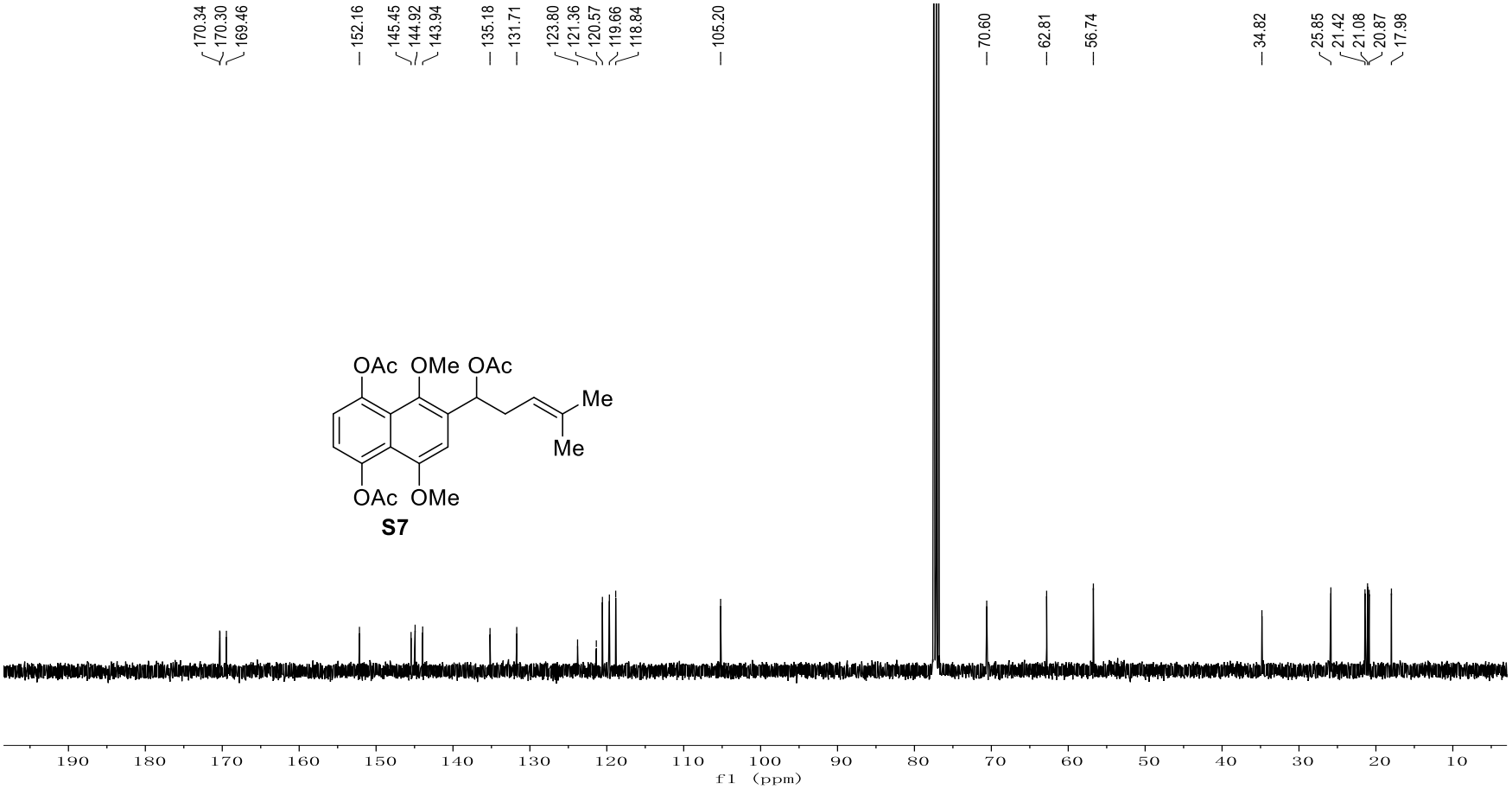
^{13}C NMR Spectrum of S6 (101 MHz, $CDCl_3$)



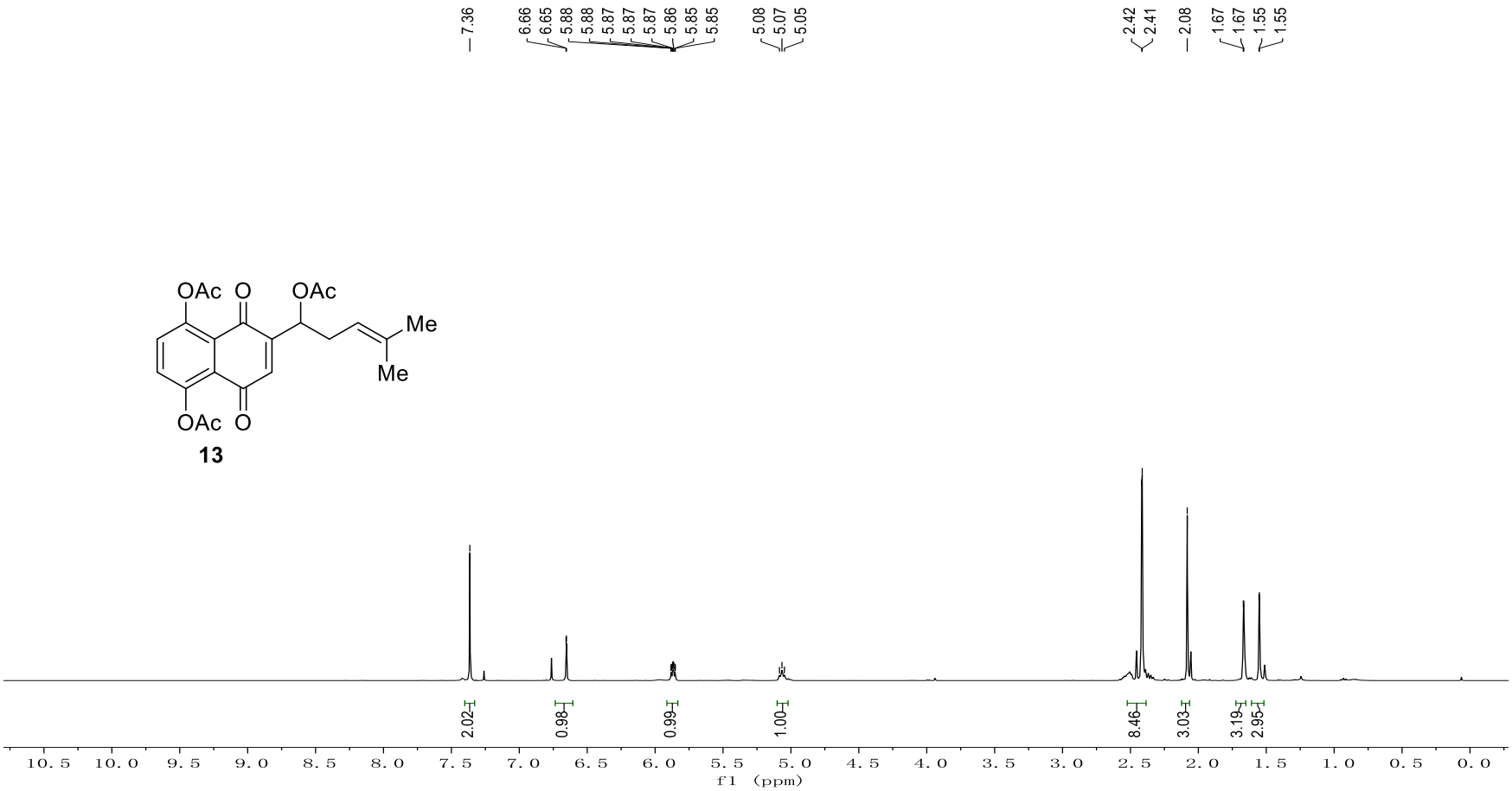
^{1}H NMR Spectrum of S7 (400 MHz, $CDCl_3$)



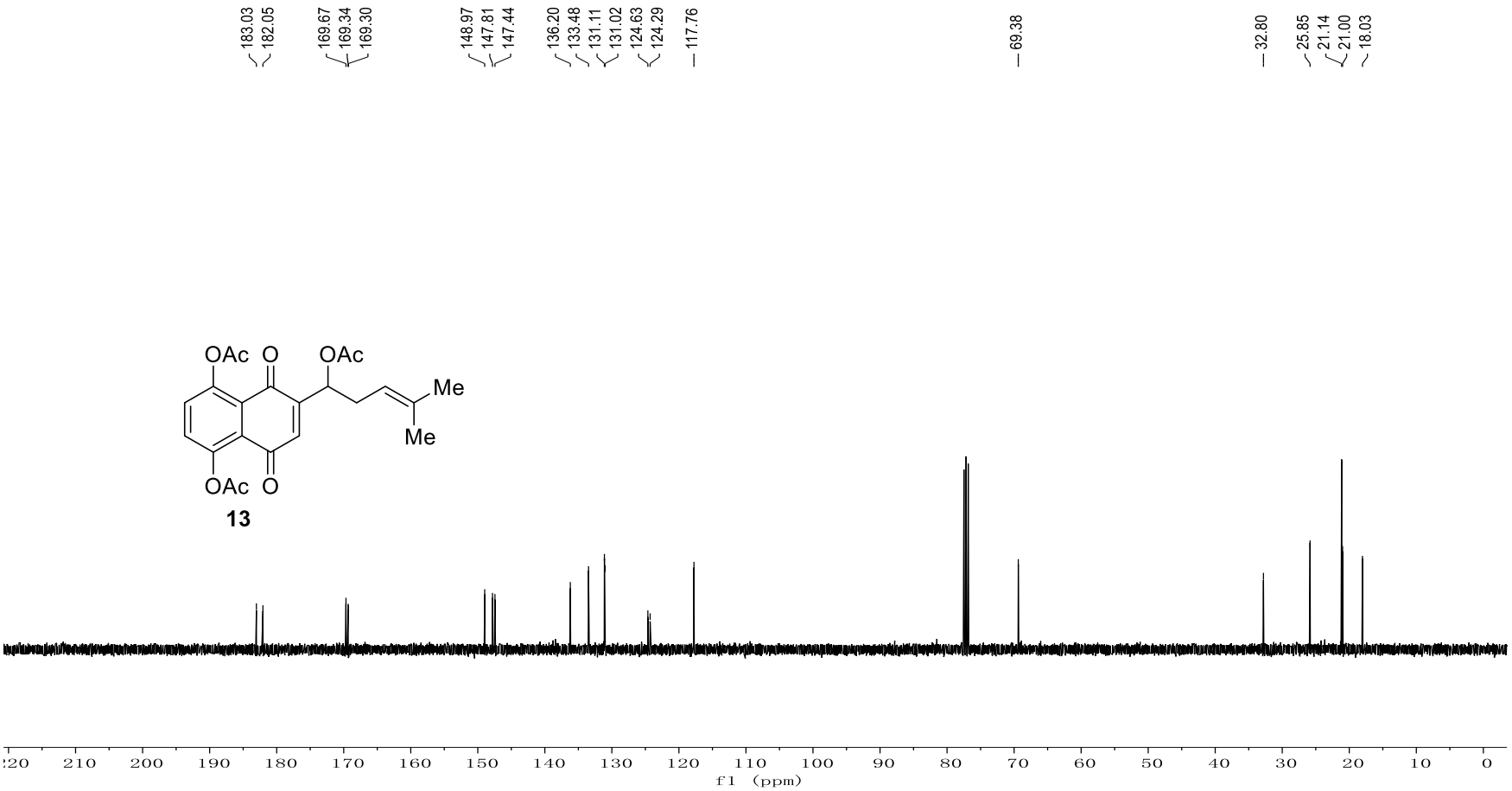
^{13}C NMR Spectrum of S7 (101 MHz, $CDCl_3$)



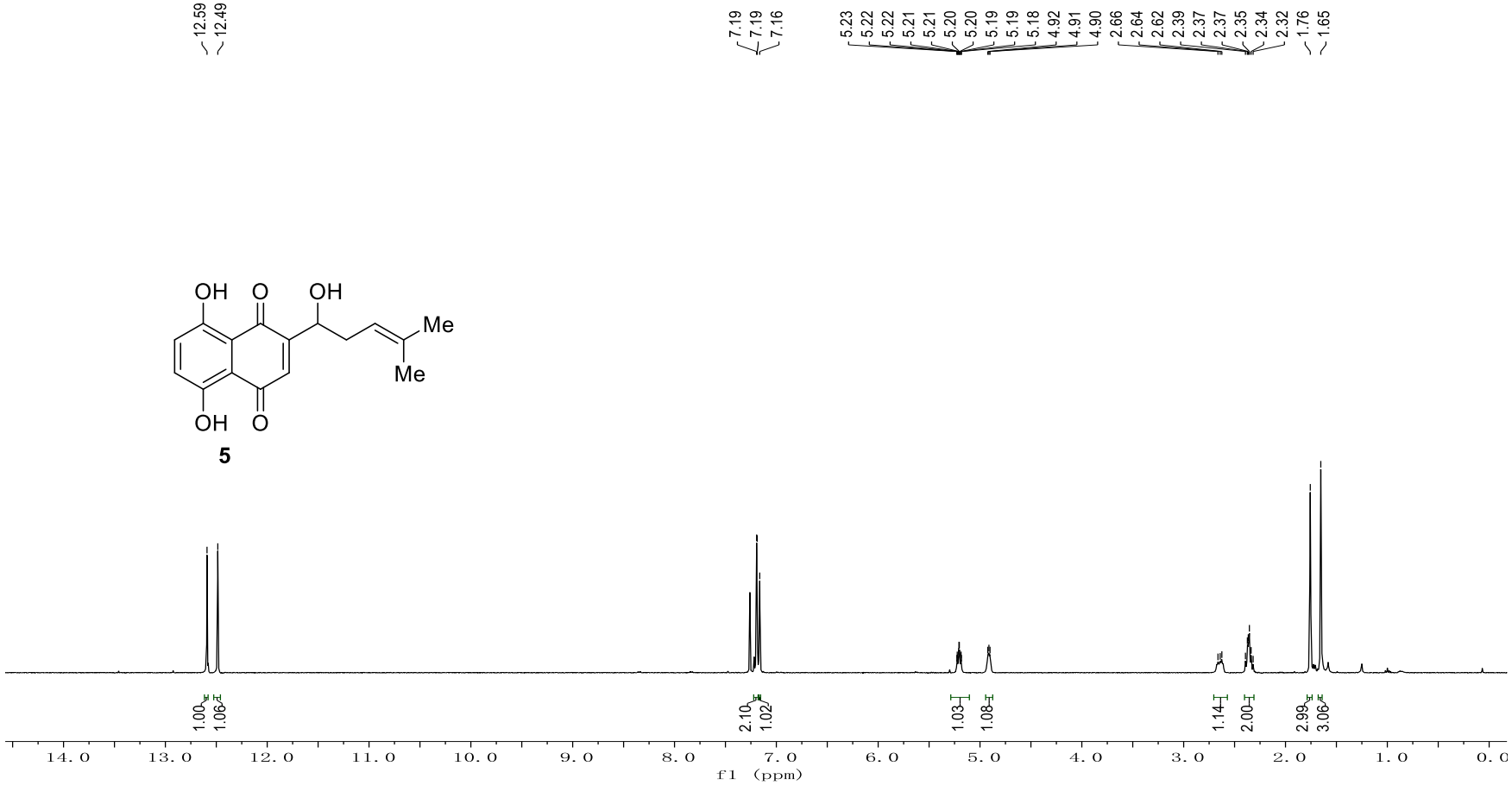
^{1}H NMR Spectrum of 13 (400 MHz, $CDCl_3$)



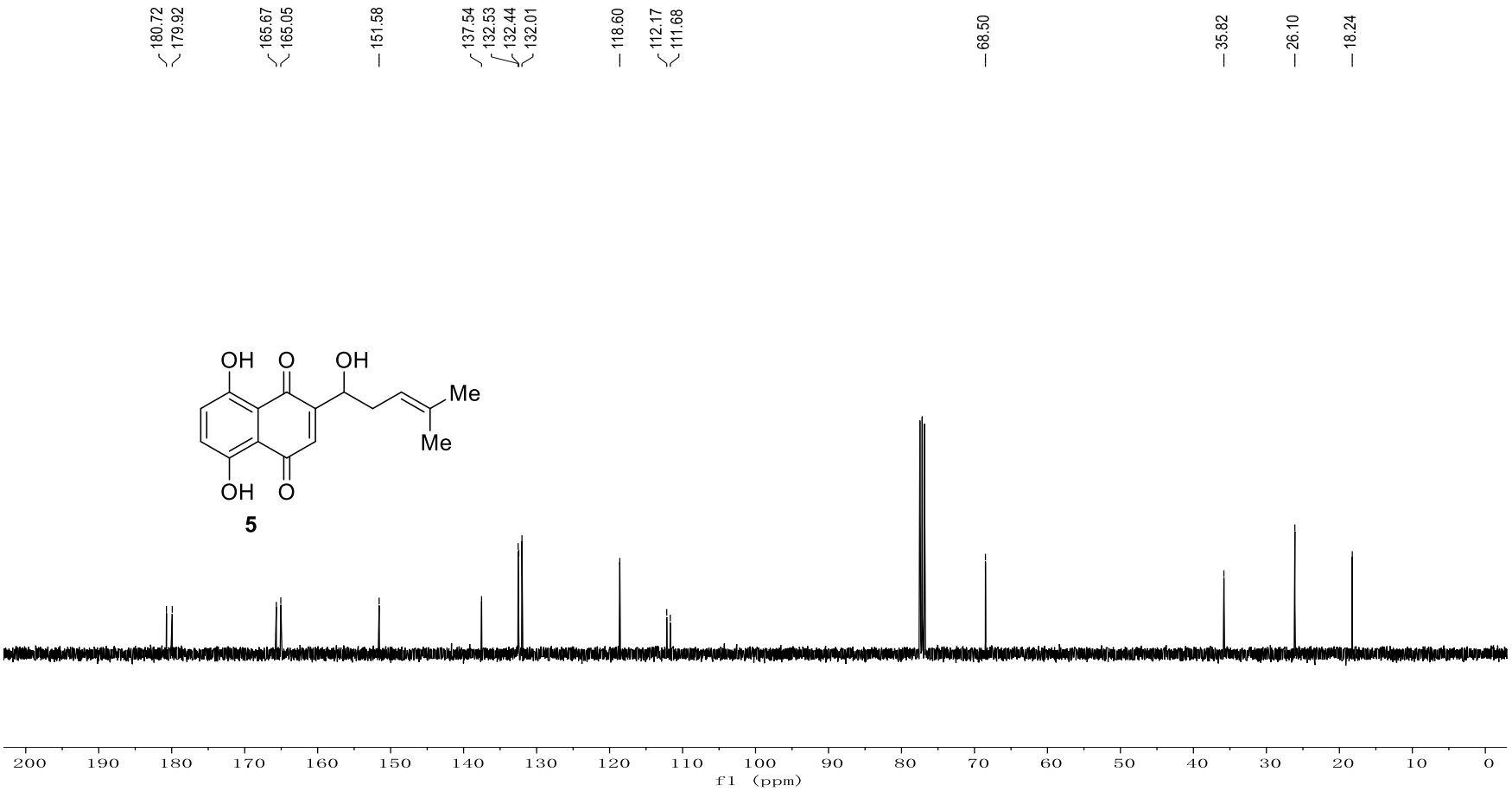
^{13}C NMR Spectrum of 13 (101 MHz, $CDCl_3$)



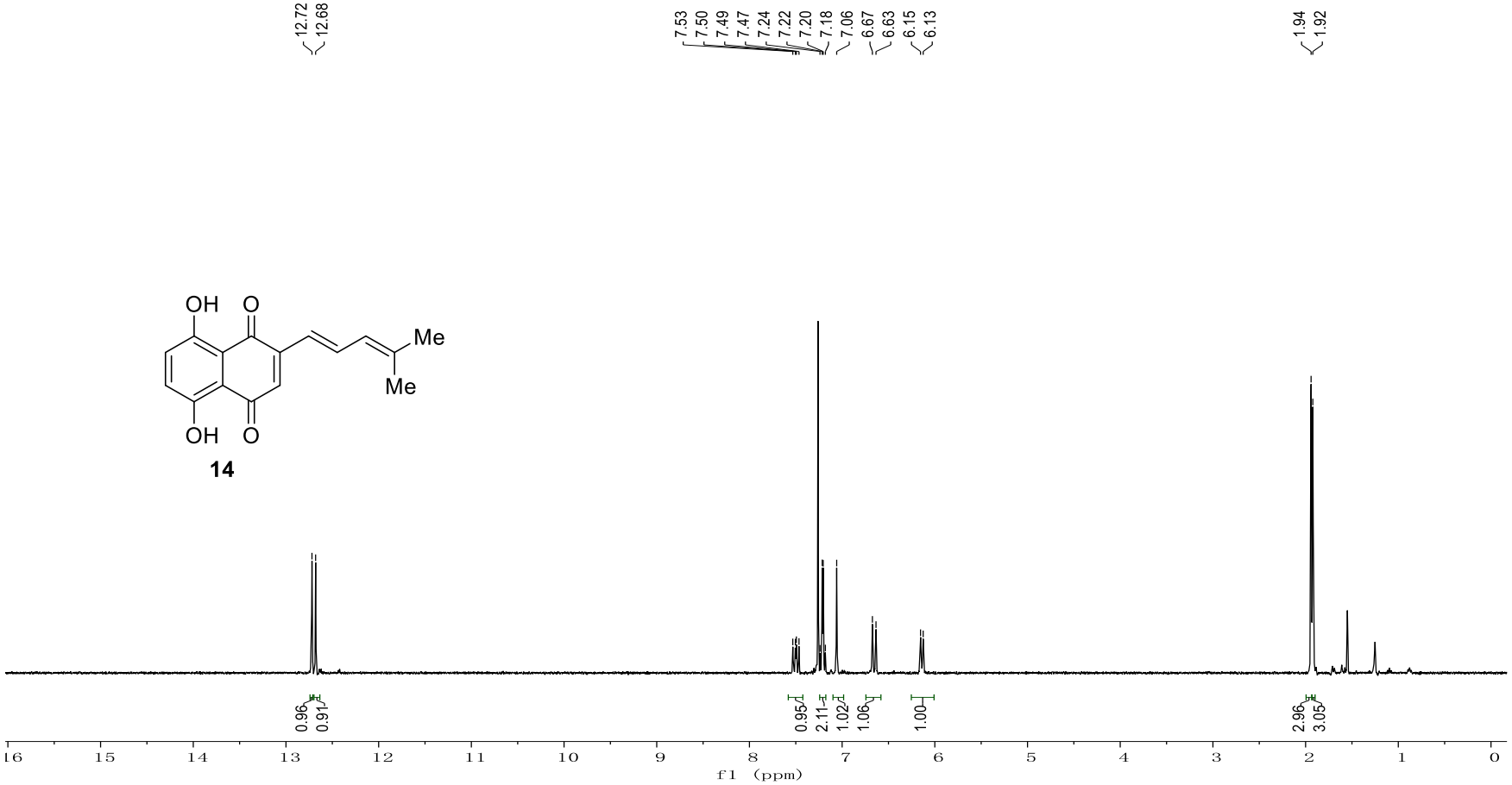
^{1}H NMR Spectrum of 5 (400 MHz, $CDCl_3$)



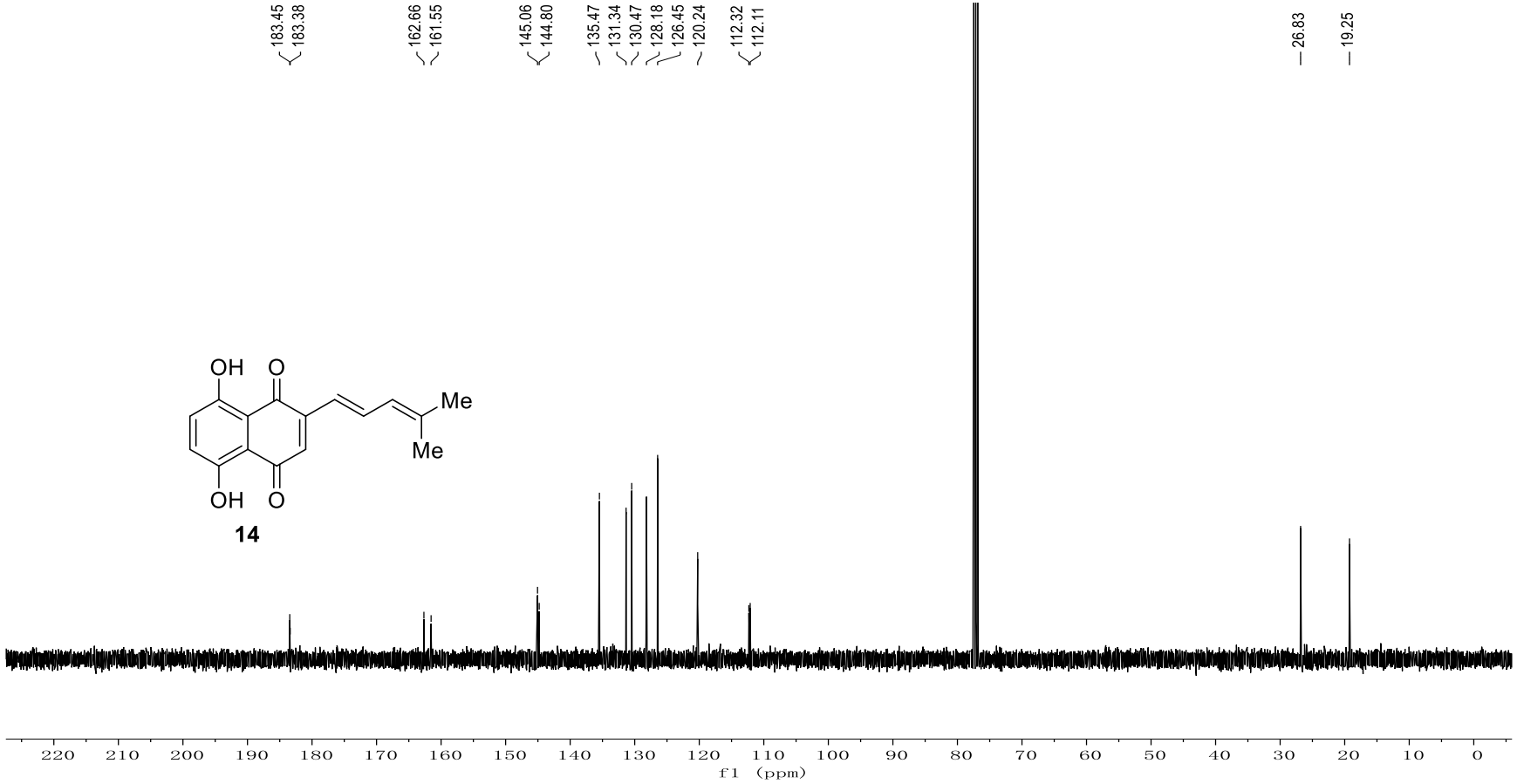
^{13}C NMR Spectrum of 5 (101 MHz, $CDCl_3$)



^{1}H NMR Spectrum of 14 (400 MHz, $CDCl_3$)

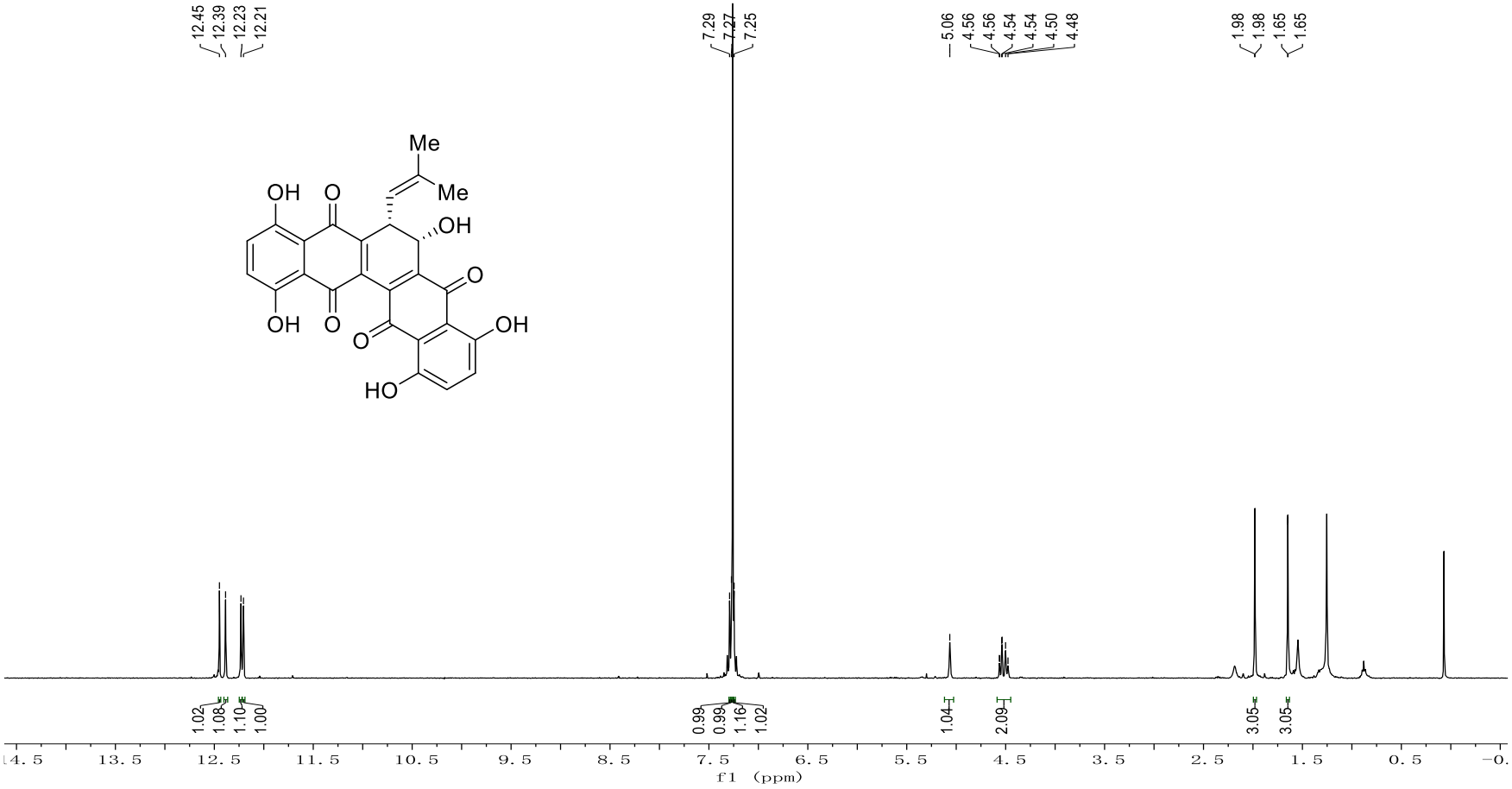


^{13}C NMR Spectrum of 14 (101 MHz, $CDCl_3$)

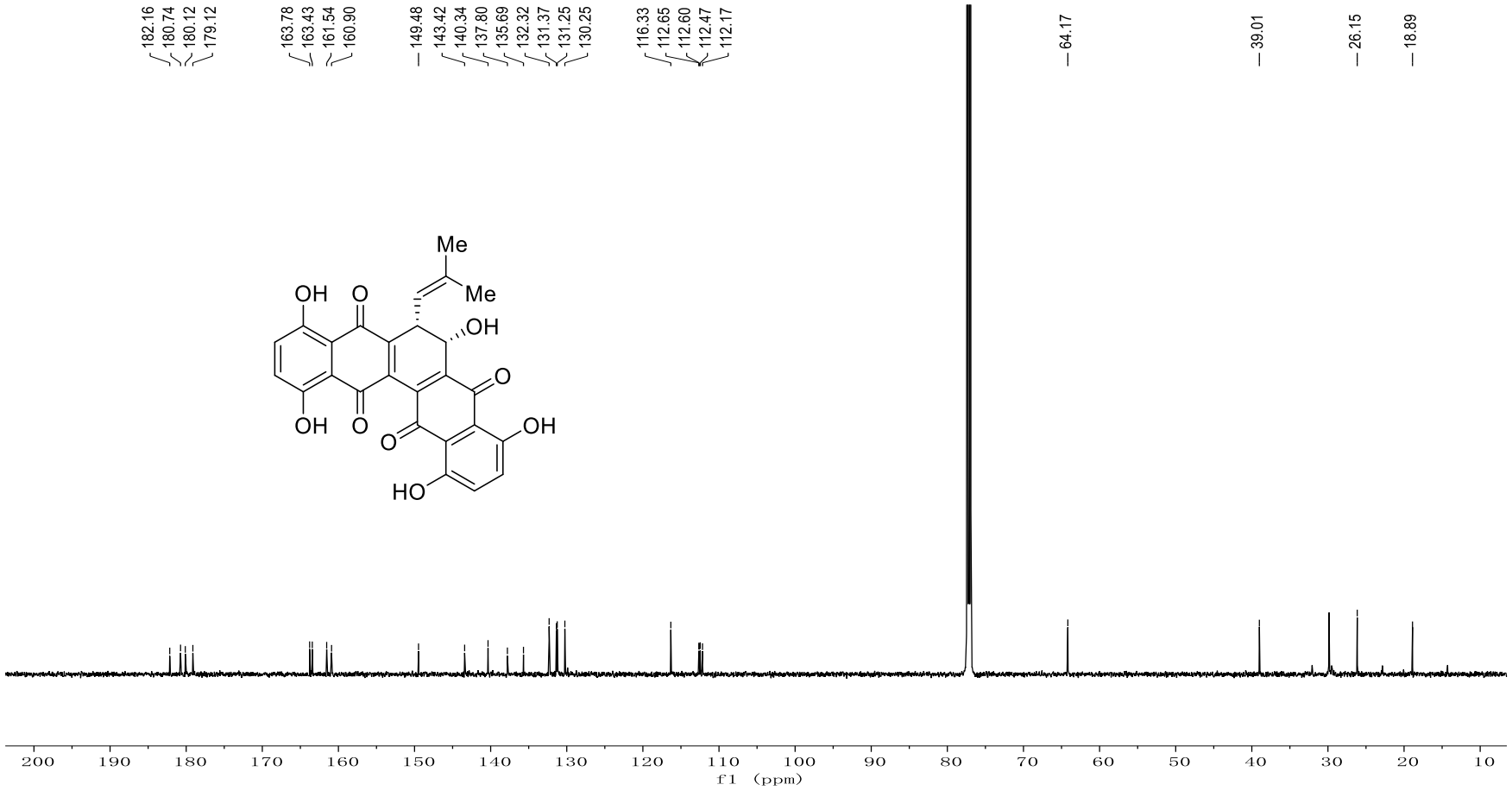


NMR Spectra of 17 (400 MHz, $CDCl_3$)

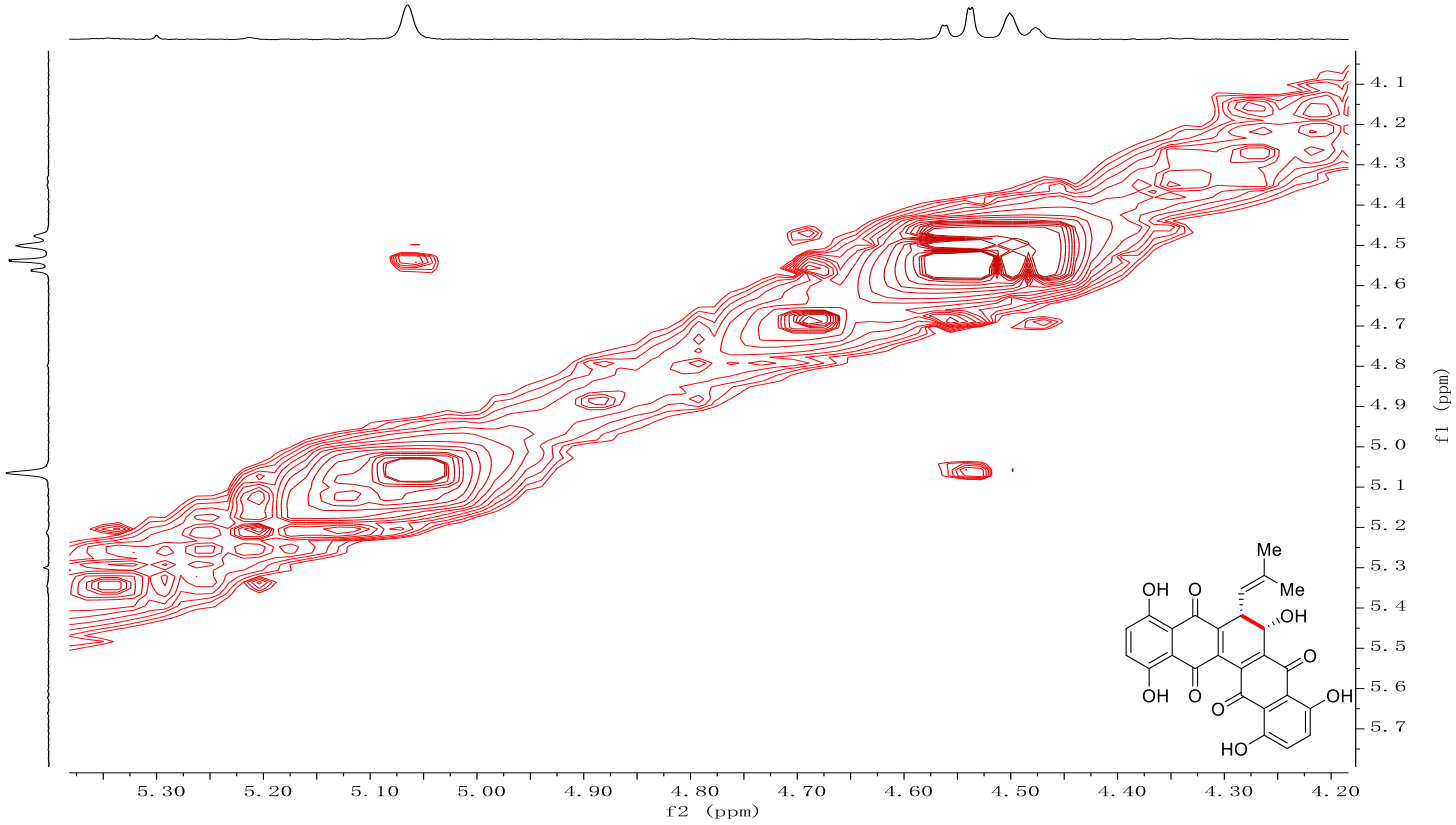
^{1}H NMR Spectrum of 17 (400 MHz, $CDCl_3$)

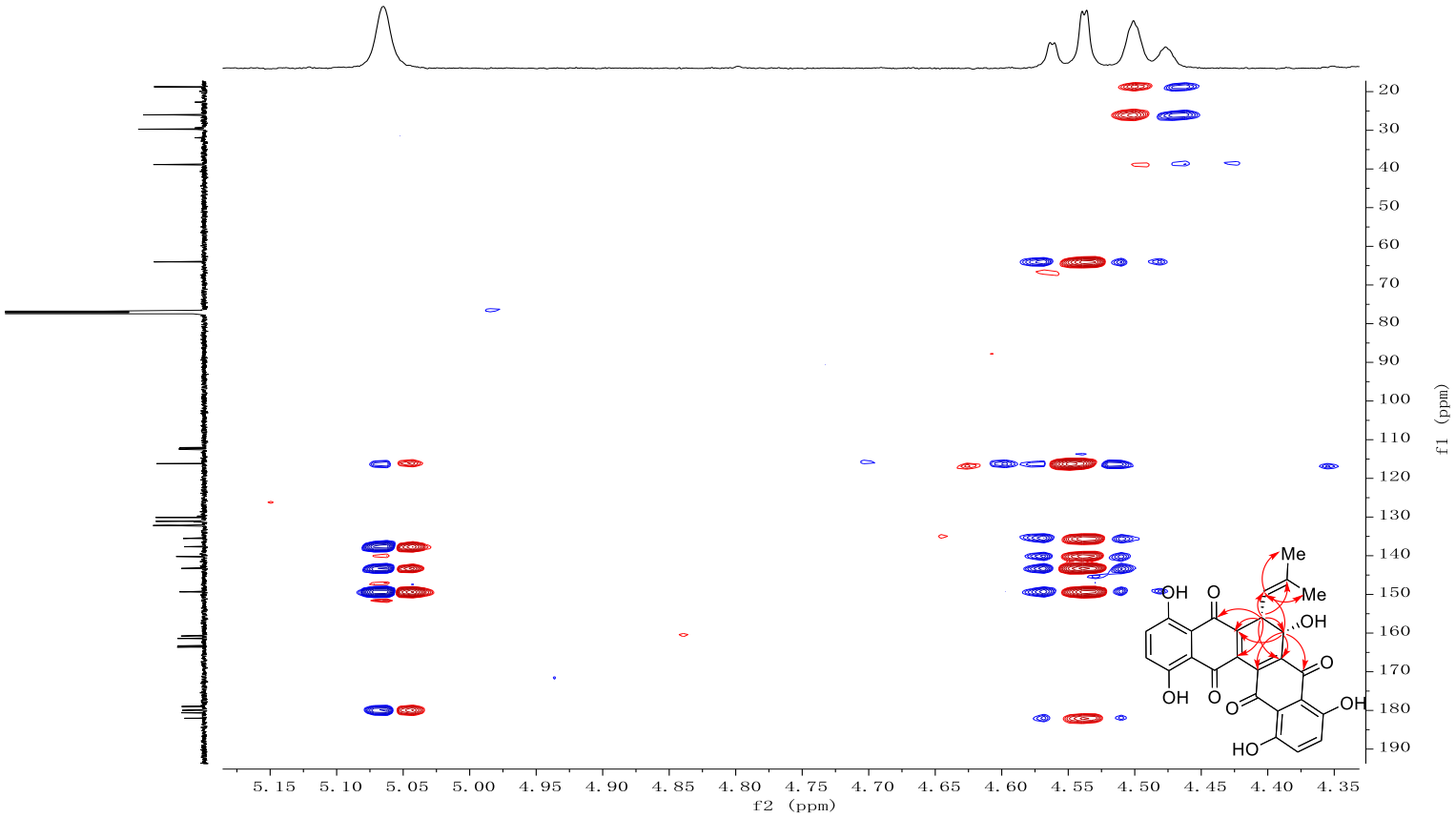


^{13}C NMR Spectrum of 17 (150 MHz, $CDCl_3$)

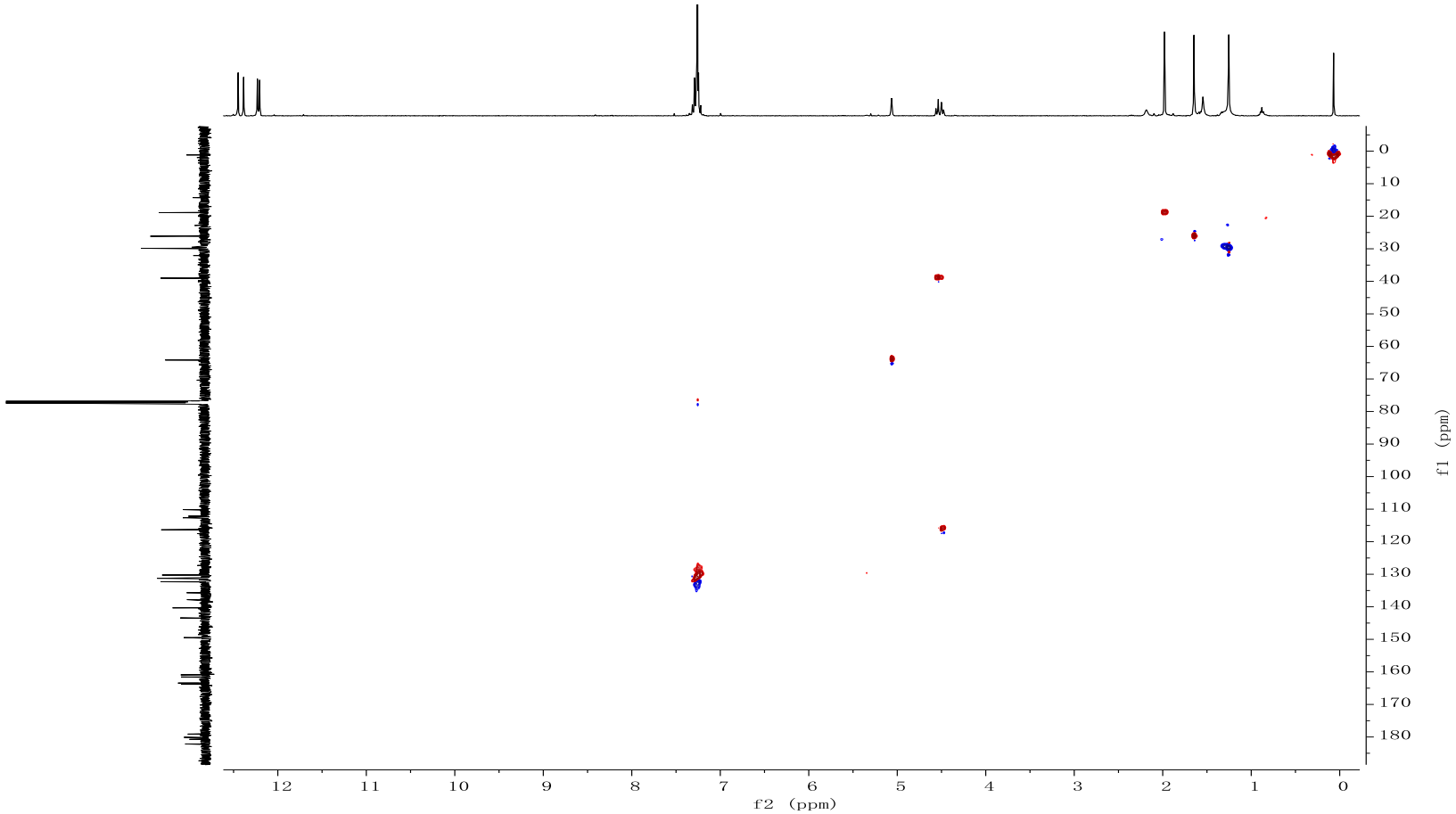


The key COSY and HMBC correlations of 17

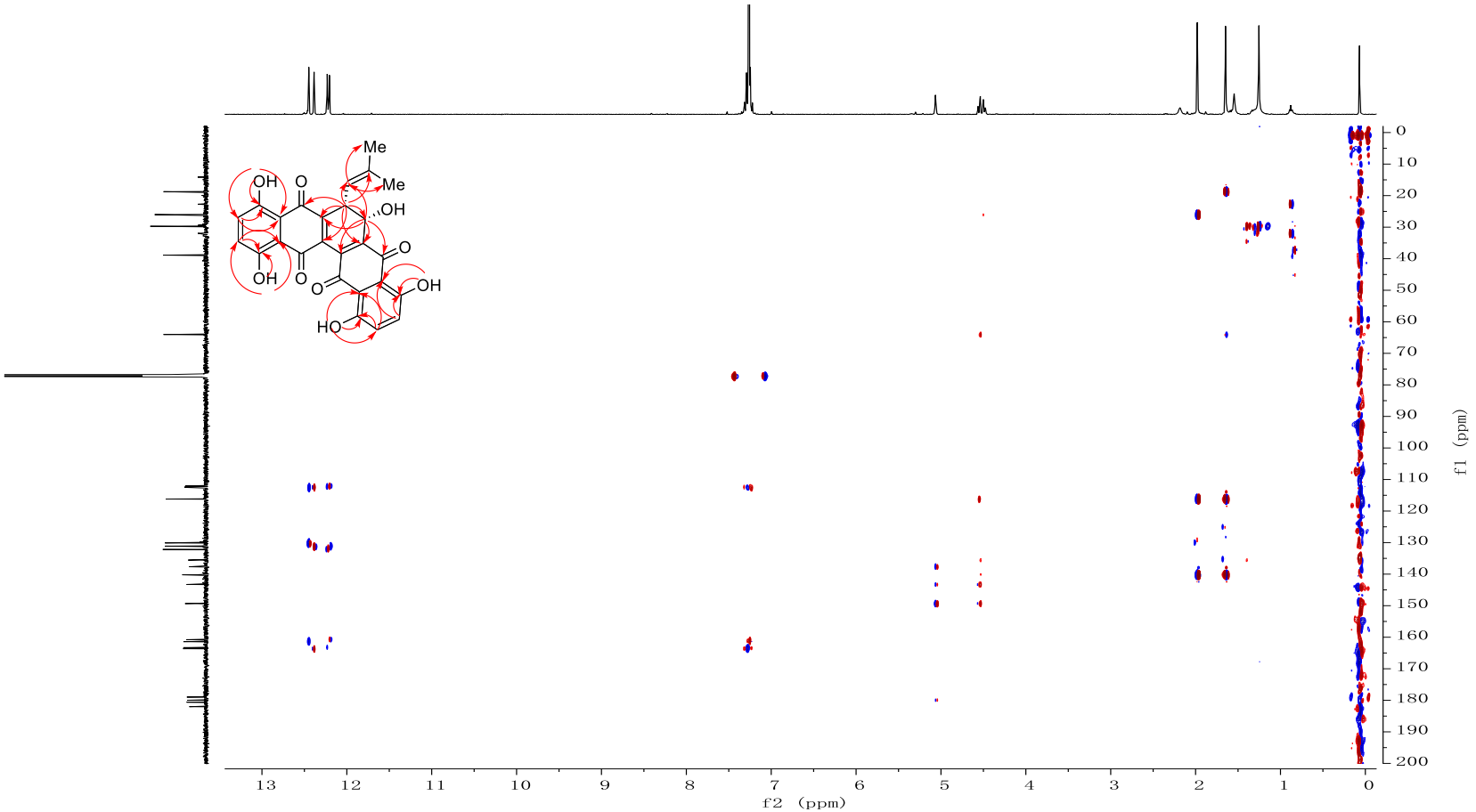




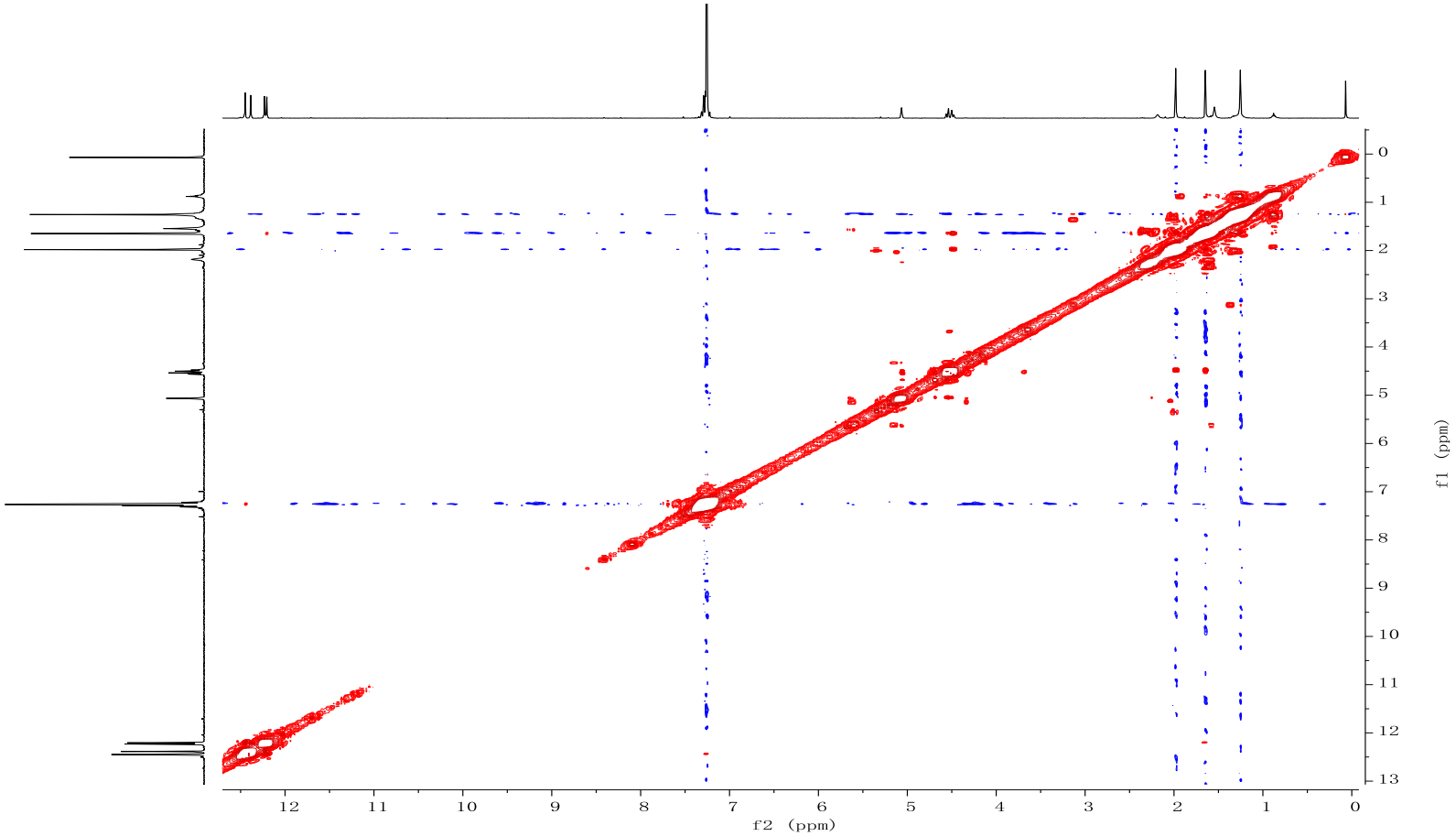
HSQC Spectrum of 17 (150 MHz, $CDCl_3$)


0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
f1 (ppm)
12
11
10
9
8
7
6
5
4
3
2
1
0
f2 (ppm)

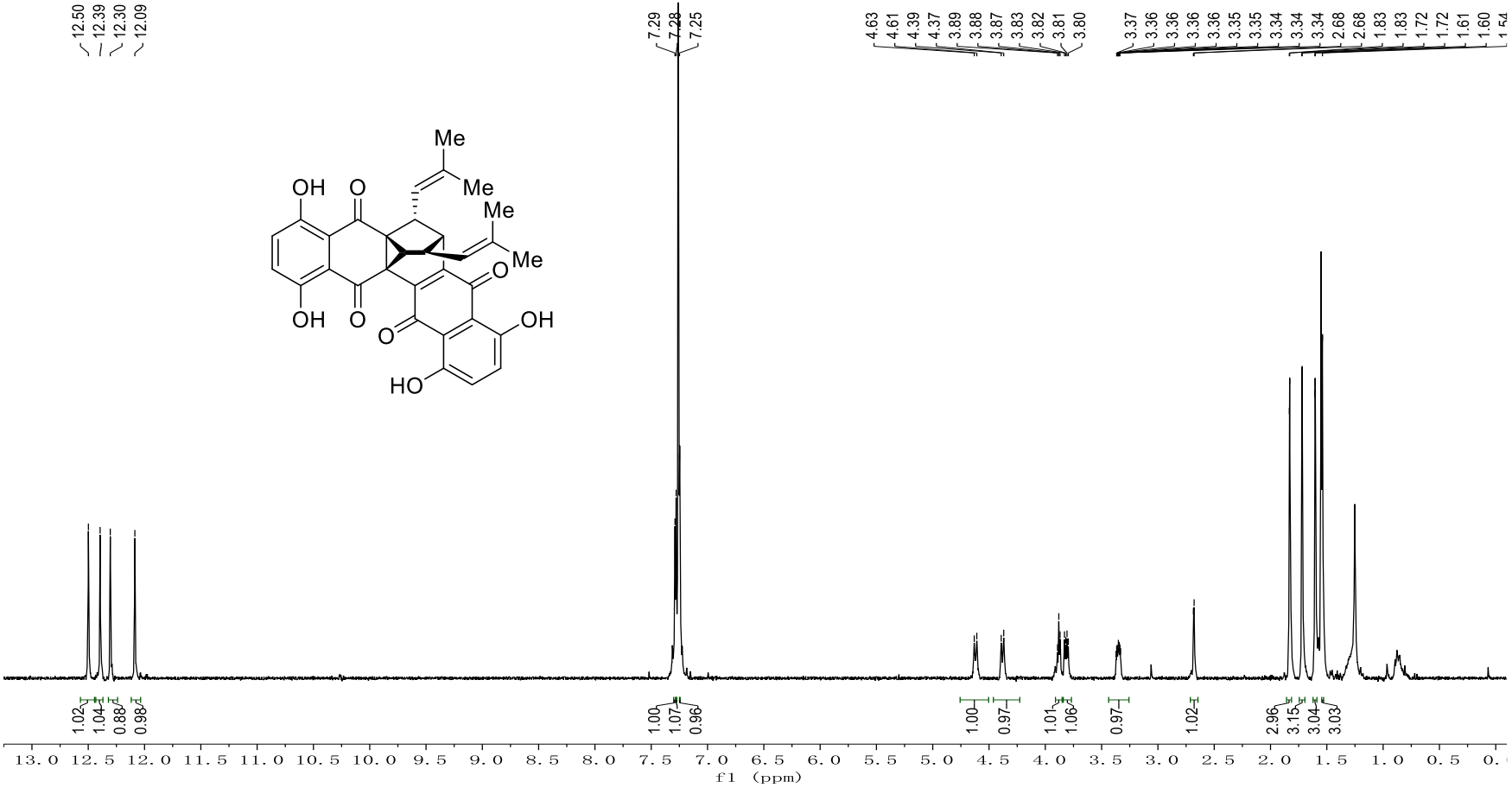
HMBC Spectrum of 17 (150 MHz, $CDCl_3$)



^{1}H-^{1}H COSY Spectrum of 17 (150 MHz, $CDCl_3$)



^{1}H NMR Spectrum of arnebidin (400 MHz, $CDCl_3$)



^{13}C NMR Spectrum of arnebidin (150 MHz, $CDCl_3$)