Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry.

Supporting Information

Asymmetric Syntheses of *ent*-Pimarane Diterpenoids

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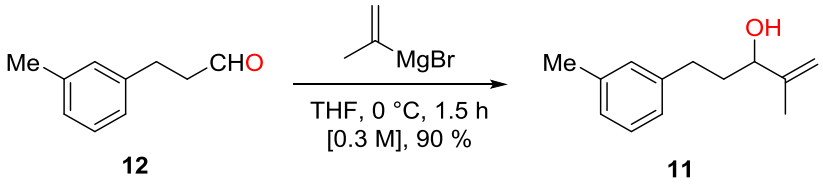
1. General information

All reactions were performed under an argon atmosphere with dry solvents under anhydrous conditions unless otherwise stated. DCM, toluene, DMPU and DMF were distilled from 5% w/v calcium hydride under argon; DIPA was distilled from 5% w/v sodium hydride under argon; Methyl propionate was first dried with 5% w/v Na_2CO_3 then distilled from 2% w/v P_2O_5; TFA was distilled from 0.5% v/v TFAA under argon; 2,2,2-Trifluoroethanol was distilled from 5% w/v $CaSO_4$ and 1% w/v $NaHCO_3$; MeOH was distilled from 5% w/v magnesium turnings and 1% w/v iodine under argon; THF was distilled from 2% w/v sodium with 0.2% w/v benzophenone as indicator under argon. Unless otherwise noted, all the other chemicals were purchased commercially and used without further purification. Reactions requiring anhydrous conditions were carried out under dry atmosphere filled with argon; glassware was dried using an industrial heating gun (550 ºC air temperature) for at least 5 minutes prior to use (for small scale reactions), or by placing in an oven (120°C) for at least 6 hours and allowed to cool under an argon atmosphere (for large scale reactions); liquid reagents, solutions or solvents were added via syringe through rubber septum. Column chromatography was performed using silica gel (200-300 mesh or 300-400 mesh). Thin layer chromatography (TLC) was used for monitoring reactions and visualized by a UV lamp (254 nm and 365 nm), I_2 and developing the plates with *p*-anisaldehyde or phosphomolybdic acid. ^1H, ^{13}C and ^{19}F NMR spectra were recorded on Bruker DRX-400 MHz NMR spectrometer with TMS as internal standard and were calibrated using residual solvent as internal reference ($CDCl_3$: ^1H NMR = 7.260 ppm, ^{13}C NMR = 77.160 ppm, CD_3OD: ^1H NMR = 4.870 ppm, ^{13}C NMR = 49.000 ppm, pyridine-d5: ^1H NMR = 8.740 ppm, ^{13}C NMR = 150.350 ppm). Abbreviations: in ^1H NMR data are illustrated as follows: s = singlet, d = doublet, t = triplet, dd =doublet of doublet, ddd = doublet of doublet of doublet, dddd= doublet of doublet of doublet of doublet, dt = doublet of triplet, td =triplet of doublet, tdd = triplet of doublet of doublet, m = multiplet, br = broad. Coupling constants (*J*) are reported in Hertz (Hz). Optical rotations were recorded on digital automatic polarimeter with a 100 mm path length cell. High resolution mass spectra (HRMS) were recorded on a Bruker-FT-MS spectrometer (ESI-FTMS). Infrared (IR) spectra were recorded as thin-films on a Perkin-Elmer Spectrum One FT-IR instrument and are reported in wavenumbers (cm^{-1}).

2. Experimental Procedures and Characterization Data

2.1. Synthesis of known compound **11** by a modified procedure [1]

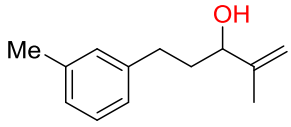


12 **11**

To an oven dried 1 L three necked thick-wall flask equipped with a thermometer, a dropping funnel, a magnetic stir bar and fitted with rubber septum, was added dry THF (150 mL) via a cannula, followed by isopropenyl magnesium bromide solution (1.0 M in THF, 146 mmol, 146 mL, 1.05 eq.). The reaction was cooled at 0 °C for 0.5 h, then 3-*m*-tolylpropanal (**12**, 20.5 g, 138 mmol, 1.0 eq.) in dry THF (150 mL) was added through a dropping funnel over 1 h. The resulting mixture was stirred at 0 °C for 0.5 h and quenched by pouring slowly into a conical flask containing saturated NH_4Cl solution (500 mL). The mixture was extracted by ethyl acetate (3 × 250 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (200 ~ 300 mesh) using ethyl acetate/petroleum ether 1:25 as eluent to give compound **11** as a colorless oil (26.7 g, 90% yield).

Compound 11:

2-methyl-5-(*m*-tolyl)pent-1-en-3-ol



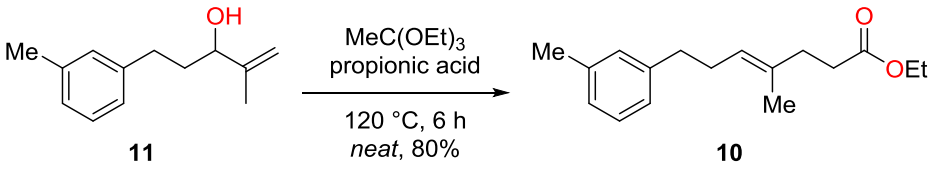
Physical state: colorless oil

TLC (ethyl acetate/petroleum ether 1:10): R_f 0.3 (UV, grey stain, *p*-anisaldehyde)

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.19 (t, *J* = 7.5 Hz, 1H), 7.08 – 6.99 (m, 3H), 4.99 (dt, *J* = 1.8, 0.9 Hz, 1H), 4.89 (p, *J* = 1.6 Hz, 1H), 4.11 (t, *J* = 6.0 Hz, 1H), 2.71 (ddd, *J* = 13.8, 9.1, 6.8 Hz, 1H), 2.62 (ddd, *J* = 13.8, 9.2, 7.0 Hz, 1H), 2.35 (s, 3H), 1.93 – 1.83 (m, 2H), 1.77 (t, *J* = 1.2 Hz, 3H)

^{13}C NMR (101 MHz, $CDCl_3$): δ 147.6, 142.1, 138.0, 129.4, 128.4, 126.7, 125.6, 111.3, 75.4, 36.7, 31.9, 21.5, 17.7.

2.2. Procedure for the synthesis of compound **12**

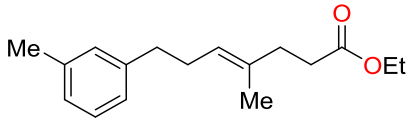


11 **10**

To an oven dried two necked thick-wall 250 mL flask was equipped with a thermometer, a magnetic stir bar and compound **11** (26.7 g, 130 mmol, 1.0 eq.). The mixture was added triethyl orthoacetate (70.4 g, 80 mL, 434 mmol, 3.3 eq.) and propionic acid (0.98 g, 1.0 mL, 0.1 eq.) in sequence. The reaction mixture was stirred at 120 °C for 6 h. The resulting solution was cooled to room temperature and quenched by addition of 2 N hydrochloric acid solution (400 mL). The mixture was stirred for another 0.5 h before the organic layer was separated. The aqueous layer was extracted with ethyl acetate (3 × 200 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (200 ~ 300 mesh) using ethyl acetate/petroleum ether 1:80 as eluent to give compound **10** as a colorless oil (27.3 g, 80% yield).

Compound 10:

ethyl (*E*)-4-methyl-7-(*m*-tolyl)hept-4-enoate



Physical state: colorless oil

TLC (ethyl acetate/petroleum ether 1:20): R_f 0.6 (UV, I_2, reddish pink stain, *p*-anisaldehyde)

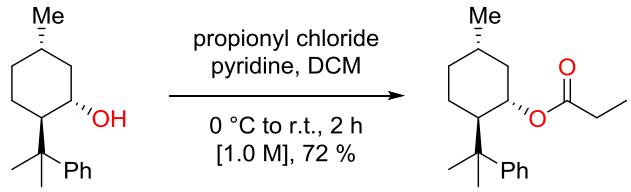
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.16 (t, *J* = 7.7 Hz, 1H), 7.04 – 6.94 (m, 3H), 5.22 (ddt, *J* = 7.0, 5.7, 1.3 Hz, 1H), 4.12 (q, *J* = 7.1 Hz, 2H), 2.58 (dd, *J* = 9.1, 6.7 Hz, 2H), 2.43 – 2.34 (m, 2H), 2.33 (d, *J* = 0.8 Hz, 3H), 2.34 – 2.24 (m, 4H), 1.57 (s, 3H), 1.25 (t, *J* = 7.1 Hz, 3H)

^{13}C NMR (101 MHz, $CDCl_3$): δ 173.7, 142.3, 137.9, 134.2, 129.4, 128.3, 126.6, 125.6, 124.7, 60.4, 36.0, 34.8, 33.4, 30.1, 21.5, 16.0, 14.4.

IR (neat): *v* 2924, 2855, 1608,1449,1372, 1157, 1095, 1040, 781, 699, 440 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{17}H_{24}NaO_2^+$ $[M+Na]^+$ 283.1669, found 283.1667

2.3. Procedure for the synthesis of compound **9**

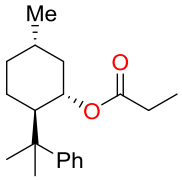


(+)-phenylmenthol **9**

To an oven dried 50 mL flask was charged with (+)-phenylmenthol (this compound was synthesized from (+)-isopulegol in 2 steps according to the known work [2]) (6.2 g, 26.7 mmol, 1.0 eq.), and 25 mL dry DCM. The reaction was cooled to 0 ºC and stirred for 0.5 h. Dry pyridine (2.4 g, 2.5 mL, 29.4 mmol, 1.1 eq.) was added via a syringe over 1 min, then propionyl chloride (2.78 g, 2.63 mL, 29.4 mmol, 1.1 eq.) was slowly added via a syringe over 2 min. The resulting mixture was stirred at room temperature for another 2 h and quenched by addition of deionized water (50 mL). The mixture was extracted with DCM (3 × 60 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (200 ~ 300 mesh) using ethyl acetate/petroleum ether 1:100 as eluent to give compound **9** as a colorless oil (5.54 g, 72% yield).

Compound 9:

(1*S*,2*R*,5*S*)-5-methyl-2-(2-phenylpropan-2-yl)cyclohexyl propionate



Physical state: colorless oil

TLC (methyl *tert*-butyl ether/petroleum ether 1:20): R_f 0.6 (UV, I_2, gray stain, phosphomolybdic acid)

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30 – 7.24 (m, 4H), 7.12 (tt, *J* = 4.8, 3.4 Hz, 1H), 4.82 (td, *J* = 10.7, 4.5 Hz, 1H), 2.01 (ddd, *J* = 12.3, 10.6, 3.5 Hz, 1H), 1.89 – 1.75 (m, 2H), 1.73 – 1.59 (m, 3H), 1.53 – 1.41 (m, 1H), 1.31 (s, 3H), 1.21 (s, 3H), 1.10 (qd, *J* = 12.9, 12.5, 3.1 Hz, 1H), 1.00 – 0.89 (m, 4H), 0.86 (d, *J* = 6.5 Hz, 4H)

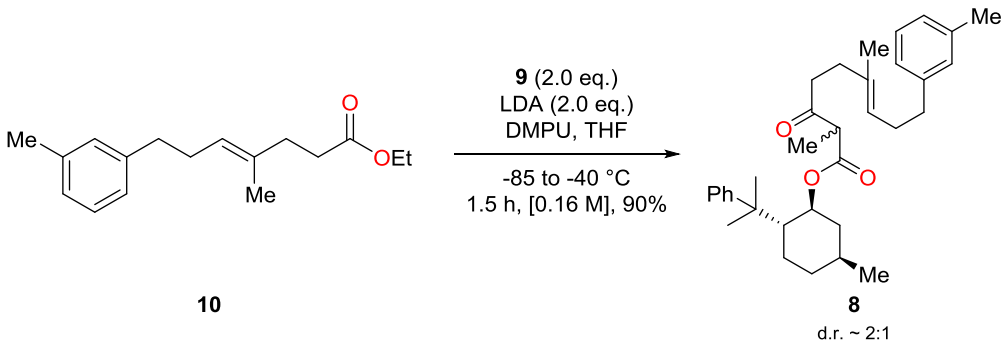
^{13}C NMR (101 MHz, $CDCl_3$): δ 173.9, 151.9, 128.0, 125.5, 125.2, 73.9, 50.5, 41.9, 39.8, 34.7, 31.4, 28.2, 27.6, 26.7, 24.9, 21.9, 8.9.

IR (neat): *v* 2952, 2921, 1600, 1457, 1367, 1190, 1086, 1010, 978, 958, 906, 846, 805, 764, 699, 562 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{19}H_{28}NaO_2^+$ $[M+Na]^+$ 311.1982, found 311.1980

$[\alpha]_D^{22}$: +1.3 (*c* = 3.0, DCM)

2.4. Procedure for the synthesis of compound **8**



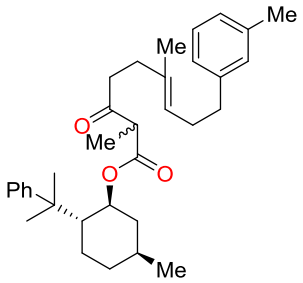
10 **8**

d.r. ~ 2:1

A heat-gun-dried 150 mL flask was charged with a magnetic stir bar, DIPA (2.03 g, 2.82 mL, 19.84 mmol, 2.1 eq.) and dry THF (20 mL) under argon atmosphere. The solution was cooled to -20 ºC and maintained for 0.5 h. Then a solution of *n*-butyl lithium (2.5 M in hexane, 7.68 mL, 19.2 mmol, 2.0 eq.) was added dropwise over 5 min. The mixture was stirred at 0 ºC for another 1 h. Then the mixture was cooled to -85 ºC and maintained for 0.5 h. Then DMPU (6.15 g, 5.8 mL, 48.0 mmol, 5.0 eq.) was added dropwise over 3 min, followed by slow addition of a solution of **9** (5.54 g, 19.2 mmol, 2.0 eq.) in dry THF (20 mL) over 15 min. After that **10** (2.55 g, 9.6 mmol, 1.0 eq.) in dry THF (20 mL) was added dropwise over 15 min. The reaction mixture was stirred for 1.5 h while gradually warmed to -40 ºC. The mixture was poured slowly into saturated NH_4Cl solution (150 mL) at 0 ºC, and stirred for another 0.5 h. The mixture was extracted by ethyl acetate (3 × 100 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (300 ~ 400 mesh) using methyl *tert*-butyl ether/petroleum ether 1:100 as eluent to give compound **8** as a pair of inseparable diastereomers (4.93 g, 90% yield, colorless oil, d.r. ~ 2:1, determined by ^{1}H NMR.). The similar ^{1}H NMR signals was reported in literature [3].

Compound 8:

(1*S*,2*R*,5*S*)-5-methyl-2-(2-phenylpropan-2-yl)cyclohexyl (*E*)-2,6-dimethyl-3-oxo-9-(*m*-tolyl)non-6-enoate



Physical state: colorless oil

TLC (methyl *tert*-butyl ether/petroleum ether 1:20): R_f 0.5 (UV, I_2, olive stain, *p*-anisaldehyde)

^{1}H NMR (400 MHz, $CDCl_3$, mixture of diastereomers): δ 7.31 – 7.23 (m, 4H), 7.21 – 7.11 (m, 2H), 7.05 – 6.96 (m, 2H), 5.27 – 5.11 (m, 1H), 4.91 – 4.79 (m, 1H), 2.68 – 2.56 (m, 2H), 2.56 – 2.49 (m, 1H), 2.38 – 2.31 (m, 5H), 2.31 – 2.21 (m, 3H), 2.17 – 2.09 (m, 1H), 2.09 – 1.98 (m, 1H), 1.93 – 1.77 (m, 2H), 1.73 – 1.65 (m, 1H), 1.64 – 1.56 (m, 2H), 1.52 – 1.41 (m, 1H), 1.35 – 1.28 (m, 3H), 1.26 – 1.22 (m, 1H), 1.21 – 1.13 (m, 2H), 1.12 – 1.05 (m, 3H), 1.03 – 0.90 (m, 3H), 0.89 – 0.83 (m, 4H)

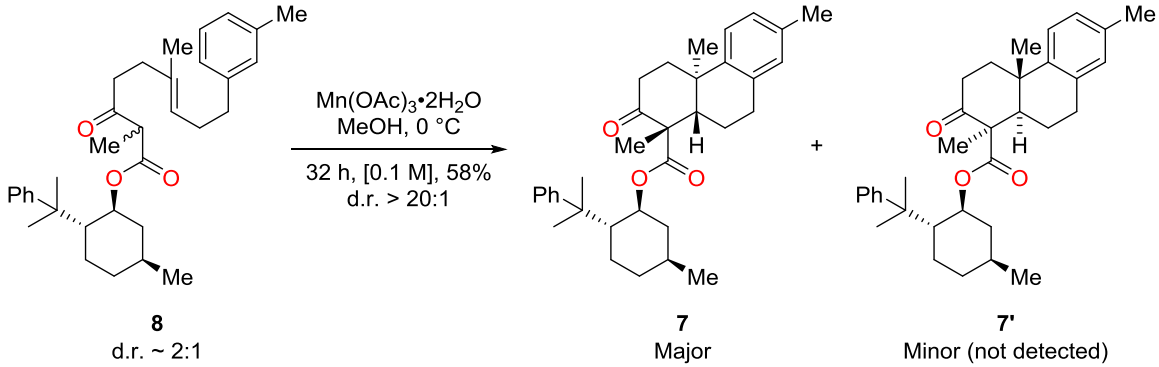
^{13}C NMR (101 MHz, $CDCl_3$): δ 206.2, 206.0, 170.4, 169.6, 152.2, 151.4, 142.2, 137.9, 134.4, 134.2, 129.4, 128.3, 128.3, 128.1, 128.1, 128.0, 126.6, 126.6, 125.6, 125.6, 125.5, 125.4, 125.2, 124.5, 124.5, 75.9, 75.0, 52.7, 52.2, 50.4, 50.2, 41.6, 41.4, 40.7, 40.3, 40.0, 39.6, 36.1, 34.6, 34.6, 33.3, 33.2, 31.4, 31.4, 30.1, 30.1, 29.3, 27.0, 26.9, 26.5, 26.4, 23.5, 21.9, 21.9, 21.5, 16.2, 12.8, 12.4.

IR (neat): *v* 2954, 2922, 1737, 1713, 1604, 1453, 1373, 1323, 1198, 1091, 978, 846, 765, 700, 562 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{34}H_{46}NaO_3^+$ $[M+Na]^+$ 525.3340, found 525.3341

$[\alpha]_D^{22}$: -9.0 (*c* = 1.8, DCM)

2.5. Procedure for the synthesis of compound **7**



8
d.r. ~ 2:1

7
Major

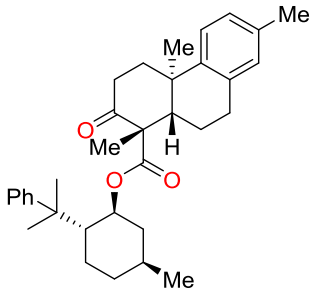
7'
Minor (not detected)

To an oven dried 250 mL flask was charged with manganese (III) triacetate

dihydrate (5.97 g, 21.6 mmol, 2.2 eq.), a magnetic stir bar and rubber septum. The reaction was added degassed MeOH (60 mL, 3 freeze-pump-thaw cycles) via a cannula under argon atmosphere. The reaction was cooled to 0 ºC and maintained for 0.5 h. Then a solution of **8** in degassed MeOH (60 mL) was added slowly via a syringe over 15 min. The reaction mixture was stirred at 0 ºC for 32 h before pouring slowly into saturated $Na_2S_2O_3$ solution (100 mL). The mixture was extracted by ethyl acetate (3 × 100 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (300 ~ 400 mesh) using methyl *tert*-butyl ether/petroleum ether 1:80 as eluent to give a white amorphous solid compound **7** as a single diastereomer (2.82 g, 58% yield), d.r. > 20:1. The desired absolute stereochemistry was determined by comparing the ^{1}H and ^{13}C NMR spectra data with reported literature [4].

Compound 7:

(1*S*,2*R*,5*S*)-5-methyl-2-(2-phenylpropan-2-yl)cyclohexyl (1*S*,4a*R*,10a*S*)-1,4a,7-trimethyl-2-oxo-1,2,3,4,4a,9,10,10a-octahydrophenanthrene-1-carboxylate



Physical state: white amorphous solid

TLC (methyl *tert*-butyl ether/petroleum ether 1:20): R_f 0.5 (UV, I_2, gray stain, *p*-anisaldehyde)

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 – 7.27 (m, 4H), 7.20 – 7.15 (m, 2H), 6.98 (dd, *J* = 8.1, 2.1 Hz, 1H), 6.90 (d, *J* = 2.0 Hz, 1H), 4.95 (td, *J* = 10.5, 4.3 Hz, 1H), 3.16 – 3.01 (m, 1H), 2.93 (ddd, *J* = 17.0, 5.5, 1.8 Hz, 1H), 2.78 (ddd, *J* = 17.4, 12.4, 6.5 Hz, 1H), 2.60 – 2.48 (m, 2H), 2.28 (s, 3H), 2.18 – 2.07 (m, 1H), 2.07 – 2.01 (m, 2H), 2.00 – 1.95 (m, 1H), 1.80 – 1.69 (m, 2H), 1.55 – 1.47 (m, 1H), 1.39 (s, 3H), 1.36 (s, 3H), 1.34 (s, 3H), 1.25 (s, 3H), 1.06 – 0.95 (m, 2H), 0.94 – 0.84 (m, 2H), 0.82 (d, *J* = 6.5 Hz, 3H), 0.78 – 0.69 (m, 1H)

^{13}C NMR (101 MHz, $CDCl_3$): δ 208.3, 173.4, 150.7, 143.6, 135.7, 134.9, 129.9, 128.3, 127.2, 125.9, 125.6, 125.3, 77.3, 58.3, 54.2, 50.0, 41.9, 40.4, 39.0, 37.8, 34.4, 31.9, 31.5, 30.1, 29.8, 27.7, 24.7, 24.0, 21.9, 21.9, 21.0, 20.9

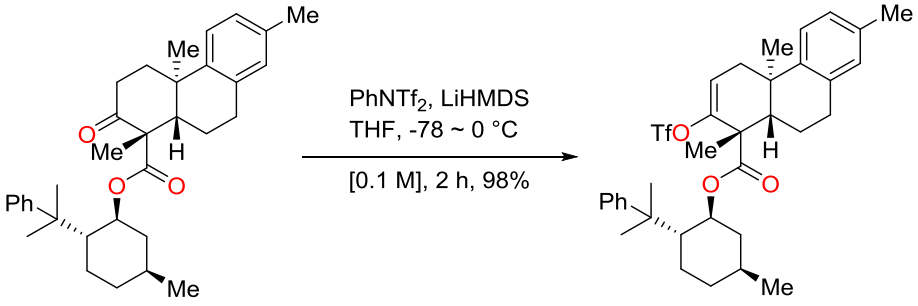
IR (neat): *v* 2953, 2921, 2869, 1600, 1456, 1377, 1316, 1235, 1191, 1091, 976, 953,

846, 815, 765, 700, 563 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{34}H_{44}NaO_3^+$ $[M+Na]^+$ 523.3183, found 523.3185

$[\alpha]_D^{22}$: -14.6 (*c* = 1.7, DCM)

2.6. Procedure for the synthesis of compound **13**

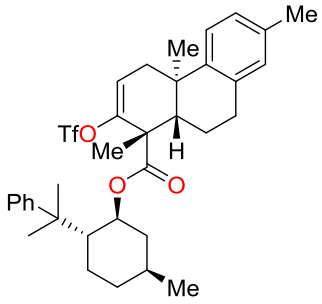


7 **13**

In the glovebox, a heat-gun-dried 50 mL flask was charged with a magnetic stir bar and LiHMDS (421 mg, 2.44 mmol, 1.2 eq.). The flask was fitted with a rubber septum and taken out. Then dry THF (10 mL) was added via a syringe. The reaction was cooled to -78 ºC and maintained for 0.5 h. A solution of **7** (1.02 g, 2.03 mmol, 1.0 eq.) in dry THF (5 mL) was added slowly via a syringe over 4 min, and the reaction mixture was stirred at 0 ºC for 0.5 h before cooling to -78 ºC for another 0.5 h. Then a solution of $PhNTf_2$ in dry THF (5 mL) was added slowly via a syringe over 4 min. The resulting mixture was stirred at room temperature for 2 h before quenched by pouring into saturated NH_4Cl solution (60 mL). The organic layer was separated, and the aqueous layer was extracted by ethyl acetate (3 × 50 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (200 ~ 300 mesh) using methyl *tert*-butyl ether/petroleum ether 1:60 as eluent to give **13** as a white amorphous solid (1.28 g, 98% yield)

Compound 13:

(1*S*,2*R*,5*S*)-5-methyl-2-(2-phenylpropan-2-yl)cyclohexyl (1*S*,4a*R*,10a*S*)-1,4a,7-trimethyl-2-(((trifluoromethyl)sulfonyl)oxy)-1,4,4a,9,10,10a-hexahydrophenanthrene-1-carboxylate



Physical state: white amorphous solid

TLC (ethyl acetate/petroleum ether 1:20): R_f 0.7 (UV, I_2, gray stain, phosphomolybdic acid)

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36 – 7.28 (m, 4H), 7.18 (tt, *J* = 5.6, 2.6 Hz, 1H), 7.14 (d, *J* = 8.1 Hz, 1H), 7.01 (dd, *J* = 8.2, 1.9 Hz, 1H), 6.93 – 6.88 (m, 1H), 5.91 (dd, *J* = 6.4, 2.2 Hz, 1H), 5.01 (td, *J* = 10.6, 4.3 Hz, 1H), 2.98 – 2.88 (m, 1H), 2.77 (dt, *J* = 16.8, 5.4 Hz, 2H), 2.36 – 2.25 (m, 4H), 2.20 – 2.11 (m, 1H), 2.05 (tdd, *J* = 16.1, 8.1, 3.5 Hz, 2H), 1.89 – 1.75 (m, 2H), 1.57 – 1.49 (m, 1H), 1.42 (t, *J* = 4.7 Hz, 1H), 1.39 (s, 3H), 1.34 (s, 3H), 1.30 (s, 3H), 1.26 (s, 3H), 1.06 – 0.95 (m, 2H), 0.91 – 0.84 (m, 2H), 0.84 – 0.78 (m, 3H), 0.75 (dd, *J* = 12.7, 3.4 Hz, 1H).

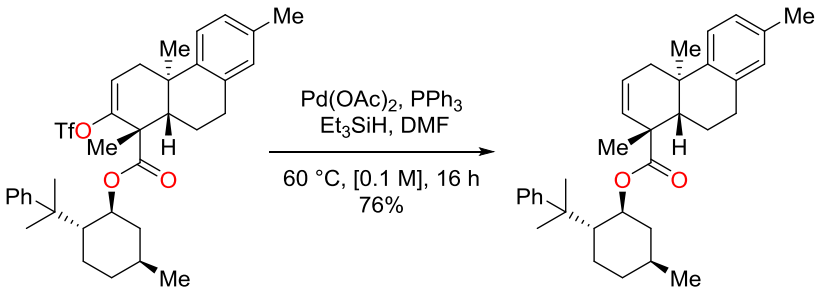
^{13}C NMR (101 MHz, $CDCl_3$): δ 171.7, 150.8, 150.0, 142.8, 135.7, 134.6, 129.6, 128.3, 127.5, 126.1, 125.8, 125.6, 120.1, 116.9, 77.5, 52.0, 49.9, 49.6, 42.0, 40.4, 39.0, 36.7, 34.5, 31.6, 31.5, 29.4, 27.6, 27.1, 25.2, 24.7, 22.9, 21.9, 21.7, 20.9.

IR (neat): *v* 2922, 1719, 1414, 1243, 1207, 1142, 1082, 1031, 1004, 894, 814, 764, 737, 700, 622, 562 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{35}H_{43}F_3NaO_5S^+$ $[M+Na]^+$ 655.2676, found 655.2673

$[\alpha]_D^{22}$: -74.5 (*c* = 2.2, DCM)

2.7. Procedure for the synthesis of compound **14**



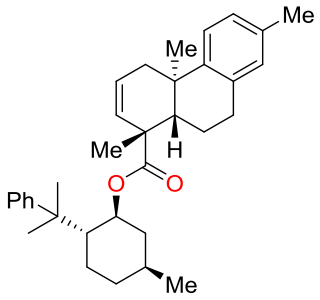
13 **14**

In the glove box, to an oven-dried 50 mL flask was equipped with a magnetic stir bar, **13** (921 mg, 1.45 mmol, 1.0 eq.), $Pd(OAc)_2$ (49 mg, 0.29 mmol, 0.2 eq.) and PPh_3 (154 mg, 0.58 mmol, 0.4 eq.) in sequence. Then the flask was fitted with a rubber

septum and taken out. Dry DMF (15 mL) was added under argon atmosphere at room temperature, followed by a quick addition of Et_3SiH over 30 seconds. The reaction mixture was stirred at 60 °C for 16 h. Upon completion of the reaction, saturated NH_4Cl solution (15 mL) and deionized water (15 mL) was added in sequence. The organic layer was separated, and the aqueous layer was extracted by ethyl acetate (3 × 50 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (200 ~ 300 mesh) using methyl *tert*-butyl ether/petroleum ether 1:80 as eluent to give **14** as a white amorphous solid (537 mg, 76% yield)

Compound 14:

(1*S*,2*R*,5*S*)-5-methyl-2-(2-phenylpropan-2-yl)cyclohexyl (1*R*,4a*R*,10a*S*)-1,4a,7-trimethyl-1,4,4a,9,10,10a-hexahydrophenanthrene-1-carboxylate



Physical state: white amorphous solid

TLC (methyl *tert*-butyl/petroleum ether 1:20): R_f 0.7 (UV, I_2, gray stain, phosphomolybdic acid)

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30 (d, *J* = 4.2 Hz, 4H), 7.21 – 7.12 (m, 2H), 7.02 – 6.95 (m, 1H), 6.89 (d, *J* = 1.7 Hz, 1H), 5.70 (d, *J* = 2.9 Hz, 2H), 4.86 (td, *J* = 10.6, 4.1 Hz, 1H), 2.88 (ddd, *J* = 16.4, 4.5, 2.3 Hz, 1H), 2.72 (ddd, *J* = 16.9, 12.1, 6.0 Hz, 1H), 2.57 – 2.47 (m, 1H), 2.28 (s, 3H), 2.17 – 2.07 (m, 2H), 2.06 (d, *J* = 6.1 Hz, 1H), 1.97 (ddd, *J* = 12.1, 10.3, 3.5 Hz, 2H), 1.71 (dd, *J* = 11.5, 2.9 Hz, 1H), 1.53 – 1.43 (m, 1H), 1.41 (s, 3H), 1.30 (s, 3H), 1.24 (s, 3H), 1.21 (s, 3H), 1.02 – 0.87 (m, 2H), 0.90 – 0.82 (m, 1H), 0.81 (d, *J* = 6.5 Hz, 3H), 0.73 (qd, *J* = 12.8, 2.8 Hz, 1H)

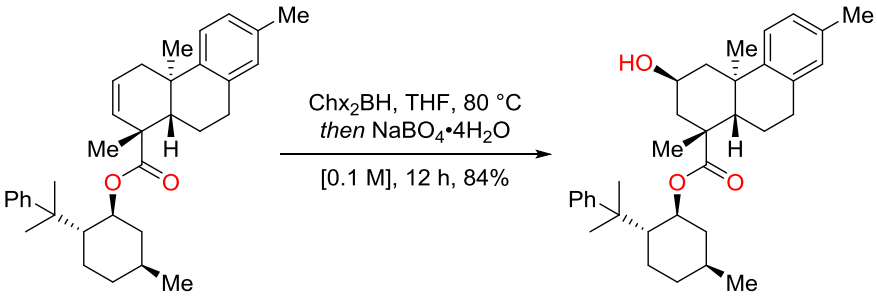
^{13}C NMR (101 MHz, $CDCl_3$): δ 175.2, 151.1, 144.2, 135.6, 135.0, 131.9, 129.6, 128.2, 127.1, 126.6, 125.9, 125.5, 124.8, 75.9, 50.7, 50.4, 45.5, 41.8, 41.0, 40.5, 36.8, 34.7, 32.2, 31.5, 30.8, 27.8, 27.7, 27.1, 24.7, 23.8, 21.9, 21.7, 21.0

IR (neat): *v* 3026, 2956, 2920, 2870, 1600, 1496, 1455, 1373, 1266, 1192, 1108, 1092, 979, 959, 914, 763, 741, 722, 700, 560 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{34}H_{44}NaO_2^+$ $[M+Na]^+$ 507.3234, found 507.3233

$[\alpha]_D^{22}$: - 110.9 (*c* = 0.4, DCM)

2.8. Procedure for the synthesis of compound **15**

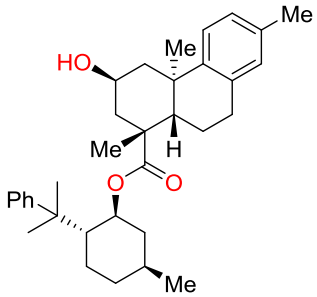


14 **15**

In the glove box, to a heat-gun-dried 50 mL flask was equipped with a magnetic stir bar and Chx_2BH (424 mg, 2.37 mmol, 2.5 eq.). The flask was fitted with a rubber septum and taken out. Dry THF (8 mL) was added under argon atmosphere at room temperature. Then **14** (460 mg, 0.95 mmol, 1.0 eq.) in dry THF (4 mL) was added dropwise over 1 min. The reaction mixture was stirred at 80 °C for 12 h. Then the flask was cooled to 0 °C and maintained for 0.5 h. The mixture was charged with $NaBO_4•4H_2O$ (730 mg, 4.75 mmol, 5.0 eq.) in one portion, followed by dropwise addition of deionized water (8 mL) over 2 min. The resulting mixture was stirred at room temperature for 2 h. Then the organic layer was separated, and the aqueous layer was extracted by ethyl acetate (3 × 40 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (200 ~ 300 mesh) using ethyl acetate/petroleum ether 1:20 as eluent to give **15** as a white amorphous solid (401 mg, 84% yield)

Compound 15:

(1*S*,2*R*,5*S*)-5-methyl-2-(2-phenylpropan-2-yl)cyclohexyl (1*R*,3*S*,4a*R*,10a*S*)-3-hydroxy-1,4a,7-trimethyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene-1-carboxylate



Physical state: white amorphous solid

TLC (ethyl acetate/petroleum ether 1:20): R_f 0.3 (UV, I_2, teal stain, *p*-anisaldehyde)

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 – 7.27 (m, 4H), 7.18 (dq, *J* = 8.4, 2.8 Hz, 2H), 6.97 (dd, *J* = 8.1, 2.0 Hz, 1H), 6.89 (d, *J* = 2.0 Hz, 1H), 4.96 (td, *J* = 10.6, 4.3 Hz, 1H), 4.31 (q, *J* = 9.3 Hz, 1H), 2.96 – 2.86 (m, 1H), 2.77 (ddd, *J* = 17.4, 12.5, 6.4 Hz, 1H), 2.56 (dddd, *J* = 29.0, 12.6, 4.4, 2.1 Hz, 2H), 2.28 (s, 3H), 2.11 – 1.84 (m, 3H), 1.78 – 1.60 (m, 1H), 1.54 – 1.44 (m, 2H), 1.39 (s, 3H), 1.37 – 1.28 (m, 2H), 1.26 (s, 3H), 1.22 (s, 3H), 1.18 (d, *J* = 20.9 Hz, 1H), 1.13 (s, 3H), 1.07 – 1.01 (m, 1H), 0.94 (dddd, *J* = 16.5, 12.1, 6.9, 3.9 Hz, 2H), 0.79 (d, *J* = 6.5 Hz, 3H), 0.77 – 0.68 (m, 1H).

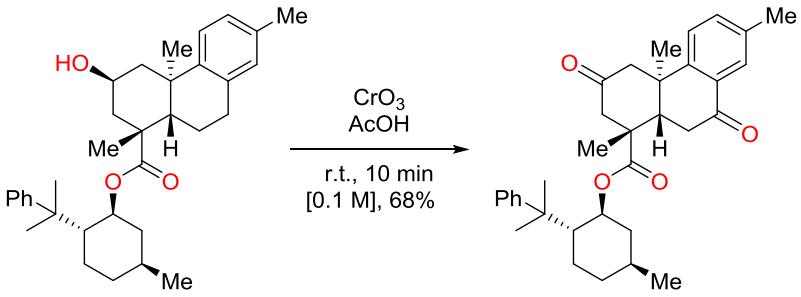
^{13}C NMR (101 MHz, $CDCl_3$): δ 176.6, 151.0, 144.7, 135.3, 134.8, 129.8, 128.3, 127.0, 125.9, 125.6, 125.2, 76.4, 65.1, 52.2, 50.1, 47.9, 47.2, 45.6, 42.1, 40.5, 39.6, 34.5, 31.9, 31.5, 30.2, 28.6, 27.8, 25.6, 24.7, 21.9, 20.9.

IR (neat): *v* 3364, 2955, 2922, 1600, 1455, 1373, 1225, 1185, 1151, 1126, 1091, 1028, 973, 816, 763, 700, 562 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{34}H_{46}NaO_3^+$ $[M+Na]^+$ 525.3339, found 525.3337

$[\alpha]_D^{22}$: - 30.1 (*c* = 0.9, DCM)

2.9. Procedure for the synthesis of compound **16**



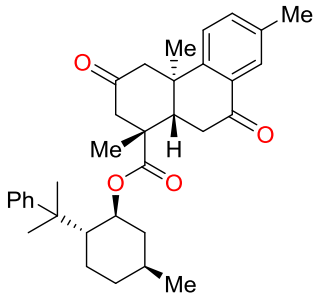
15 **16**

To an oven-dried 10 mL reaction tube was equipped with a magnetic stir bar, **15** (100.5 mg, 0.2 mmol, 1.0 eq.) and AcOH (2 mL). CrO_3 (powdered, 61.2 mg, 0.6 mmol, 3.0 eq.) was added slowly to the tube via a funnel over 2 min and the mixture was stirred at room temperature for another 5 min. Then another portion of CrO_3 (powdered, 61.2 mg, 0.6 mmol, 3.0 eq.) was added over 2 min. The mixture was stirred for another 5 min. Upon completion of the reaction, the mixture was added dropwise into a 1:1 saturated $Na_2S_2O_3$ and $NaHCO_3$ solution (10 mL) via a pipette. Ethyl acetate (5 mL) was added and the mixture was stirred for 10 min before the organic layers were separated, and the aqueous layer was extracted by ethyl acetate (3 × 10 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (200 ~ 300 mesh) using ethyl acetate/petroleum ether 1:6 as eluent to give **16** as a light yellow

amorphous solid (70 mg, 68% yield)

Compound 16:

(1*S*,2*R*,5*S*)-5-methyl-2-(2-phenylpropan-2-yl)cyclohexyl (1*R*,4a*R*,10a*S*)-1,4a,7-trimethyl-3,9-dioxo-1,2,3,4,4a,9,10,10a-octahydrophenanthrene-1-carboxylate



Physical state: light yellow amorphous solid

TLC (ethyl acetate/petroleum ether 1:4): R_f 0.4 (UV, I_2, gray stain, phosphomolybdic acid)

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (dd, *J* = 2.0, 0.9 Hz, 1H), 7.38 (ddd, *J* = 8.1, 2.2, 0.7 Hz, 1H), 7.31 (d, *J* = 4.6 Hz, 4H), 7.20 – 7.15 (m, 2H), 5.02 (td, *J* = 10.6, 4.5 Hz, 1H), 3.11 (dd, *J* = 13.9, 2.2 Hz, 1H), 3.04 – 2.95 (m, 3H), 2.60 – 2.46 (m, 2H), 2.37 (s, 3H), 2.15 – 2.03 (m, 2H), 1.98 – 1.90 (m, 1H), 1.55 – 1.48 (m, 1H), 1.47 – 1.35 (m, 1H), 1.33 (s, 3H), 1.25 (s, 1H), 1.24 (s, 3H), 1.22 (s, 3H), 1.16 (s, 3H), 1.07 – 0.92 (m, 2H), 0.83 – 0.71 (m, 1H), 0.79 (d, *J* = 6.5 Hz, 3H).

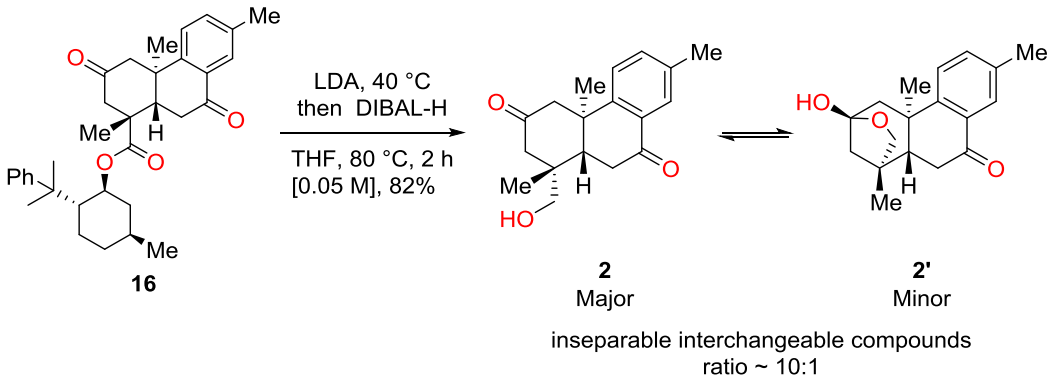
^{13}C NMR (101 MHz, $CDCl_3$): δ 206.1, 197.7, 174.7, 150.8, 150.1, 137.1, 135.7, 130.0, 128.4, 127.8, 125.8, 125.7, 124.3, 77.4, 77.3, 53.6, 51.6, 49.7, 49.4, 48.1, 42.1, 42.0, 40.4, 37.4, 34.3, 31.5, 29.3, 27.5, 27.0, 25.6, 24.1, 21.9, 20.9.

IR (neat): *v* 2956, 2923, 1721, 1685, 1612, 1461, 1411, 1378, 1294, 1181, 1121, 976, 954, 825, 765, 701 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{34}H_{42}NaO_4^+$ $[M+Na]^+$ 537.2975, found 537.2978

$[\alpha]_D^{22}$: - 13.7 (*c* = 0.3, DCM)

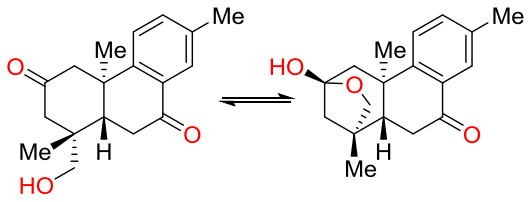
2.10. Procedure for the synthesis of compound **2**



To a heat-gun-dried reaction tube was equipped with a magnetic stir bar and rubber septum. The reaction was then added dry THF (1 mL), followed by addition of DIPA (18.7 mg, 26 μL, 0.180 mmol, 3.1 eq.) via a syringe under argon atmosphere. Then the tube was cooled to -20 °C and maintained for 15 minutes before dropwise addition of *n*-butyl lithium (2.5 M in hexane, 70 μL, 0.175 mmol, 3.0 eq.). The mixture was stirred at 0 °C for 0.5 h, then **16** (30.0 mg, 0.058 mmol, 1.0 eq.) in dry THF (0.5 mL) was added slowly over 1 min. The mixture was stirred at 40 °C for 0.5 h before dropwise addition of DIBAL-H (1.5 M in toluene, 470 μL, 0.700 mmol, 12.0 eq.) over 1 min and the resulting mixture was stirred at 80 °C for 2 h. Upon completion, the reaction mixture was added dropwise into a 2:1 saturated potassium sodium tartrate and NH_4Cl solution (15 mL) and the cloudy solution was stirred until clear (6 h). Then the organic layers were separated, and the aqueous layer was extracted by ethyl acetate (3 × 10 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified via flash column chromatography on silica gel (200 ~ 300 mesh) using ethyl acetate/petroleum ether 1:2 as eluent to give a white amorphous solid **2** (13.7 mg, 82% yield).

Notably, we observed ketal tautomerism in compound **2** where **2** and its hemiketal isomer **2'** were formed as a 10:1 ratio in pyridine-d_5. This ketal tautomerism is also observed in related literature [5].

Compound 2 (major):
19-hydroxy-15-devinyl-*ent*-pimar-8,11,13-triene-2,7-dione
Compound 2' (minor):
(2S,5*R*,5a*S*,11b*R*)-2-hydroxy-5,9,11b-trimethyl-1,4,5,5a,6,11b-hexahydro-2,5-methanonaphtho[1,2-*d*]oxepin-7(2*H*)-one



2
Major

2'
Minor

inseparable interchangeable compounds
ratio ~ 10:1

Physical state: white amorphous solid

TLC (ethyl acetate/petroleum ether 1:1): R_f 0.3 (UV, I_2, gray stain, *p*-anisaldehyde)

^{1}H NMR (major, 400 MHz, pyridine-d$_5$): δ 8.11 (d, *J* = 2.3 Hz, 1H), 7.37 (dd, *J* = 8.2, 2.1 Hz, 1H), 7.26 (d, *J* = 8.1 Hz, 1H), 6.59 (s, 1H), 3.88 (d, *J* = 2.5 Hz, 2H), 3.27 (dd, *J* = 18.0, 14.1 Hz, 1H), 3.23 (dd, *J* = 13.0, 2.2 Hz, 1H), 3.15 (dd, *J* = 18.0, 3.8 Hz, 1H), 2.94 (dd, *J* = 13.5, 2.2 Hz, 1H), 2.77 (dt, *J* = 13.1, 1.0 Hz, 1H), 2.56 (dd, *J* = 14.1, 3.8 Hz, 1H), 2.39 (d, *J* = 13.5 Hz, 1H), 2.28 (s, 3H), 1.40 (d, *J* = 0.8 Hz, 3H), 1.28 (s, 3H). (characterization data for minor isomer listed in **Table S3**)

^{1}H NMR (major, 400 MHz, MeOH-d$_4$): δ 7.80 (dd, *J* = 1.9, 0.9 Hz, 1H), 7.46 (ddd, *J* = 8.1, 2.1, 0.7 Hz, 1H), 7.31 (d, *J* = 8.1 Hz, 1H), 3.62 – 3.55 (m, 2H), 3.06 (dd, *J* = 13.1, 2.2 Hz, 1H), 2.99 (dd, *J* = 18.0, 14.1 Hz, 1H), 2.89 (dd, *J* = 18.1, 3.8 Hz, 1H), 2.80 (dt, *J* = 13.1, 1.0 Hz, 1H), 2.63 (dd, *J* = 14.1, 3.8 Hz, 1H), 2.57 (dd, *J* = 13.7, 2.2 Hz, 1H), 2.40 (dt, *J* = 13.7, 0.8 Hz, 1H), 2.37 (s, 3H), 1.31 (d, *J* = 0.9 Hz, 3H), 1.20 (s, 3H). (characterization data for minor isomer listed in **Table S4**)

^{13}C NMR (major, 101 MHz, pyridine-d$_5$): δ 209.6, 198.3, 152.3, 137.0, 135.8, 131.1, 128.3, 125.0, 65.7, 54.0, 51.4, 49.5, 43.8, 43.1, 37.3, 27.3, 25.6, 21.1. (characterization data for minor isomer listed in **Table S3**)

^{13}C NMR (major, 101 MHz, MeOH-d$_4$): δ 212.3, 200.3, 152.9, 137.9, 136.7, 131.1, 128.3, 125.3, 66.0, 54.2, 51.2, 50.0, 44.1, 43.7, 37.3, 26.8, 25.3, 20.8. (characterization data for minor isomer listed in **Table S4**)

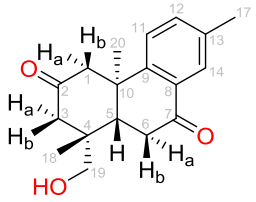
IR (neat): *v* 3452, 2959, 2925, 1707, 1680, 1611, 1492, 1454, 1410, 1289, 1201, 1186, 1043, 956, 827, 736, 603, 554 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{18}H_{22}NaO_3^+$ $[M+Na]^+$ 309.1461 found 309.1460

$[\alpha]_D^{25}$: - 36.0 (*c* = 0.1, MeOH)

Table S1

Table S1. Comparison of ^{1}H-NMR data for natural and synthetic **2**

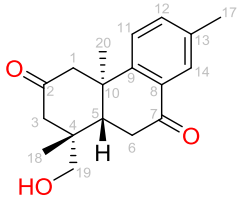


2

Proton #	Natural **2** ^{1}H-NMR, 400 MHz, pyridine-d_5 ^{1}H [δ, multi., *J* (Hz)]	Synthetic **2** ^{1}H-NMR, 400 MHz, pyridine-d_5 ^{1}H [δ, multi., *J* (Hz)]	Chemical Shift Difference, Δδ, ppm
1a	3.17 (m)	3.23 (dd, 13.0, 2.2)	+0.05
1b	2.73 (d, 13.3)	2.77 (dt, 13.1, 1.0)	+0.04
3a	2.92 (dd, 13.3, 2.4)	2.94 (13.5, 2.2)	+0.02
3b	2.35 (d, 13.3)	2.39 (d, 13.5)	+0.04
5	2.52 (dd, 14.0, 3.8)	2.56 (dd, 14.1, 3.8)	+0.04
6a	3.23 (m)	3.27 (dd, 18.0, 14.1)	+0.04
6b	3.12 (dd, 14.0, 3.8)	3.15 (dd, 18.0, 3.8)	+0.03
11a	7.22 (d, 8.0)	7.26 (d, 8.1)	+0.04
12a	7.33 (dd, 8.0, 1.2)	7.37 (dd, 8.2, 2.1)	+0.04
14	8.07 (d, 1.2)	8.11 (d, 2.3)	+0.04
17	2.24 (s, 3H)	2.28 (s, 3H)	+0.04
18	1.24 (s, 3H)	1.28 (s, 3H)	+0.04
19a	3.84 (brs)	3.88 (d, 2.5)	+0.04
19b	3.84 (brs)	3.88 (d, 2.5)	+0.04
20	1.36 (s, 3H)	1.40 (d, 0.8, 3H)	+0.04

Table S2

Table S2. Comparison of ^{13}C-NMR data for natural and synthetic **2**

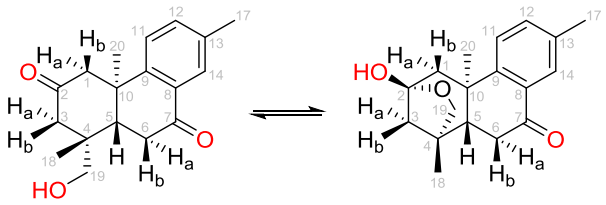


2

Carbon #	Natural **2** ^{13}C-NMR, 100 MHz, pyridine-d_5 ^{13}C (δ) ppm	Synthetic **2** ^{13}C -NMR, 101 MHz, pyridine-d_5 ^{13}C (δ) ppm	Chemical Shift Difference, Δδ, ppm
1	54.5	54.0	-0.5
2	210.0	209.6	-0.4
3	51.9	51.4	-0.5
4	44.3	43.8	-0.5
5	50.0	49.5	-0.5
6	37.8	37.3	-0.5
7	198.7	198.3	-0.4
8	131.6	131.1	-0.5
9	152.7	152.3	-0.4
10	43.5	43.1	-0.4
11	125.4	125.0	-0.4
12	135.9	135.8	-0.1
13	137.4	137.0	-0.4
14	128.7	128.3	-0.4
17	21.5	21.1	-0.4
18	27.8	27.3	-0.5
19	66.1	65.7	-0.4
20	26.0	25.6	-0.4

Table S3

Table S3. Comparison of ^{1}H-NMR and ^{13}C NMR data for **2** and **2'** in pyridine-d_5



2
Major

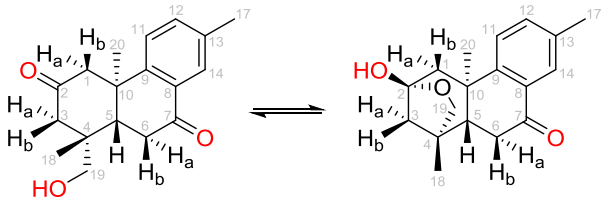
2'
Minor

inseparable interchangeable compounds
ratio ~ 12:1

Position #	**2**		**2'**	
	δ(H) [δ, multi., *J* (Hz)]	δ(C) [ppm]	δ(H) [δ, multi., *J* (Hz)]	δ(C) [ppm]
1a	3.15 (dd, 18.0, 3.8)	54.0	not determined	52.9
1b	2.77 (dt, 13.1, 1.0)		not determined	
2	-	209.6	-	107.1
3a	2.94 (dd, 13.5, 2.2)	51.4	not determined	49.0
3b	2.39 (d, 13.5)		not determined	
4	-	43.8	-	44.1
5	2.56 (dd, 14.1, 3.8)	49.5	not determined	49.0
6a	3.27 (dd, 18.0 14.1)	37.3	not determined	37.2
6b	3.23 (dd, 13.0, 2.2)		not determined	
7	-	198.3	-	199.4
8	-	131.1	-	132.0
9	-	152.3	-	154.9
10	-	43.0	-	39.5
11	7.26 (d, 8.1)	125.0	7.15 (d, 7.9)	not determined
12	7.37 (dd, 8.2, 2.1)	135.8	7.31 (dd, 8.0, 2.1)	135.1
13	-	137.0	-	136.1
14	8.11 (d, 2.3)	128.3	8.04 (d, 2.0)	128.8
17	2.28 (s, 3H)	21.1	2.27 (s, 3H)	20.8
18	1.28 (s, 3H)	27.3	0.91 (s, 3H)	30.4
19a	3.88 (d, 2.5)	65.6	4.03 (dd, 8.3, 1.2)	72.3
19b	3.88 (d, 2.5)		3.68 (dd, 8.3, 1.5)	
20	1.40 (d, 0.8, 3H)	25.6	1.51 (s, 3H)	25.6

Table S4

Table S4. Comparison of ^{1}H-NMR and ^{13}C NMR data for **2** and **2'** in MeOH-d_4



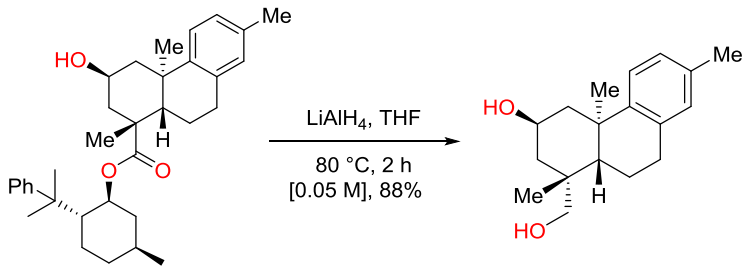
2
Major

2'
Minor

inseparable interchangeable compounds
ratio ~ 8:1

Position #	**2**		**2'**	
	δ(H) [δ, multi., *J* (Hz)]	δ(C) [ppm]	δ(H) [δ, multi., *J* (Hz)]	δ(C) [ppm]
1a	3.06 (dd, 13.1, 2.2)	54.2	not determined	52.3
1b	2.80 (dt, 13.1, 1.0)		2.25 (m)	
2	-	212.3	-	107.3
3a	2.57 (dd, 13.7, 2.2)	51.2	1.96 (dd, 11.0, 2.8)	48.4
3b	2.40 (dt, 13.7, 0.8)		1.73 (10.9, 1.2)	
4	-	44.1	-	44.6
5	2.63 (dd, 14.1, 3.8)	50.0	2.25 (m)	49.7
6a	2.99 (dd, 18.0, 14.1)	37.3	2.73 (d, 13.6)	37.3
6b	2.89 (dd, 18.1, 3.8)		2.69 (d 5.0)	
7	-	200.3	-	201.6
8	-	131.1	-	132.0
9	-	152.9	-	155.5
10	-	43.7	-	39.9
11	7.31 (d, 8.1)	125.3	7.17 (d, 7.9)	123.8
12	7.46 (ddd, 8.1, 2.1, 0.7)	136.7	7.41 (ddd, 8.0, 2.1, 0.8)	136.0
13	-	137.9	-	137.2
14	7.80 (dd, 1.9, 0.9)	128.3	7.71 (d, 2.0)	128.9
17	2.37 (s, 3H)	20.8	2.36 (s, 3H)	20.6
18	1.20 (s, 3H)	26.8	1.10 (s, 3H)	27.1
19a	3.59 (m)	66.0	4.02 (dd, 8.3, 1.3)	72.7
19b	3.59 (m)		3.63 (m)	
20	1.31 (d, 0.9, 3H)	25.3	1.37 (s, 3H)	25.3

2.11. Procedure for the synthesis of compound **1**

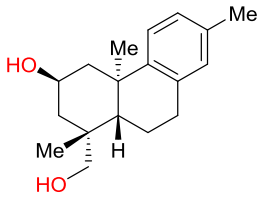


15 **1**

To a heat-gun-dried 10 mL reaction tube was charged with a magnetic stir bar, a rubber septum, **15** (25 mg, 0.05 mmol, 1.0 eq.) and dry THF (1.0 mL). Then $LiAlH_4$ solution (1.0 M in THF, 150 μL, 3.0 eq.) was added under argon atmosphere via a syringe dropwise at room temperature. The reaction mixture was stirred at 80 °C for 2 h. Upon completion, the reaction mixture was added dropwise into 2:1 potassium sodium tartrate and NH_4Cl solution (15 mL) using a pipette. The resultant cloudy solution was stirred at room temperature until clear (5 h). Then the organic layer was separated, and the aqueous layer was extracted by DCM (3 × 10 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography on silica gel (200 ~ 300 mesh) using DCM/MeOH 20:1 as eluent to give **1** as a white amorphous powder (12.0 mg, 88% yield)

Compound 1:

(1*R*,3*S*,4a*R*,10a*S*)-1-(hydroxymethyl)-1,4a,7-trimethyl-1,2,3,4,4a,9,10,10a-octahydrophenanthren-3-ol



Physical state: white amorphous powder

TLC (DCM/MeOH 20:1): R_f 0.3 (gray, phosphomolybdic acid)

^{1}H NMR (400 MHz, Methanol-d$_4$): δ 7.14 (d, *J* = 8.1 Hz, 1H), 6.91 (dd, *J* = 8.3, 2.0 Hz, 1H), 6.85 – 6.81 (m, 1H), 3.99 (tt, *J* = 11.6, 4.1 Hz, 1H), 3.75 (d, *J* = 11.1 Hz, 1H), 3.45 (dd, *J* = 11.2, 1.2 Hz, 1H), 3.37 (s, 1H), 2.90 (ddd, *J* = 17.3, 6.7, 1.8 Hz, 1H), 2.79 (ddd, *J* = 17.5, 11.5, 7.2 Hz, 1H), 2.62 (ddd, *J* = 12.1, 4.1, 2.2 Hz, 1H), 2.29 – 2.21 (m, 1H), 2.24 (s, 3H), 2.01 (ddt, *J* = 13.4, 7.3, 2.0 Hz, 1H), 1.73 (tdd, *J* = 13.1, 11.5, 6.7 Hz, 1H), 1.44 (dd, *J* = 12.8, 2.1 Hz, 1H), 1.28 (t, *J* = 11.3 Hz, 1H), 1.19 (s, 3H), 1.10 (s,

3H), 0.95 (ddd, J = 13.0, 11.8, 1.2 Hz, 1H)

^{13}C NMR (101 MHz, Methanol-d$_4$): δ 147.5, 135.8, 135.4, 130.5, 127.6, 125.1, 65.6, 65.5, 52.3, 49.0, 45.1, 41.2, 40.1, 31.8, 27.8, 27.1, 20.9, 20.0

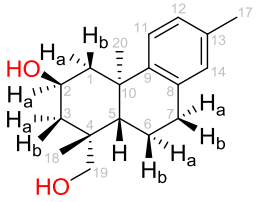
IR (neat): v 3338, 2924, 1454, 1433, 1262, 1037, 969, 814, 749, 670 cm^{-1}

HRMS (ESI-FTMS): *m/z* calcd for $C_{18}H_{26}NaO_2^+$ $[M+Na]^+$ 297.1825, found 297.1823

$[\alpha]_D^{25}$: - 83.7 (c = 0.1, MeOH)

Table S5

Table S5. Comparison of ^{1}H-NMR data for natural **1** and synthetic **1**



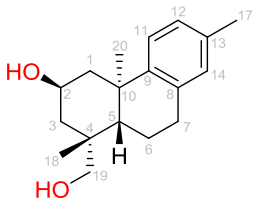
1

Proton #	Natural **1** ^{1}H-NMR, 400 MHz, Methanol-d_4 ^{1}H [δ, multi., *J* (Hz)]	Synthetic **1** ^{1}H-NMR, 400 MHz, Methanol-d_4 ^{1}H [δ, multi., *J* (Hz)]	Chemical Shift Difference, Δδ, ppm
1a	2.59 (brd, 11.7)	2.62 (ddd, 17.3 6.7 1.8)	+0.03
1b	1.25 (t, 11.7)	1.28 (t, 11.3)	+0.03
2a	3.96 (m)	3.99 (tt, 11.6, 4.1)	+0.03
3a	2.23 (m)	2.25 (m)	+0.02
3b	0.93 (m)	0.95 (ddd, 13.0, 11.8, 1.2)	+0.02
5	1.41 (dd, 12.8, 1.6)	1.44 (dd, 12.8, 2.1)	+0.03
6a	1.98 (m)	2.01 (ddt, 13.4, 7.3, 2.0)	+0.03
6b	1.70 (m)	1.73 (tdd, 13.1, 11.5, 6.7)	+0.03
7a	2.78 (m)*	2.90 (ddd, 17.3, 6.7, 1.8)	-
7b	2.78 (m)*	2.79 (ddd, 17.5, 11.5, 7.2)	-
11a	6.88 (d, 8.1)	6.91 (dd, 8.3, 2.0)	+0.03
12a	7.11 (d, 8.1)	7.14 (d, 8.1)	+0.03
14	6.81 (s)	6.83 (m)	+0.02
17	2.22 (s, 3H)	2.24 (s, 3H)	+0.02
18	1.07 (s, 3H)	1.10 (s, 3H)	+0.03
19a	3.72 (d, 11.2)	3.75 (d, 11.1)	+0.03
19b	3.42 (d, 11.2)	3.45 (dd, 11.2, 1.2)	+0.03
20	1.16 (s, 3H)	1.19 (s, 3H)	+0.03

*multiplet marked as “m” in original article, rendering it incomparable.

Table S6

Table S6. Comparison of ^{13}C-NMR data for **1**



1

Carbon #	Natural **1** ^{13}C-NMR, 100 MHz, Methanol-d_4 ^{13}C (δ) ppm	Synthetic **1** ^{13}C -NMR, 101 MHz, Methanol-d_4 ^{13}C (δ) ppm	Chemical Shift Difference, Δδ, ppm
1	48.9	49.0	+0.1
2	65.5	65.5	0
3	45.1	45.1	0
4	41.2	41.2	0
5	52.3	52.3	0
6	20.0	20.0	0
7	31.8	31.8	0
8	135.4	135.4	0
9	147.4	147.5	+0.1
10	40.1	40.1	0
11	125.1	125.1	0
12	127.6	127.6	0
13	135.8	135.8	0
14	130.5	130.5	0
17	20.9	20.9	0
18	27.8	27.8	0
19	65.6	65.6	0
20	27.1	27.1	0

3. Reference

[1] Ruairí, O. M.; Eoin, M. S. A Sequential Acyl Thiol–Ene and Thiolactonization Approach for the Synthesis of δ-Thiolactones. *Org. Lett.*, **2019**, 21 (9), 3460 – 3464.

[2] Steven, W. M. C.; Ruben, M. M.; Sebastián, G. Z.; Ryan, A. S. *Org. Lett.* **2016** 18 (11), 2620 – 2623.

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[4] a) Qingwei, Z.; Raju, M. M.; Laura, C.; Sophia, K.; Daniel, P.; Bruce, M. F.; and Barry, B. S.; Asymmetric induction in manganese(III)-based oxidative free-radical cyclizations of phenylmenthyl acetoacetates and 2,5-dimethylpyrrolidine acetoacetamides. *J. Org. Chem.*, **1993**, 58 (27), 7640 – 7651. b) Dan, Y.; Xiangyang, Y.; and Ming, X.; Enantioselective Total Synthesis of (−)-Triptolide, (−)-Triptonide, (+)-Triptophenolide, and (+)-Triptoquinonide. *J. Org. Chem.*, **2000**, 65 (7), 2208 – 2217.

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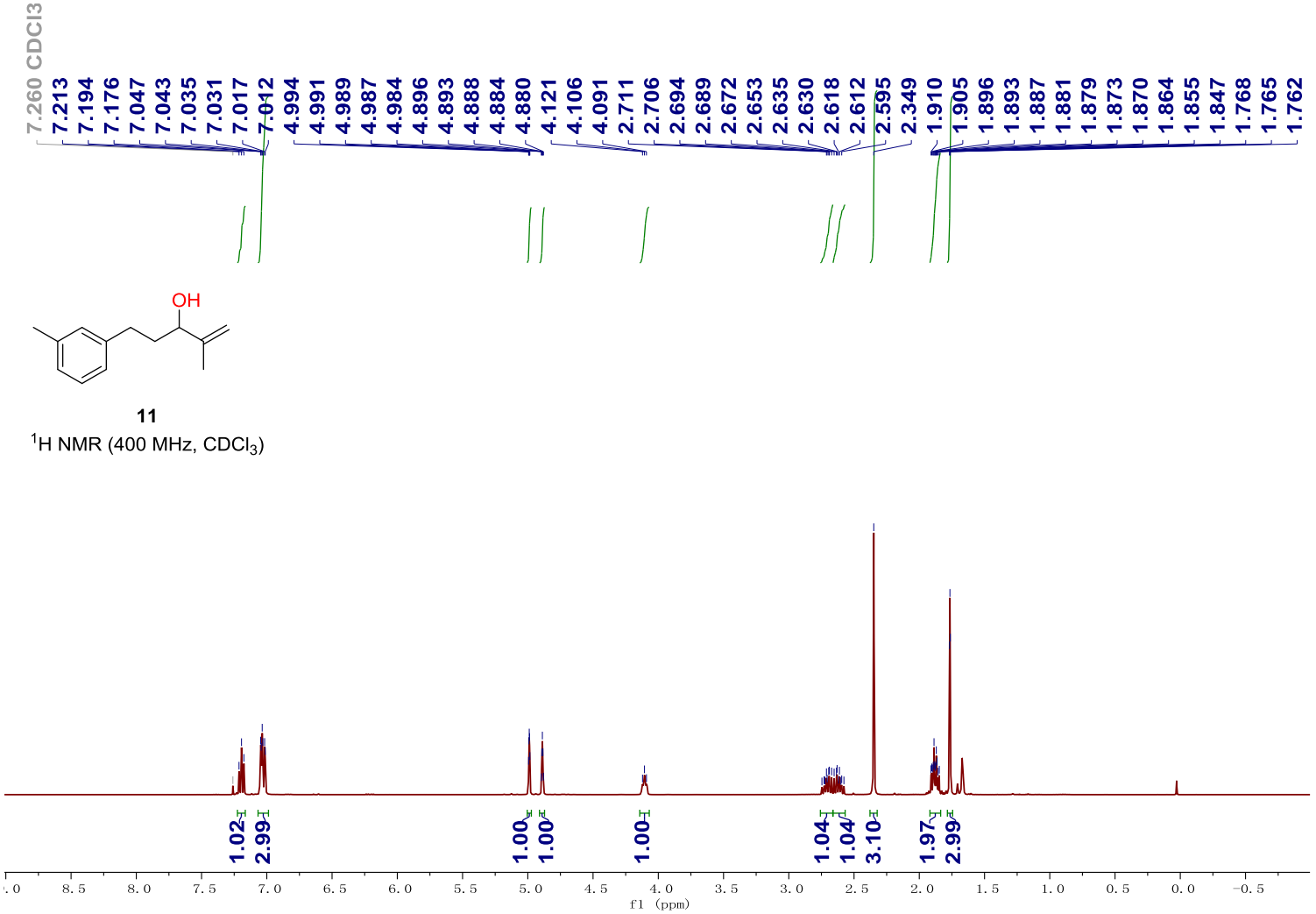
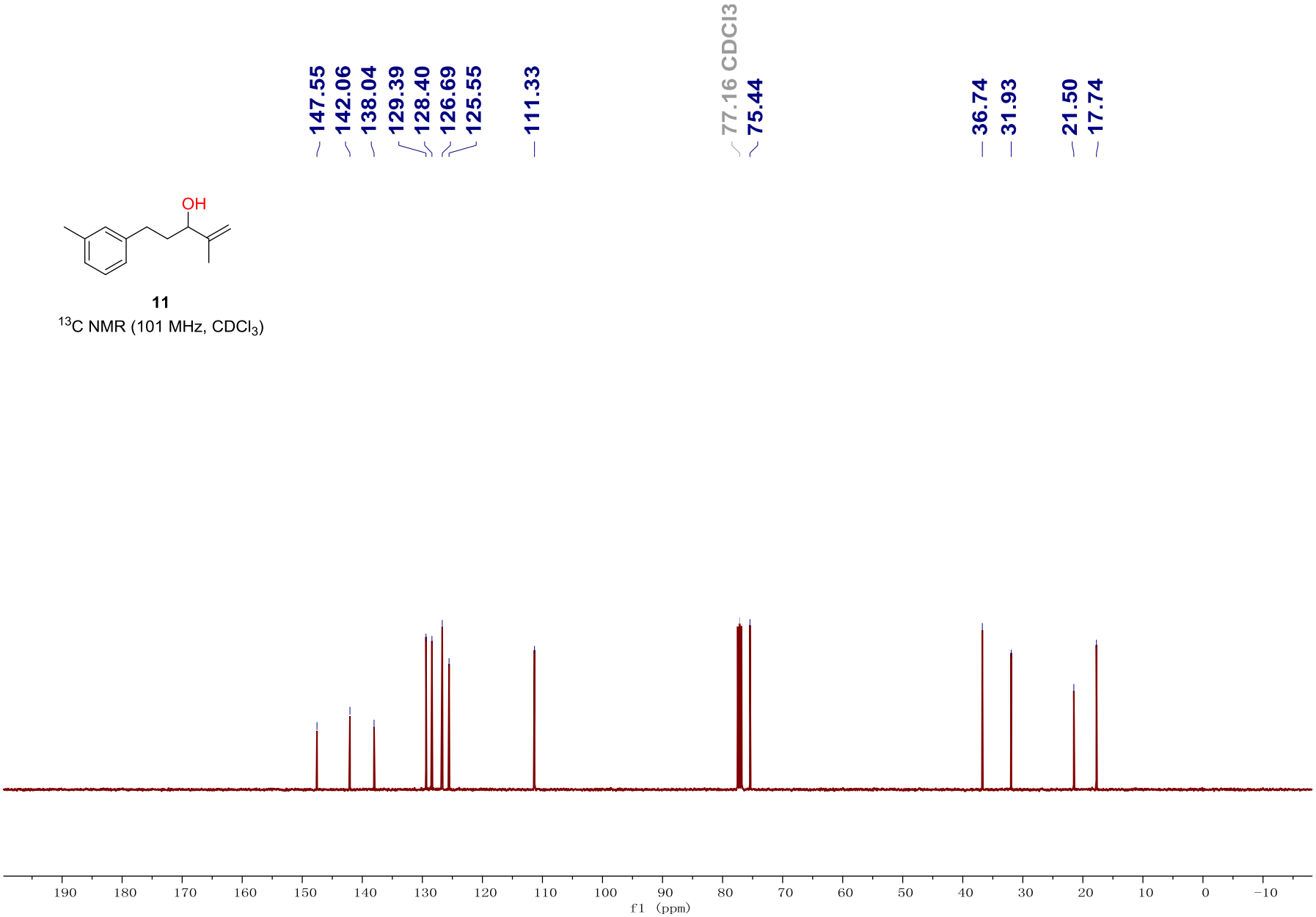
4. NMR Spectra

4.1. Spectra for known compound **11**

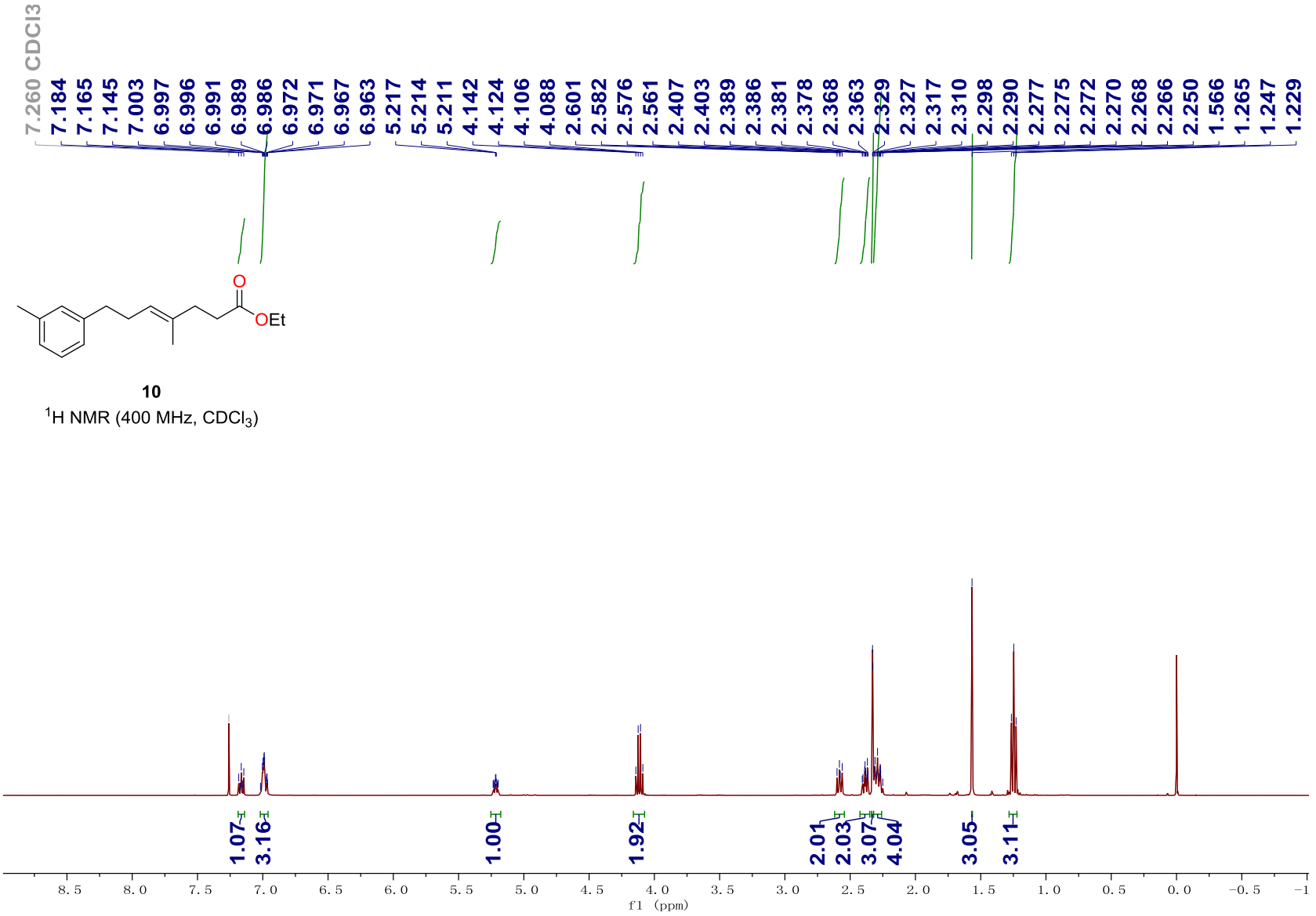




11

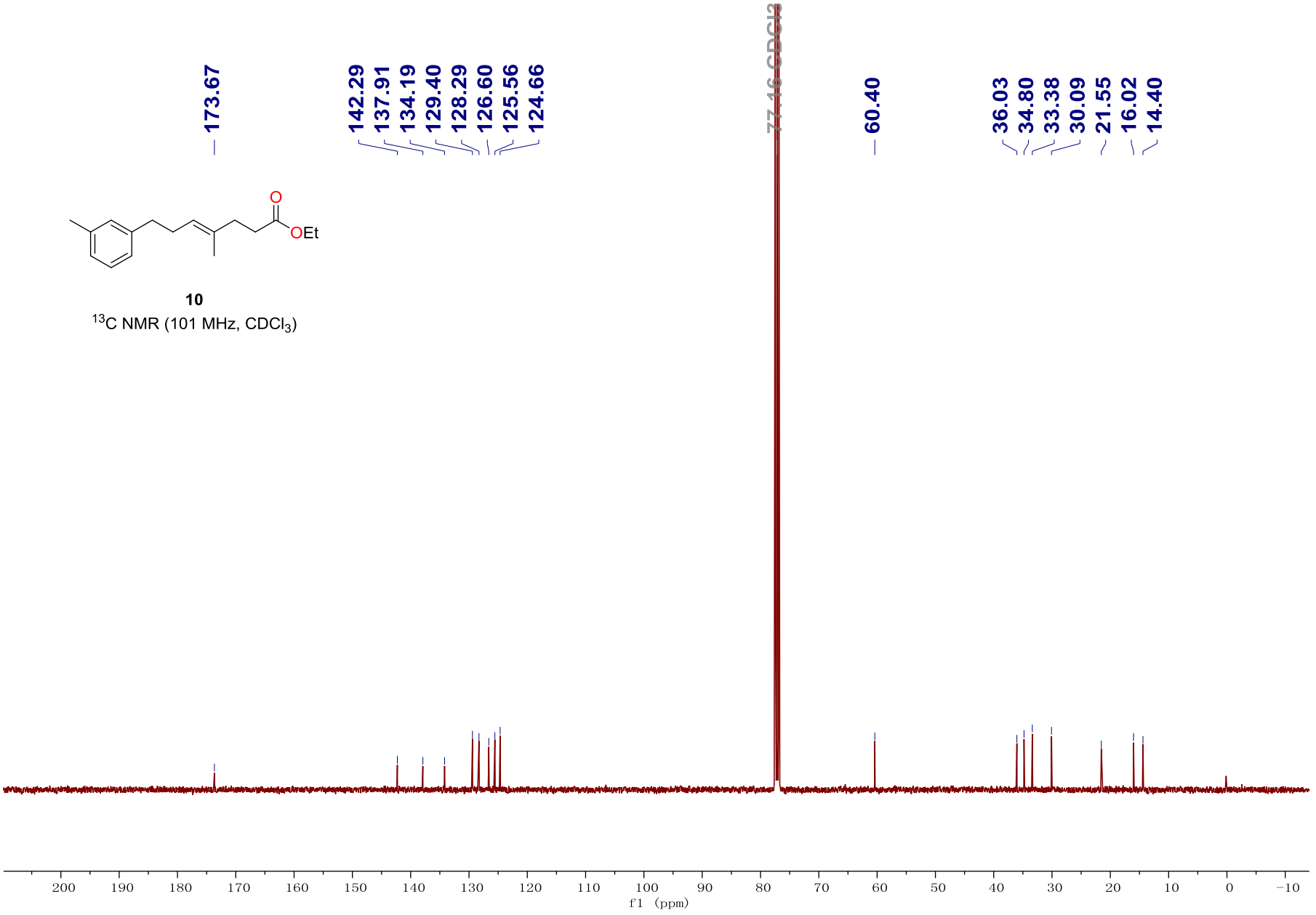
^{13}C NMR (101 MHz, $CDCl_3$)

4.2. Spectra for new compounds



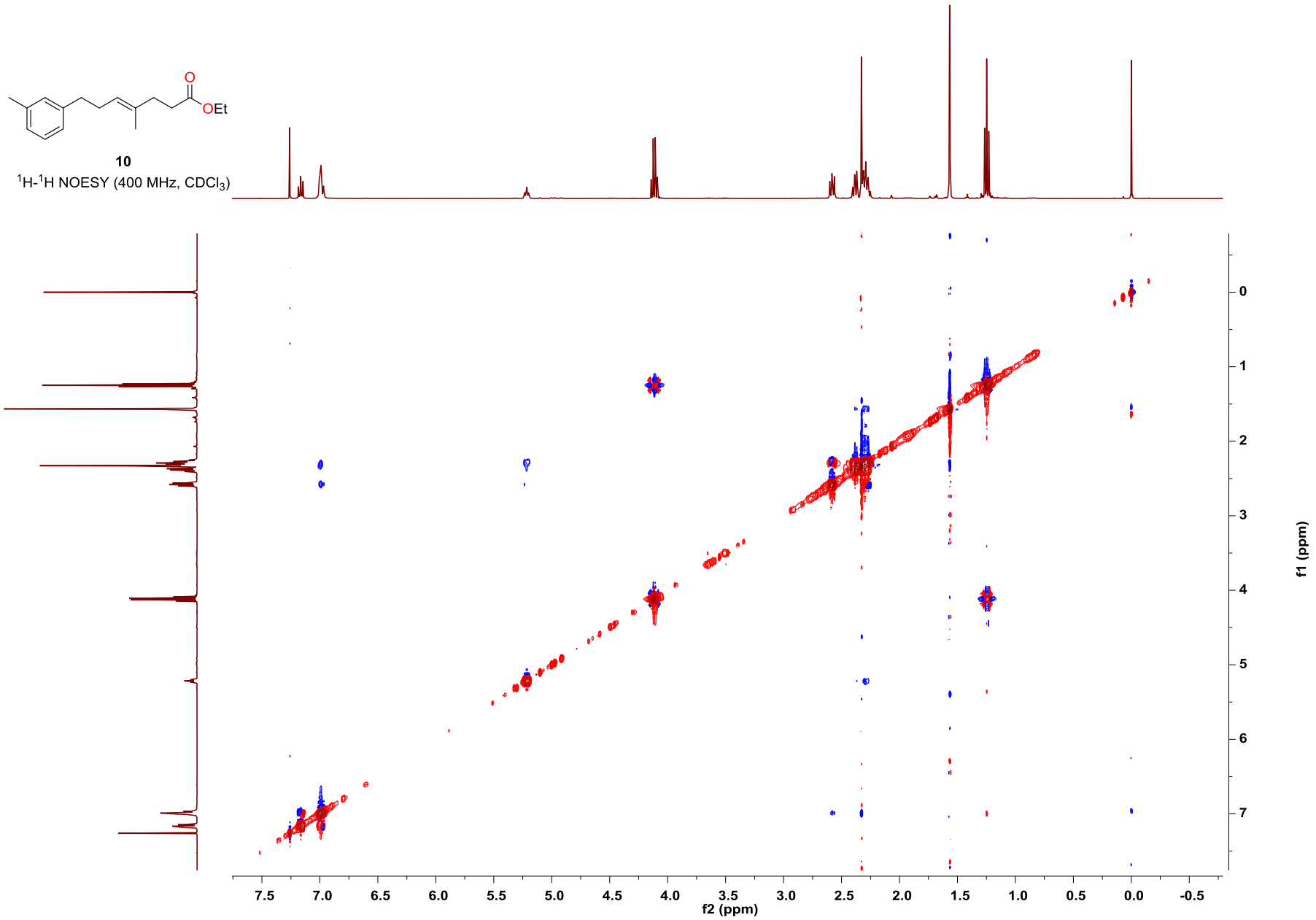
10

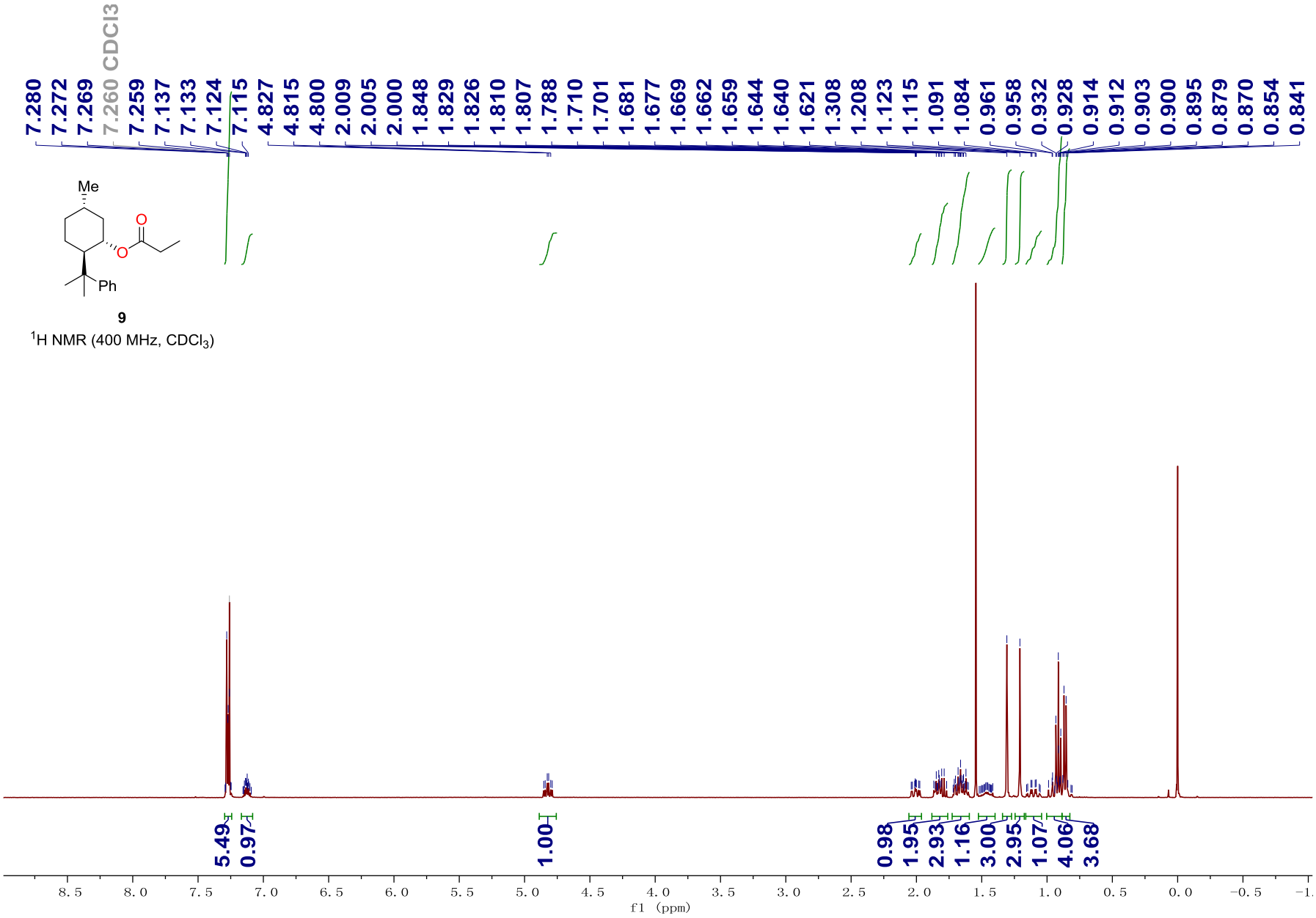
^{1}H NMR (400 MHz, $CDCl_3$)



10

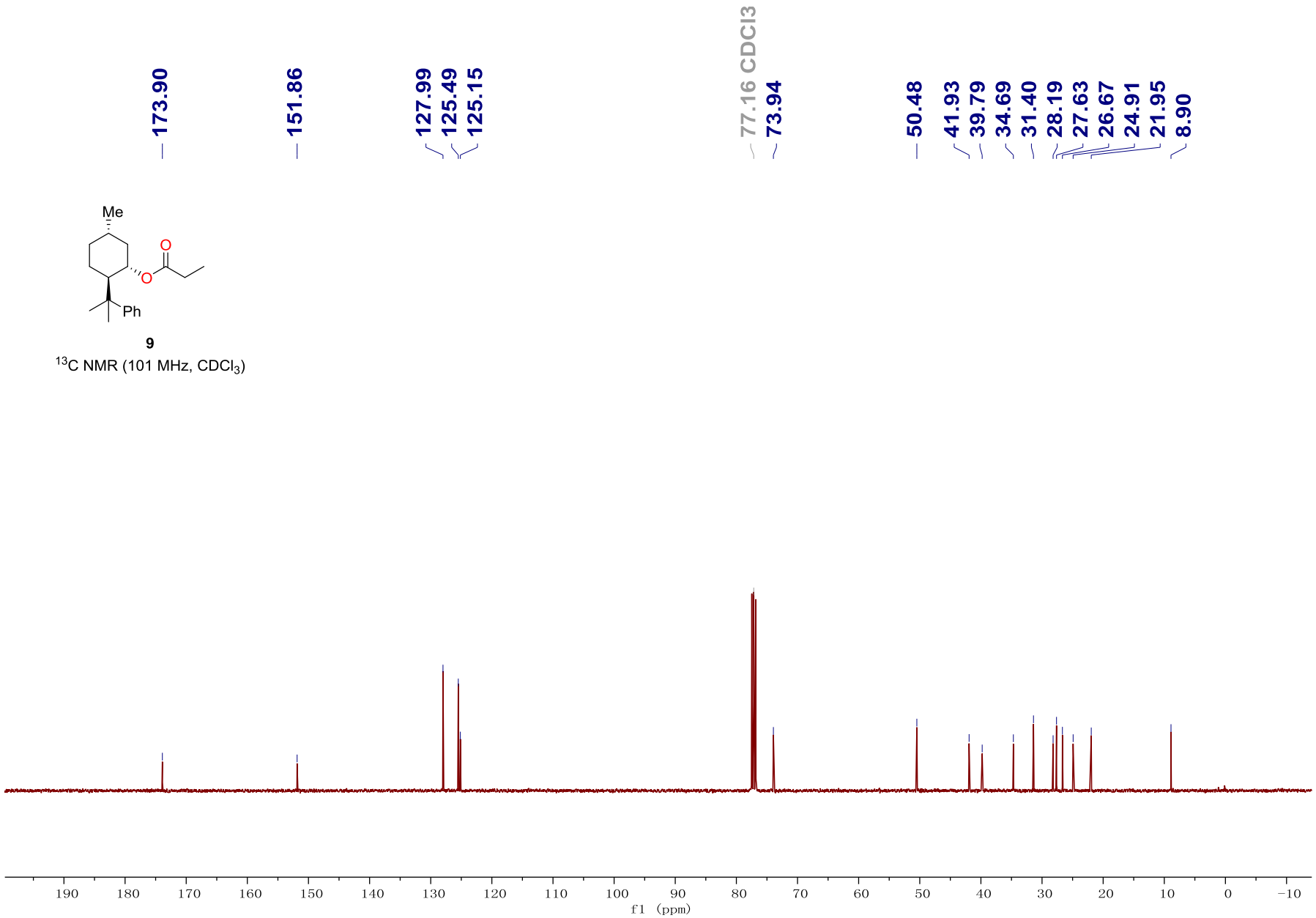
^{13}C NMR (101 MHz, $CDCl_3$)


O
OEt
10
^{1}H-^{1}H NOESY (400 MHz, CDCl$_3$)
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
f1 (ppm)



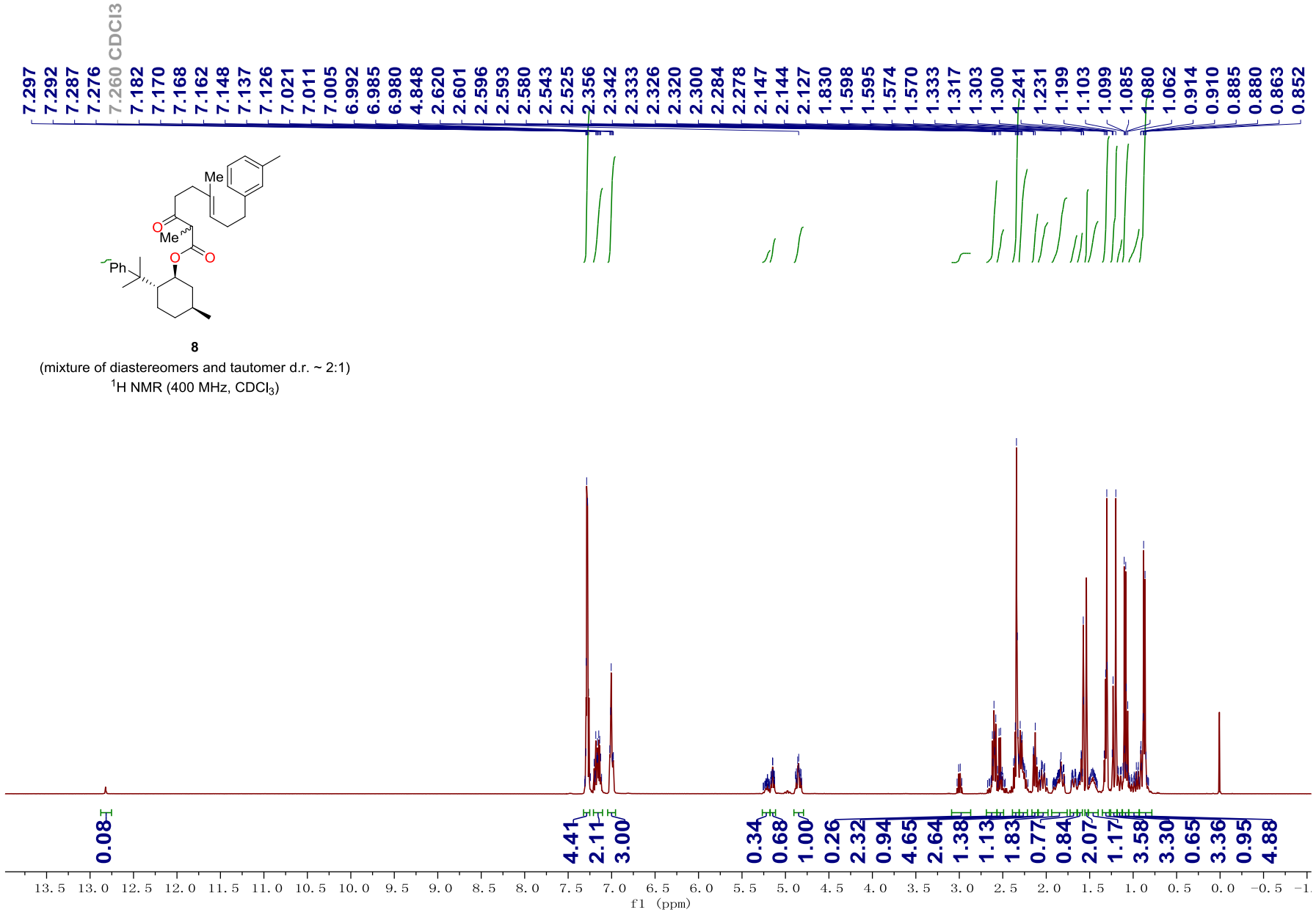
9

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



9

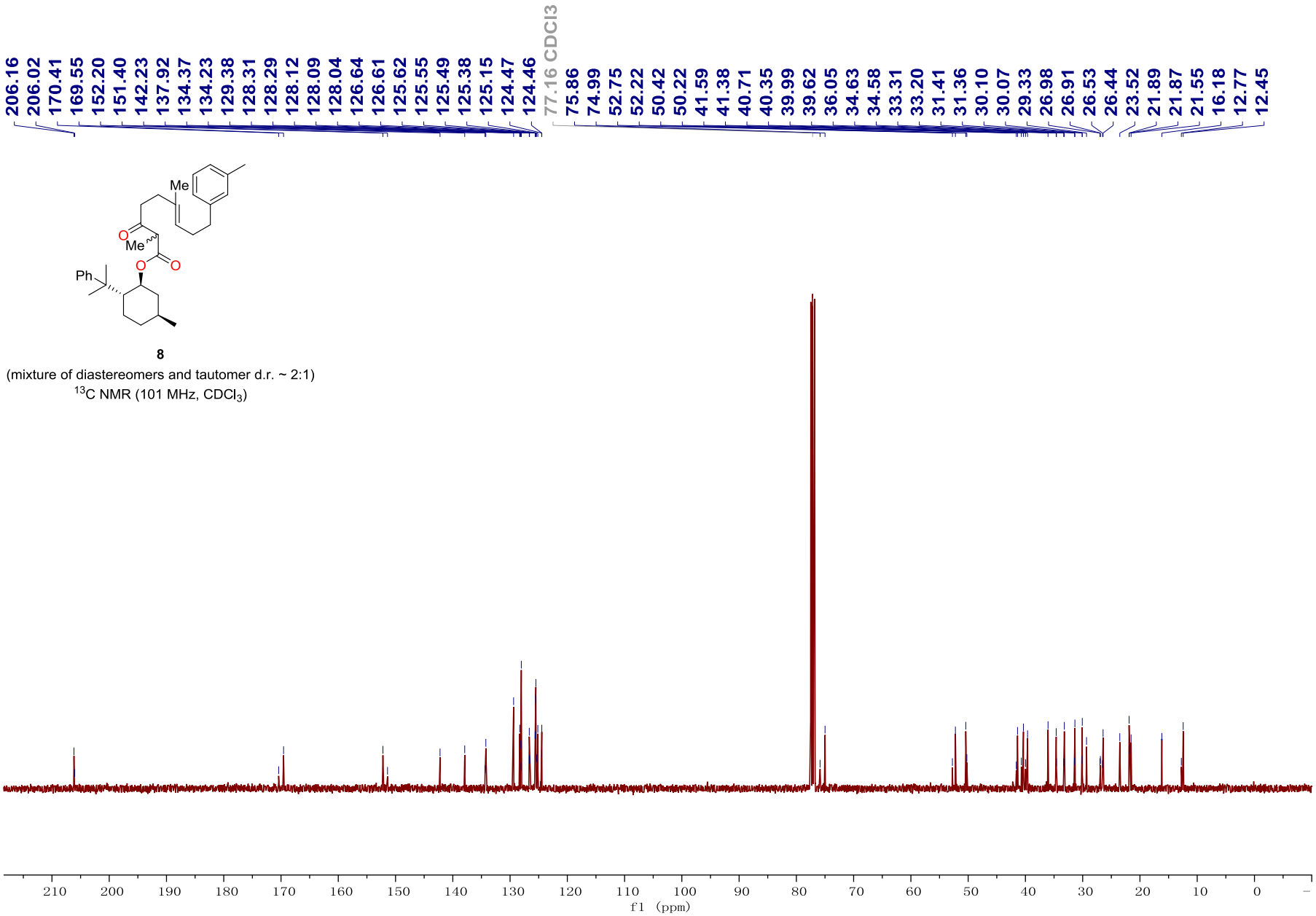
^{13}C NMR (101 MHz, $CDCl_3$)



8

(mixture of diastereomers and tautomer d.r. ~ 2:1)

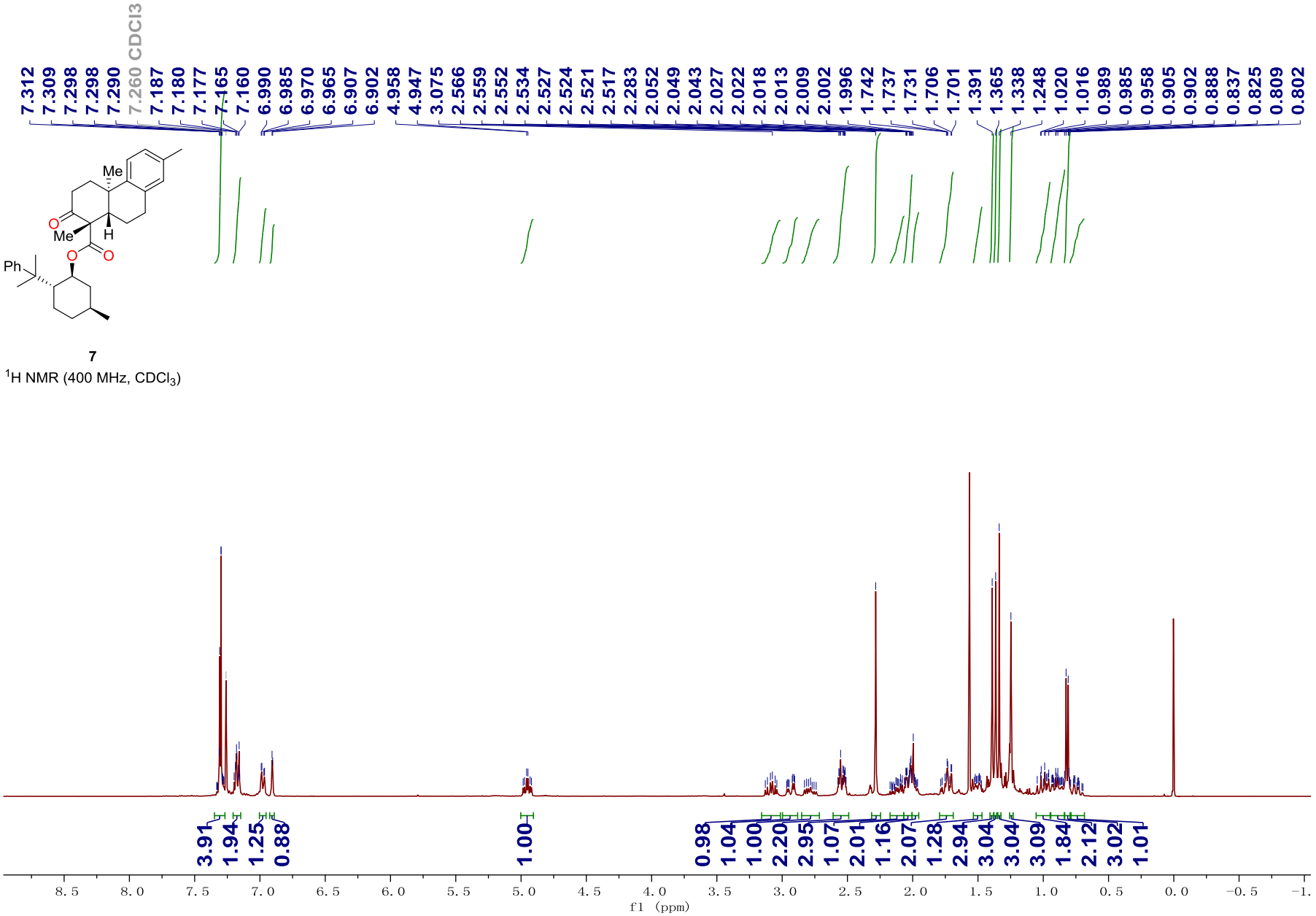
^{1}H NMR (400 MHz, $CDCl_3$)



8

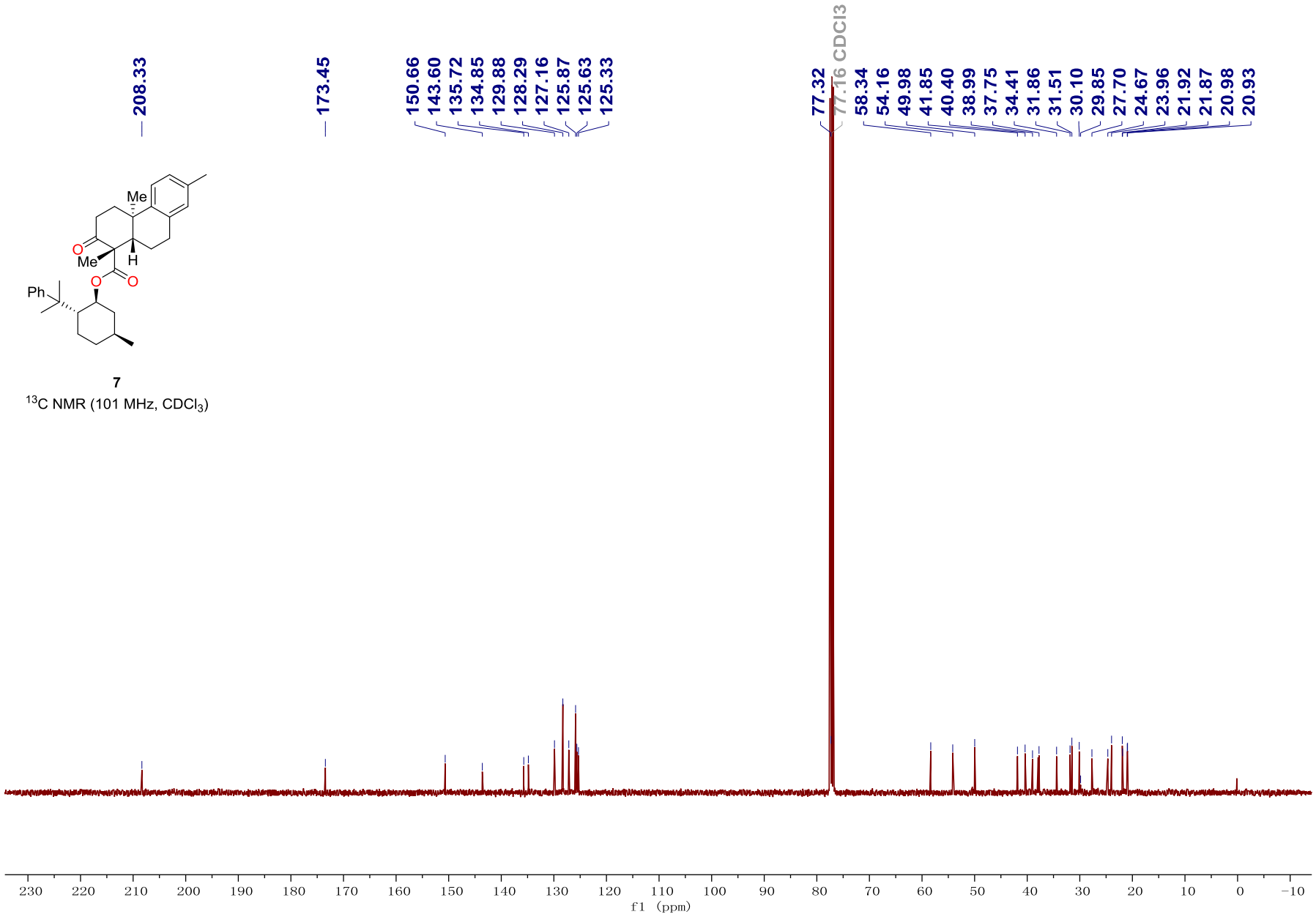
(mixture of diastereomers and tautomer d.r. ~ 2:1)

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



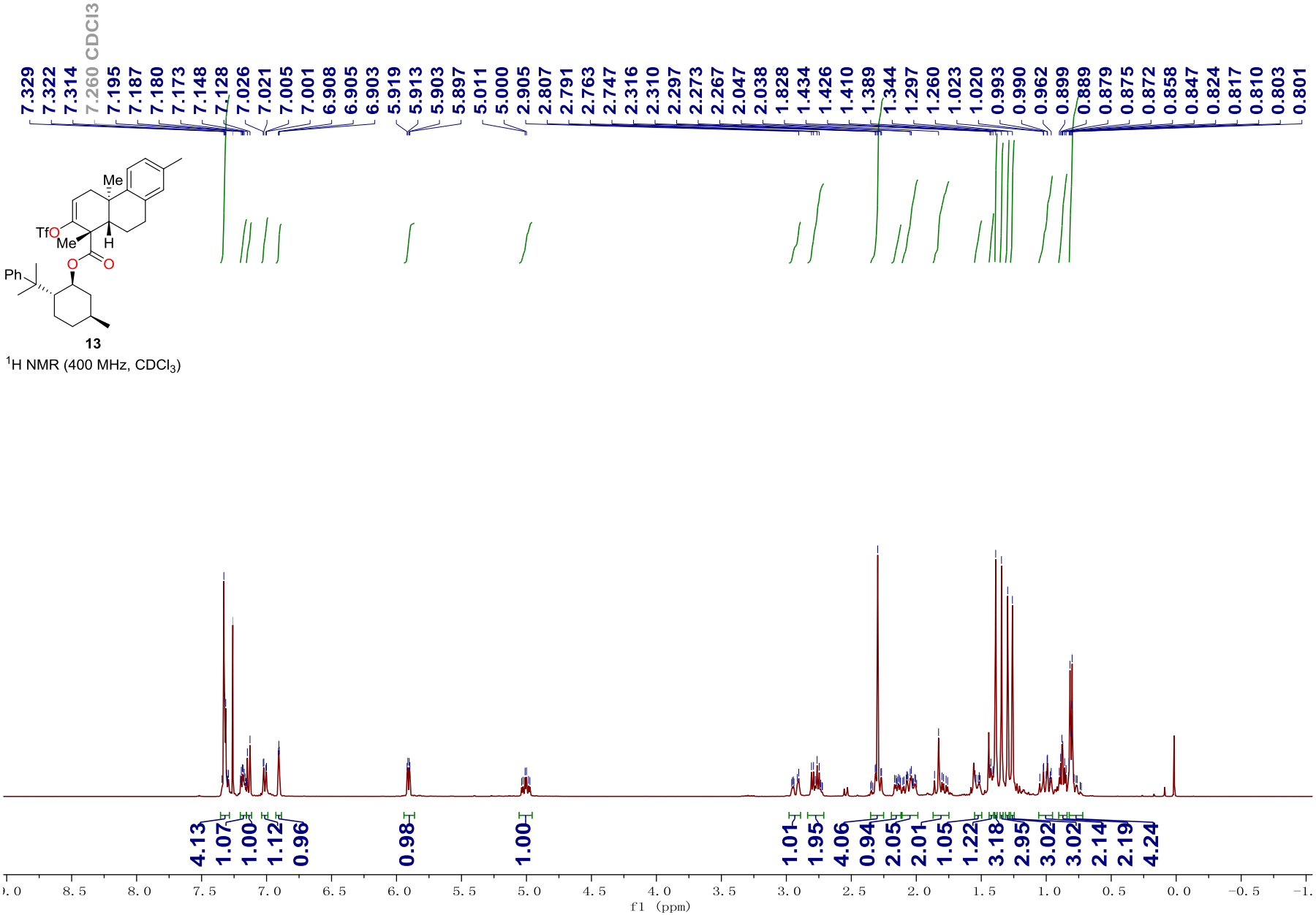
7

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



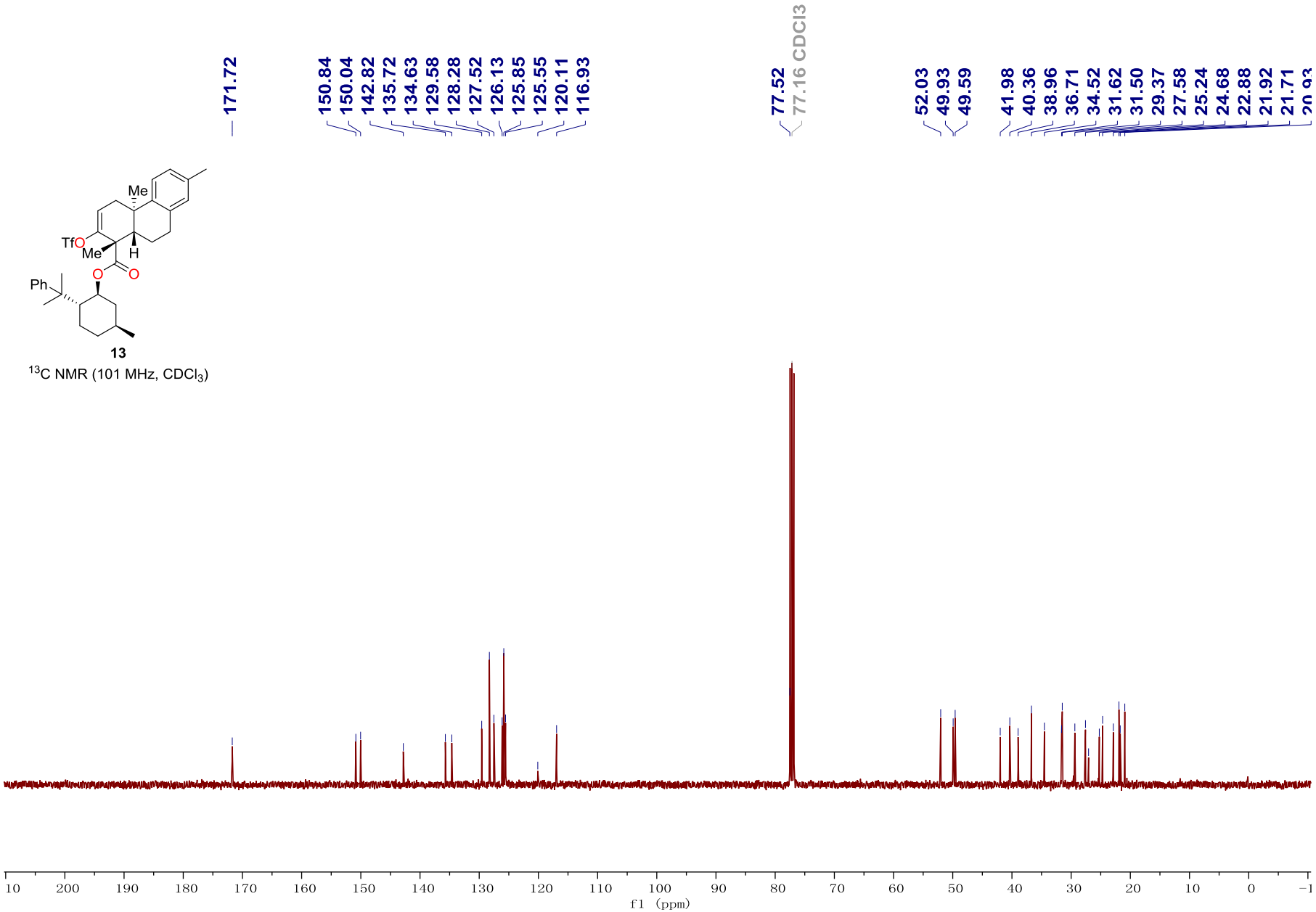
7

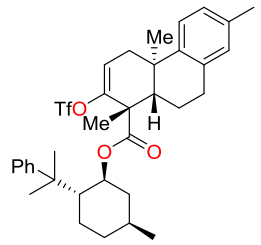
^{13}C NMR (101 MHz, $CDCl_3$)



13

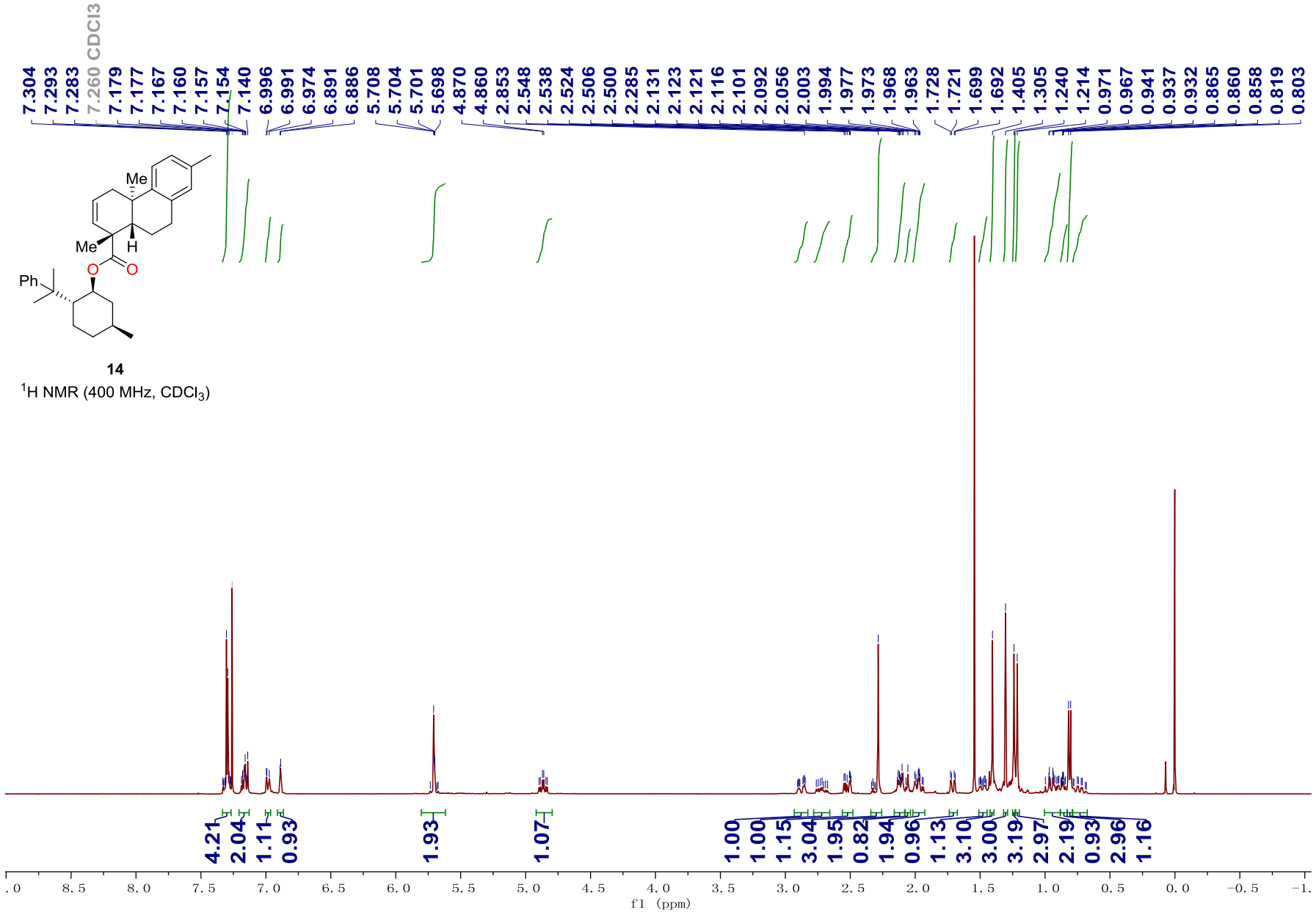
^{1}H NMR (400 MHz, $CDCl_3$)


171.72
150.84
150.04
142.82
135.72
134.63
129.58
128.28
127.52
126.13
125.85
125.55
120.11
116.93
77.52
77.16 CDCl3
52.03
49.93
49.59
41.98
40.36
38.96
36.71
34.52
31.62
31.50
29.37
27.58
25.24
24.68
22.88
21.92
21.71
Me
TfO
Me
H
O
O
Ph
13
13C NMR (101 MHz, CDCl3)
f1 (ppm)



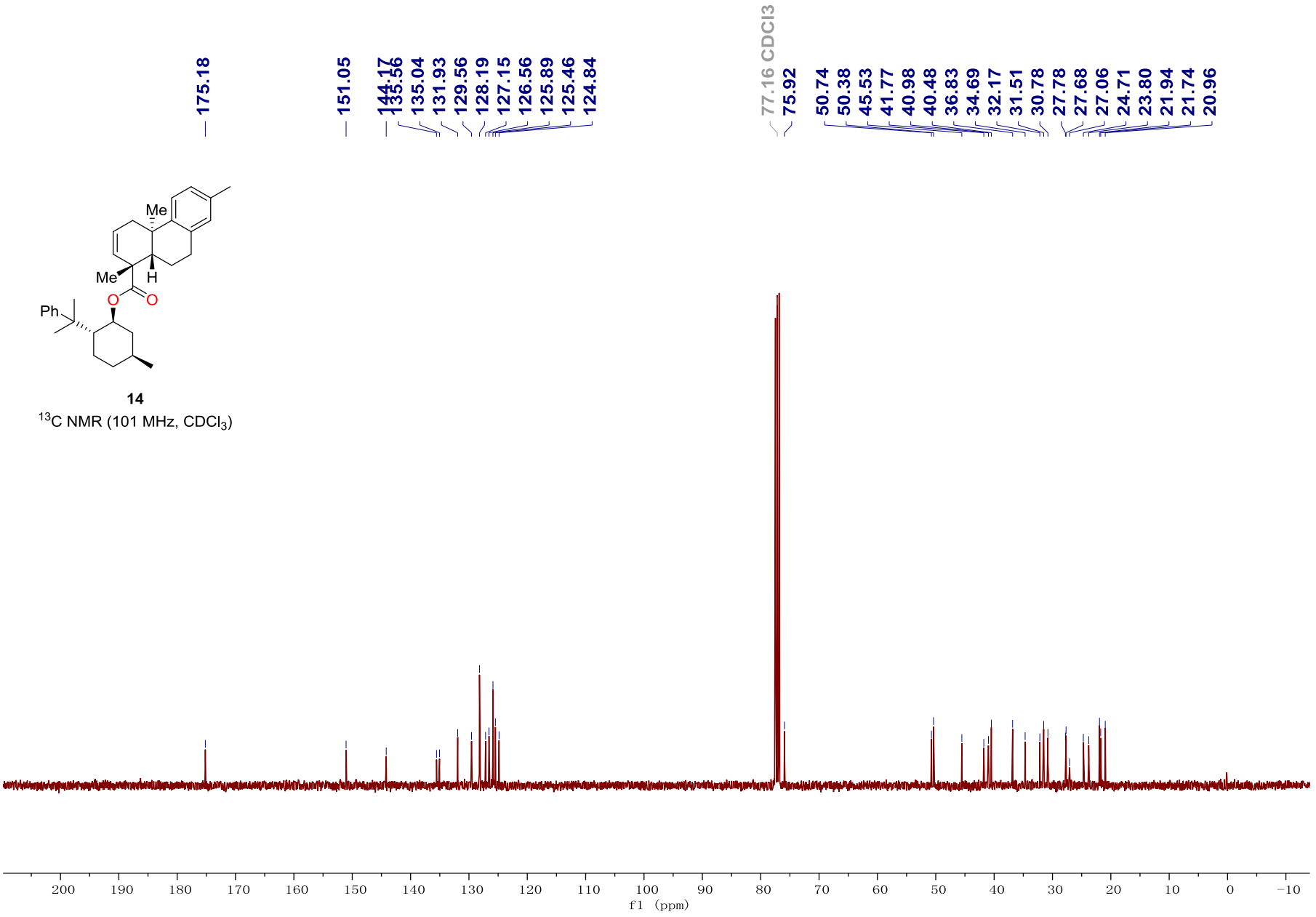
13

^{19}F NMR (376 MHz, $CDCl_3$)



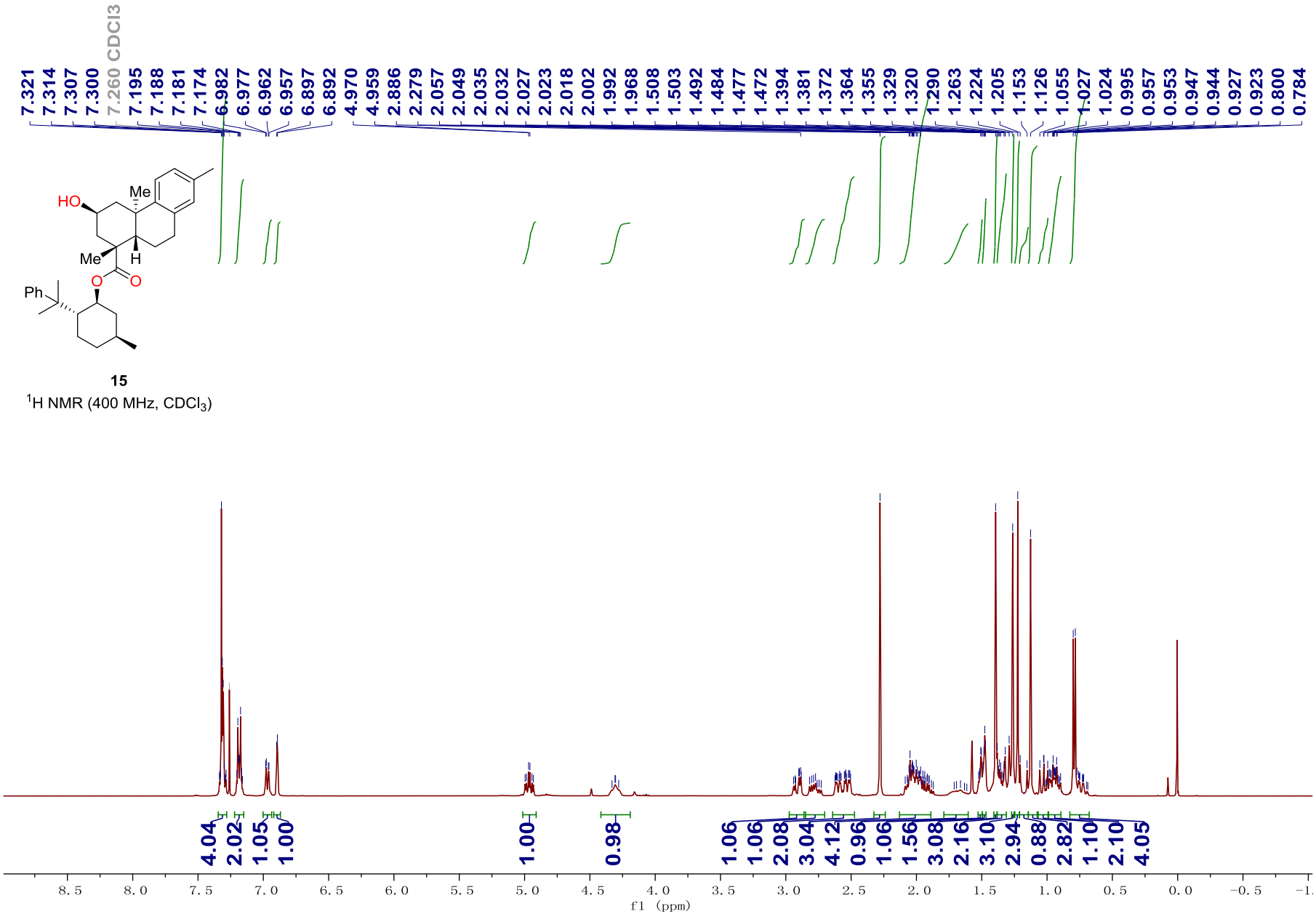
14

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



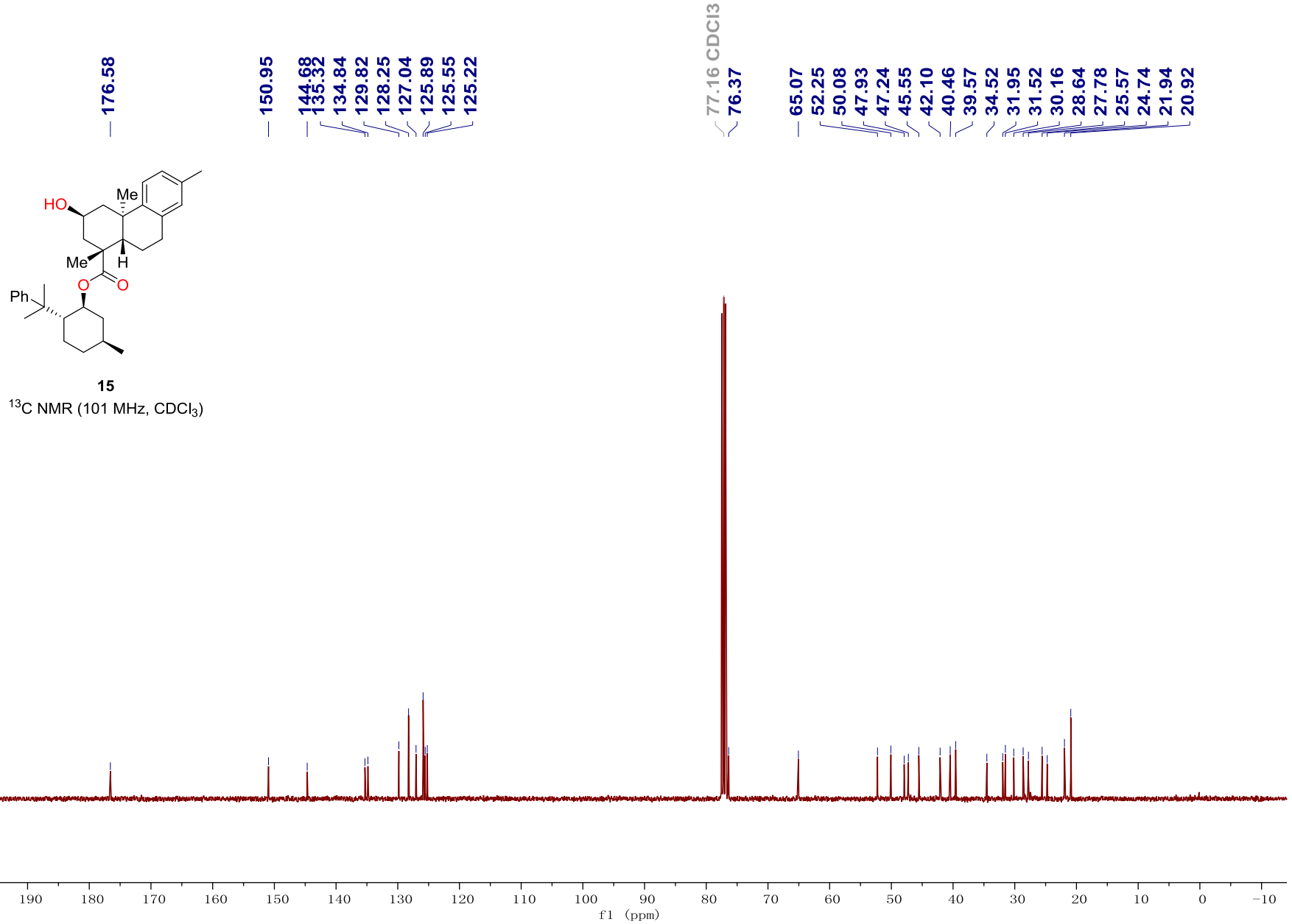
14

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



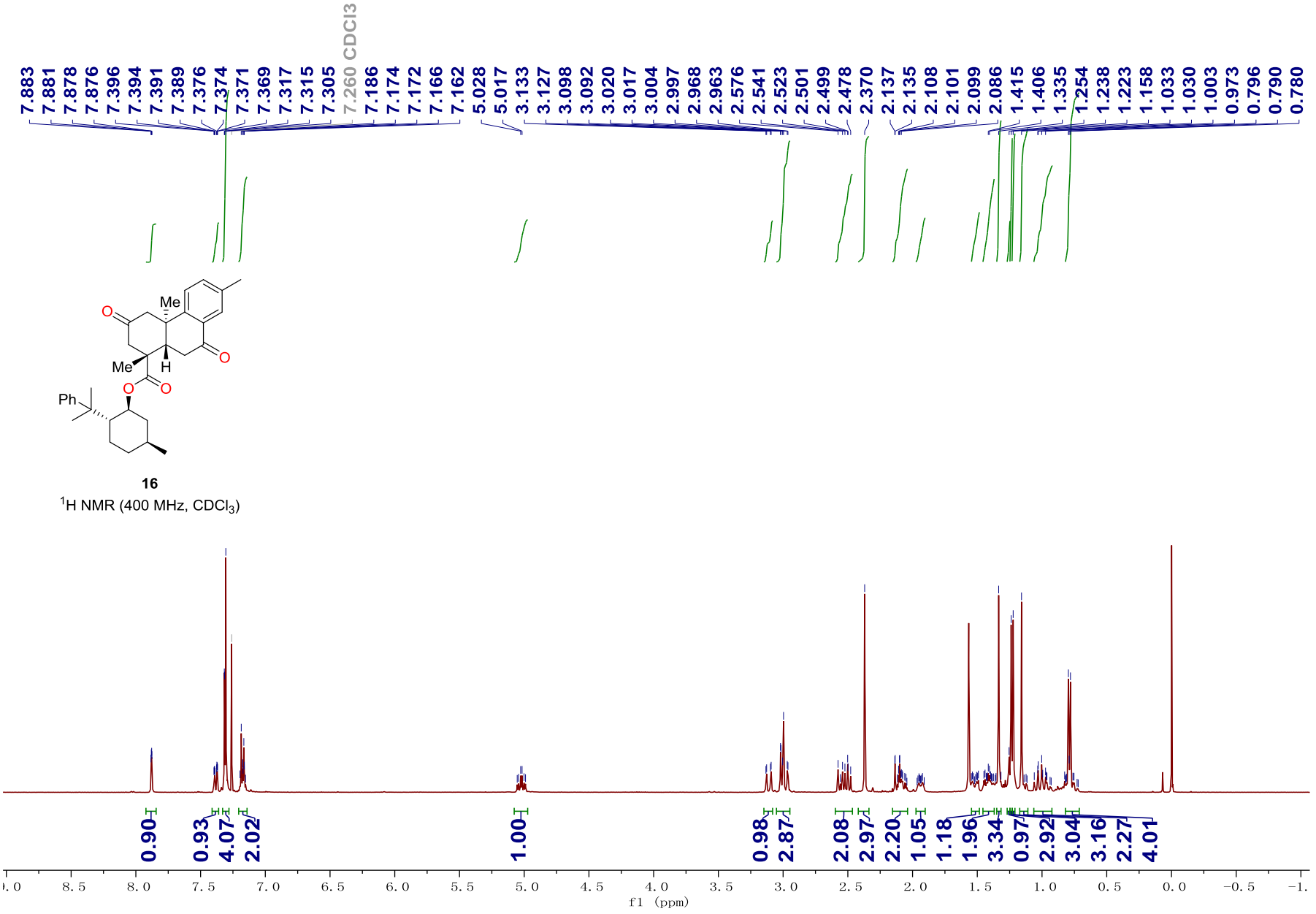
15

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



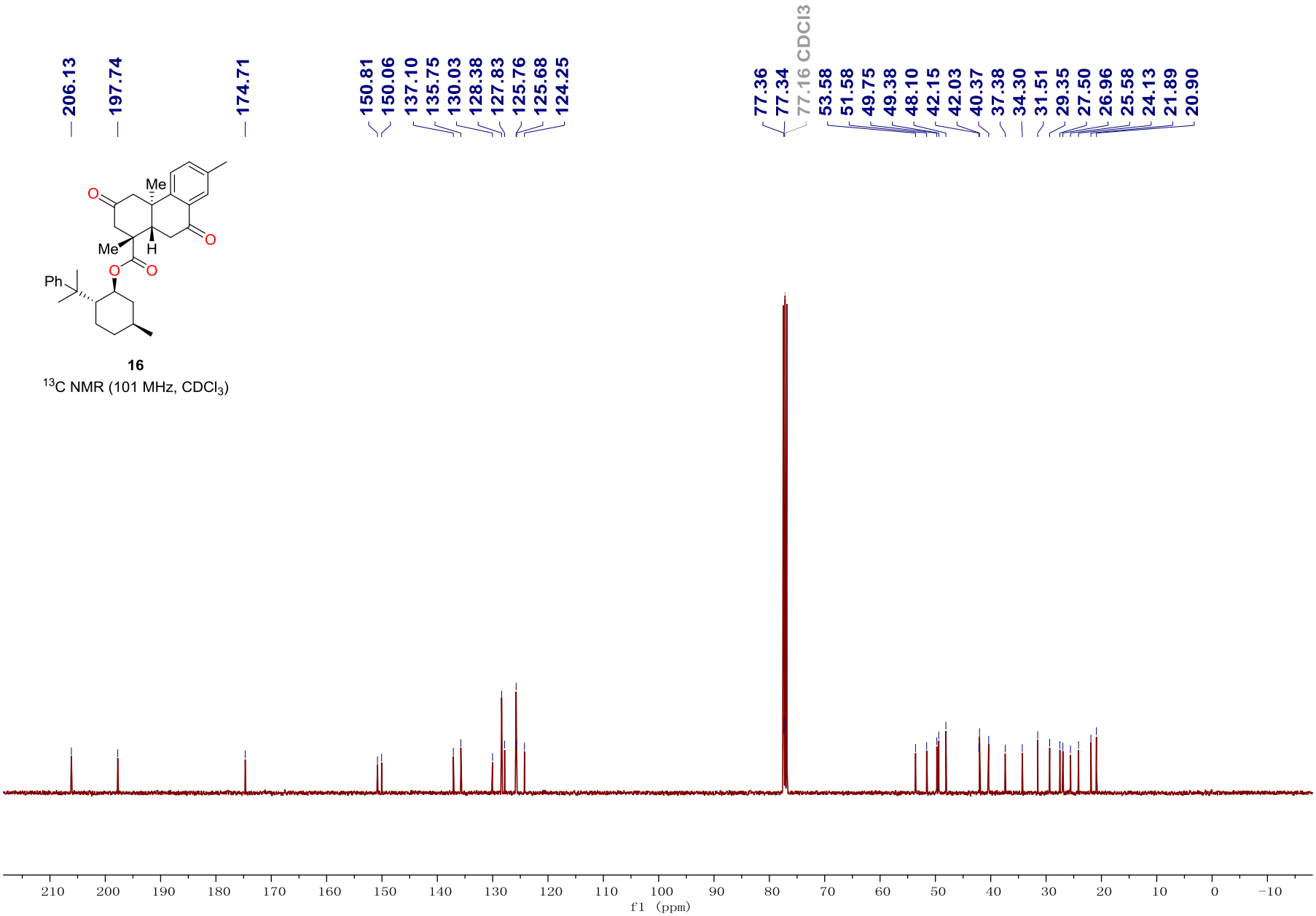
15

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



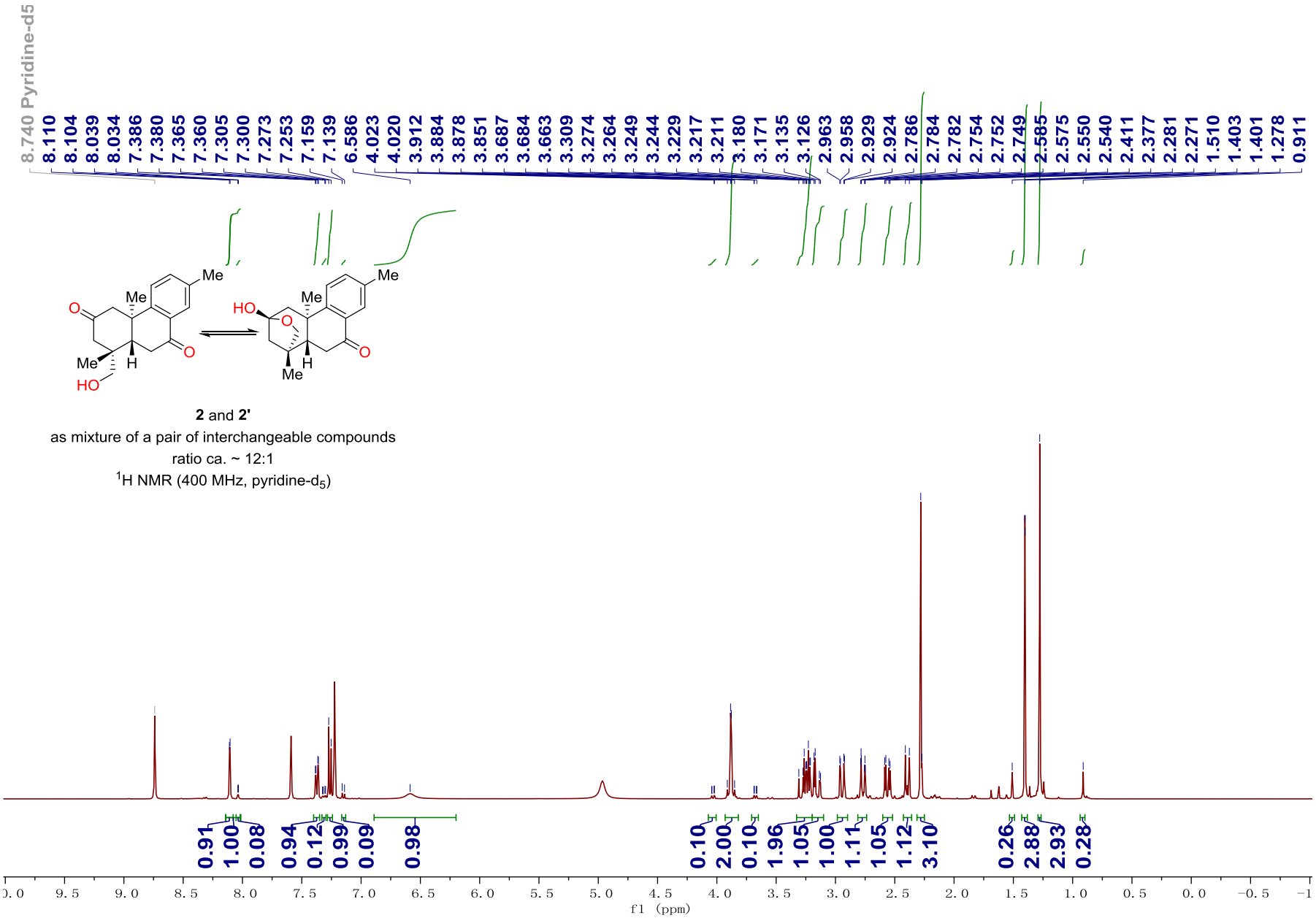
16

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



16

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

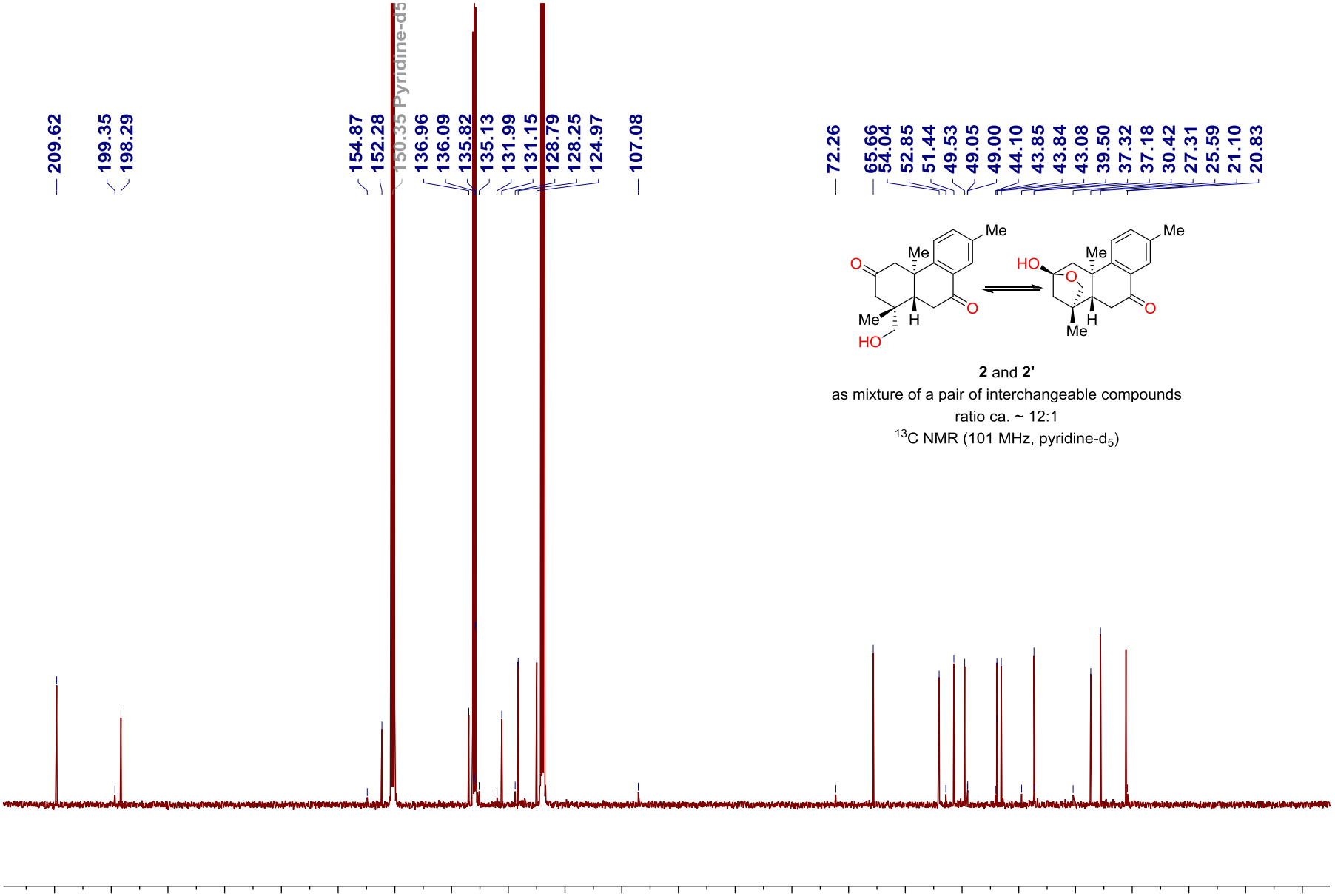


2 and **2'**

as mixture of a pair of interchangeable compounds

ratio ca. ~ 12:1

^{1}H NMR (400 MHz, pyridine-d_5)

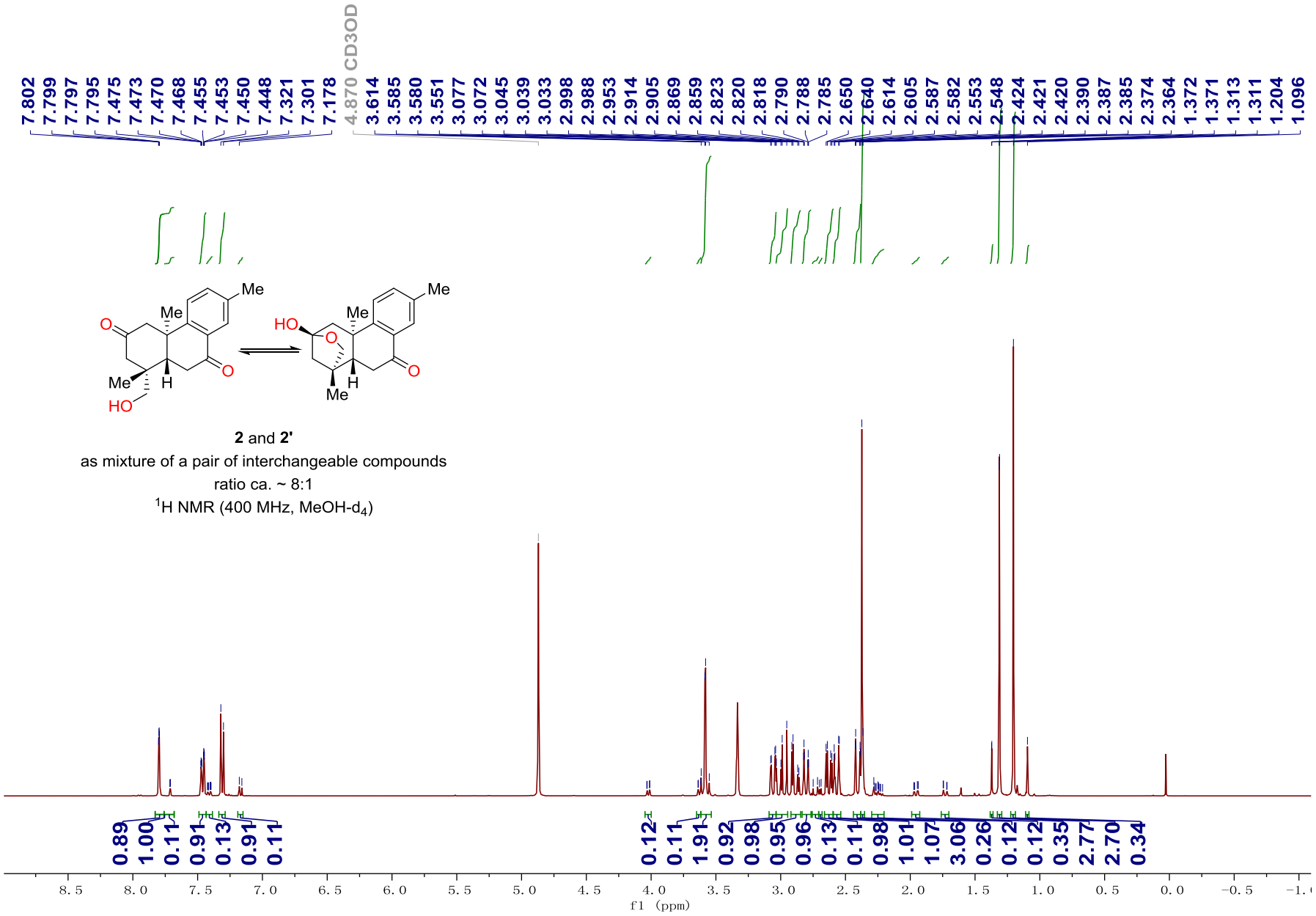


2 and **2'**

as mixture of a pair of interchangeable compounds

ratio ca. ~ 12:1

^{13}C NMR (101 MHz, pyridine-d_5)

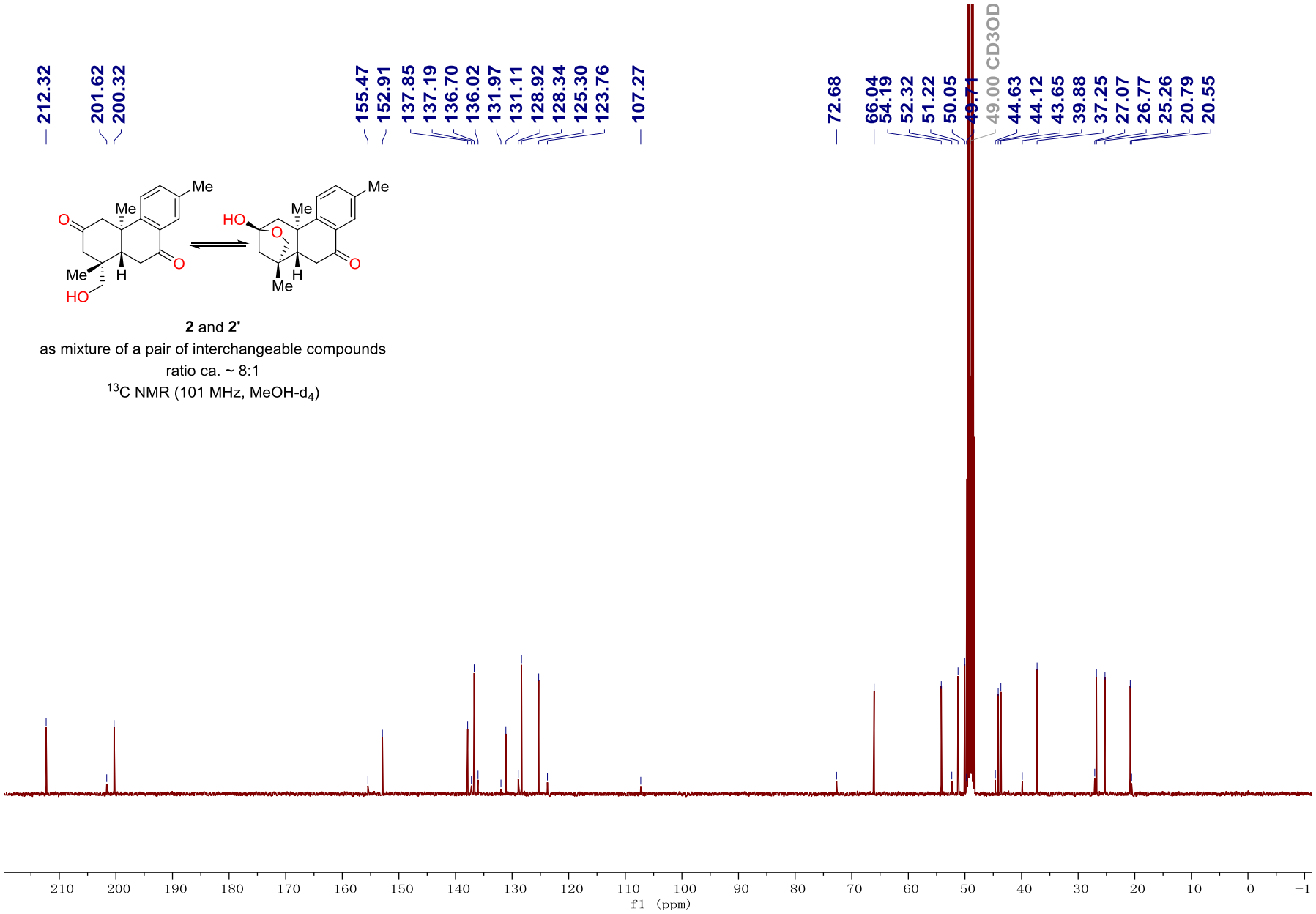


2 and **2'**

as mixture of a pair of interchangeable compounds

ratio ca. ~ 8:1

^{1}H NMR (400 MHz, MeOH-d_4)

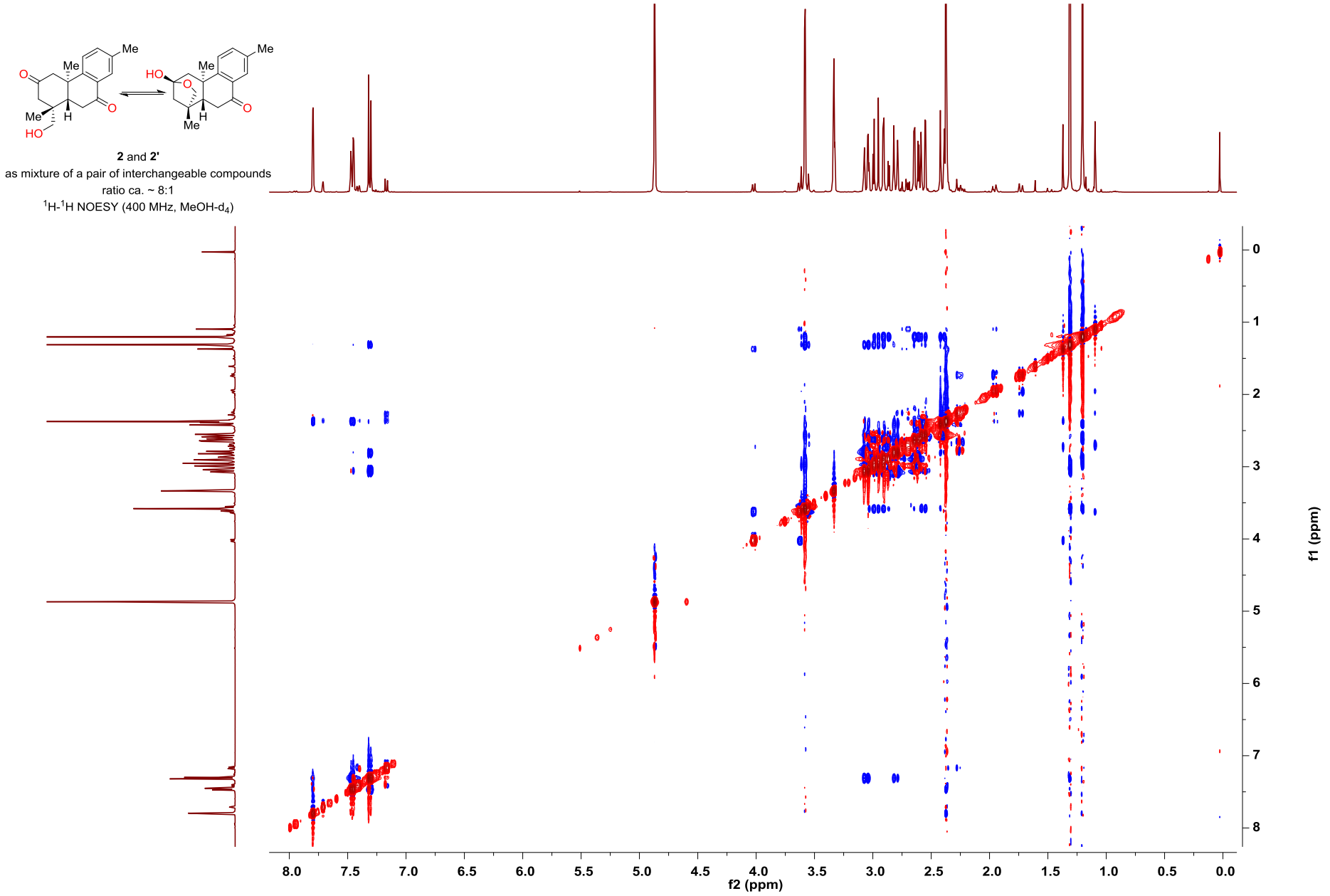


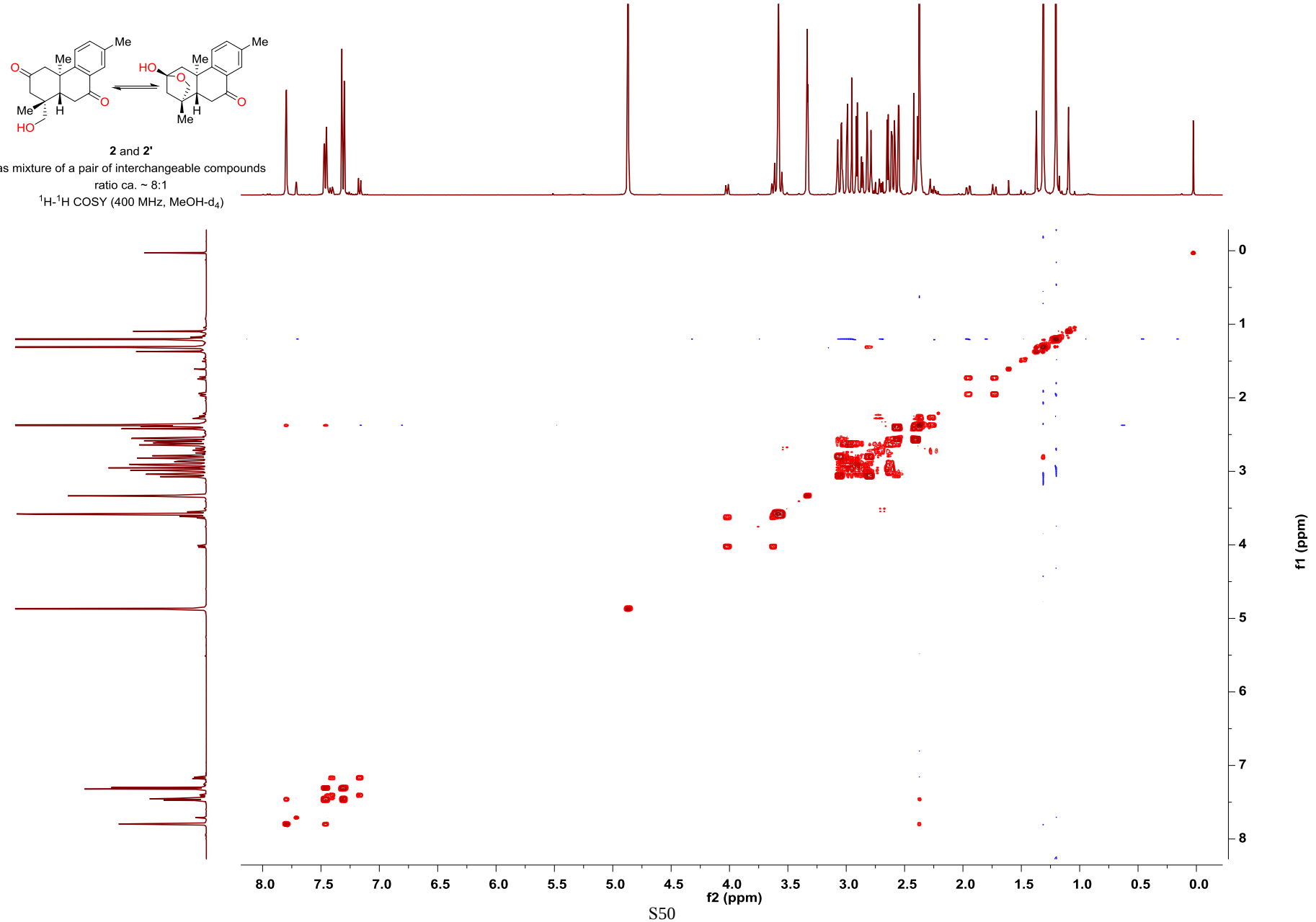
2 and **2'**

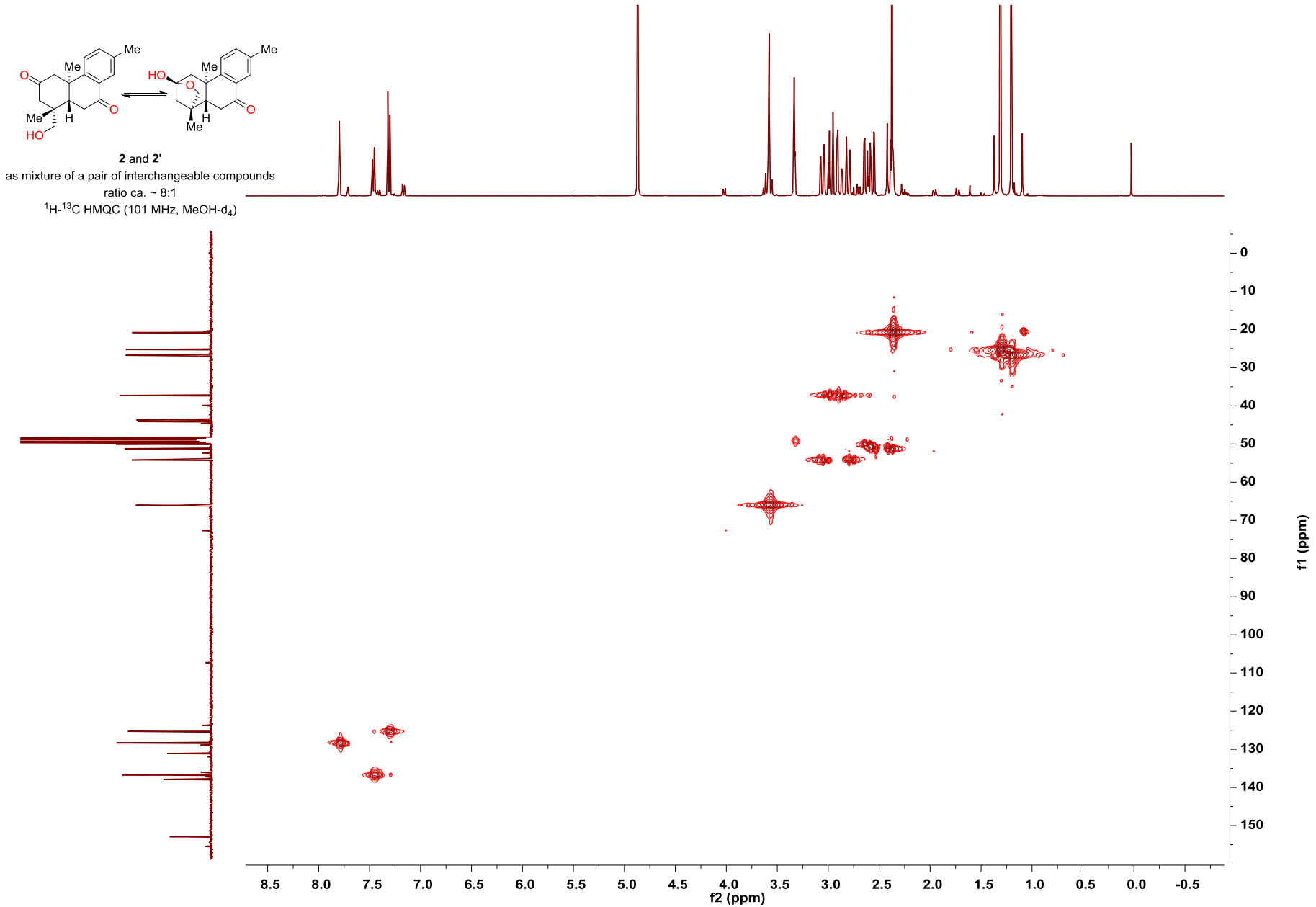
as mixture of a pair of interchangeable compounds

ratio ca. ~ 8:1

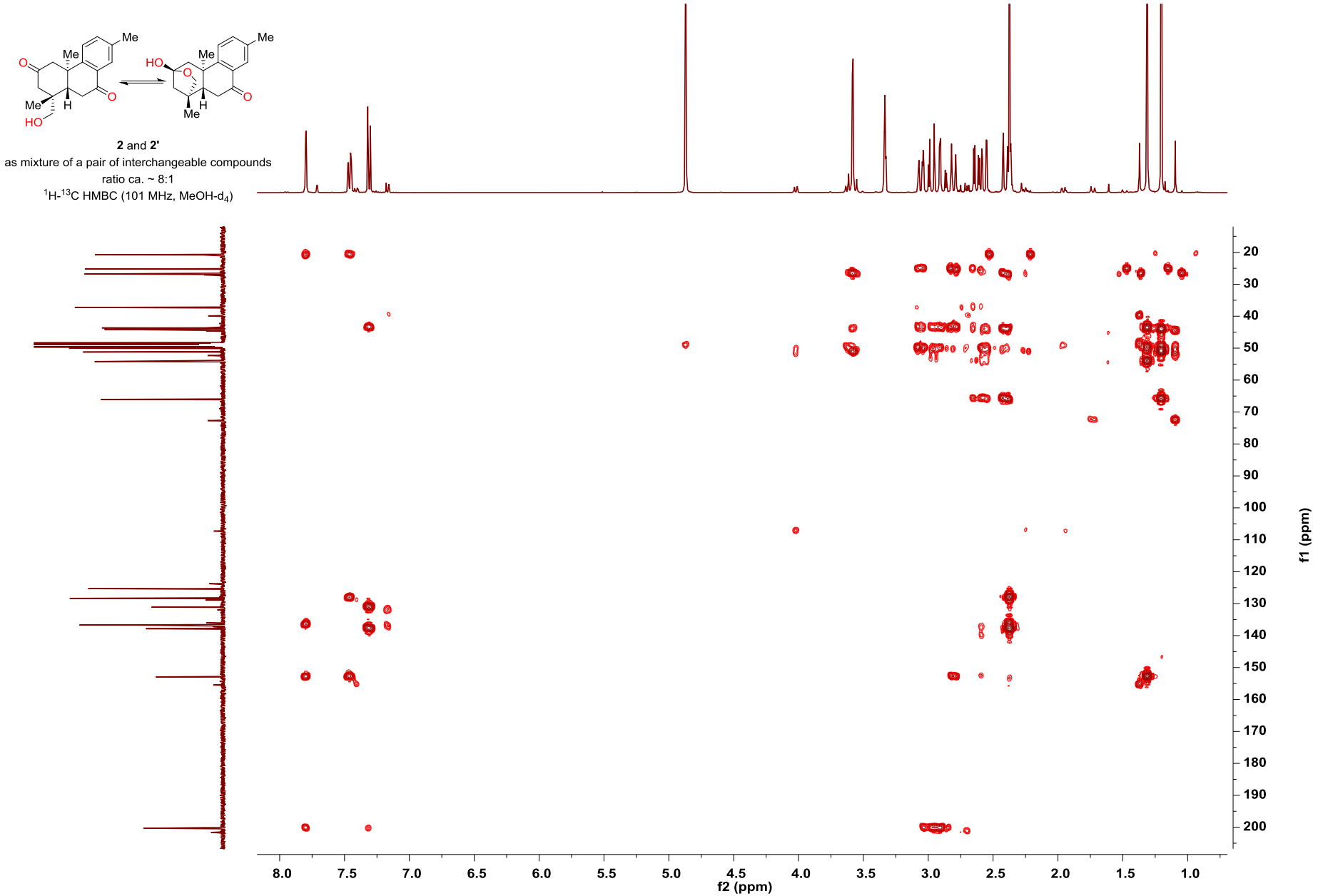
^{13}C NMR (101 MHz, MeOH-d_4)

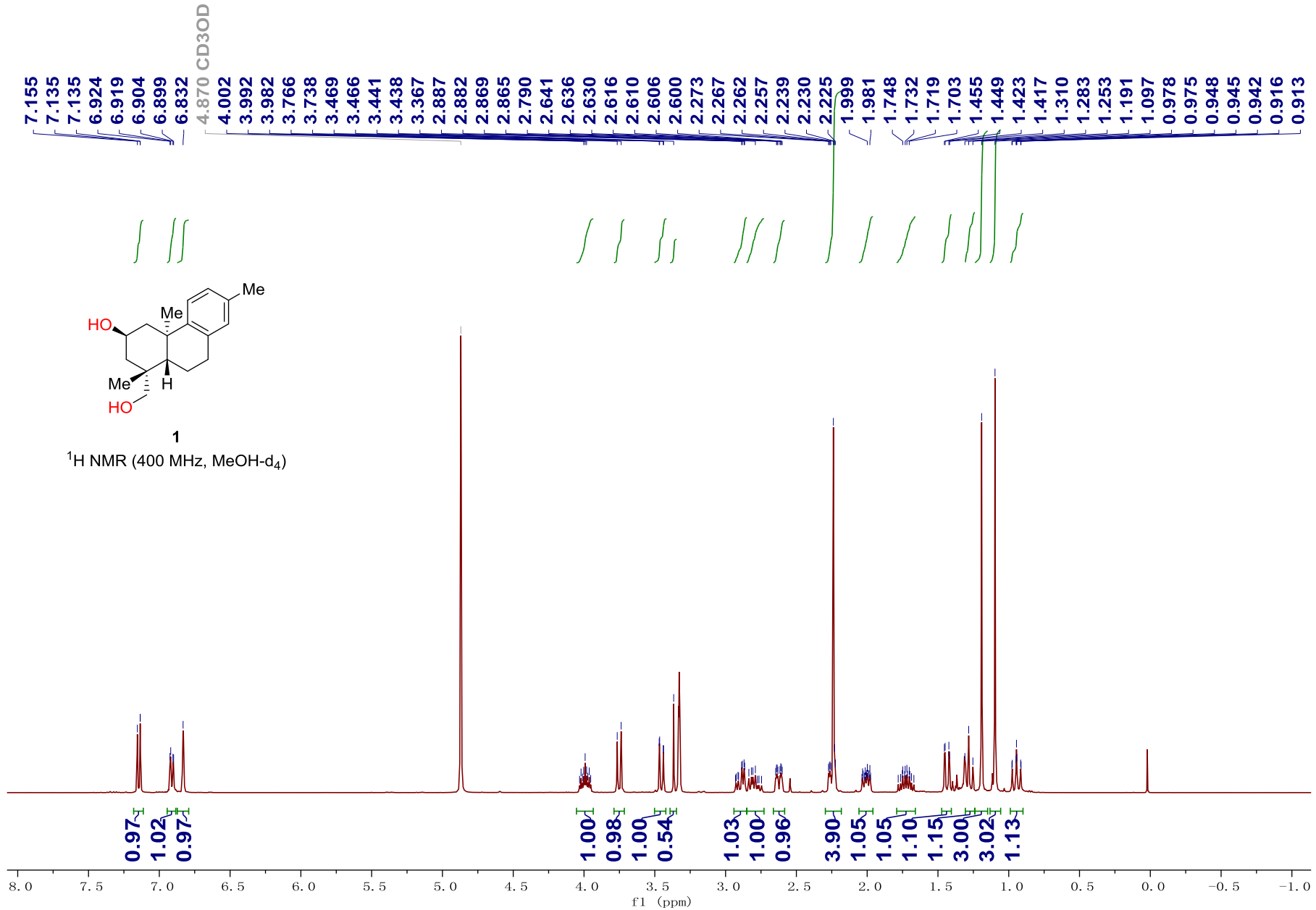

Me
Me
O
O
Me
H
HO
HO
Me
Me
O
O
Me
H
Me
2 and 2'
as mixture of a pair of interchangeable compounds
ratio ca. ~ 8:1
1H-1H NOESY (400 MHz, MeOH-d4)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f2 (ppm)
0
1
2
3
4
5
6
7
8
f1 (ppm)


Me
Me
O
Me
H
HO
O
HO
Me
Me
O
Me
H
Me
O
2 and 2'
as mixture of a pair of interchangeable compounds
ratio ca. ~ 8:1
1H-1H COSY (400 MHz, MeOH-d4)
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)



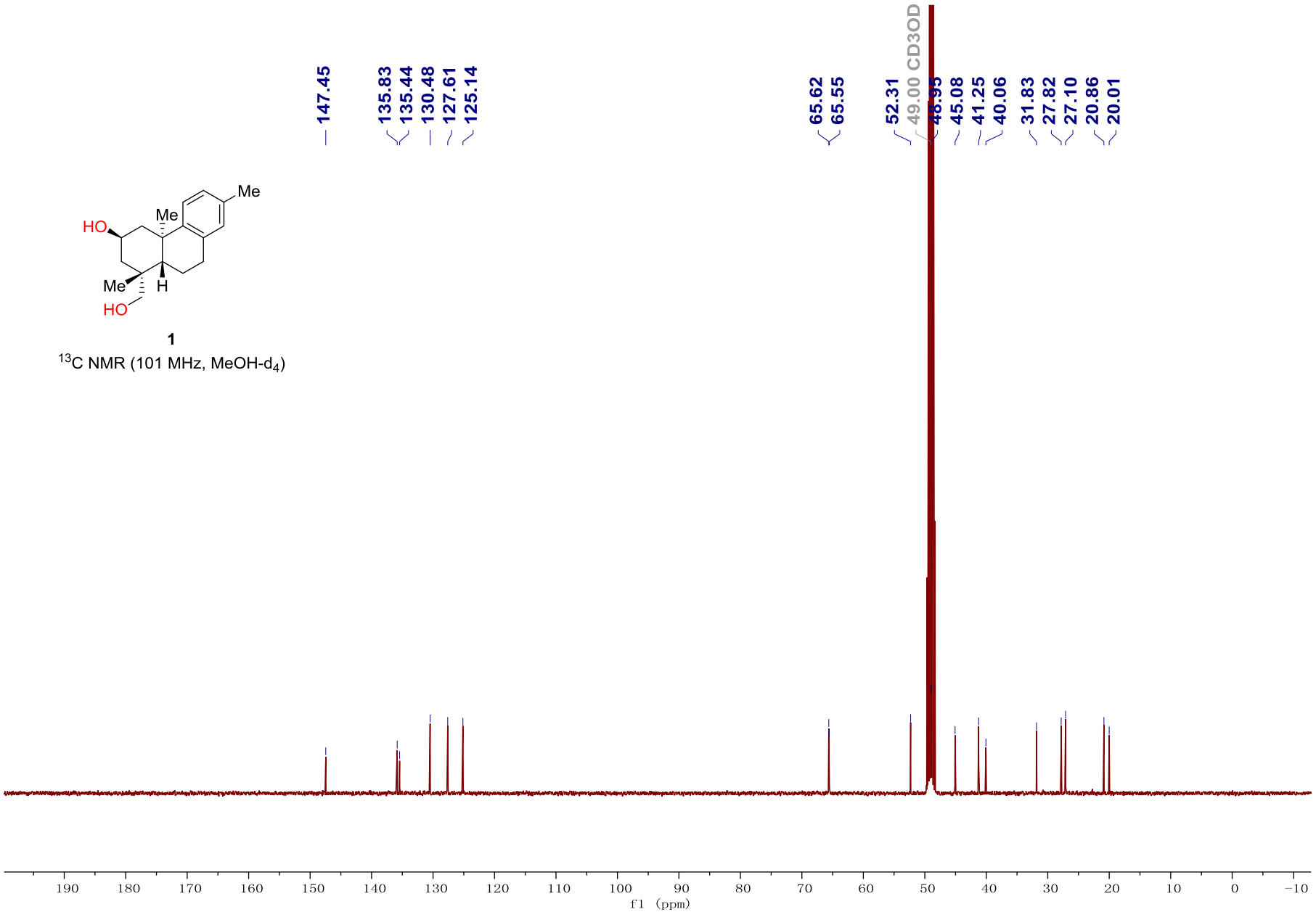
2 and **2'**
as mixture of a pair of interchangeable compounds
ratio ca. ~ 8:1
^{1}H-^{13}C HMQC (101 MHz, MeOH-d_4)


Me
Me
O
Me
H
HO
O
HO
Me
Me
O
Me
H
O
Me
2 and 2'
as mixture of a pair of interchangeable compounds
ratio ca. ~ 8:1
1H-13C HMBC (101 MHz, MeOH-d4)
f2 (ppm)
f1 (ppm)



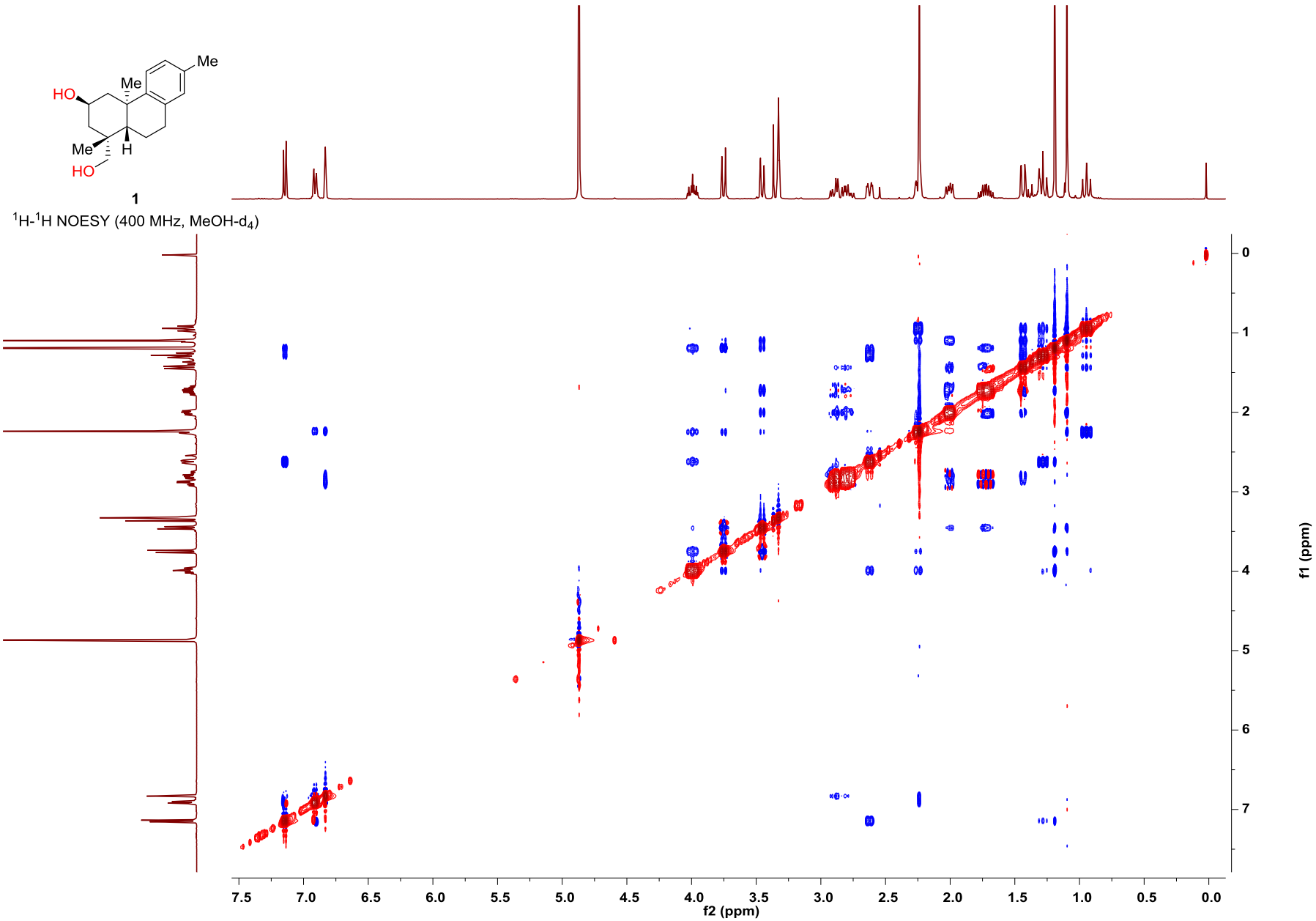
1

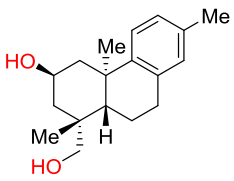
^{1}H NMR (400 MHz, MeOH-d_4)



1

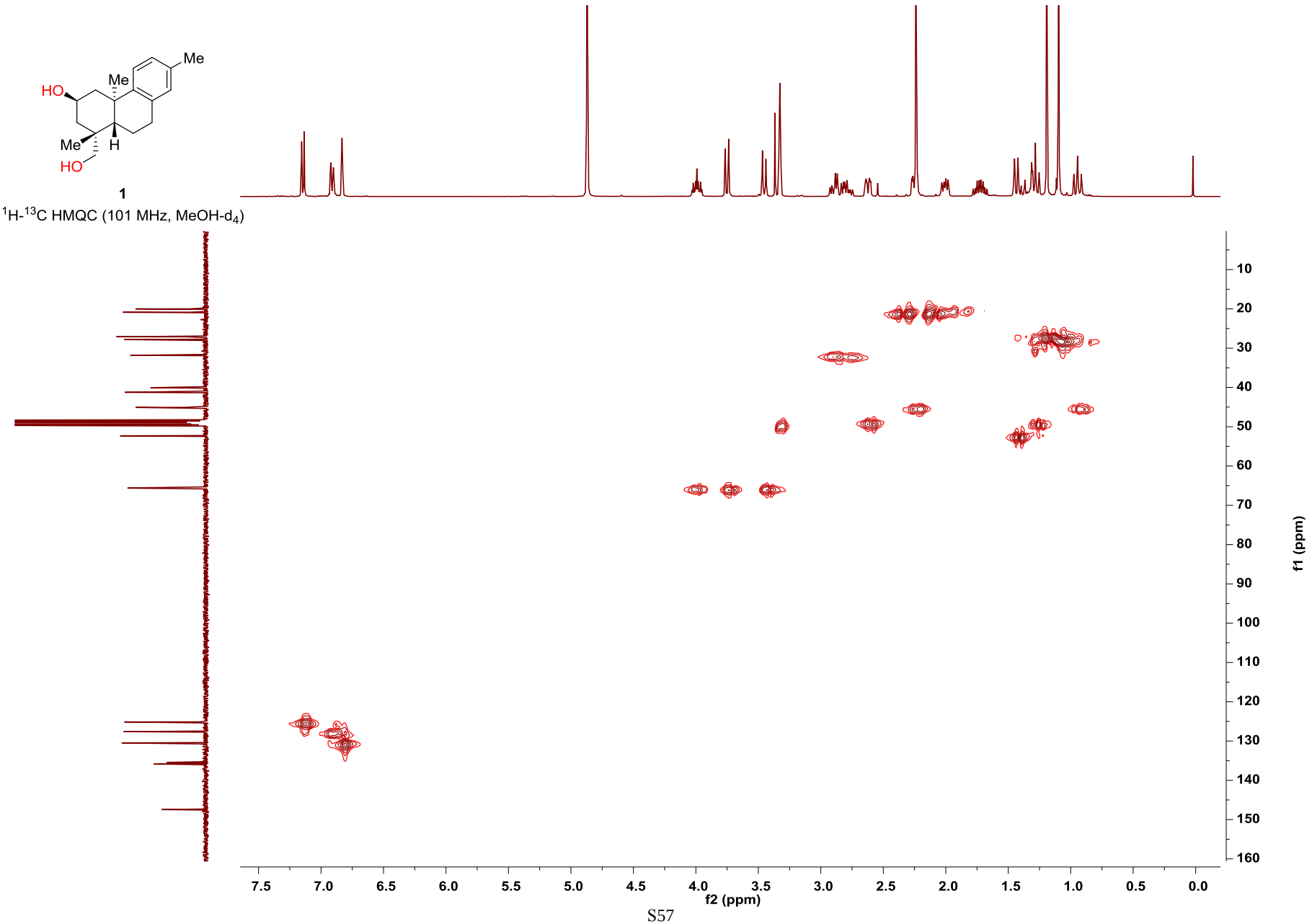
^{13}C NMR (101 MHz, MeOH-d_4)

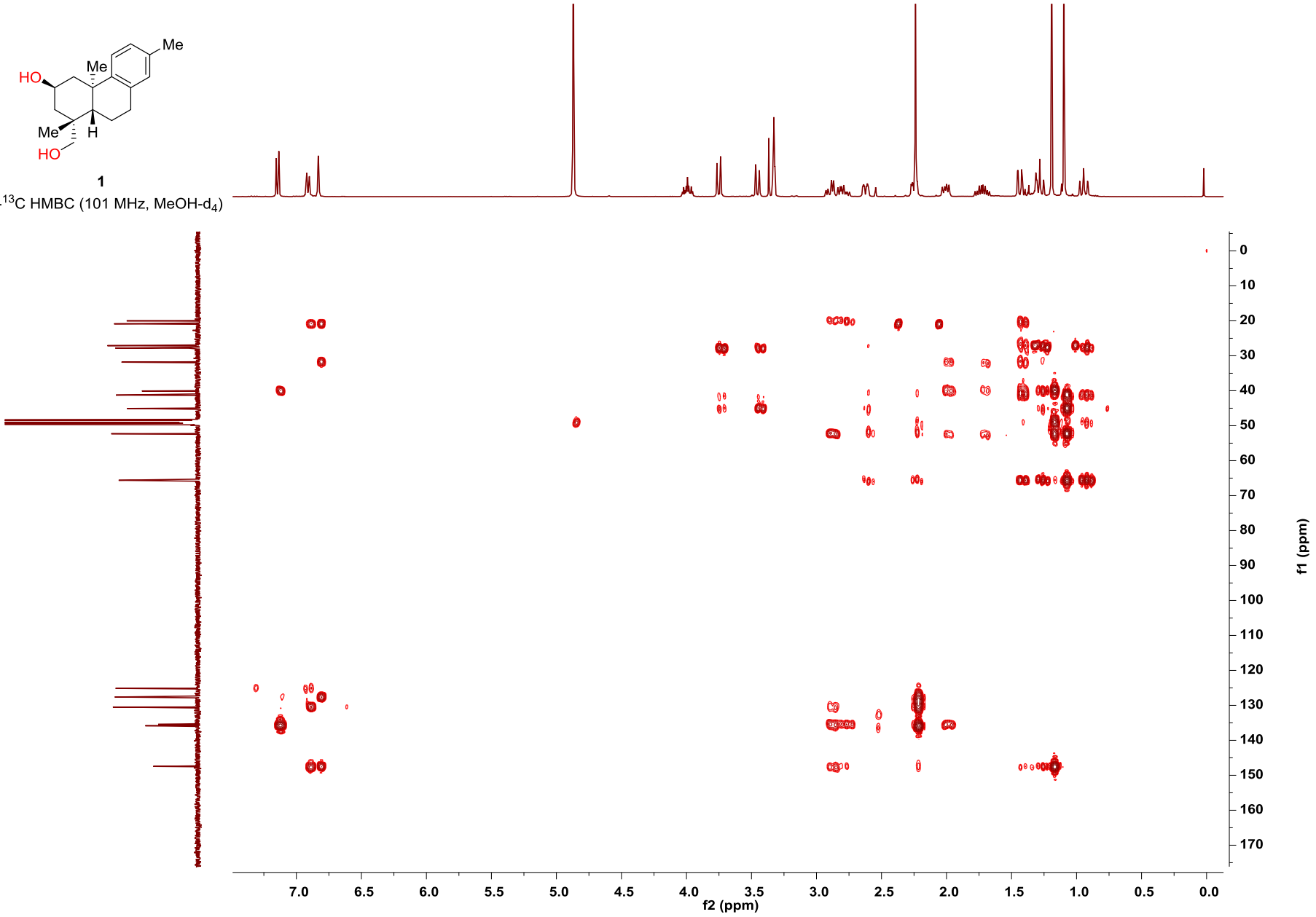

HO
Me
Me
Me
H
HO
1
^{1}H-^{1}H NOESY (400 MHz, MeOH-d$_4$)
f2 (ppm)
f1 (ppm)



1

^{1}H-^{1}H COSY (400 MHz, MeOH-d_4)


HO
Me
Me
Me
H
HO
1
^{1}H-^{13}C HMQC (101 MHz, MeOH-d$_4$)
f2 (ppm)
f1 (ppm)


HO
Me
Me
Me
H
HO
1
^{1}H-^{13}C HMBC (101 MHz, MeOH-d$_4$)
f2 (ppm)
f1 (ppm)

5. Abbreviations

Abbreviation	Full Name
c	concentration
DCM	dichloromethane
d.r.	diastereomeric ratio
h	hour/hours
r.t.	Room temperature
min	minute/minutes
THF	tetrahydrofuran
DIPA	N,N-diisopropylamine
DMPU	N,N'-dimethylpropylene urea
DMF	N,N-dimethylformamide
TFA	trifluoroacetic acid
TFAA	trifluoroacetic acid anhydride