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Supplementary Material

Efficient Synthesis of an Indinavir Precursor from Biomass Derived (-)-Levoglucosenone

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Contents

General Experimental

Solvents were dried using literature procedures.[1] (-)-Levoglucosenone (**1**) and 6,8-dioxabicyclo[3.2.1]octan-4-one (**2**) (Cyrene) were obtained from Circa, Melbourne, Australia. All other reagents were commercially available and were used as purchased. ^{1}H NMR spectra were referenced to TMS δ 0.00 ppm and ^{13}C NMR to residual solvent ($CDCl_3$, δ 77.0 ppm; DMSO-d_6, δ 39.5 ppm).[2] Melting points are uncorrected. HRMS were recorded in positive ASAP mode. NMR were assigned using COSY, NOESY, HSQC and HMBC experiments.

Attempted synthesis of 9a/10a by the alkylation of ketone 2

(1*S*,5*R*)-3,3-Dibenzyl-6,8-dioxabicyclo[3.2.1]octan-4-one (11). Ketone **2** (0.50 g, 3.90 mmol) and BnBr (1.47 g, 8.59 mmol, 2.2 equiv.) were dissolved in THF (5 mL) under N_2 and then potassium *tert*-butoxide (1.06 g, 8.59 mmol) was added. The solution was stirred at 25 °C for 1.5 h then filtered, the precipitate washed with ether and then the filtrate concentrated under reduced pressure. The residue was recrystallised from *i*-Pr_2O to afford colourless crystals (0.830 g, 69 %). Flash chromatography (1:9 EtOAc/hexanes) of the mother liquor gave additional colourless crystals (0.129, 19%, combined yield 88%); mp 113-115 °C; $[\alpha]_D^{36}$ -17 (*c* = 0.81, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30-7.22 (m, 6H), 7.12-7.07 (m, 4H), 5.04 (s, 1H), 4.53 (br. t, *J* = 5.7 Hz, 1H), 3.53 (dd, *J* = 6.2, 1H), 3.29 (d, *J* = 9.7 Hz, 1H), 3.26 (d, *J* = 9.7 Hz, 1H), 3.10 (d, *J* = 7.20 Hz, 1H), 2.75 (d, *J* = 13.3 Hz, 1H), 2.58 (d, *J* = 13.3 Hz, 1H), 2.39 (dd, *J* = 14.7, 6.4 Hz, 1H), 1.75 (d, *J* = 14.7 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 204.2, 136.8, 136.7, 131.1, 131.0, 128.3, 128.1, 127.0, 126.8, 100.1, 72.6, 67.9, 49.7, 46.5, 45.7, 32.0; FT-IR (neat) 2972, 2921, 1724, 1600, 1495, 1453, 1436, 1329, 1299, 1261, 1206, 1120, 1100, 1087, 1073, 1050, 1031, 701 cm^{-1}; MS (EI) *m/z* 308.1 ($[M]^+$, trace), 234.1 (13), 193.1 (14), 171.1 (14), 144.1 (15), 143.1 (100), 129.1 (17), 128 (28), 117 (13), 115.1 (25), 91.1 (90); HRMS (ASAP) *m/z* $[M + H]^+$ Calcd for $C_{20}H_{21}O_3$ 309.1485; Found 309.1502.

(1R,1'S,5S,5'R)-3'-Benzyl-6',7,8,8'-tetraoxa[2,3'-bi(bicyclo[3.2.1]octan)]-2-en-4'-one (12). A dry Schlenk flask was charged with diisopropylamine (1.33 mL, 9.37 mmol) and THF (20 mL) under N_2 then cooled to -78 °C. A solution of 10M BuLi (0.86 mL, 8.6 mmol) was added and the mixture allowed to stir for 10 min. Ketone **2** (1.0 g, 7.80 mmol) was then added dropwise and allowed to stir for 5 min before rapid addition of BnBr (1.02 mL, 8.58 mmol). The reaction was stirred at -78 °C for 1 hr before raising to 25 °C and stirring for an additional 48 hrs. The mixture was diluted with sat. $NaHCO_3$ (30 mL) and extracted with DCM (30 mL x 3). The organic phase was concentrated and purified via column chromatography (3:7 EtOAc/hexanes) to afford a colourless oil (0.21 g, 16%); ^{1}H NMR (500 MHz,

$CDCl_3$) δ 7.30-7.22 (m, 3H), 7.13-7.11 (m, 2H), 5.30 (dddd, *J* = 4.2, 2.7, 1.4, 1.4 Hz, 1H), 5.19 (br. d, *J* = 1.4 Hz, 1H), 5.14 (br. s, 1H), 4.69-4.65 (m, 1H), 4.59-4.55 (m, 1H), 4.18 (br dd, *J* = 7.1, 0.6 Hz, 1H), 3.93 (ddd, *J* = 7.4, 6.0, 2.2, 1H), 3.69-3.66 (m, 2H), 3.15 (d, *J* = 13.8 Hz, 1H), 2.84 (d, *J* = 13.8 Hz, 1H), 2.74 (dddd, 18.0, 4.5, 2.5, 2.5 Hz, 1H), 2.32 (ddd, *J* = 14.5, 4.2, 1.3 Hz, 1H), 2.24 (dd, *J* = 14.5, 1.6 Hz, 1H), 1.93 (ddd, *J* = 18.0, 4.5, 0.6 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 200.7, 139.7, 136.2, 131.0, 128.3, 126.9, 120.8, 101.2, 96.9, 73.3, 71.4, 68.7, 65.9, 52.4, 44.3, 34.5, 32.5; FT-IR (neat) 2963, 2919, 2854, 1724, 1494, 1453, 1330, 1180, 1123, 1021 cm^{-1}; MS (EI) *m/z* 329.0 ($[M+H]^+$, trace), 191.2 (7), 177.2 (8), 176.2 (60), 134.1 (5), 92.1 (8), 91.1 (100), 65.1 (6), 43.1 (3), 42.1 (3), 41.1 (4).

Aldol condensations between ketone 2 and aldehydes

Method I for aldol condensations. To a solution of aldehyde (2.4 mmol) in TMG (250 µL, 2.0 mmol) heated to 100 °C was added 6,8-dioxabicyclo[3.2.1]octan-4-one (**2**) (256 mg, 2.0 mmol) and the mixture stirred for the time and temperature indicated in Table 2. The reaction mixture was applied directly to a column of silica and product eluted with EtOAc/hexanes (3:17-7:3) to give the aldol adduct which was then further purified as specified.

Method II for aldol condensations. To a solution of 6,8-dioxabicyclo[3.2.1]octan-4-one (**2**) (256 mg, 2.0 mmol) in MeCN (1 mL) was added aldehyde (2.2 mmol) then TMG (12.5 µL, 0.1 mmol) and the mixture heated to 50 °C and stirred for the time indicated in Table 2. The reaction mixture was concentrated under reduced pressure and the residue purified by column chromatography (3:17-7:3 EtOAc/hexanes) to give the aldol adduct which was then further purified as specified.

(1S,3E,5R)-3-Benzylidene-6,8-dioxabicyclo[3.2.1]octan-4-one (13a). Treatment of **2** (256 mg, 2.0 mmol) with benzaldehyde (254 mg, 2.4 mmol) as per Method I with purification by column chromatography (1:4 EtOAc/hexanes) gave **13a** as a yellow crystalline solid that was further purified by recrystallisation from diisopropyl ether (354 mg, 82%); $[\alpha]_D^{18}$ -269 (*c* 1.22, $CHCl_3$); mp 107-110 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.72 (br. dd, *J* = 2.8, 1.4 Hz, 1H), 7.51-7.34 (m, 5H), 5.37 (s, 1H), 4.88 (dd, *J* = 5.3, 5.0 Hz, 1H), 3.95 (ddd, *J* = 7.3, 5.3, 1.4 Hz, 1H), 3.81 (dd, *J* = 7.3, 1.2 Hz, 1H), 3.36 (dddd, *J* = 16.8, 5.0, 2.8, 1.4 Hz, 1H), 2.89 (br d, *J* = 16.8 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 189.7, 139.9, 134.6, 130.4, 129.6, 128.7, 128.1, 101.0, 72.5, 68.4, 34.6; FT-IR (neat) 3372, 2968, 2903, 1693, 1589, 1569, 1492, 1478, 1446, 1334, 1322, 1294, 1266, 1254, 1197, 1186, 1159, 1105 cm^{-1}; MS (EI) *m/z* 216.1 ($[M]^+$, trace), 170.1 (76), 143.1 (25), 142.1 (97), 141.1 (72), 130.1 (29), 129 (79), 128.1 (100),

115.1 (73), 102.1 (49), 91.1 (25); HRMS (ASAP) *m/z*: $[M + H]^+$ Calcd for $C_{13}H_{13}O_3$ 217.0859; Found 217.0860.

(1S,3E,5R)-3-(2-Chlorobenzylidene)-6,8-dioxabicyclo[3.2.1]octan-4-one (13b). Treatment of **2** (256 mg, 2.0 mmol) with 2-chlorobenzaldehyde (308 mg, 2.2 mmol) as per Method II and purification by column chromatography (1:4 EtOAc/hexanes) gave **13b** as a straw coloured oil (411 mg, 82%); $[\alpha]_D^{26}$ -232 (*c* 2.2, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (br. s, 1H), 7.45 (dd, *J* = 7.0, 2.1 Hz, 1H), 7.34-7.27 (m, 3H), 5.36 (s, 1H), 4.82 (br. dd, *J* = 5.5, 5.1 Hz, 1H), 3.92 (ddd, *J* = 7.3, 5.5, 1.5 Hz, 1H), 3.82 (br. dd, *J* = 7.3, 0.8 Hz, 1H), 3.22 (dddd, *J* = 16.6, 5.1, 3.2, 1.4 Hz, 1H), 2.72 (br. d, *J* = 16.8 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 189.4, 136.5, 135.1, 133.0, 130.7, 130.3, 130.1, 129.7, 126.5, 101.0, 72.6, 68.2, 34.4; FT-IR (neat) 2969, 2899, 1705, 1616, 1467, 1435, 1250, 1199, 1110, 1051, 1034 cm^{-1}; MS (ESI) *m/z* 275.1 ($[M(^{37}Cl) + Na]^+$, 38), 273.1 ($[M(^{35}Cl) + Na]^+$, 100); HRMS (ASAP) *m/z* $[M+H]^+$ Calcd for $C_{13}H_{12}ClO_3$ 251.0469; Found 251.0467.

Synthesis of 14b. A mixture of **2** (1.0 g, 7.8 mmol), 2-chlorobenzaldehyde (1.76 mL, 15.6 mmol) and TMG (1.96 mL, 15.6 mmol) was stirred at 100 °C for 48 h. The reaction mixture was purified twice by flash chromatography (1:4 EtOAc/hexanes) yielding a yellow oil (765 mg) consisting of approximately 81% (1*S*,5*R*)-3-(2-chlorobenzyl)-6,8-dioxabicyclo[3.2.1]oct-2-en-4-one (**14b**) by GCMS (adjusted yield 620 mg, 32%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35-7.39 (m, 1H), 7.20-7.23 (m, 3H), 6.63 (ddd, *J* = 4.8, 1.6, 1.6 Hz, 1H), 5.42 (s, 1H), 4.95 (dd, *J* = 4.8, 4.8 Hz, 1H), 3.86 (dd, *J* = 6.7, 4.8 Hz, 1H), 3.70 (d, *J* = 6.7 Hz, 1H), 3.69 (dd, *J* = 16.5, 1.6 Hz, 1H), 3.62 (br. d, *J* = 16.5 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 188.6, 142.8, 135.9, 135.3, 134.4, 131.6, 129.7, 128.3, 127.1, 101.2, 72.2, 66.5, 31.6.

(1S,3E,5R)-3-(4-Methoxybenzylidene)-6,8-dioxabicyclo[3.2.1]octan-4-one (13c). Treatment of **2** (256 mg, 2.0 mmol) with anisaldehyde (326 mg, 2.4 mmol) as per Method I and purification by flash chromatography (3:17 EtOAc/hexanes) followed by recrystallisation from methanol gave **13c** as a tan coloured oil (284 mg, 58%); $[\alpha]_D^{24}$ -236 (*c* 1.49, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (br. s, 1H), 7.45-7.43 (m, 2H), 6.95-6.93 (m, 2H), 5.34 (s, 1H), 4.89 (dd, *J* = 5.1, 5.1 Hz, 1H), 3.94 (ddd, *J* = 7.2, 5.1, 1.3 Hz, 1H), 3.85 (s, 3H), 3.82 (dd, *J* = 7.2, 1.3 Hz, 1H), 3.35 (dddd, *J* = 16.5, 5.1, 2.8, 1.3 Hz, 1H), 2.86 (br d, *J* = 16.5 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 189.8, 160.7, 139.9, 132.5, 127.5, 125.4, 114.2, 101.1, 72.5, 68.5, 55.4, 34.6; FT-IR (neat) 2966, 2900, 2840, 1697, 1584, 1509, 1464, 1439, 1417, 1300, 1255, 1203, 1174, 1106, 1019 cm^{-1}; MS (EI) *m/z* 261.1 ($[M]^+$, 26), 201.1 (31), 200.1 (34),

172.1 (100), 160.1 (36), 159.1 (50), 158.1 (41), 157.1 (30), 145.1 (38), 129.1 (28), 115.1 (39); HRMS (ASAP) *m/z* $[M+H]^+$ Calcd for $C_{14}H_{15}O_4$ 247.0965; Found 247.0965.

(1S,3E,5R)-3-(3,4-Dimethoxybenzylidene)-6,8-dioxabicyclo[3.2.1]octan-4-one (13d). Treatment of **2** (256 mg, 2.0 mmol) with veratraldehyde (398 mg, 2.4 mmol) as per Method I and purification by flash chromatography (2:3 EtOAc/hexanes) gave a solid that was recrystallised from hot methanol to afford **13d** as yellow needles (332 mg, 60%); $[\alpha]_D^{22}$ -261 (*c* 0.67, $CHCl_3$); mp 121-123 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (br. s, 1H), 7.11 (dd, *J* = 8.5, 2.0 Hz, 1H), 6.98 (d, *J* = 2.0 Hz, 1H), 6.92 (d, *J* = 8.5 Hz, 1H), 5.35 (s, 1H), 4.90 (br. dd, *J* = 5.4, 5.4 Hz, 1H), 3.95 (ddd, *J* = 7.2, 5.6, 1.5 Hz, 1H), 3.93 (s, 3H), 3.90 (s, 3H), 3.83 (d, *J* = 7.2, 1.2 Hz, 1H), 3.35 (dddd, *J* = 16.5, 4.7, 2.9, 1.6 Hz, 1H), 2.89 (br. d, *J* = 16.5 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 189.7, 150.5, 148.8, 140.1, 127.7, 125.7, 124.3, 113.7, 111.0, 101.0, 72.4, 68.5, 55.94, 55.92, 34.5; FT-IR (neat) 2963, 2897, 2839, 1687, 1582, 1570, 1510, 1421, 1251, 1229, 1148, 1108 cm^{-1}; MS (EI) *m/z* 276.1 ($[M]^+$, 92), 230.1 (69), 217.1 (43), 202.1 (84), 189.1 (100), 187.1 (63), 172.1 (58), 171.1 (75), 159.1 (46), 115.1 (64); HRMS (ASAP) *m/z* $[M+H]^+$ Calcd for $C_{15}H_{17}O_5$ 277.1071; Found 277.1069.

(1S,3E,5R)-3-(3-Nitrobenzylidene)-6,8-dioxabicyclo[3.2.1]octan-4-one (13e). Treatment of **2** (256 mg, 2.0 mmol) with 3-nitrobenzaldehyde (332 mg, 2.2 mmol) as per Method II and purification by flash chromatography (3:7 EtOAc/hexanes) gave **13e** as a bright yellow oil (471 mg, 90%); $[\alpha]_D^{21}$ -146 (*c* 1.98, $CHCl_3$); ^{1}H NMR (500 MHz , $CDCl_3$) δ 8.30 (dd, *J* = 1.9, 1.9 Hz, 1H), 8.23 (ddd, *J* = 8.3, 2.3, 1.0 Hz, 1H), 7.75 (br. d, *J* = 8.0 Hz, 1H), 7.71 (br. s., 1H), 7.63 (dd, *J* = 8.3, 7.8 Hz, 1H), 5.38 (s, 1H), 4.93 (br. dd, *J* = 5.2, 5.2 Hz, 1H), 3.97 (dddd, *J* = 7.4, 5.4, 1.6, 0.4 Hz, 1H), 3.83 (dd, *J* = 7.4, 1.2 Hz, 1H), 3.42 (dddd, *J* = 16.7, 5.1, 3.2, 1.5 Hz, 1H), 2.90 (br. d, *J* = 16.7 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 188.9, 148.3, 136.7, 136.2, 136.1, 131.1, 129.8, 124.1, 123.9, 100.8, 72.3, 68.5, 34.4; FT-IR (neat) 2969, 2901, 1705, 1607, 1524, 1478, 1429, 1349, 1253, 1203, 1104, 1032 cm^{-1}; MS (EI) *m/z* 261.1 ($[M]^+$, trace), 244.1 (41), 215.1 (52), 187.1 (30), 142.1 (49), 141.1 (88), 129.1 (63), 128.1 (70), 127.1 (32), 115.1 (100), 101.1 (35); HRMS (ASAP) *m/z* $[M+H]^+$ Calcd for $C_{13}H_{12}NO_5$ 262.0710; Found 262.0706.

(1S,3E,5R)-3-(Naphthalen-2-ylmethylene)-6,8-dioxabicyclo[3.2.1]octan-4-one (13f). Treatment of **2** (256 mg, 2.0 mmol) with 2-napthaldehyde (343 mg, 2.2 mmol) as per Method II and purification by flash chromatography (1:4 EtOAc/hexanes) gave **13f** as a white crystalline solid that was then recrystallised from hot ethanol (280 mg, 53%); $[\alpha]_D^{22}$ -232 (*c* 1.1, $CHCl_3$); mp 156-157 °C; ^{1}H NMR

(500 MHz, $CDCl_3$) δ 7.94 (br. s, 1H), 7.90-7.80 (m, 4H), 7.62-7.47 (m, 3H), 5.39 (s, 1H), 4.92 (dd, *J* = 5.4, 5.1 Hz, 1H), 3.96 (ddd, *J* = 7.1, 5.4, 1.1 Hz, 1H), 3.83 (dd, *J* = 7.1, 1.0 Hz, 1H), 3.47 (dddd, *J* = 16.6, 5.1, 2.9, 1.3 Hz, 1H), 3.01 (br. d, *J* = 16.6 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 189.7, 140.1, 133.4, 133.0, 132.2, 130.9, 128.6, 128.34, 128.28, 127.7, 127.4, 127.1, 126.7, 101.1, 72.6, 68.5, 34.8; FT-IR (neat) 3007, 2969, 2902, 1697, 1583, 1240, 1103, 816 cm^{-1}; MS (EI) *m/z* 266.1 ($[M]^+$, 67), 207.1 (41), 193.1 (77), 191.1 (52), 179.1 (62), 178.1 (98), 165.1 (62), 141.1 (100), 128.1 (79), 115.1 (55); HRMS (ASAP) *m/z* $[M+H]^+$ Calcd for $C_{17}H_{15}O_3$ 267.1016; Found 267.1024.

(1S,3E,5R)-3-(Pyridin-2-ylmethylene)-6,8-dioxabicyclo[3.2.1]octan-4-one (13g). Treatment of **2** (256 mg, 2.0 mmol) with pyridine-2-carboxaldehyde (235 mg, 2.2 mmol) as per Method II and purification by flash chromatography (7:3 EtOAc/hexanes) gave **13g** as a white crystalline solid that was recrystallised from hot diisopropyl ether (376 mg, 87%); $[\alpha]_D^{23}$ -216 (*c* 0.6, $CHCl_3$); mp 76-77 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 8.72 (d, *J* = 2.0 Hz, 1H), 8.60 (dd, *J* = 4.8, 1.4 Hz, 1H), 7.74 (ddd, *J* = 7.9, 2.0, 1.4 Hz, 1H), 7.67 (br. s, 1H), 7.36 (dd, *J* = 7.9, 4.9 Hz, 1H), 5.38 (s, 1H), 5.00 (br. dd, *J* = 5.3, 5.3 Hz, 1H), 3.96 (ddd, *J* = 7.3, 5.3, 1.4 Hz, 1H), 3.83 (dd, *J* = 7.3, 0.9 Hz, 1H), 3.37 (dddd, *J* = 16.8, 5.3, 3.1, 1.2 Hz, 1H), 2.88 (br. d, *J* = 16.8 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 188.9, 151.1, 150.0, 136.9, 136.0, 130.6, 130.5, 123.5, 100.9, 72.3, 68.5, 34.6; FT-IR (neat) 3030, 2953, 2900, 1699, 1603, 1482, 1412, 1253, 1222, 1116, 1100 cm^{-1}; MS (EI) *m/z* 217.1 ($[M]^+$, 5), 172.1 (27), 171.1 (70), 144.1 (79), 143.1 (100), 142.1 (50), 130.1 (75), 117.1 (54), 103.1 (67), 89.1 (27), 77.1 (26); HRMS (ASAP) *m/z* $[M+H]^+$ Calcd for $C_{12}H_{12}NO_3$ 218.0812; Found 218.0809.

(1S,3E,5R)-3-(Benzo[d][1,3]dioxol-5-ylmethylene)-6,8-dioxabicyclo[3.2.1]octan-4-one (13h). Treatment of **2** (256 mg, 2 mmol) with piperonal (360 mg, 2.4 mmol) as per Method I, and purification by flash chromatography (1:9 MeOH/toluene) gave solid **13h** which was recrystallised from hot MeOH to afford fine yellow crystals (317 mg, 61%); $[\alpha]_D^{21}$ -261 (*c* 0.86, $CHCl_3$); mp 129-131 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 7.64 (br. s, 1H), 7.00 (br. d, *J* = 7.9 Hz, 1H), 6.96 (br. s, 1H), 6.86 (d, *J* = 7.9 Hz, 1H), 6.02 (s, 2H), 5.34 (s, 1H), 4.88 (dd, *J* = 5.2, 5.2 Hz, 1H), 3.94 (br. dd, *J* = 7.0, 5.2 Hz, 1H), 3.81 (d, *J* = 7.0 Hz, 1H), 3.32 (br. d, *J* = 16.8 Hz, 1H), 2.85 (d, *J* = 16.8 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 189.7, 148.9, 148.0, 139.9, 129.0, 126.6, 126.0, 109.8, 108.7, 101.6, 101.0, 72.4, 68.5, 34.6; FT-IR (neat) 2971, 2898, 1689, 1576, 1500, 1488, 1436, 1237, 1101, 1031, 923 cm^{-1}; MS (EI) *m/z* 260.1 ($[M]^+$,46), 214.1 (82), 186.1 (93), 174 (45), 173.1 (100), 157.1 (36), 145.1 (37), 129.1 (52), 128.1 (82), 115.1 (57); HRMS (ASAP) *m/z* $[M+H]^+$ Calcd for $C_{14}H_{13}O_5$ 261.0757; Found 261.0769.

(1S,3E,5R)-3-((1H-Pyrrol-2-yl)methylene)-6,8-dioxabicyclo[3.2.1]octan-4-one (13i). Treatment of **2** (256 mg, 2.0 mmol) with pyrrole-2-carboxaldehyde (209 mg, 2.2 mmol) as per Method II and purification by flash chromatography (2:3 EtOAc/hexanes) gave **13i** as a 50:11 mixture of *E* and *Z* isomers as an orange solid. This orange solid was recrystallised from acetone/hexanes to give fine orange crystals of **(*E*)-13i** (199 mg, 48%); $[\alpha]_D^{22}$ -294 (*c* 0.78, $CHCl_3$); mp 167-168 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.13 (br. s, 1H), 7.69 (br. s, 1H), 7.05 (ddd, *J* = 2.6, 2.6, 1.2 Hz, 1H), 6.60 (br. s, 1H), 6.40 (dddd, *J* = 3.2, 2.6, 2.6, 0.6 Hz, 1H), 5.34 (s, 1H), 4.95 (br. dd, *J* = 5.5, 5.5 Hz, 1H), 3.98 (ddd, *J* = 7.0, 5.5, 1.3 Hz, 1H), 3.83 (dd, *J* = 7.0, 1.2 Hz, 1H), 3.23 (dddd, *J* = 16.8, 5.5, 2.6, 1.3 Hz, 1H), 2.70 (br. d, *J* = 16.8 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 189.6, 129.8, 128.8, 123.2, 120.6, 115.1, 112.1, 100.9, 72.2, 68.9, 34.0; FT-IR (neat) 3383, 3130, 2966, 2905, 1669, 1566, 1445, 1416, 1313, 1269, 1197, 1112, 1100, 1045, 743 cm^{-1}; MS (EI) *m/z* 205.1 ([M]$^+$, 100), 160.1 (42), 132.1 (85), 131.1 (73), 130.1 (80), 119 (56), 118.1 (48), 117.1 (58), 91.1 (56), 32 (39); HRMS (ASAP) *m/z* [M+H]$^+$ Calcd for $C_{11}H_{11}NO_3$ 206.0812; Found 206.0826.

(1R,4S)-3,4,5,11a-Tetrahydro-1H-1,4-epoxyoxepino[3,4-b]chromen-11a-ol (15). To a solution of **2** (256 mg, 2.0 mmol) and salicylaldehyde (269 mg, 2.2 mmol) in MeCN (1 mL) was added TMG (12 mg, 12.5 µL, 0.10 mmol) and the mixture heated to 50 °C for 5 days. Another portion of TMG (104 mg, 113 µL, 0.9 mmol) was added and the mixture stirred for a further 29 h before concentration under reduced pressure. The residue was purified by flash chromatography (1:1 EtOAc/hexanes) to give **15** as a colourless crystalline solid after recrystallising from ethanol (309 mg, 67%); $[\alpha]_D^{26}$ -35 (*c* 1.26, EtOH); mp 190-192 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 7.17-7.11 (m, 2H), 6.95-6.90 (m, 2H), 6.87 (br. d, *J* = 7.7 Hz, 1H), 6.49 (br. s, 1H), 5.21 (s, 1H), 4.70 (br. s, 1H), 3.68 (br. d, *J* = 7.1 Hz, 1H), 3.65 (br dd, *J* = 7.1, 5.3 Hz, 1H), 2.85 (br. d, *J* = 14.3 Hz, 1H), 2.36 (br. d, *J* = 14.3 Hz, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 151.1, 129.7, 128.3, 126.1, 122.3, 121.1, 120.8, 116.0, 101.4, 93.1, 73.2, 67.2, 34.5; FT-IR (neat) 3417, 2975, 2947, 2890, 1664, 1606, 1576, 1486, 1461, 1427, 1402, 1356, 1332, 1240, 1189, 1125, 1097 cm^{-1}; MS (EI) *m/z* 232.1 ([M]$^+$, trace), 187.1 (40), 186.1 (100), 185.1 (31), 171 (42), 159 (49), 158.1 (23), 157.1 (33), 131.1 (47), 128.1 (17), 115.1 (40); HRMS (ASAP) *m/z* [M+H]$^+$ Calcd for $C_{13}H_{13}O_4$ 233.0814; Found 233.0821.

Synthesis of lactone 7a and 7f from 13a and 13f

(1S,3R,5R)-3-Benzyl-6,8-dioxabicyclo[3.2.1]octan-4-one (9a). To a solution of aldol adduct **9a** (216 mg, 1.00 mmol) in EtOAc (3 mL) was added 10% Pd/C (22 mg) and the mixture stirred under an atmosphere of H_2 for 18 h. The reaction mixture was filtered through Celite and concentrated under reduced pressure, with purification of the residue by flash chromatography (3:17 EtOAc/hexanes)

yielding a mixture of **9a**/**10a** (4:3) as a colourless oil (182 mg, 84%). A portion of this mixture (119 mg, 0.546 mmol) was taken up in (i-Pr)$_2$EtN (2 mL) and stirred for 18 h. Concentration under reduced pressure followed by flash chromatography (3:17 EtOAc/hexanes) yielded a mixture of **9a**/**10a** (97:3) as a colourless oil (113 mg, 95%); $[\alpha]_D^{18}$ -219 (*c* 1.12, DCM); FT-IR (neat) 3071, 3025, 2961, 2914, 2854, 1733, 1602, 1496, 1453, 1113 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.25-7.18 (m, 2H), 7.14 (m, 1H), 7.07 (m, 2H), 5.11 (s, 1H), 4.70-4.49 (m, 1H), 3.90 (d, *J* = 7.9 Hz, 1H), 3.82 (ddd, *J* = 7.9, 5.5, 0.9 Hz, 1H), 3.29 (dd, *J* = 14.0, 4.1 Hz, 1H), 2.85 (dddd, *J* = 11.4, 9.6, 8.2, 4.1 Hz, 1H), 2.38 (dd, *J* = 14.0, 9.6 Hz, 1H), 1.93-1.80 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 201.7, 138.8, 129.0, 128.5, 126.4, 101.3, 73.5, 67.5, 42.4, 37.2, 34.7; MS (EI) *m/z* 218.1 ([M]$^+$, trace) 186.1 (48), 142.1 (39), 141.1 (88), 129.1 (71), 128.1 (28), 115.1 (29), 107.1 (47), 79.1 (100), 77.1 (83), 51.1 (23); HRMS (ASAP) *m/z* [M + H]$^+$ Calcd for $C_{13}H_{15}O_3$ 219.1016; Found 219.1013. (1*S*,3*S*,5*R*)-3-Benzyl-6,8-dioxabicyclo[3.2.1]octan-4-one (**10a**). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32-6.96 (m, 5H), 5.10 (s, 1H), 4.61 (dd, *J* = 6.4, 5.2 Hz, 1H), 3.73 (ddd, *J* = 7.3, 5.2, 1.2 Hz, 1 H), 3.69 (d, *J* = 7.3 Hz, 1H), 3.12 (dd, *J* = 13.7, 4.9 Hz, 1H), 2.75 (dddd, *J* = 9.8, 9.8, 4.9, 4.9 Hz, 1H), 2.65 (dd, *J* = 13.7, 9.8 Hz, 1H), 2.27 (dddd, *J* = 14.5, 9.8, 6.4, 1.2 Hz, 1H), 1.49 (ddd, *J* = 14.5, 4.9, 0.9 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 203.2, 138.6, 129.0, 128.4, 126.6, 100.0, 72.2, 69.3, 42.4, 38.1, 30.0; GC-MS (EI) *m/z* 218.1 ([M]$^+$, trace) 172.1 (30), 144.1 (52), 143.1 (15), 129.1 (73), 117.1 (17), 115.1 (16), 104.1 (69), 92.1 (14), 91.1 (100), 65.1 (16).

(3R,5S)-3-Benzyl-5-(hydroxymethyl)dihydrofuran-2(3H)-one (7a).[17] To a solution of **9a**/**10a** (97:3, 157 mg, 0.73 mmol) in DCM (2 mL) was added 32% peracetic acid (1.0 mL, 7.2 mmol) and the mixture stirred for 18 h. The reaction was quenched with 10% Pd/C (15 mg) and stirred until the evolution of O_2 had ceased and a negative test for peroxides was obtained (starch/iodide paper). The mixture was then filtered through Celite, concentrated under reduced pressure and taken up in 1:1 THF/1M HCl (3 mL) and stirred for 3 h. The volatiles were removed under reduced pressure and the residue purified by flash chromatography (1:1 EtOAc/hexanes) to give **7a** as a colourless oil that crystallised on standing. Subsequent recrystallisation from diisopropyl ether gave the title compound as a white crystalline solid (130 mg, 87%); $[\alpha]_D^{25}$ -9.4 (*c* 0.64, $CHCl_3$), Lit. [17] -2.22 (*c* 0.006, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62-7.05 (m, 5H), 4.43 (dddd, *J* = 8.1, 4.9, 4.3, 3.0 Hz, 1H), 3.84 (br. ddd, *J* = 12.4, 5.8, 3.0 Hz, 1H), 3.60 (br. ddd, *J* = 12.4, 5.8, 5.8 Hz, 1H), 3.21 (dd, *J* = 13.7, 4.6 Hz, 1H), 3.10 (dddd, *J* = 9.3, 9.3, 8.1, 4.6 Hz, 1H), 2.81 (dd, *J* = 13.7, 9.3 Hz, 1 H), 2.30 (br. dd, *J* = 5.8, 5.8 Hz, 1H), 2.21 (ddd, *J* = 13.1, 9.5, 4.3 Hz, 1H), 2.08 (ddd, *J* = 13.1, 8.1, 8.1 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 179.1, 138.1, 128.9, 128.7, 126.8, 78.6, 64.4, 41.3, 36.8. 28.7; FT-IR (neat) 3400, 3035, 2995, 2949, 2874, 1724, 1601, 1362, 1213 cm^{-1}; MS (ESI) *m/z* 207.1 [M + H]$^+$, 229.1 [M + Na]$^+$, 245.1 [M + K]$^+$.

(3R,5S)-5-(Hydroxymethyl)-3-(naphthalen-2-ylmethyl)dihydrofuran-2(3H)-one (7f). 2-Naphthyl adduct **13f** (150 mg, 0.56 mmol) and 10% Pd/C (12 mg) were dissolved in EtOAc (5 mL), then the flask was evacuated and filled with H_2 three times before allowing to stir at 25 °C for 26 h. The solution was filtered through celite, the filter cake washed with ethyl acetate and then the filtrate concentrated under reduced pressure. The residue was purified by flash chromatography (1:4 EtOAc/hexanes) to afford a mixture of **9f**/**10f** (67:33) as a pale yellow oil (148 mg, 99%). The oil was then taken up in $(i\text{-}Pr)_2EtN$ (2.0 mL) and stirred at 25 °C for 27 h then concentrated under reduced pressure to afford a mixture of **9f**/**10f** (93:7) as a yellow oil (146 mg, 97%) that was used without further purification. **9f**: R_f (1:4 EtOAc/hexanes) 0.59; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.81-7.77 (m, 3H), 7.59 (br. s, 1H), 7.48-7.42 (m, 2H), 7.28-7.25 (m, 1H), 5.20 (s, 1H), 4.64 (br. s, 1H), 3.95 (d, *J* = 7.3 Hz, 1H), 3.89-3.87 (m, 1H), 3.52 (dd, *J* = 14.1, 4.0 Hz, 1H), 3.04-2.98 (m, 1H), 2.62 (dd, J = 14.1, 9.7 Hz, 1H), 1.97-1.94 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 201.6, 136.3, 133.5, 132.2, 128.2, 127.6, 127.5, 127.4, 127.2, 126.1, 125.5, 101.3, 73.5, 67.5, 42.4, 37.2, 34.9; MS (EI) *m/z* 268.1 ($[M]^+$, 31), 240.1 (17), 179.1 (43), 165.1 (20), 154.1 (45), 153.1 (26), 152.1 (16), 141.1 (100), 128.1 (21), 115.1 (25). The mixture **9f**/**10f** (148 mg, 0.55 mmol) and 32% peracetic acid (1 mL) were dissolved in DCM (2 mL) and stirred for 28 h. To quench the peroxide 10% Pd/C (50 mg) was added and stirred until a negative test for peroxides was obtained (starch/iodide paper). The solution was filtered through celite, concentrated under reduced pressure then taken up in 1M HCl (3 mL) and stirred for 2.5 h then again concentrated under reduced pressure. The residue was purified via flash chromatography (7:3 EtOAc/hexanes) then recrystallised from MeOH to afford fine white crystals (72 mg, 51%); R_f (7:3 EtOAc/hexanes) 0.69; mp 126-128 °C; $[\alpha]_D^{21}$ -9.8 (*c* = 0.51, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83-7.78 (m, 3H), 7.64 (br. s, 1H), 7.49-7.44 (m, 2H), 7.34 (d, *J* = 8.4 Hz, 1H), 4.42 (m, 1H), 3.81 (br. d, *J* = 12.4 Hz, 1H), 3.58 (br. d, *J* = 12.4 Hz, 1H), 3.36 (dd, *J* = 13.9, 4.5 Hz Hz, 1H), 3.17 (ddd, *J* = 17.4, 8.8, 4.6 Hz, 1H), 2.96 (dd, *J* = 13.8, 9.4 Hz, 1H), 2.21-1.16 (m, 1H), 2.13-2.08 (m, 1H), 1.99 (br. s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 178.9, 135.6, 133.5, 132.3, 128.5, 127.7, 127.52, 127.50, 127.1, 126.6, 125.7, 78.5, 64.5, 41.2, 37.0, 28.8; FT-IR (neat) ν = 3395, 2950, 2879, 1726, 1506, 1360, 1308, 1222, 1204, 1179, 1150, 1087, 1060, 1019, 1001 cm^{-1}; MS (EI) *m/z* 256.1 ($[M]^+$, 39), 198.1 (69), 197.1 (11), 179.1 (12), 165.1 (11), 153.1 (11), 152.1 (13), 142.1 (19), 141.1 (100), 115.1 (21); HRMS (ASAP) *m/z* $[M]^+$ Calcd for $C_{16}H_{16}O_3$ 256.1099; Found 256.1094.

Synthesis of lactone 7a using a Baylis-Hillman reaction

(1S,5R)-3-((R/S-Hydroxy(phenyl)methyl)-6,8-dioxabicyclo[3.2.1]oct-2-en-4-one (16). To a solution of LGO **1** (252 mg, 2.00 mmol) in formamide (400 µL, 10.0 mmol) was added benzaldehyde (440 µL, 4.31 mmol) then DABCO (224 mg, 2.00 mmol) and the mixture was stirred for 6 days. The reaction mixture was applied directly to a silica column and eluted with 3:7-1:1 EtOAc/hexanes to give the title

compound as a colourless syrup in a 53:47 mix of diastereomers (115 mg, 25%); **Diastereomer 1**: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35-7.20 (m, 5H), 7.06 (dd, *J* = 4.7, 1.2 Hz, 1H), 5.53 (d, *J* = 1.2 Hz, 1H), 5.26 (s, 1H), 4.99 (dd, *J* = 4.7, 4.7 Hz, 1 H), 3.81 (dd, *J* = 6.7, 4.7 Hz, 1H), 3.68 (d, *J* = 6.7 Hz, 1 H), 2.65 (br. s, 1 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 189.1, 142.0, 140.4, 139.3, 128.6, 128.2, 126.8, 101.0, 72.1, 70.6, 66.3; MS (EI) *m/z* 232.1 ($[M]^+$, trace), 186.1 (48), 142.1 (39), 141.1 (88), 129.1 (71), 128.1 (28), 115.1 (29), 107.1 (47), 79.1 (100), 77.1 (83), 51.1 (23). **Diastereomer 2:** ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35-7.17 (m, 5 H), 6.92 (dd, *J* = 4.7, 1.2 Hz, 1H), 5.49 (s, 1H), 5.28 (s, 1H), 4.96 (dd, *J* = 4.7, 4.7 Hz, 1H), 3.80 (dd, *J* = 7.0, 4.7 Hz, 1H), 3.63 (d, *J* = 7.0 Hz, 1H), 2.89 (br. s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 188.8, 142.9, 140.4, 139.6, 128.8, 128.3, 126.8, 101.3, 72.3, 70.3, 66.6; MS (EI) *m/z* 232.1 ($[M]^+$, trace), 186.1 (50), 142.1 (40), 141.1 (91), 129.1 (72), 128.1 (29), 115.1 (29), 107.1 (49), 79.1 (100), 77.1 (85), 51.1 (24); HRMS (ASAP) *m/z* $[M+H]^+$ Calcd for $C_{13}H_{13}O_4$ 233.0808; Found 233.0806.

Synthesis of 9a/10a from alcohol 16. To a solution of **16** (85 mg, 0.36 mmol) in THF (1 mL) was added $PdCl_2$ (3.3 mg, 18.3 μmol) and the mixture stirred under an atmosphere of H_2 for 18 h. The reaction mixture was filtered through Celite and concentrated under reduced pressure, with purification of the residue by flash chromatography (3:17 EtOAc/hexanes) yielding a mixture of **9a**/**10b** (97:3) as a colourless oil (33 mg, 49%) which was spectroscopically identical to the product obtained from **13a**.

References

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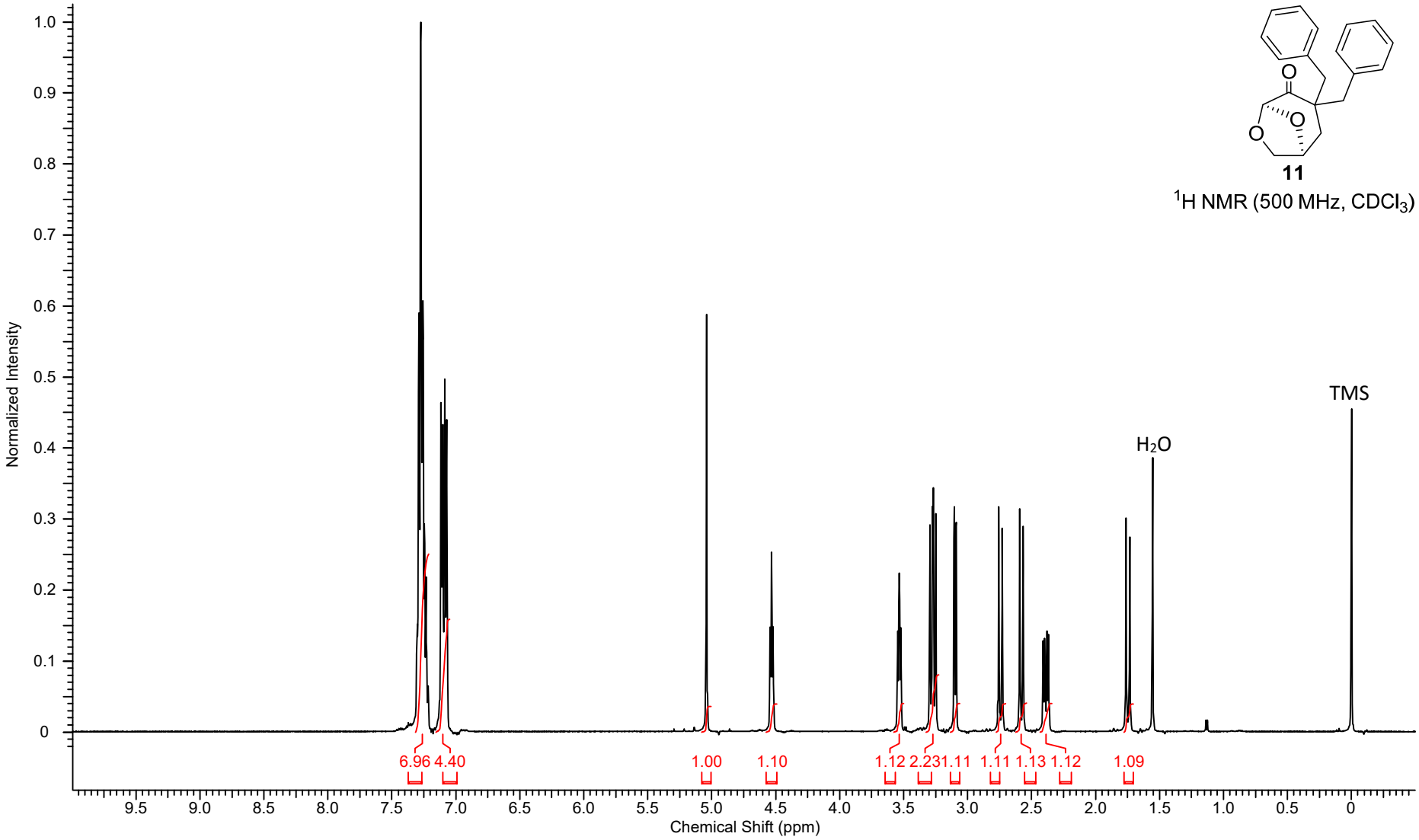
H. E. Gottlieb, V. Kotlyar and A. Nudelman, *J. Org. Chem.*, 1997, **62**, 7512-7515.

NMR Spectra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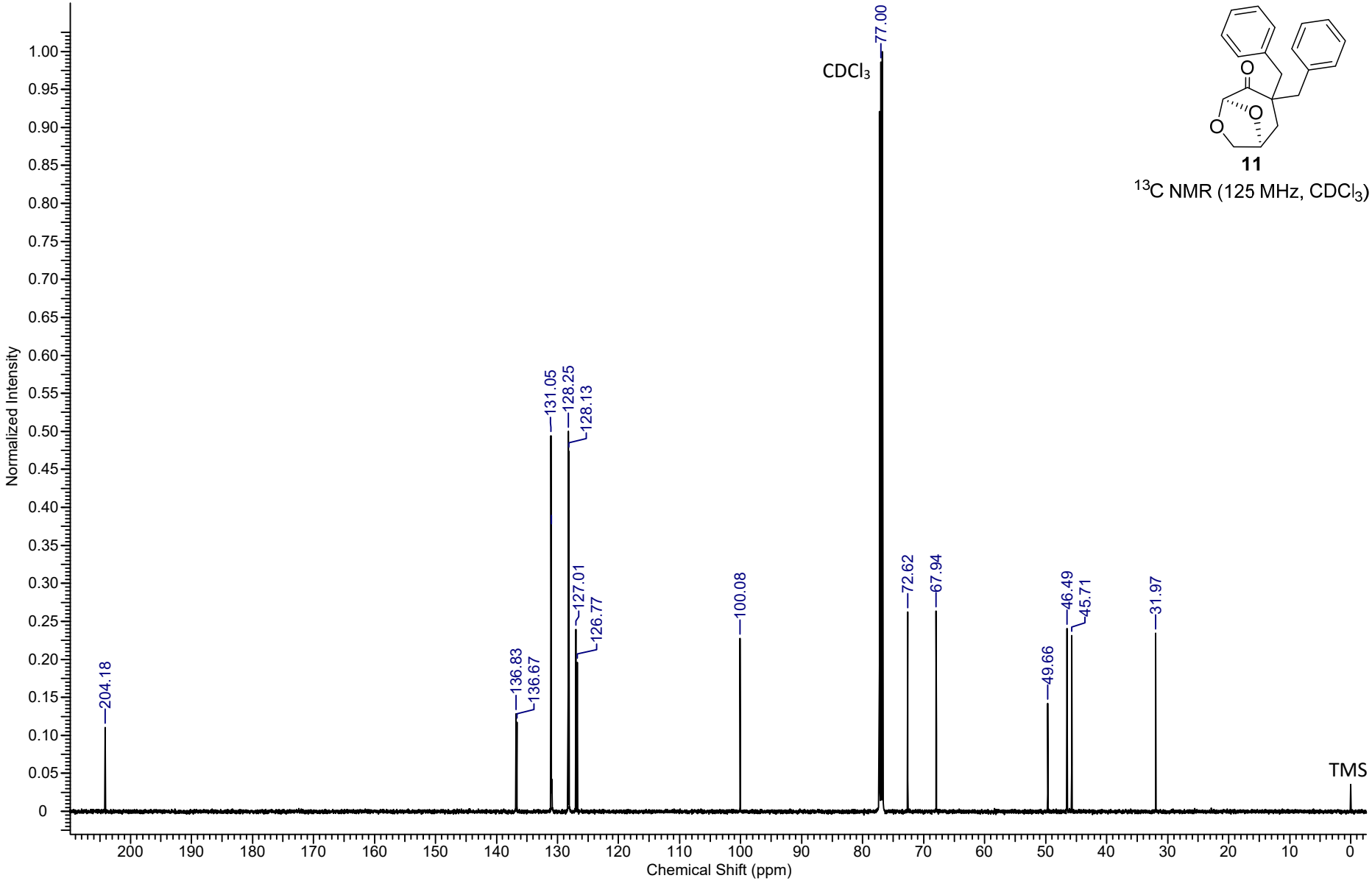
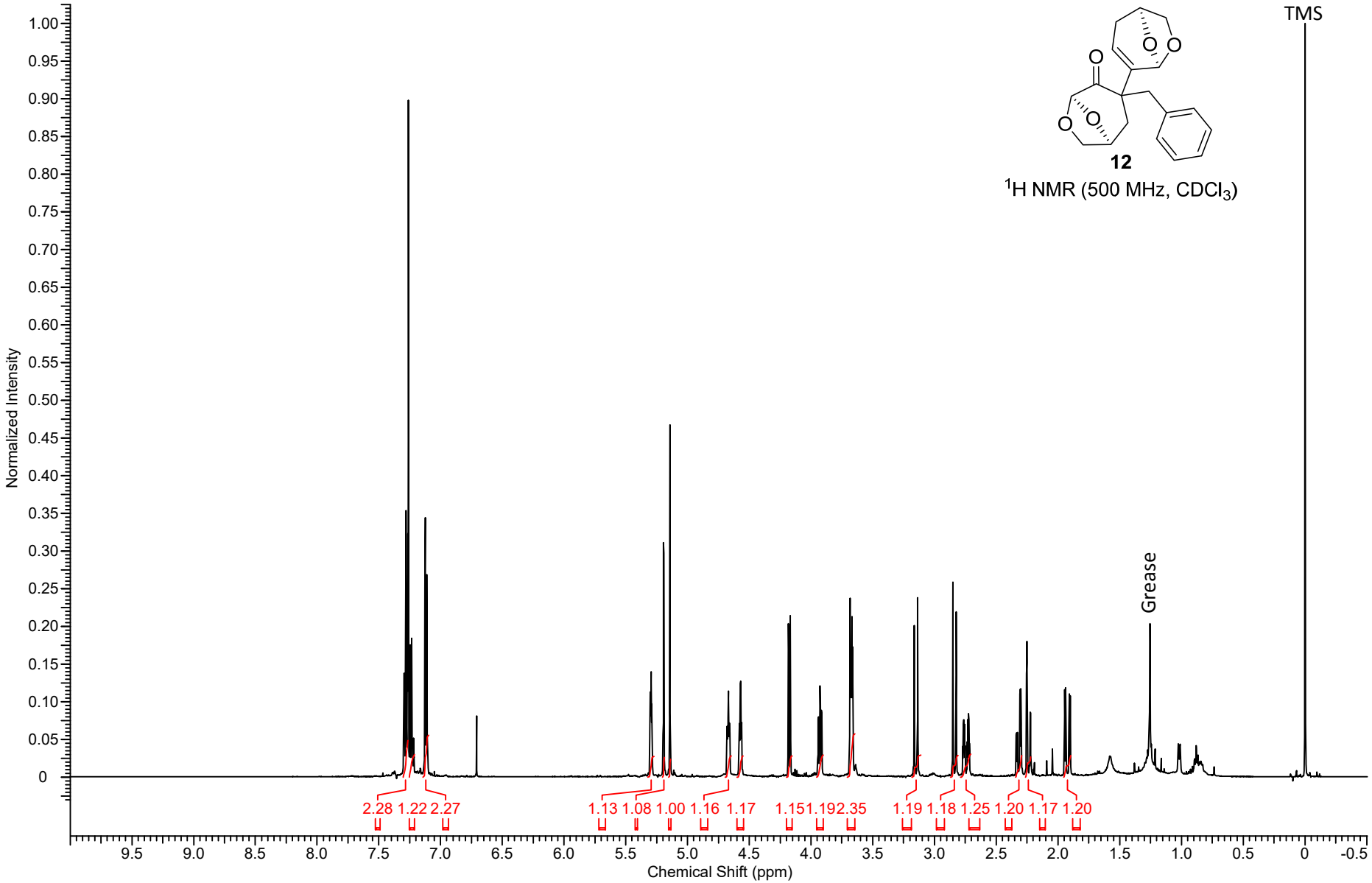
1.11
1.13
1.12
1.09



11

^{13}C NMR (125 MHz, $CDCl_3$)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12
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Grease
Normalized Intensity
Chemical Shift (ppm)
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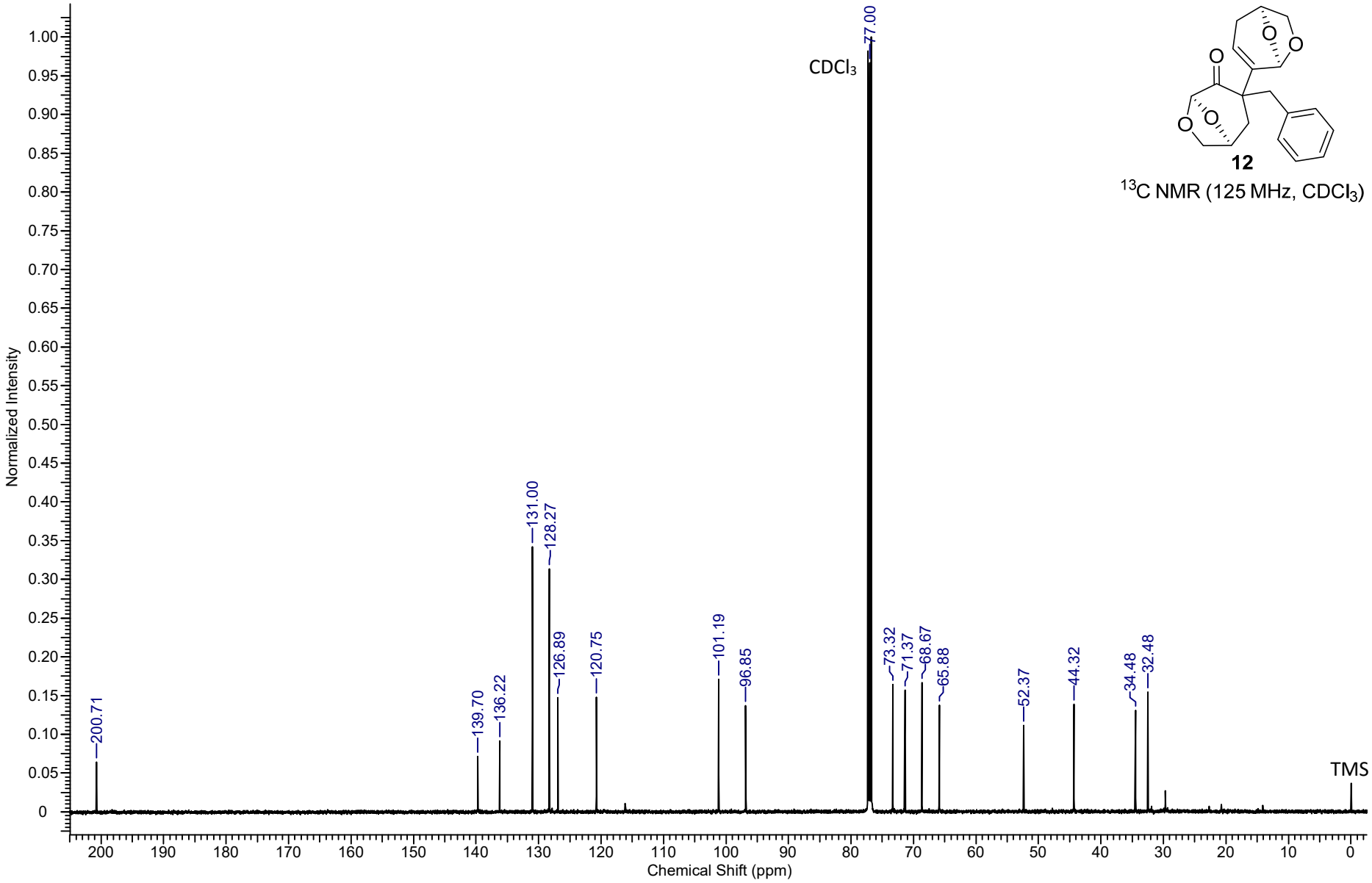
1.15 1.19 2.35
1.19 1.18 1.25 1.20 1.17 1.20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71.37
68.67
65.88
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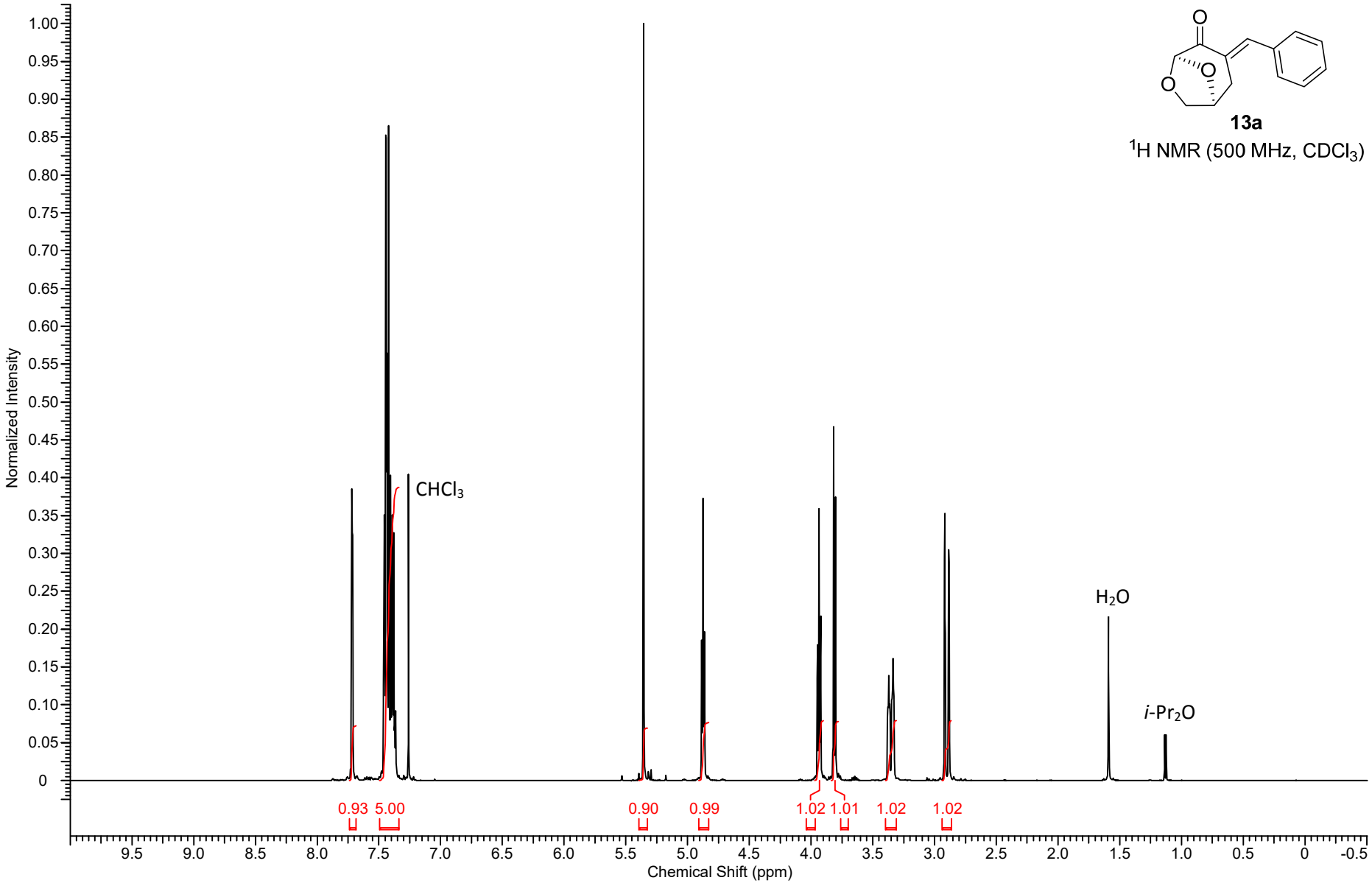
44.32
34.48
32.48
TMS
Normalized Intensity
Chemical Shift (ppm)
12
13C NMR (125 MHz, CDCl3)


13a
^{1}H NMR (500 MHz, $CDCl_3$)
Normalized Intensity
Chemical Shift (ppm)
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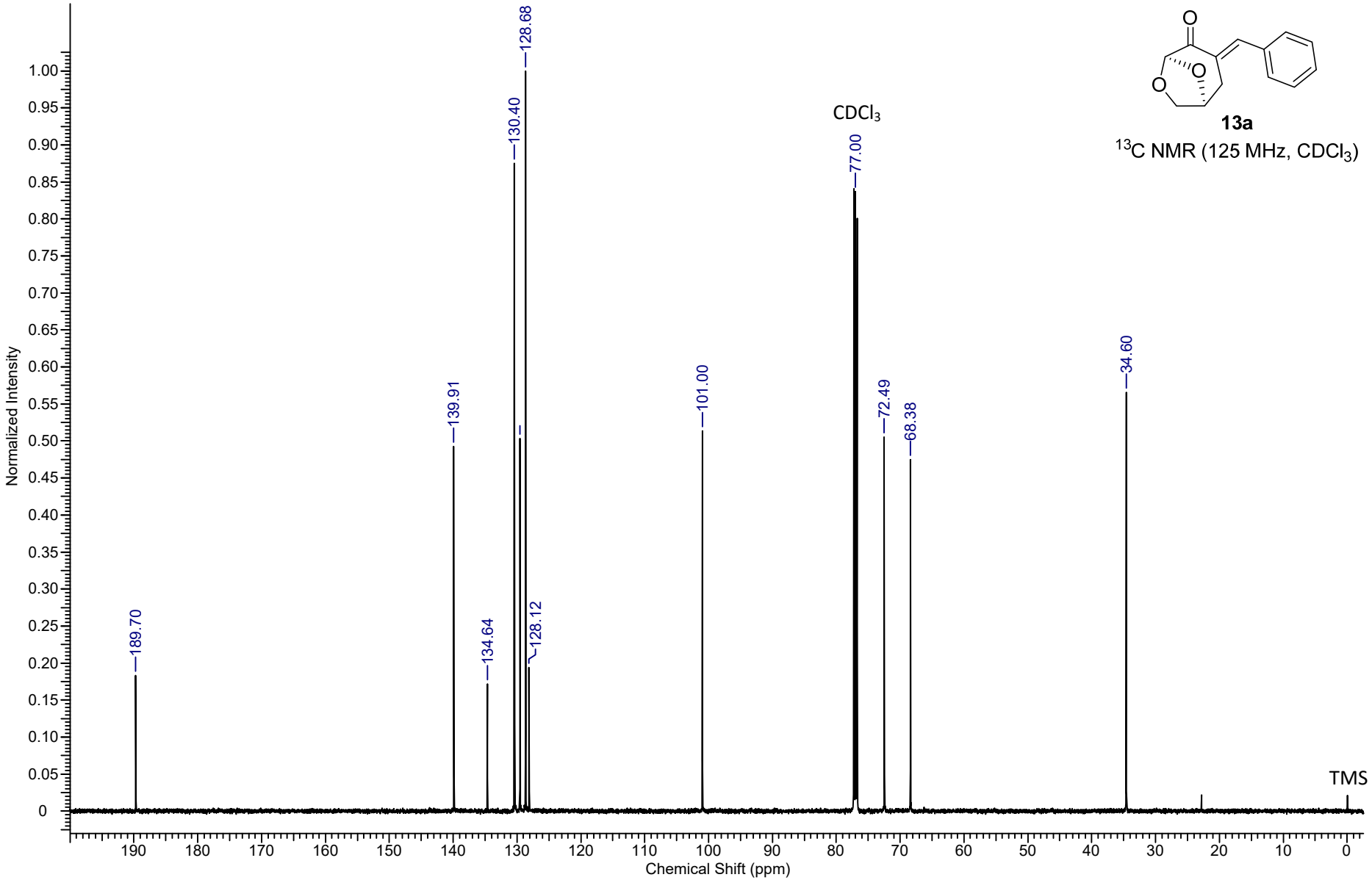
0.90 0.99
1.02 1.01 1.02 1.02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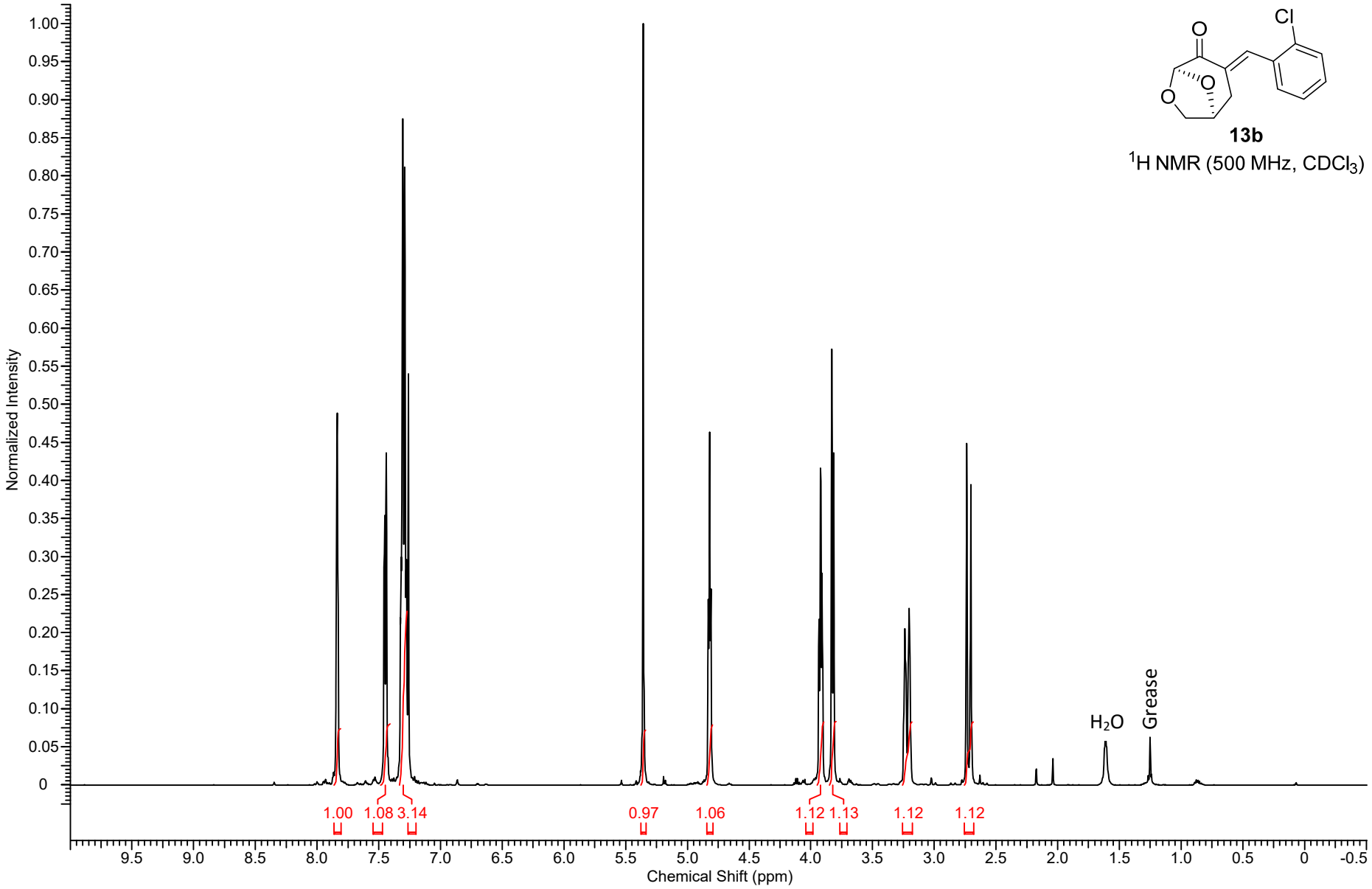
TMS
Normalized Intensity
Chemical Shift (ppm)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O
O
O
13b
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Normalized Intensity
Chemical Shift (ppm)
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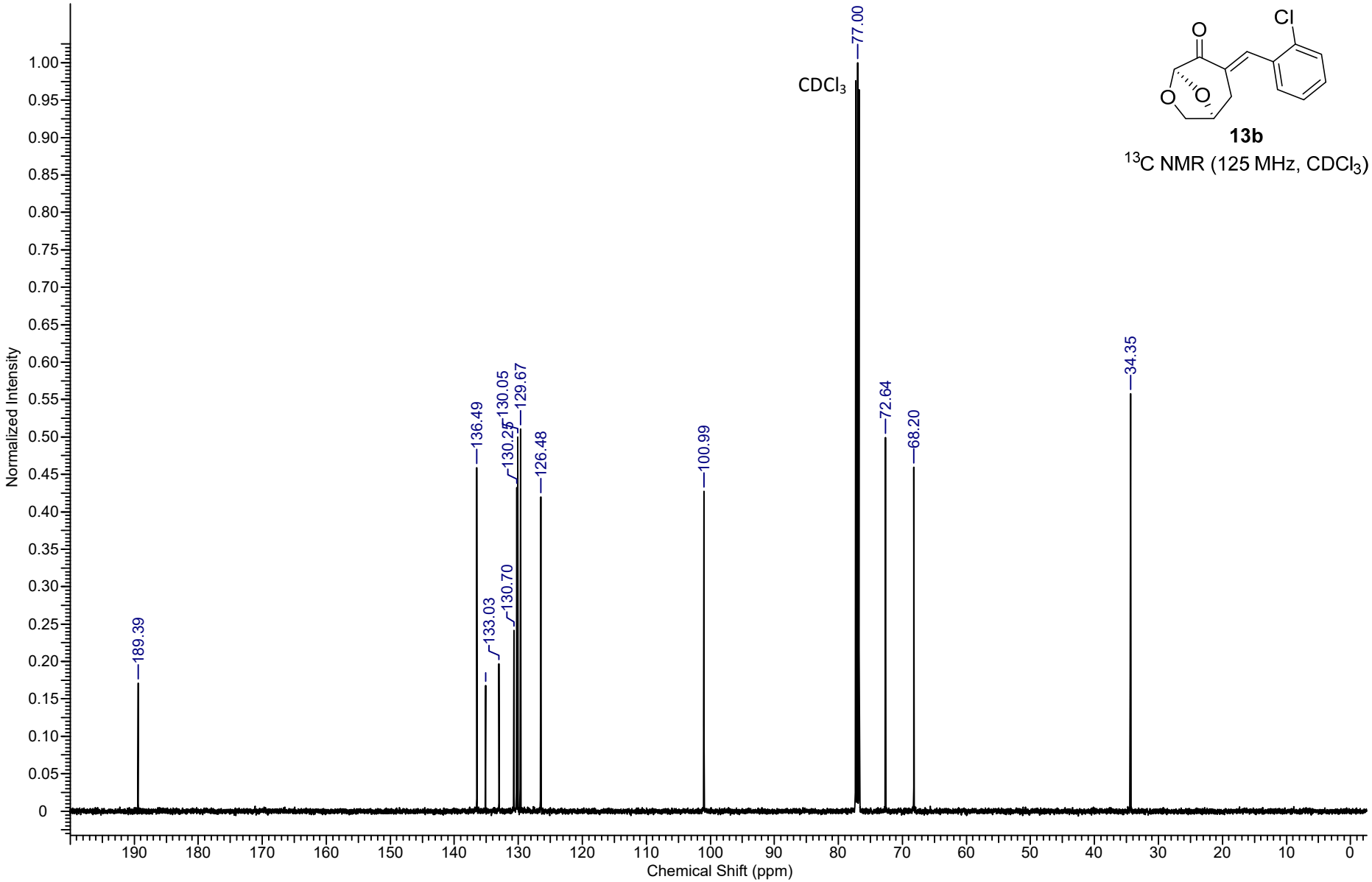
1.06
1.12 1.13
1.12
1.12
H_2O
Grease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O
O
O
13b
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$CDCl_3$
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133.03
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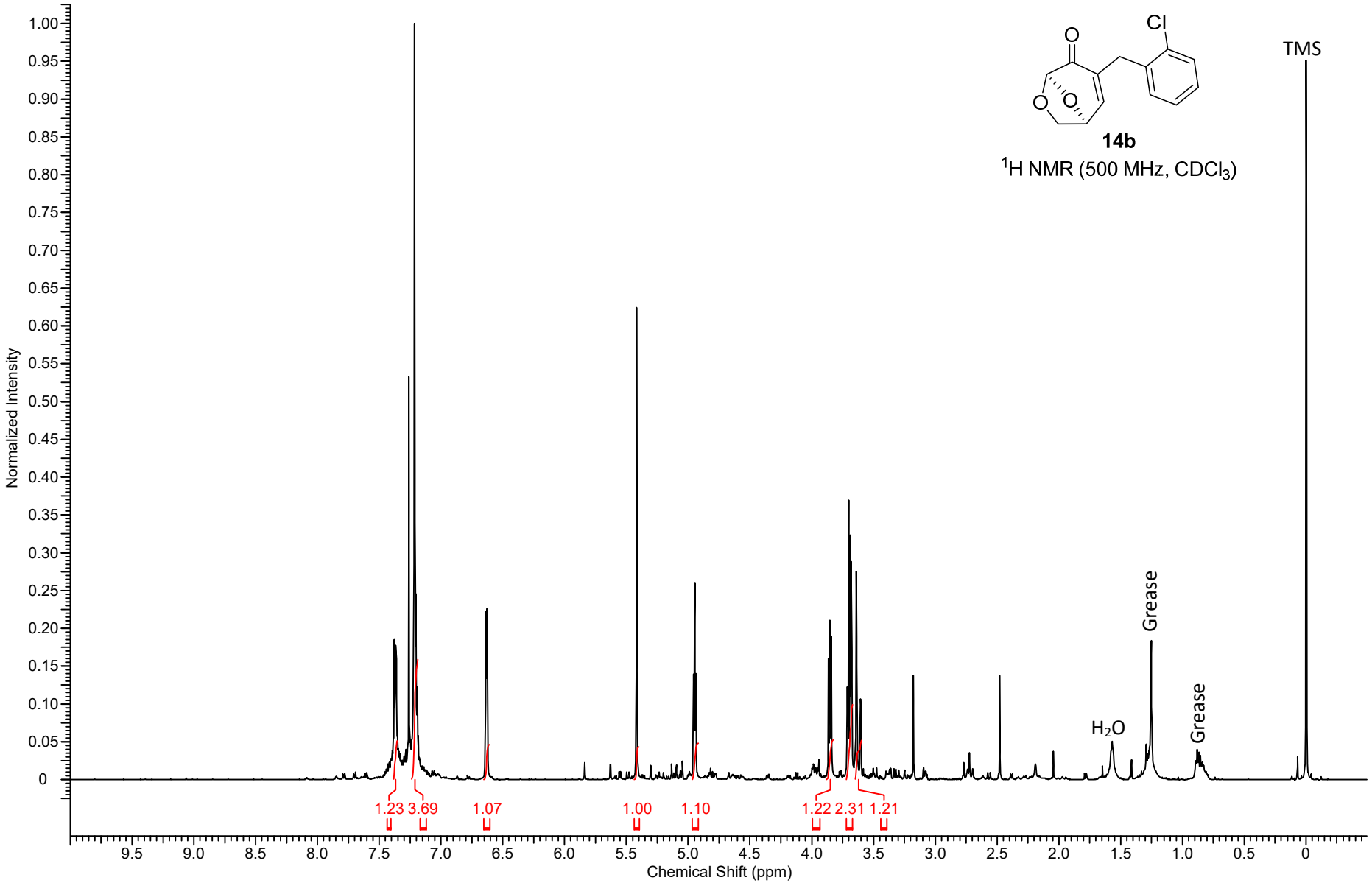
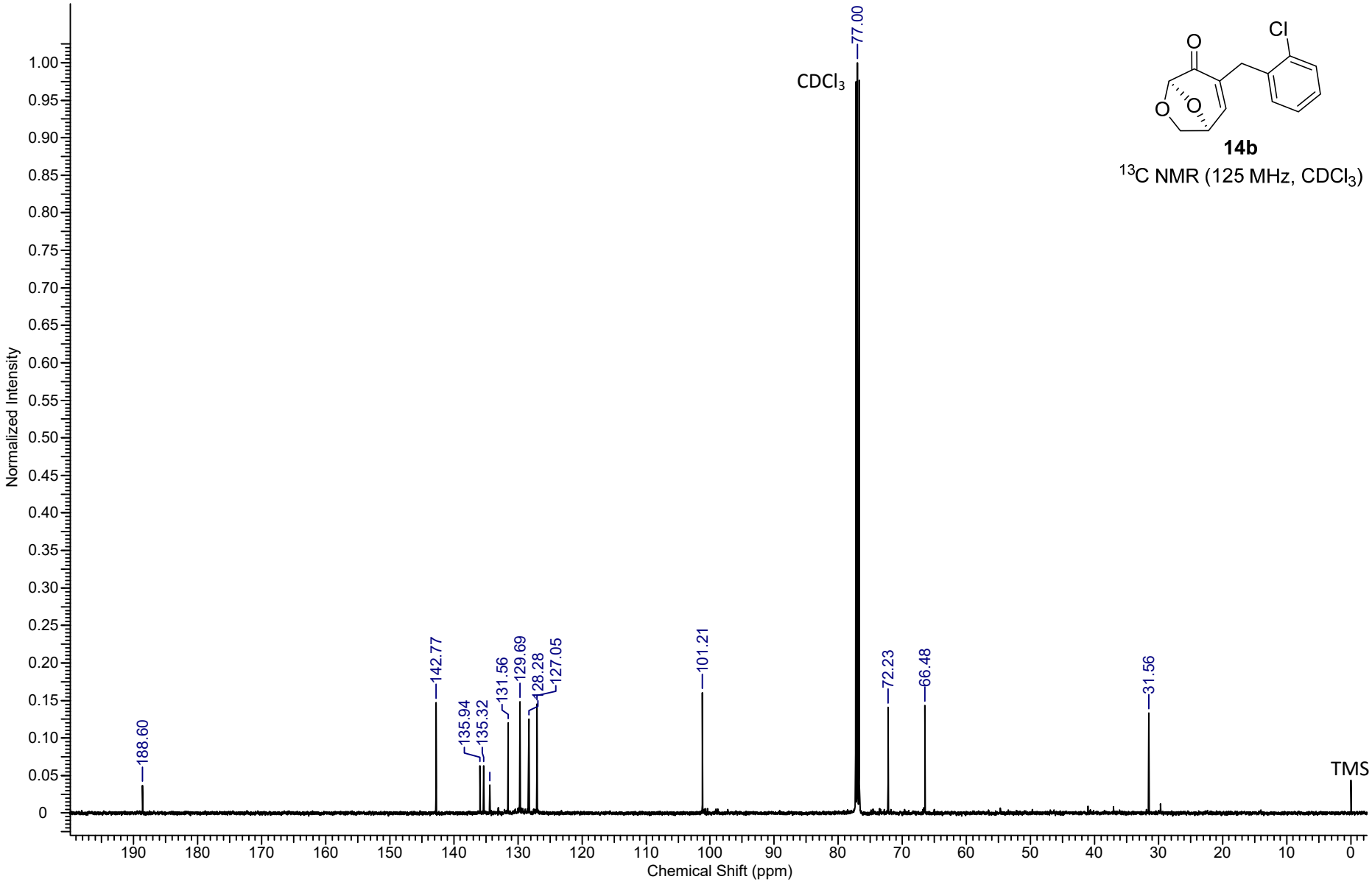
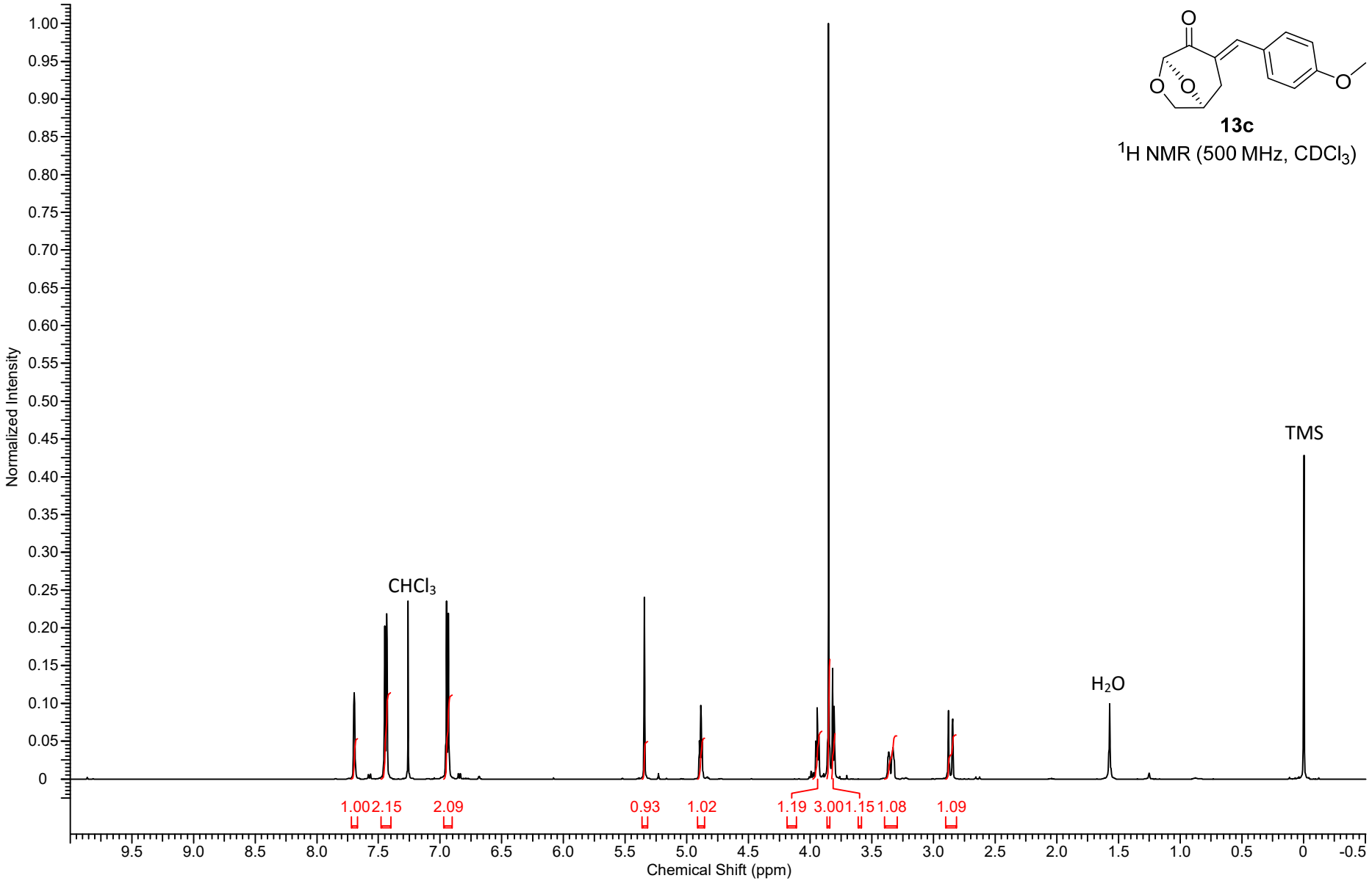
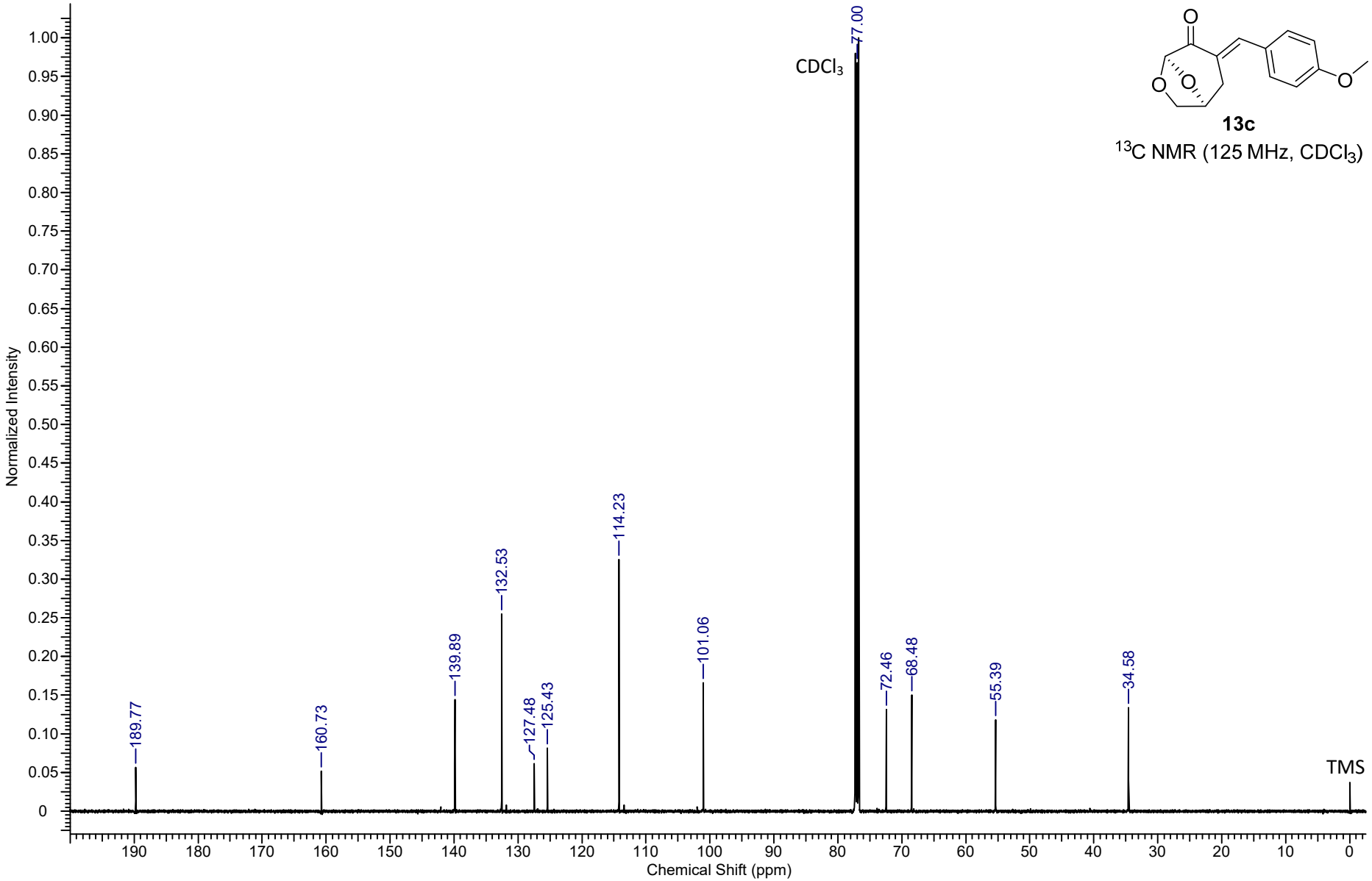
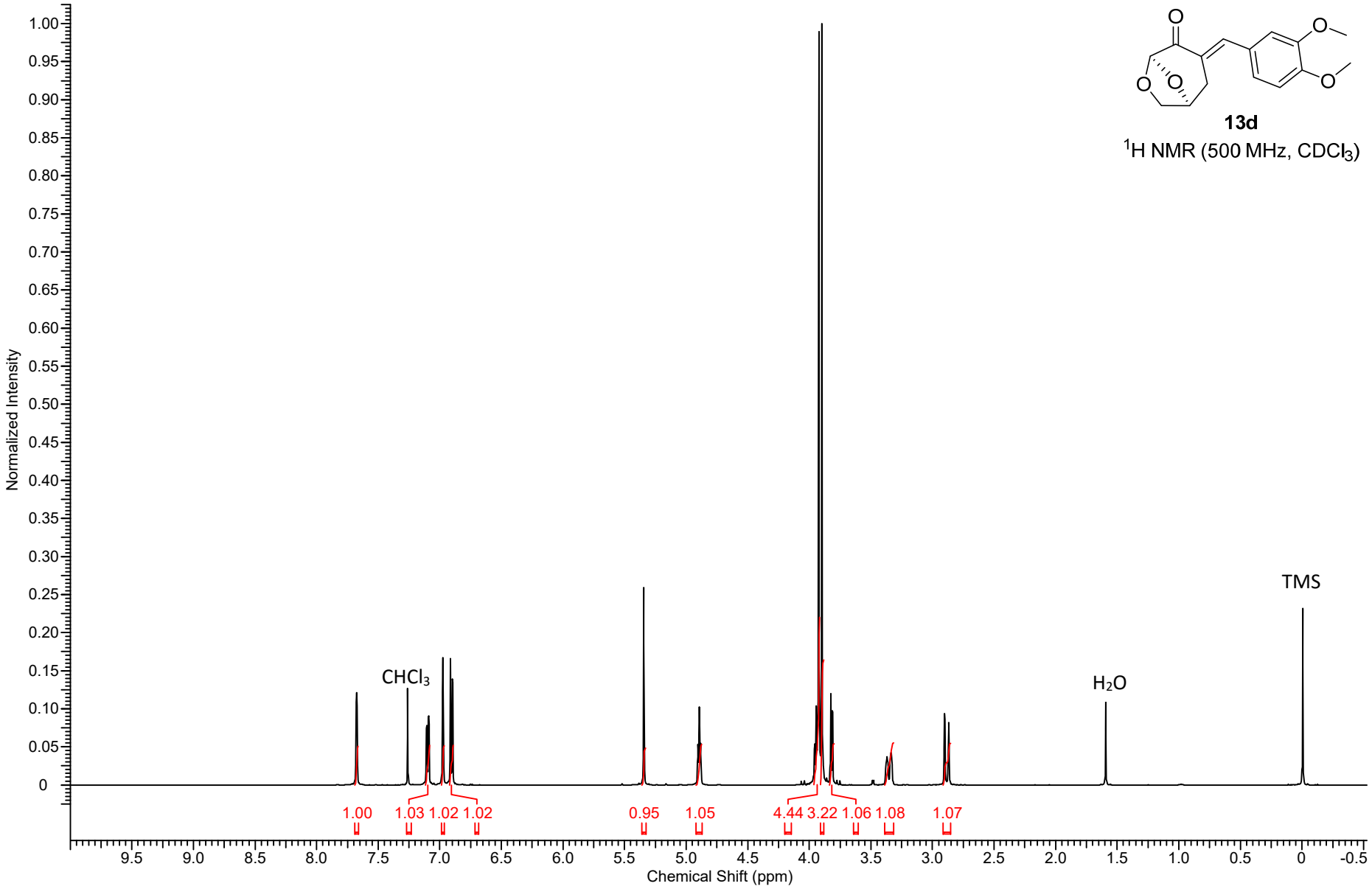
100.99
72.64
68.20
34.35
Normalized Intensity
Chemical Shift (ppm)

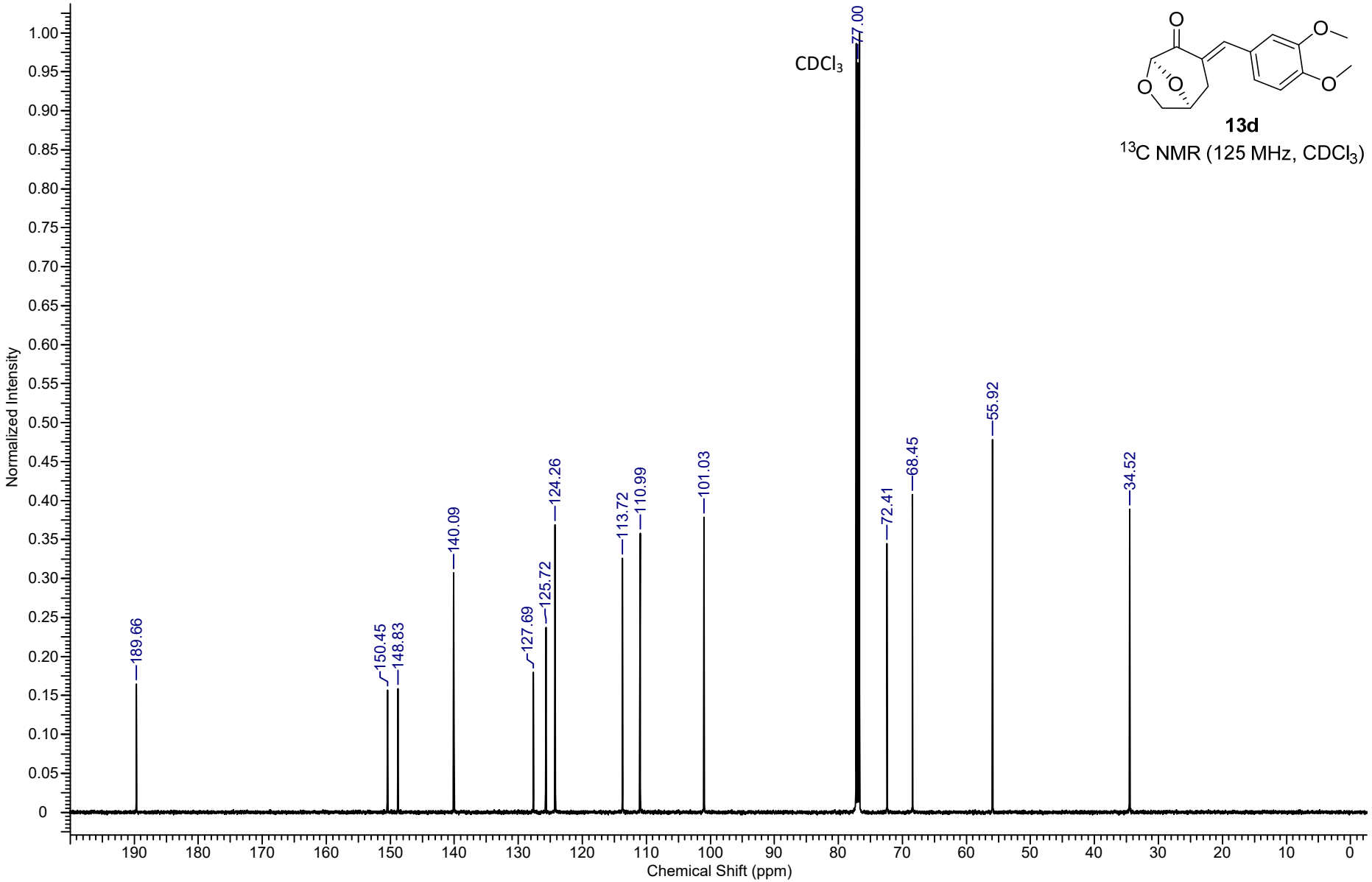

Cl
O
O
O
14b
^{1}H NMR (500 MHz, $CDCl_3$)
TMS
Grease
Grease
H_2O
1.23 3.69
1.07
1.00
1.10
1.22 2.31 1.21
Normalized Intensity
Chemical Shift (ppm)

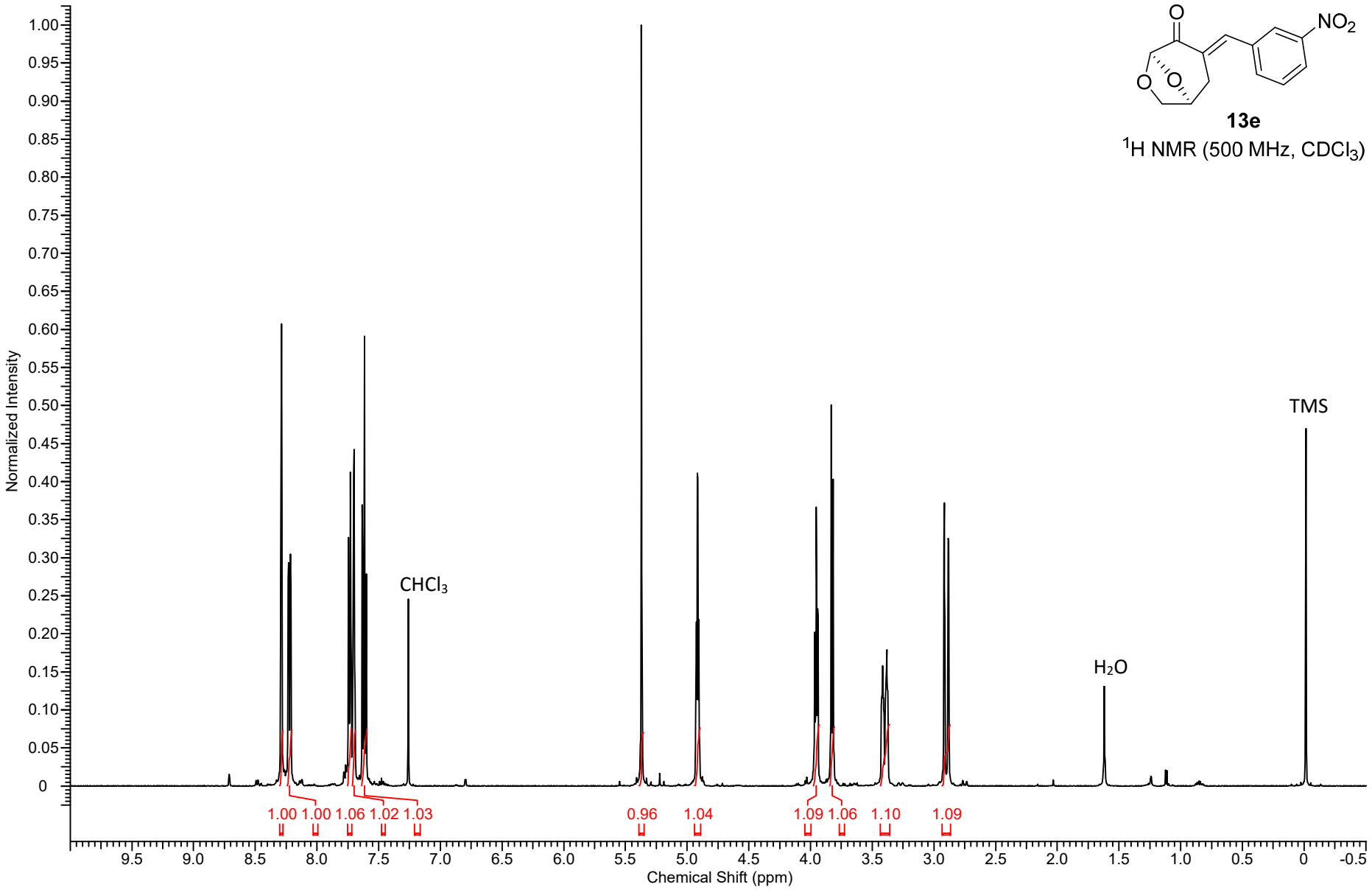

77.00
CDCl3
Cl
O
O
O
14b
13C NMR (125 MHz, CDCl3)
188.60
142.77
135.94
135.32
131.56
129.69
128.28
127.05
101.21
72.23
66.48
31.56
TMS
Normalized Intensity
Chemical Shift (ppm)

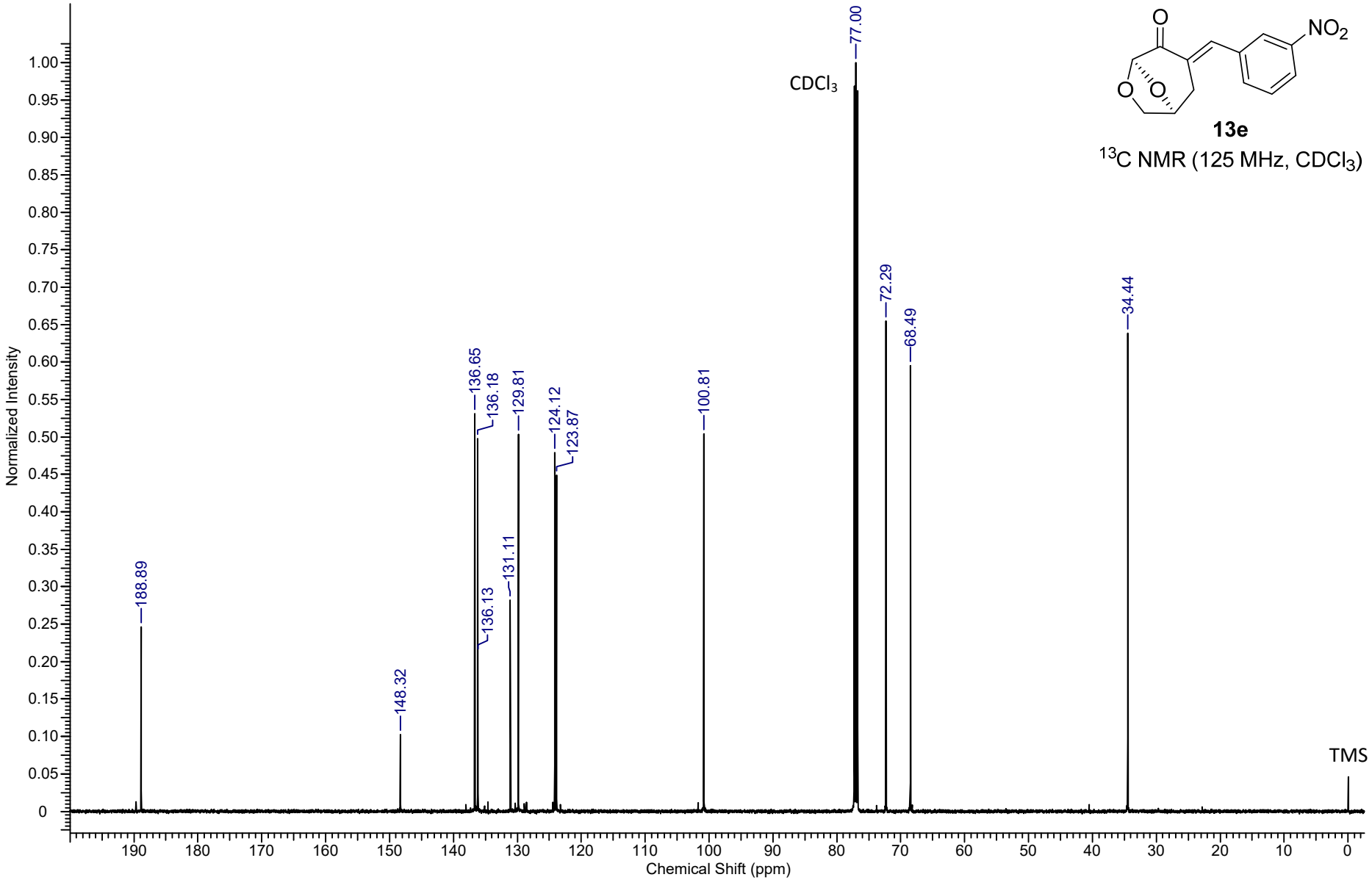

13c
^{1}H NMR (500 MHz, $CDCl_3$)
Normalized Intensity
Chemical Shift (ppm)
$CHCl_3$
H_2O
TMS
1.00 2.15 2.09 0.93 1.02 1.19 3.00 1.15 1.08 1.09

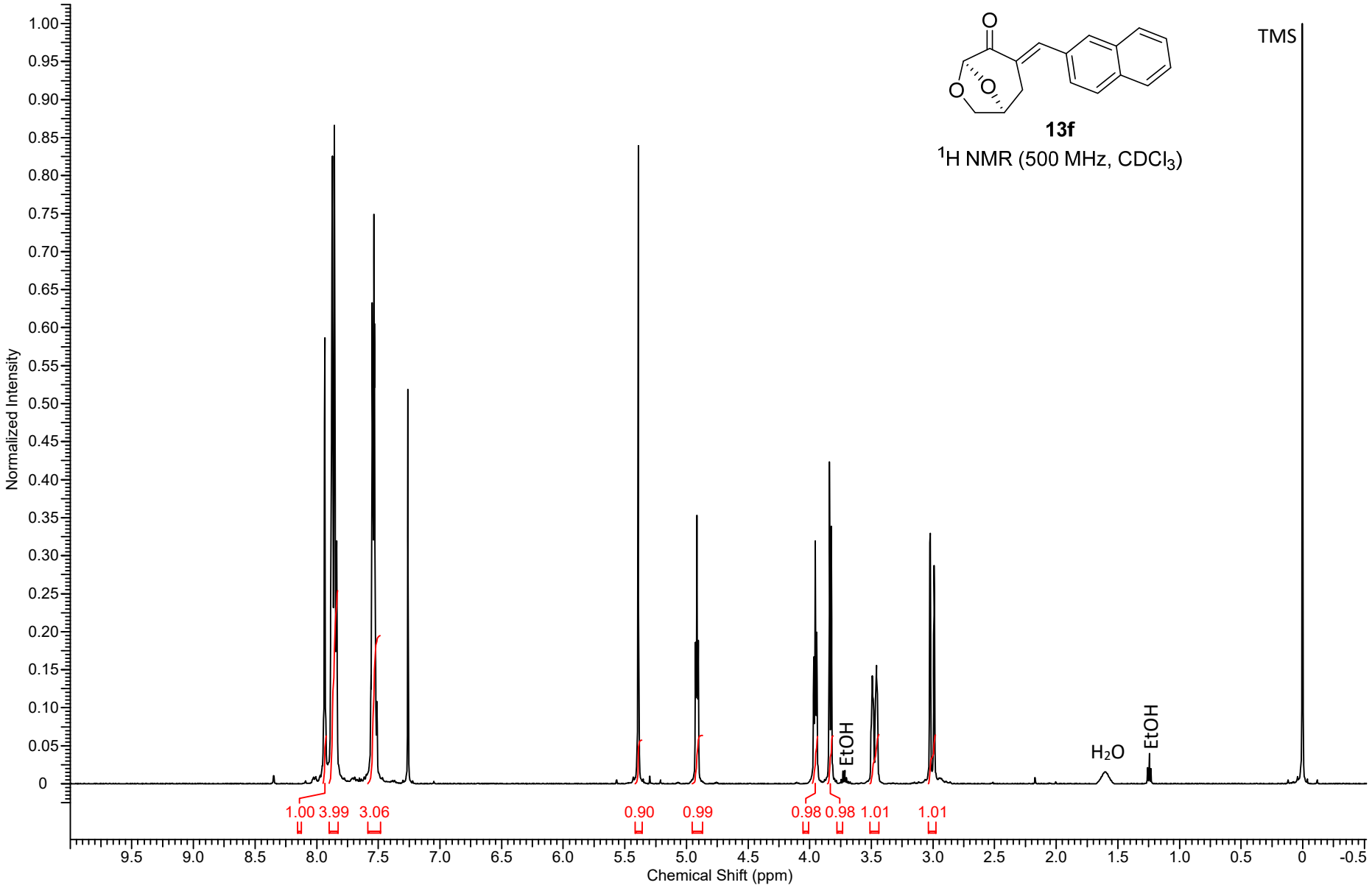

13c
^{13}C NMR (125 MHz, $CDCl_3$)
$CDCl_3$
77.00
189.77
160.73
139.89
132.53
127.48
125.43
114.23
101.06
72.46
68.48
55.39
34.58
TMS
Normalized Intensity
Chemical Shift (ppm)

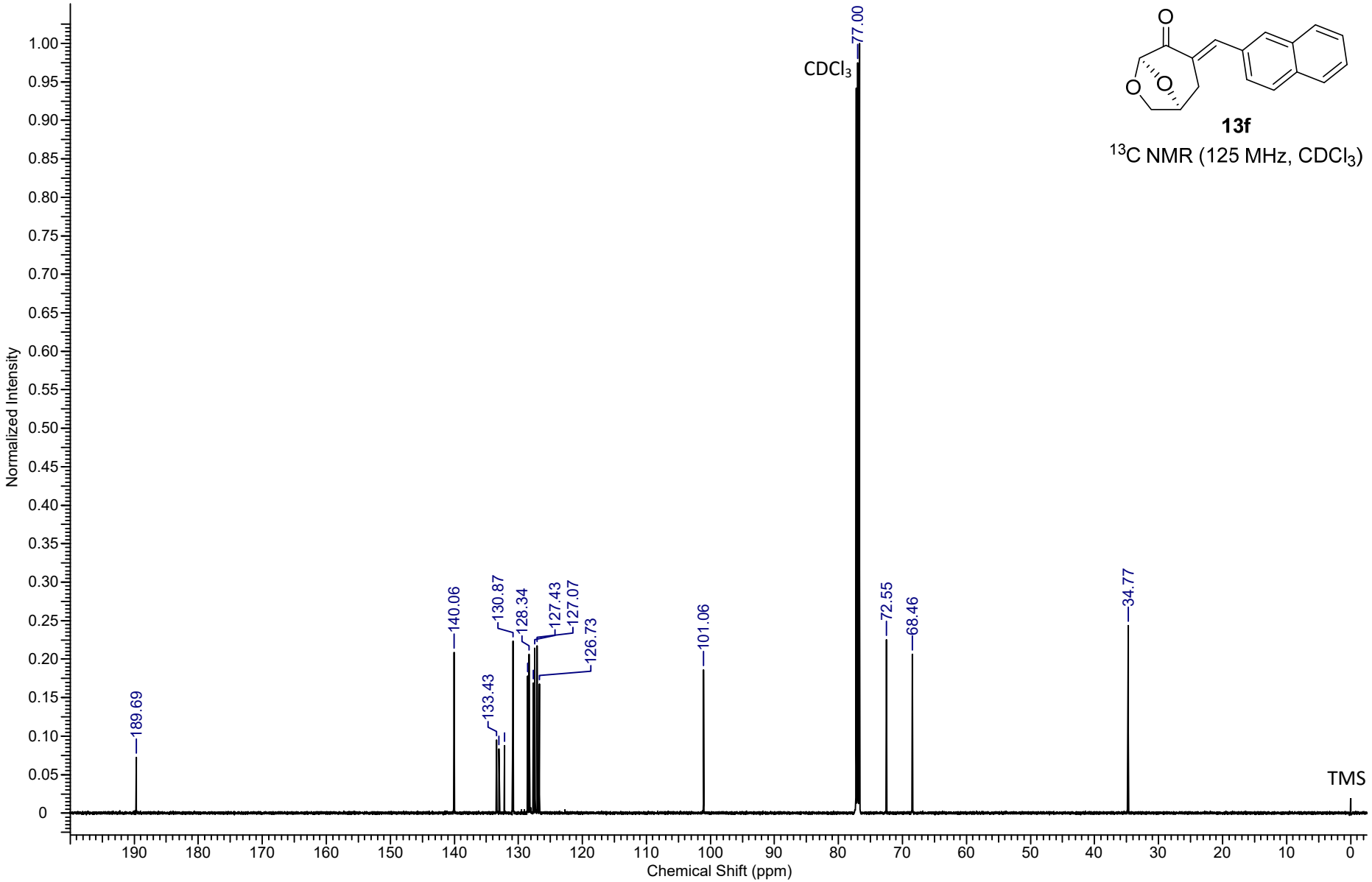

13d
^{1}H NMR (500 MHz, $CDCl_3$)
Normalized Intensity
Chemical Shift (ppm)
$CHCl_3$
H_2O
TMS
1.00
1.03
1.02
1.02
0.95
1.05
4.44
3.22
1.06
1.08
1.07

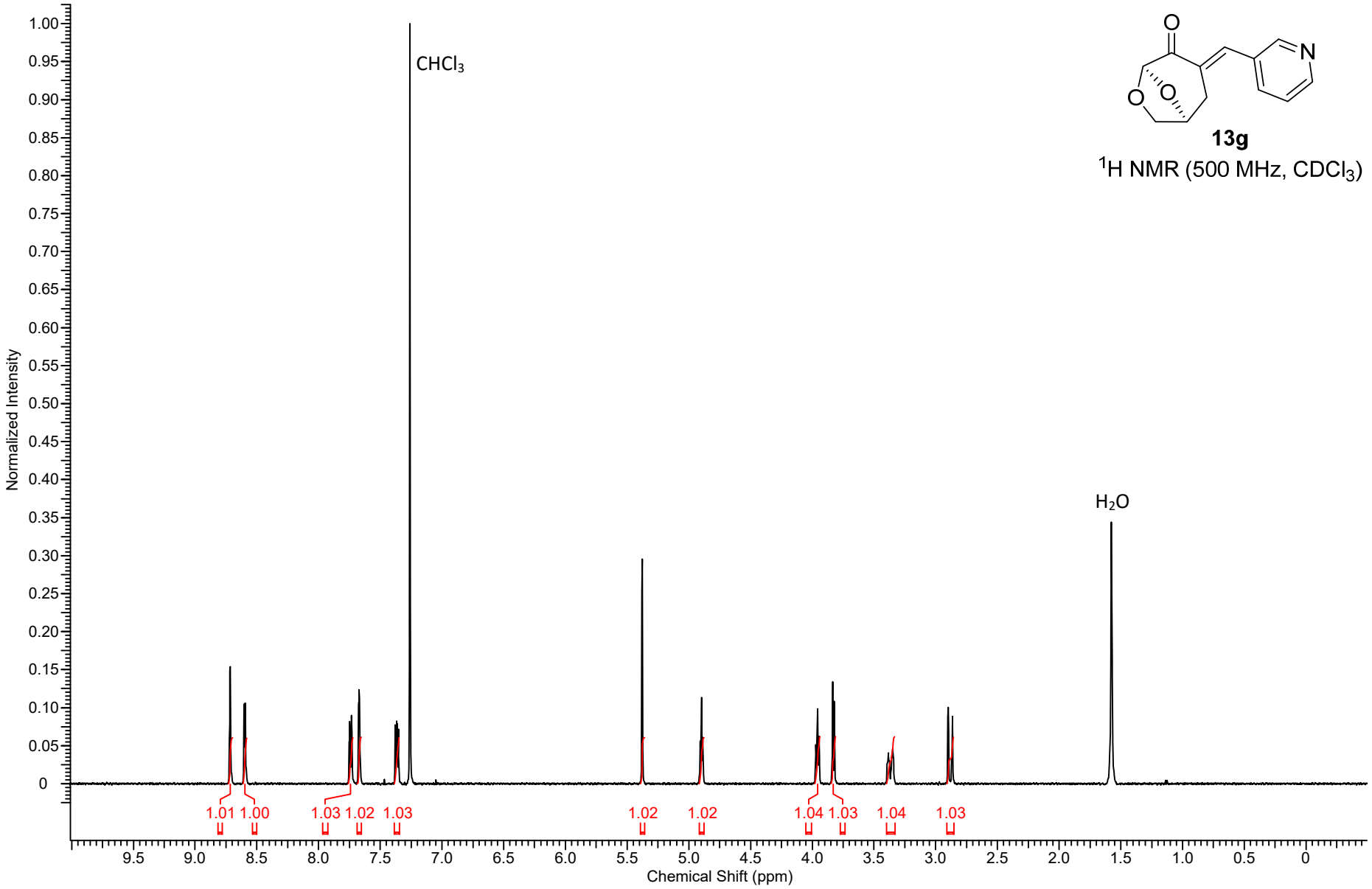

CDCl3
77.00
189.66
150.45
148.83
140.09
127.69
125.72
124.26
113.72
110.99
101.03
72.41
68.45
55.92
34.52
Normalized Intensity
Chemical Shift (ppm)
13d
13C NMR (125 MHz, CDCl3)

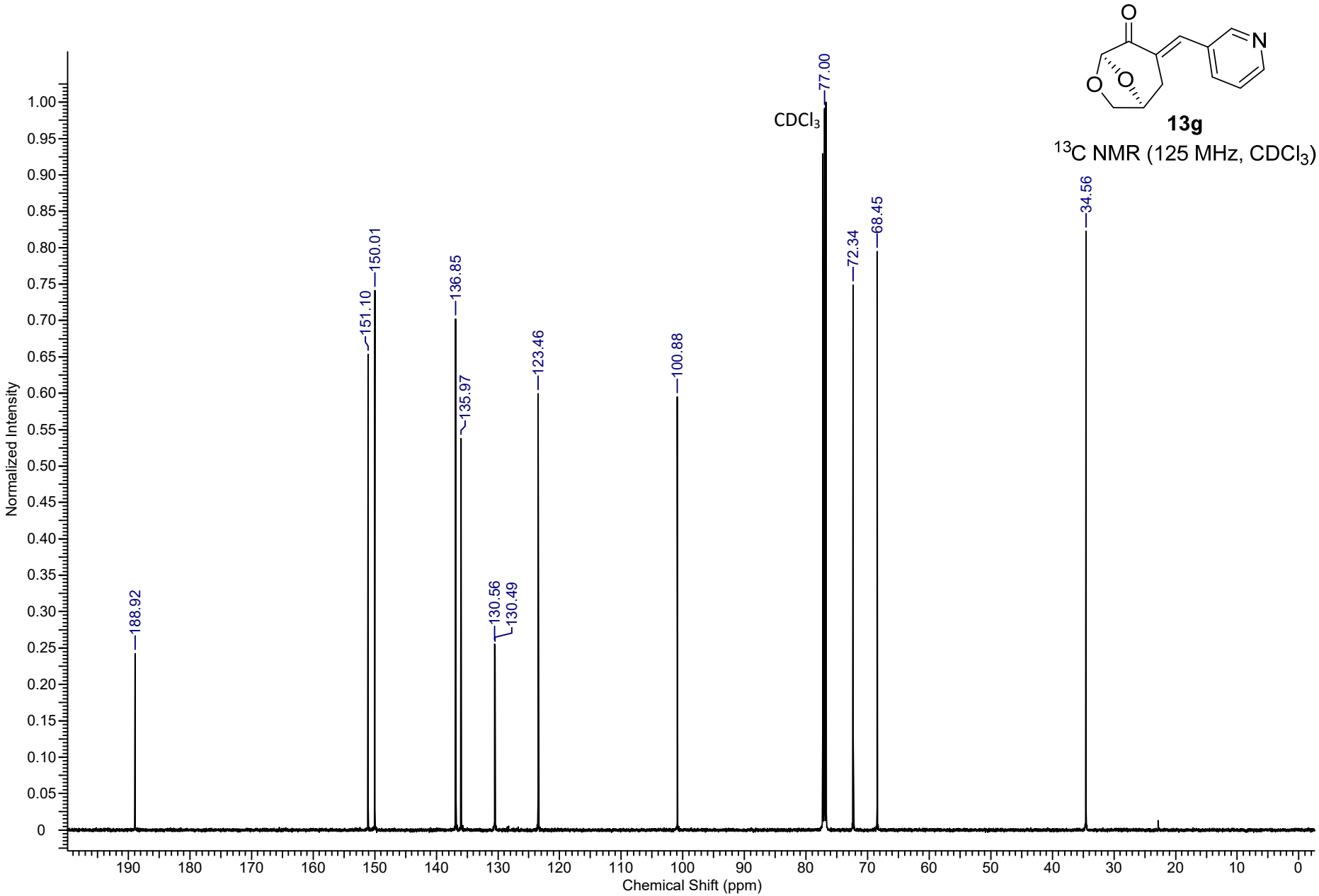

13e
^{1}H NMR (500 MHz, $CDCl_3$)
Normalized Intensity
Chemical Shift (ppm)
$CHCl_3$
H_2O
TMS
1.00 1.00 1.06 1.02 1.03
0.96
1.04
1.09 1.06
1.10
1.09

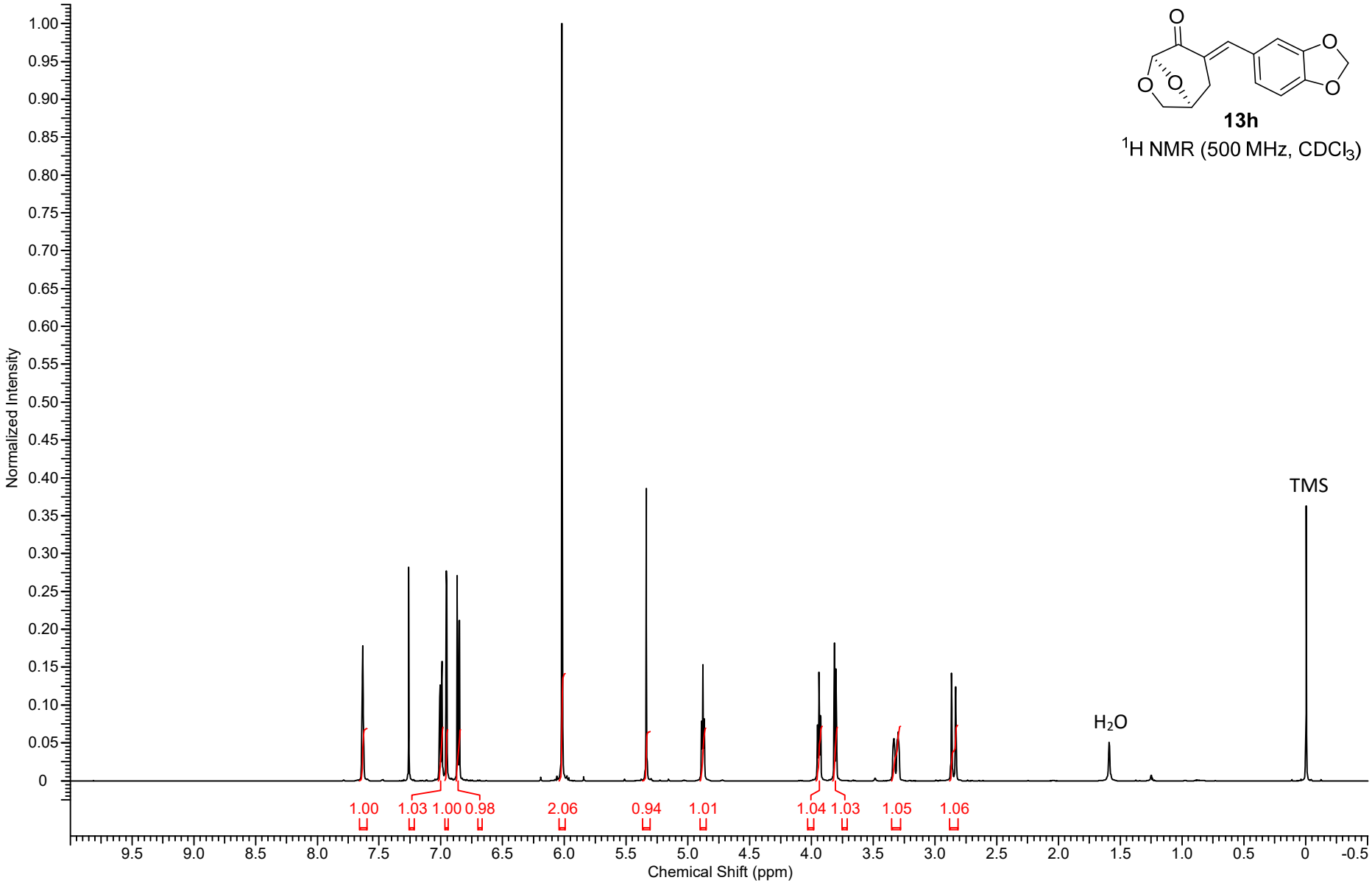

13e
^{13}C NMR (125 MHz, $CDCl_3$)
$CDCl_3$
77.00
72.29
68.49
34.44
100.81
136.65
136.18
129.81
124.12
123.87
131.11
136.13
188.89
148.32
TMS
Normalized Intensity
Chemical Shift (ppm)

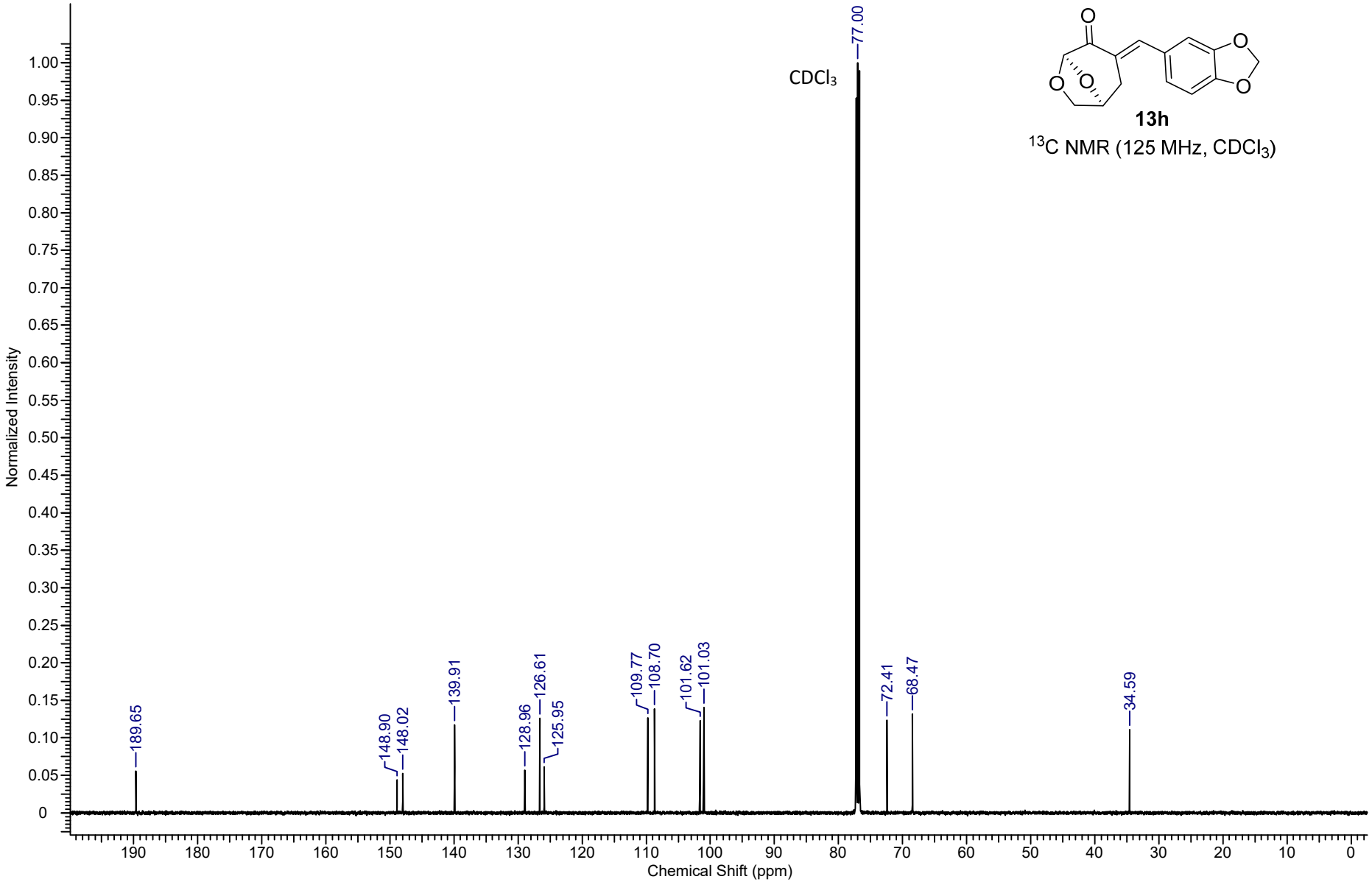

13f
^{1}H NMR (500 MHz, $CDCl_3$)
TMS
EtOH
H_2O
EtOH
1.00 3.99 3.06
0.90
0.99
0.98 0.98 1.01
1.01
Normalized Intensity
Chemical Shift (ppm)

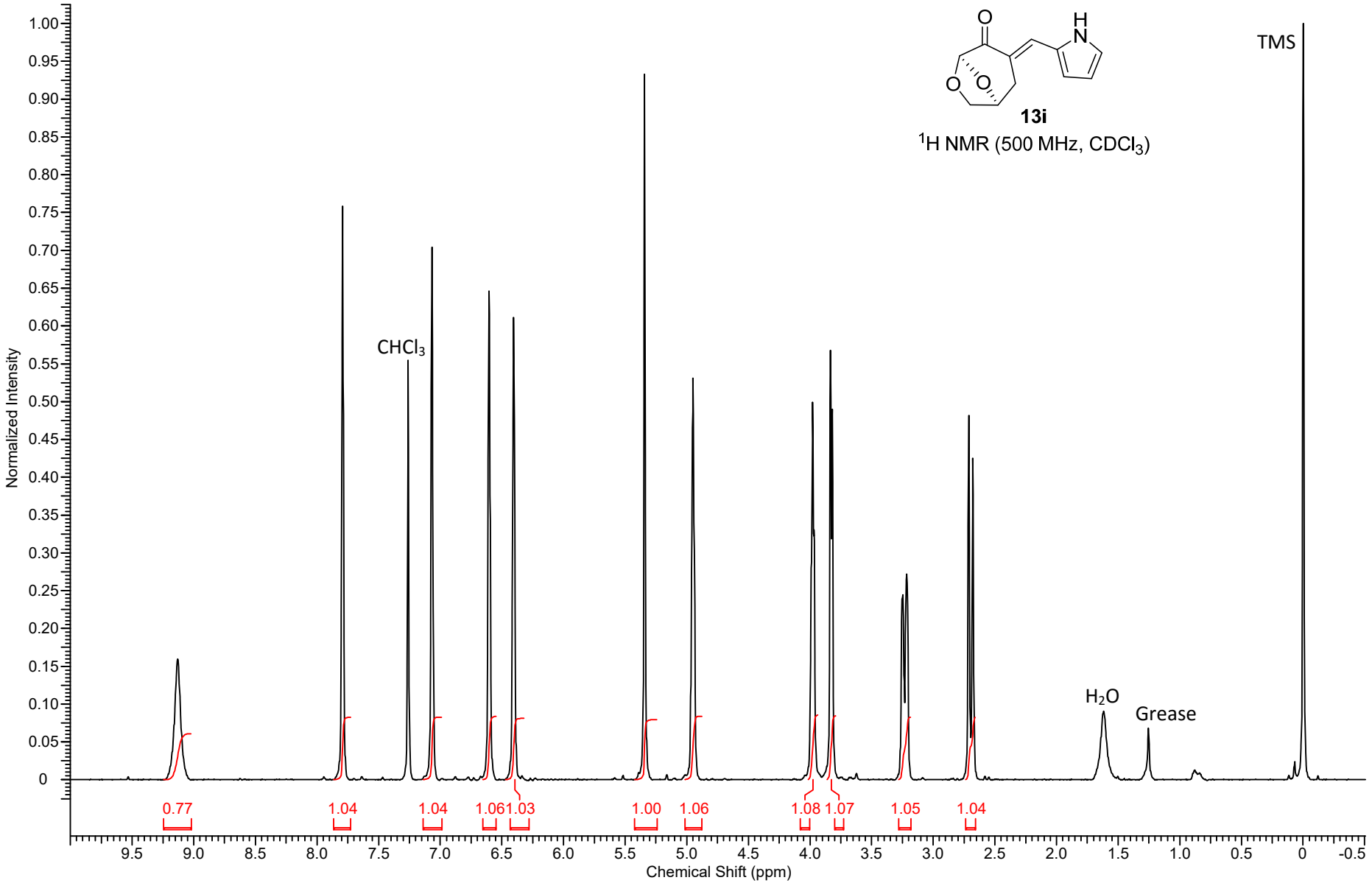

13f
^{13}C NMR (125 MHz, $CDCl_3$)
$CDCl_3$
77.00
189.69
140.06
133.43
130.87
128.34
127.43
127.07
126.73
101.06
72.55
68.46
34.77
TMS
Normalized Intensity
Chemical Shift (ppm)

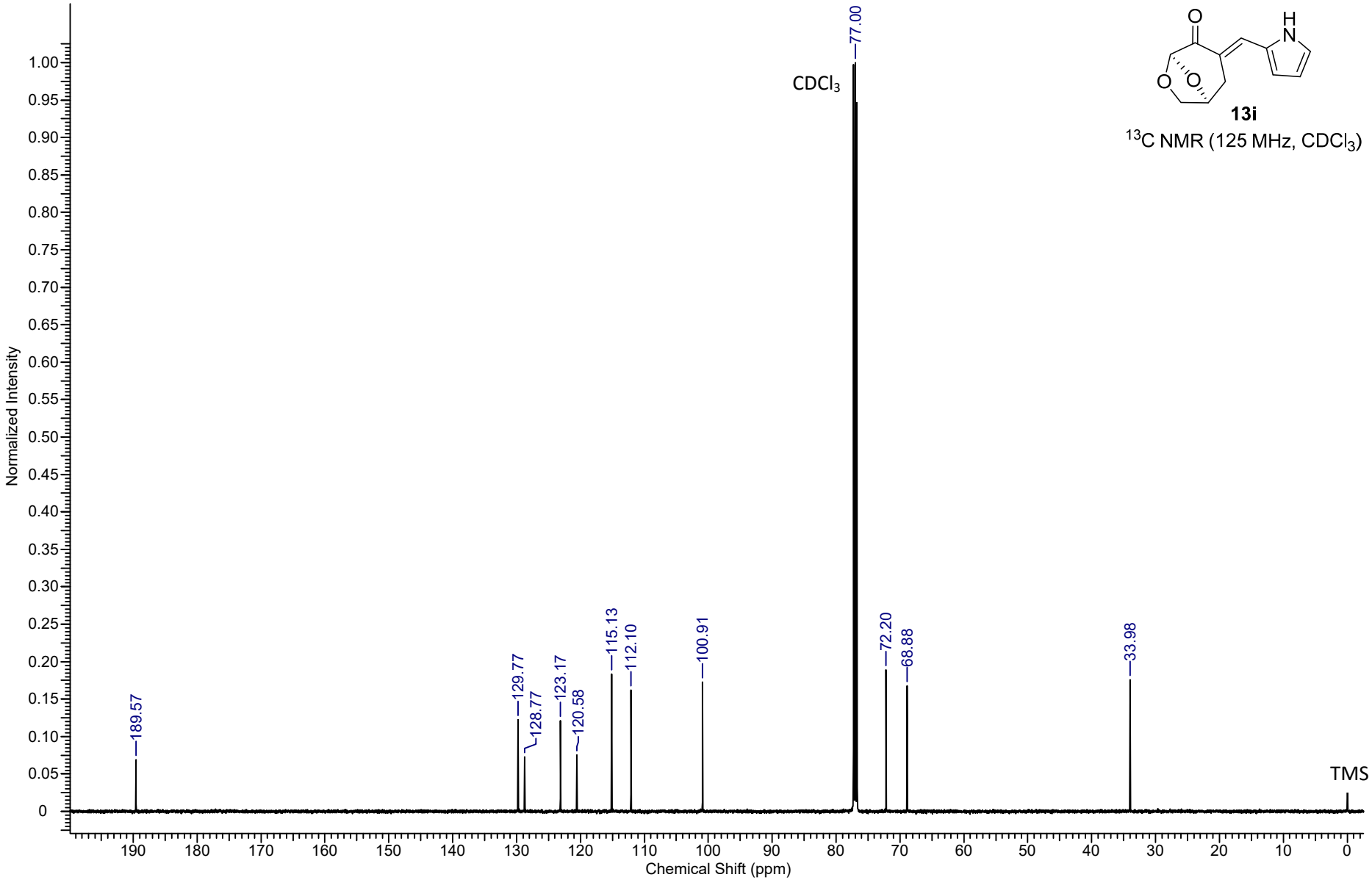

CHCl3
H2O
13g
1H NMR (500 MHz, CDCl3)
Normalized Intensity
Chemical Shift (ppm)
1.01
1.00
1.03
1.02
1.03
1.02
1.02
1.04
1.03
1.04
1.03

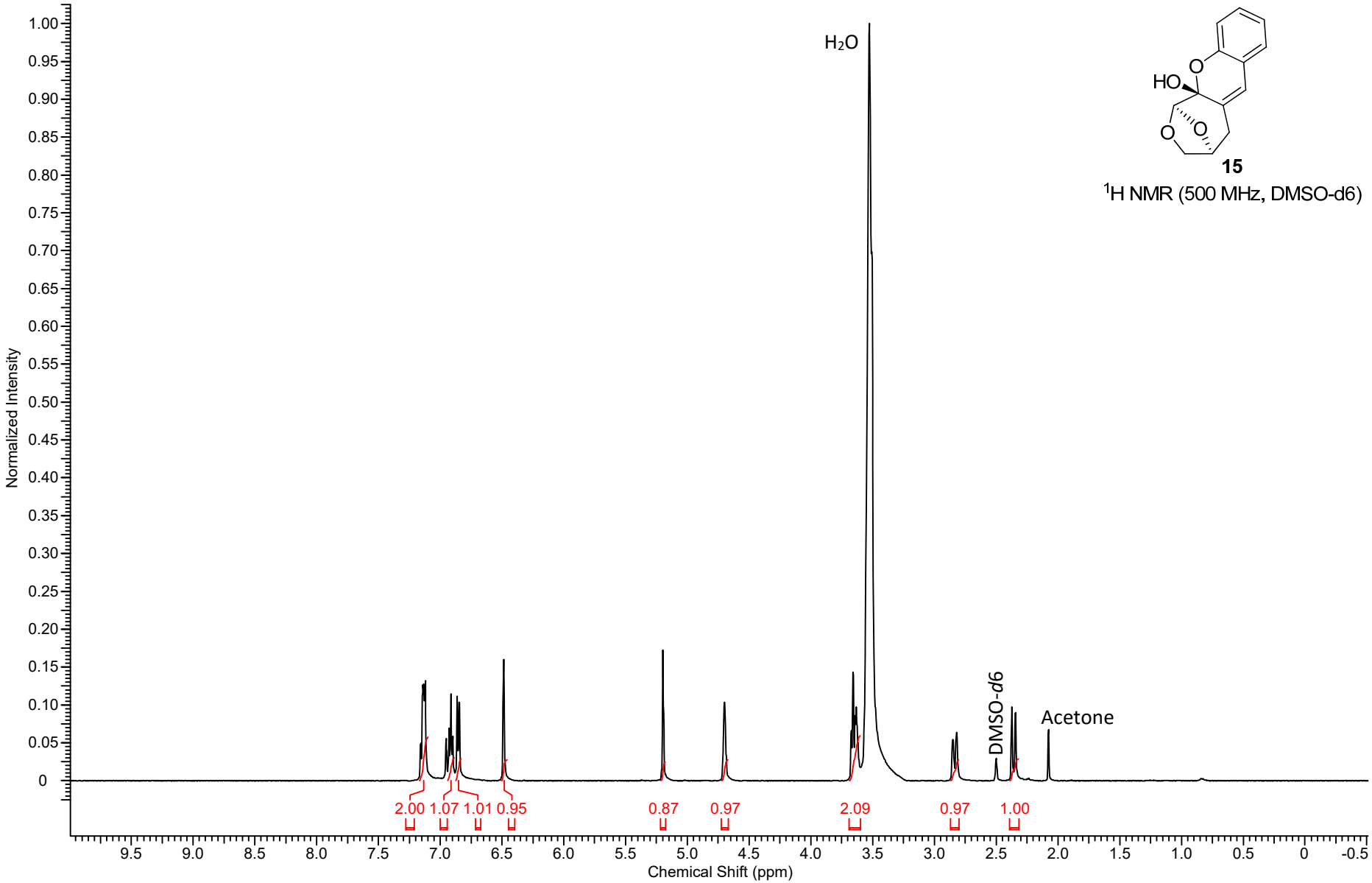

13g
^{13}C NMR (125 MHz, $CDCl_3$)
$CDCl_3$
77.00
34.56
72.34
68.45
150.01
151.10
136.85
135.97
123.46
100.88
130.56
130.49
188.92
Normalized Intensity
Chemical Shift (ppm)

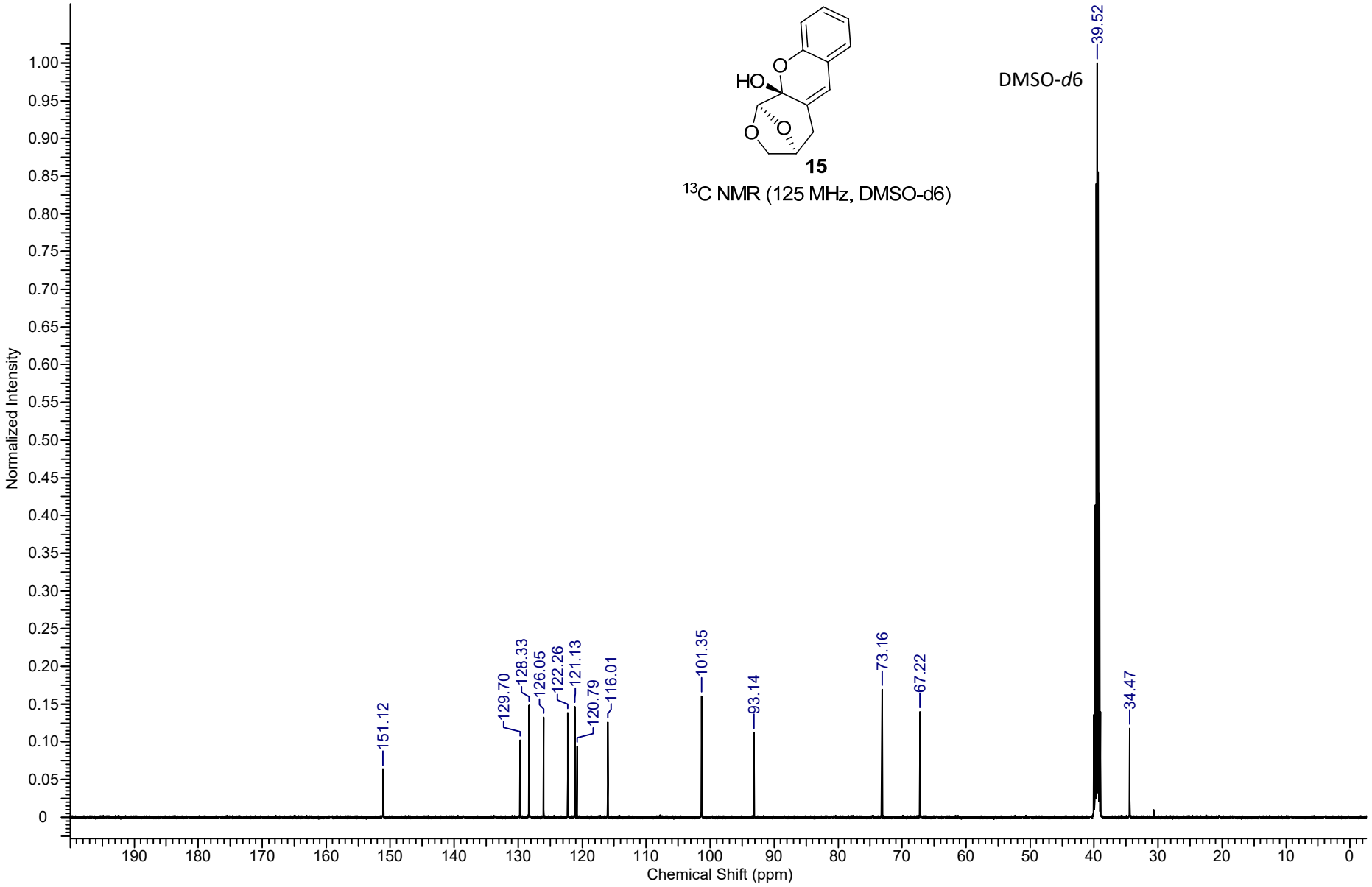

13h
^{1}H NMR (500 MHz, $CDCl_3$)
Normalized Intensity
Chemical Shift (ppm)
TMS
H_2O
1.00
1.03
1.00
0.98
2.06
0.94
1.01
1.04
1.03
1.05
1.06

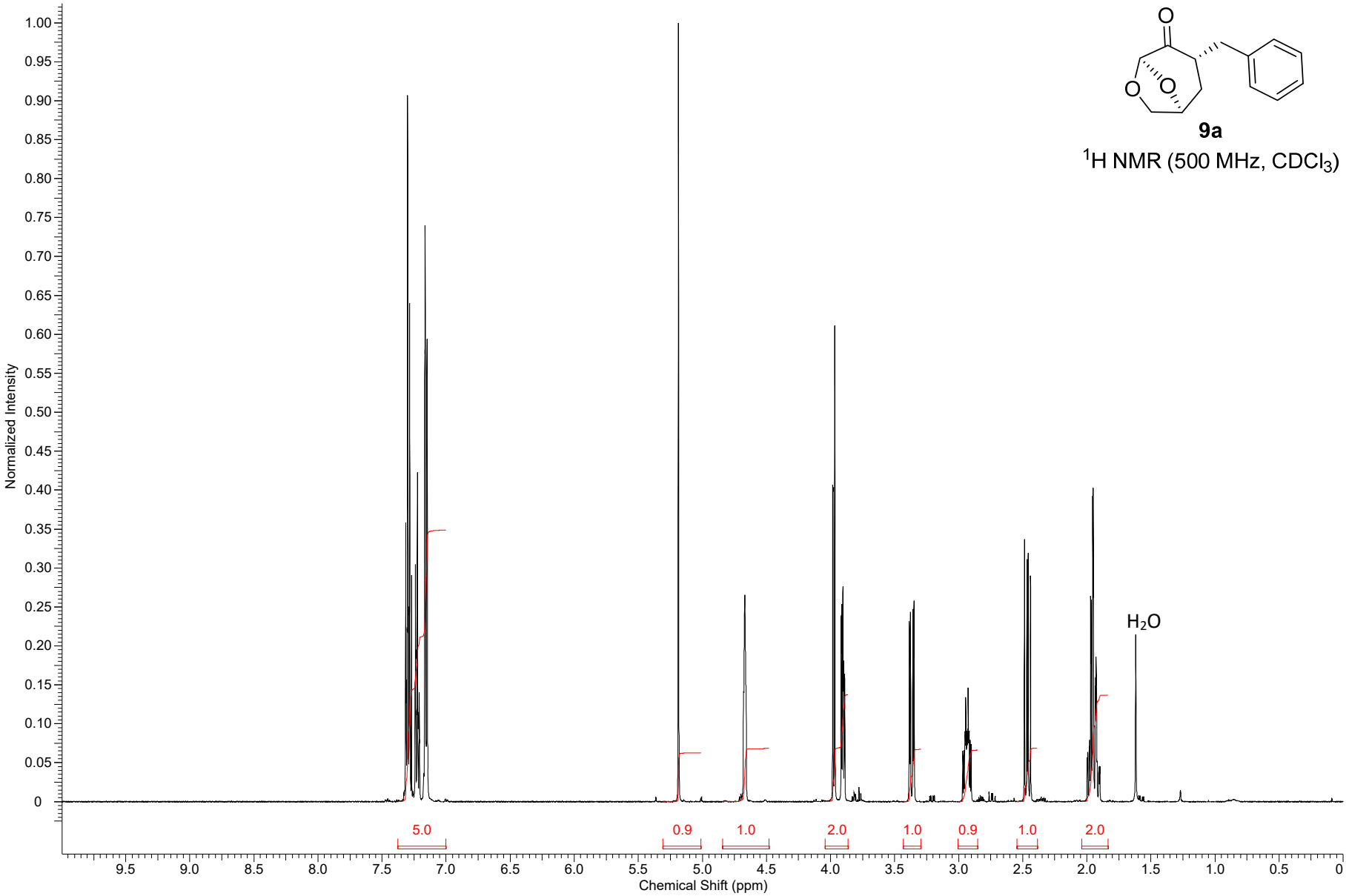

CDCl3
77.00
189.65
148.90
148.02
139.91
128.96
126.61
125.95
109.77
108.70
101.62
101.03
72.41
68.47
34.59
Normalized Intensity
Chemical Shift (ppm)
13h
13C NMR (125 MHz, CDCl3)

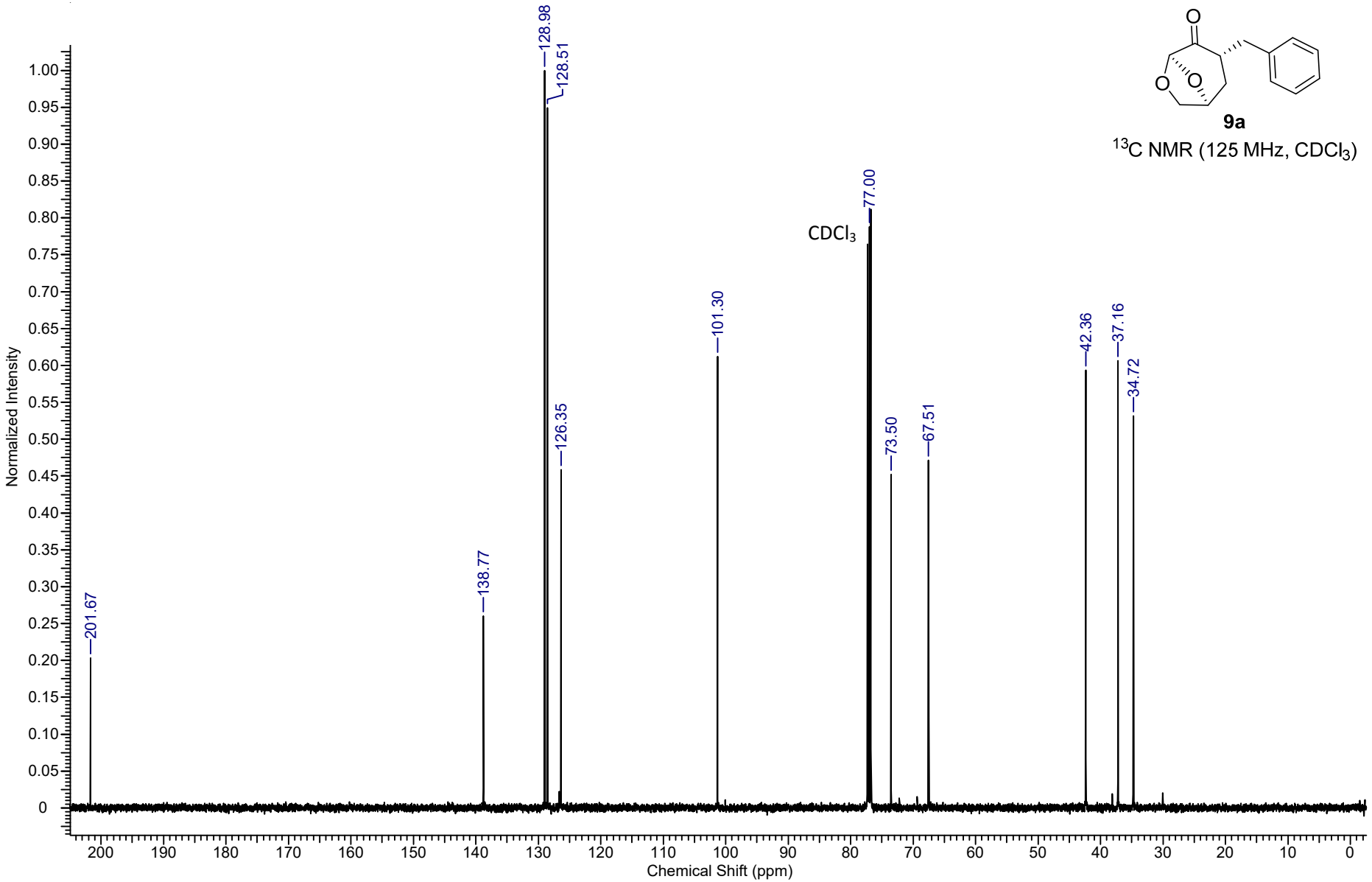

13i
^{1}H NMR (500 MHz, $CDCl_3$)
TMS
$CHCl_3$
H_2O
Grease
0.77
1.04
1.04
1.06
1.03
1.00
1.06
1.08
1.07
1.05
1.04
Normalized Intensity
Chemical Shift (ppm)

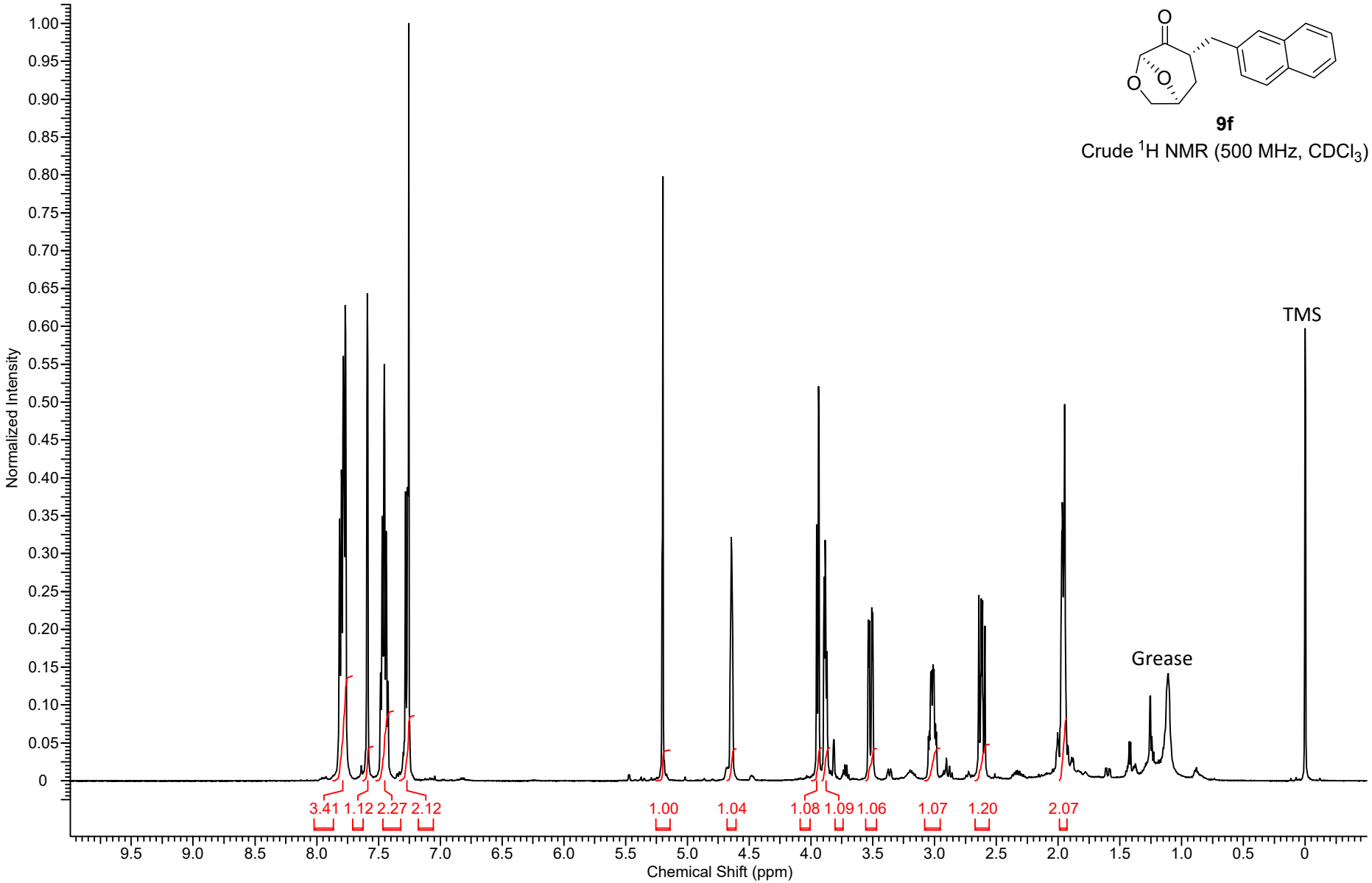

77.00
CDCl3
189.57
129.77
128.77
123.17
120.58
115.13
112.10
100.91
72.20
68.88
33.98
TMS
Normalized Intensity
Chemical Shift (ppm)
13i
13C NMR (125 MHz, CDCl3)

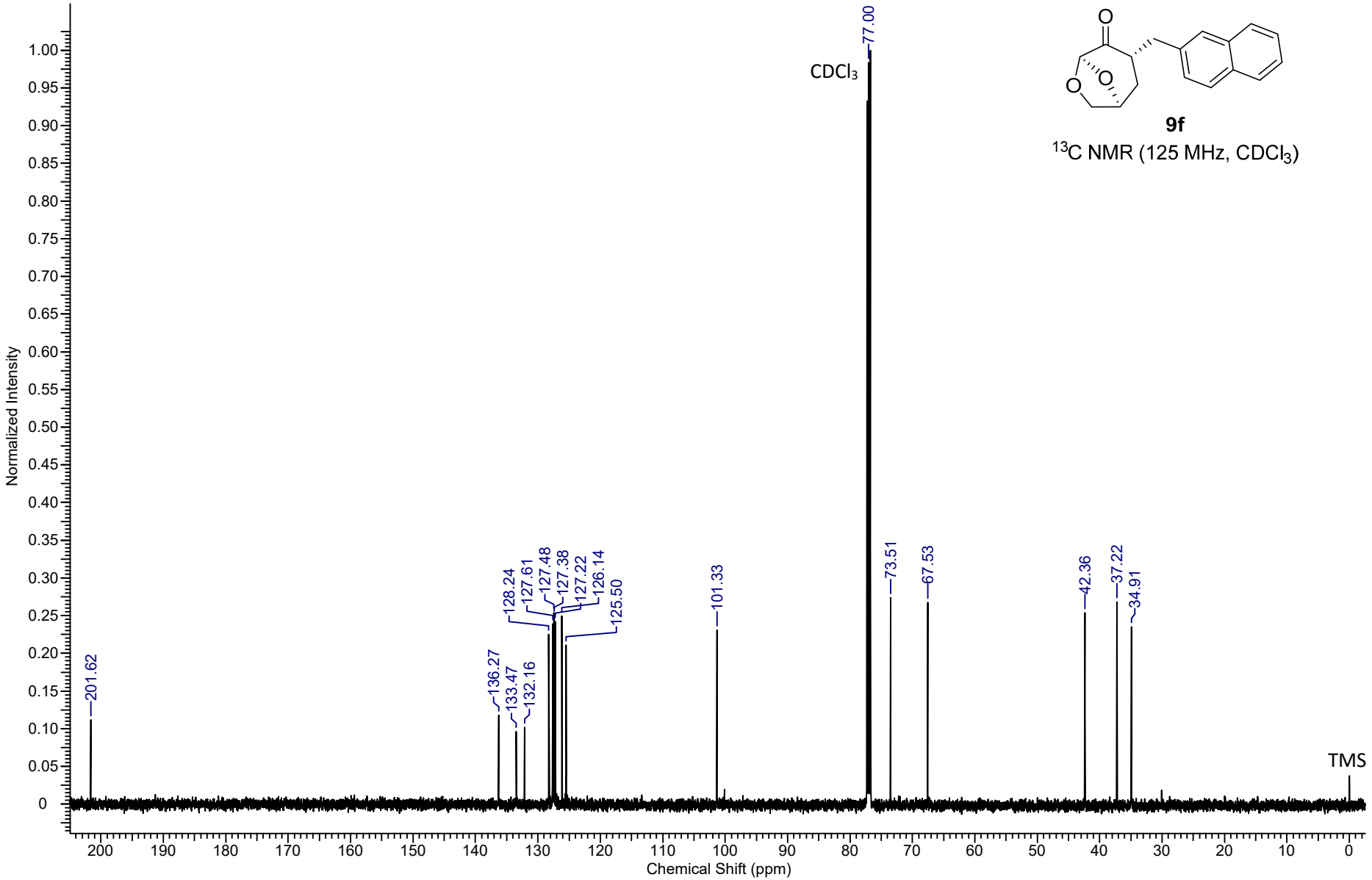

H2O
HO
O
O
O
15
1H NMR (500 MHz, DMSO-d6)
DMSO-d6
Acetone
2.00 1.07 1.01 0.95
0.87
0.97
2.09
0.97
1.00
Normalized Intensity
Chemical Shift (ppm)

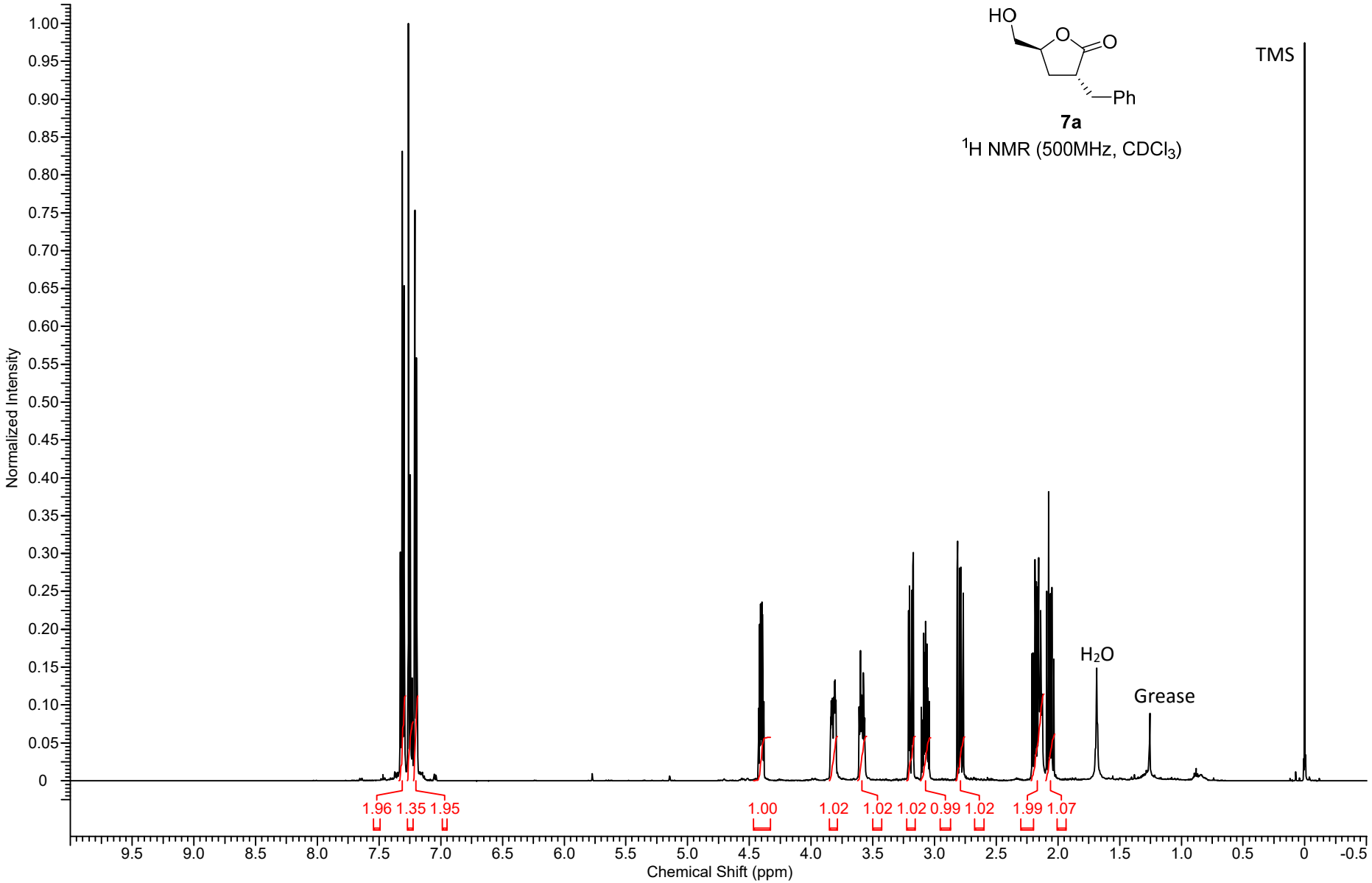

HO
O
O
O
15
13C NMR (125 MHz, DMSO-d6)
DMSO-d6
39.52
151.12
129.70
128.33
126.05
122.26
121.13
120.79
116.01
101.35
93.14
73.16
67.22
34.47
Normalized Intensity
Chemical Shift (ppm)

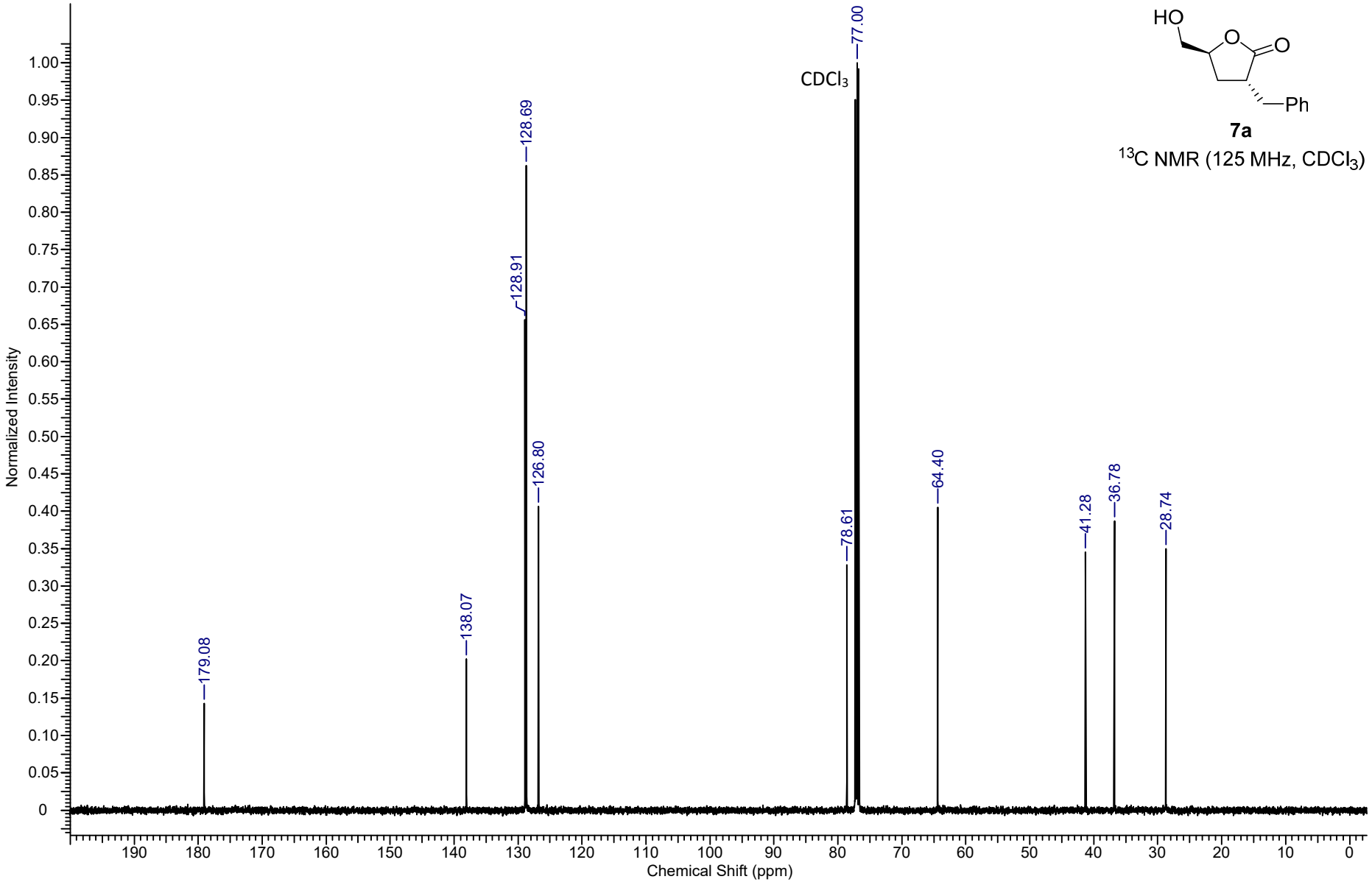

O
O
O
9a
1H NMR (500 MHz, CDCl3)
Normalized Intensity
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
H2O
5.0
0.9
1.0
2.0
1.0
0.9
1.0
2.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Chemical Shift (ppm)

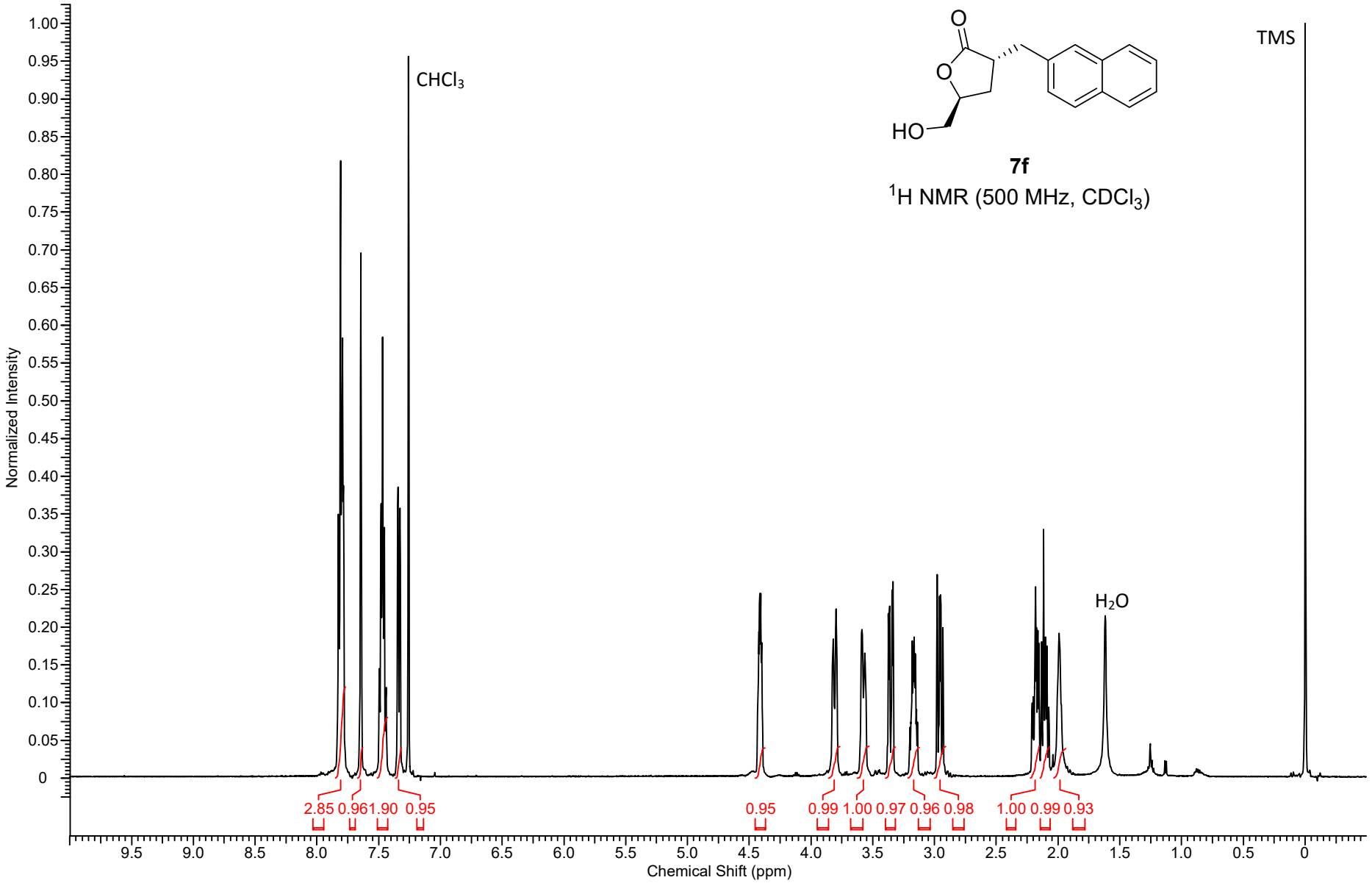

9a
^{13}C NMR (125 MHz, $CDCl_3$)
$CDCl_3$
201.67
138.77
128.98
128.51
126.35
101.30
77.00
73.50
67.51
42.36
37.16
34.72
Normalized Intensity
Chemical Shift (ppm)

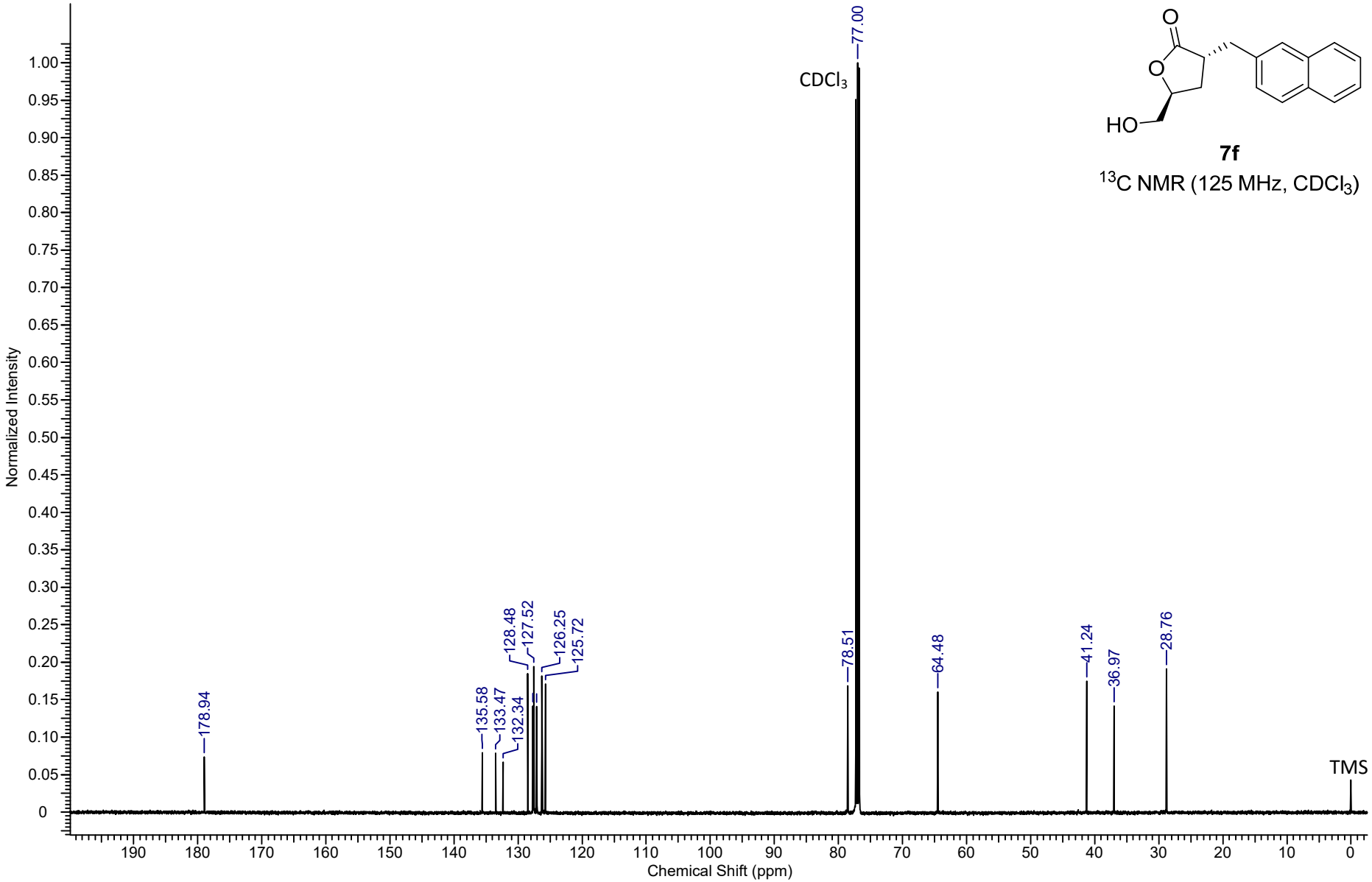

9f
Crude ^{1}H NMR (500 MHz, $CDCl_3$)
TMS
Grease
Normalized Intensity
Chemical Shift (ppm)
3.41 1.12 2.27 2.12
1.00 1.04 1.08 1.09 1.06 1.07 1.20 2.07

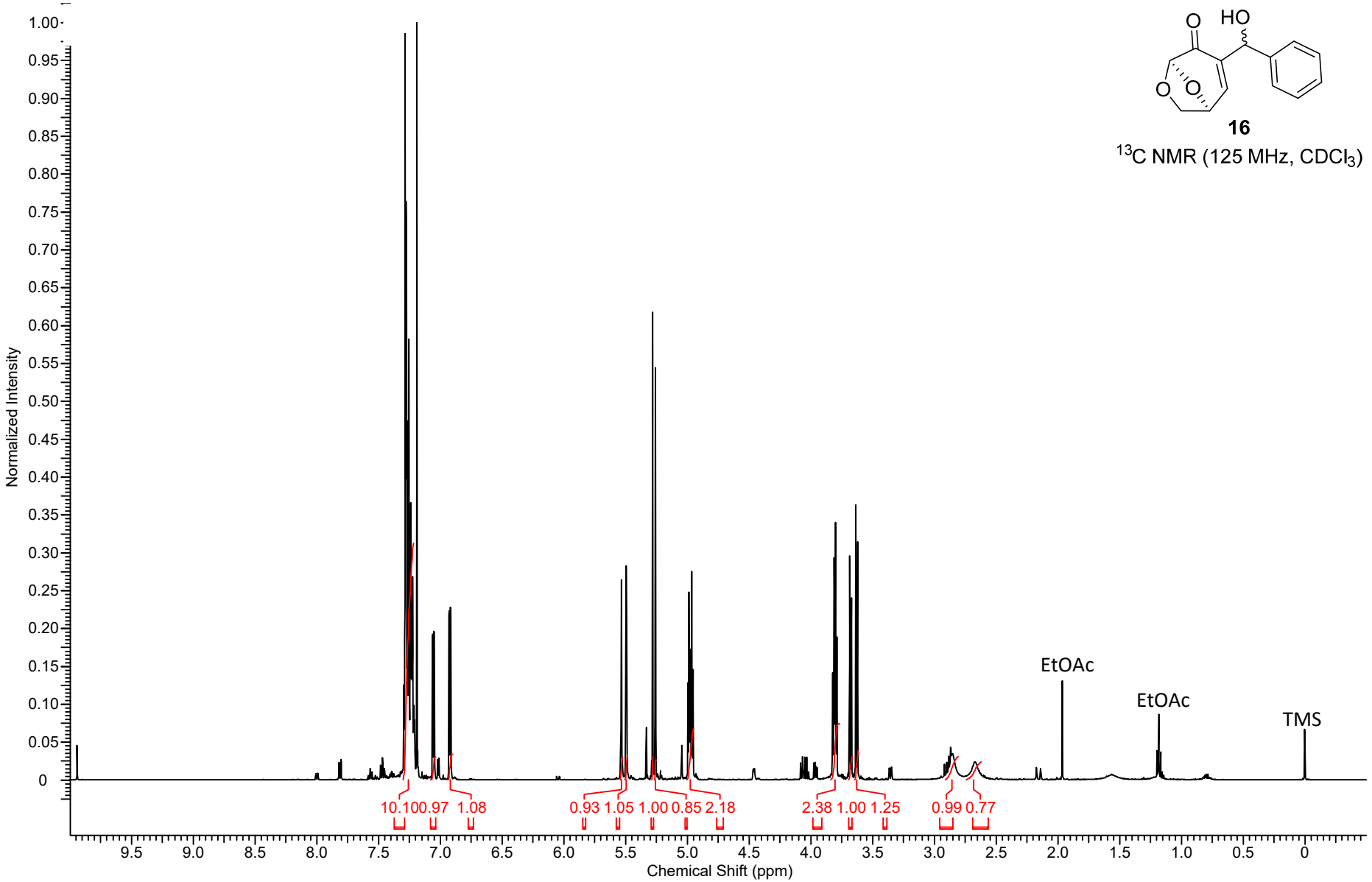

9f
^{13}C NMR (125 MHz, $CDCl_3$)
$CDCl_3$
77.00
201.62
136.27
133.47
132.16
128.24
127.61
127.48
127.38
127.22
126.14
125.50
101.33
73.51
67.53
42.36
37.22
34.91
TMS
Normalized Intensity
Chemical Shift (ppm)

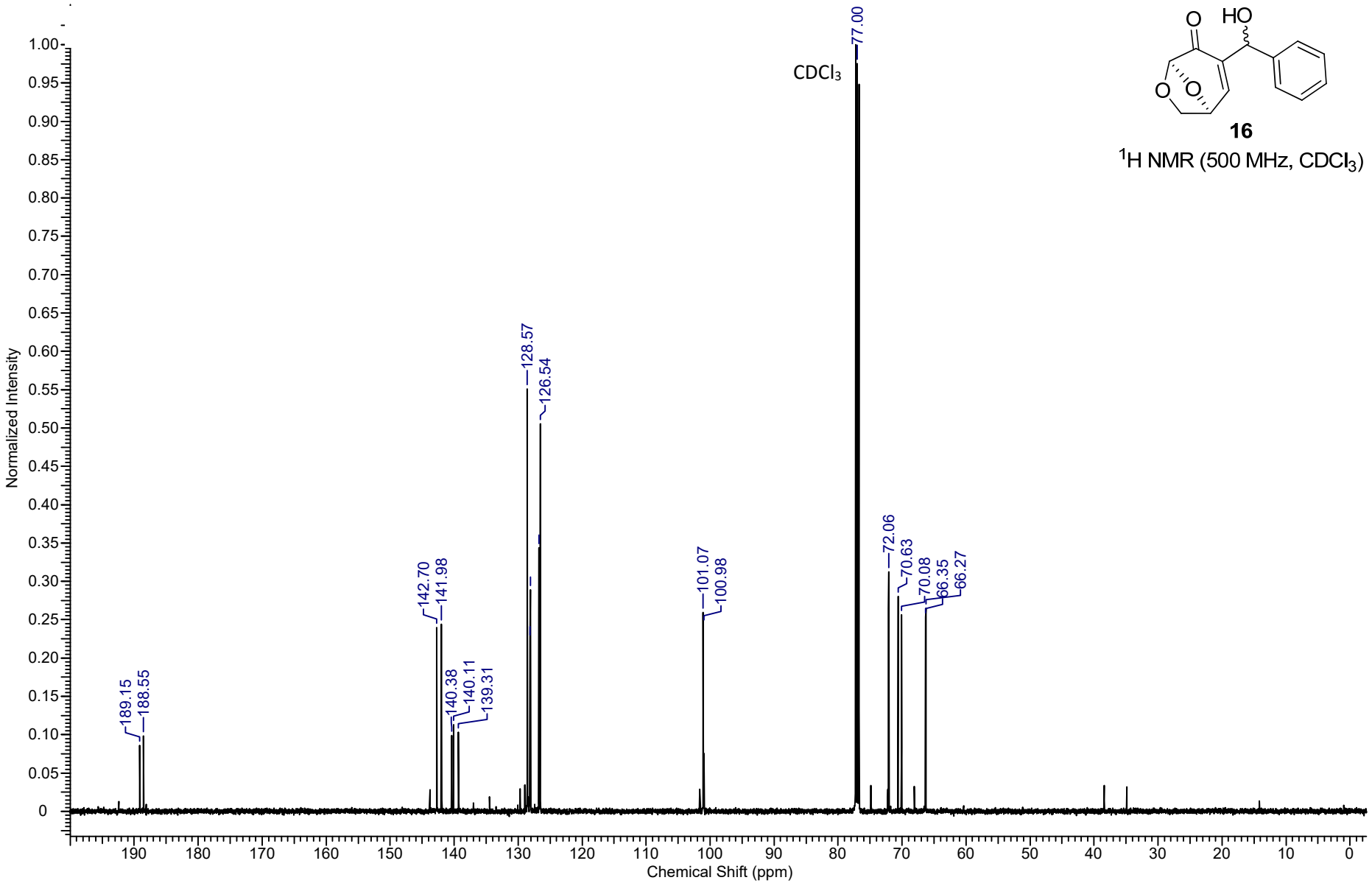

HO
O
O
Ph
7a
^{1}H NMR (500MHz, $CDCl_3$)
TMS
H_2O
Grease
Normalized Intensity
Chemical Shift (ppm)
1.96 1.35 1.95
1.00
1.02
1.02
1.02
0.99
1.02
1.99
1.07


HO
O
O
Ph
7a
^{13}C NMR (125 MHz, $CDCl_3$)
$CDCl_3$
77.00
128.69
128.91
126.80
78.61
64.40
41.28
36.78
28.74
138.07
179.08
Normalized Intensity
Chemical Shift (ppm)


CHCl3
TMS
H2O
7f
1H NMR (500 MHz, CDCl3)
Normalized Intensity
Chemical Shift (ppm)
2.85 0.96 1.90 0.95
0.95 0.99 1.00 0.97 0.96 0.98 1.00 0.99 0.93


7f
^{13}C NMR (125 MHz, $CDCl_3$)
$CDCl_3$
77.00
78.51
64.48
41.24
36.97
28.76
178.94
135.58
133.47
132.34
128.48
127.52
126.25
125.72
TMS
Normalized Intensity
Chemical Shift (ppm)


HO
O
O
O
16
13C NMR (125 MHz, CDCl3)
Normalized Intensity
Chemical Shift (ppm)
10.10 0.97 1.08
0.93 1.05 1.00 0.85 2.18
2.38 1.00 1.25
0.99 0.77
EtOAc
EtOAc
TMS


CDCl3
77.00
128.57
126.54
142.70
141.98
140.38
140.11
139.31
189.15
188.55
101.07
100.98
72.06
70.63
70.08
66.35
66.27
Normalized Intensity
Chemical Shift (ppm)
HO
O
O
O
16
1H NMR (500 MHz, CDCl3)