SUPPLEMENTARY MATERIAL

Microwave-assisted synthesis of borneol esters and their antimicrobial activity

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Abstract: Seventeen borneol esters (**1**-**17**) were synthesized by conventional and microwave-assisted methodology using DIC/DMAP, and seven are described for the first time (**8**, **9**, **10**, **12**, **13**, **16** and **17**). The microwave-assisted methodology was carried out without use of solvents, displayed short reaction times, and showed equal or higher yields for all the long-chain esters and three aromatic compounds (**11**, **12** and **14)** when compared to the conventional approach. All the borneol esters were evaluated against the bacteria *Streptococcus sanguinis*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa* and the fungus *Candida albicans*. Compounds **12**, **13** and **14** displayed promising antibacterial activity with a MIC equal to ampicilin (62.5 mg mL^{-1}) for some microorganisms. In fact, bornyl 3',4'-dimethoxybenzoate (**13**) was active against all tested bacteria and fungus.

Keywords: borneol esters; microwave irradiation; DIC/DMAP; antibacterial activity.

Experimental

Chemistry

General procedures

Commercially reagent grade chemicals were used without additional purification. All reactions were monitored by thin layer chromatography (TLC). Column chromatographic purifications were performed using silica gel 60 (70–230 Mesh). The IR spectra were carried out on a Perkin Elmer – Spectrum One (ATR) spectrometer. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker AVANCE DPX-200 spectrometer at 200 MHz and 50 MHz, respectively, using $CDCl_3$ as solvent. Chemical shifts are reported in parts per million (δ ppm) using tetramethylsilane (TMS) as internal standard. Melting points were determined on a Microquímica MQAPF 301 hot plate apparatus and are uncorrected.

Synthesis of borneol esters using DIC/DMAP through conventional method

(–)-Borneol (1 mmol) and the appropriate organic acid (5 mmol) with catalytic amount of 4-dimethylaminopyridine (DMAP) were dissolved in dichloromethane (6 mL) and cooled in an ice bath. The mixture was stirred for an additional 10 min and then diisopropylcarbodiimide (DIC, 5 mmol) was added. The mixture was removed from the ice bath and was magnetically stirred at room temperature until esterification was completed (Kane et al., 2004). The progress of the reaction was monitored by TLC. Then, the reaction mixture was evaporated in vacuum to dryness. The residue was purified by chromatographic column on silica gel using hexane/chloroform (1:1, V/V) as eluent.

Synthesis of borneol esters using DIC/DMAP through microwave irradiation

(–)-Borneol (1 mmol), the appropriate organic acid (3 mmol) and a catalytic amount of DMAP (0.25-0.33 mmol) were added in a round bottom flask in the absence of solvent. The mixture was kept under ice bath, and then DIC (3 mmol) was added. The reaction mixture was subjected to microwave irradiation in a Discover CEM® reactor. The general conditions were: temperature ranging from 25 to 170 °C (indicated in Table 1), power of 250 watts, ramp time of 2 minutes, microwave irradiation time of 5 minutes, maximum stirring and open tube. After irradiation, the products were purified by silica gel chromatographic column.

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl hexanoate (**1**): clear oil; $C_{16}H_{28}O_2$; HR-ESIMS: *m/z* Calcd for $C_{16}H_{28}O_2Na$ ($[M + Na]^+$): 275.1987, found: 275.1922; IR (ATR, cm^{-1}): 1160, 1175, 1782, 2873, 2954; ^1H and ^{13}C NMR spectral data are in accordance with data reported by Silva et al. (2016).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl octanoate (**2**): clear oil; $C_{18}H_{32}O_2$; HR-ESIMS: *m/z* Calcd for $C_{18}H_{32}O_2Na$ ($[M + Na]^+$): 303.2300, found: 303.2387; IR (ATR, cm^{-1}): 1160, 1175, 1782, 2873, 2954; ^1H and ^{13}C NMR spectral data are in accordance with data reported by Silva et al. (2016).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl decanoate (**3**): clear oil; $C_{20}H_{36}O_2$; HR-ESIMS: *m/z* Calcd for $C_{20}H_{36}O_2Na$ ($[M + Na]^+$): 331.2613, found: 331.2563; IR (KBr, cm^{-1}): 1160, 1178, 1456, 1736, 2856, 2926, 2956; ^1H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.83 (s, 3H), 0.87-0.91 (m, 9H), 0.98 (d, J= 3.4 Hz, 1H), 1.27 (sl, 14H), 1.59-1.76 (m, 4H), 1.87-2.01 (m, 1H), 2.27-2.43 (m, 3H), 4.85-4.92 (ddd, J_1= 2.0 Hz, J_2= 3.4 Hz, J_3= 10.0 Hz, 1H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.5 (CH_3), 14.1 (CH_3), 18.9 (CH_3), 19.7 (CH_3), 22.7 (CH_2), 25.2 (CH_2), 27.1 (CH_2), 28.1 (CH_2), 29.2 (CH_2),

29.3 (CH_2), 29.3 (CH_2), 29.5 (CH_2), 31.9 (CH_2), 34.7 (CH_2), 36.9 (CH_2), 44.9 (CH), 47.8 (C), 48.7 (C), 79.6 (CH), 174.2 (CO).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl dodecanoate (**4**): clear oil; $C_{22}H_{40}O_2$; HR-ESIMS: *m/z* Calcd for $C_{22}H_{40}O_2Na$ ($[M + Na]^+$): 359.2926, found: 359.2956; IR (KBr, cm^{-1}): 1025, 1160, 1180, 1736, 2854, 2925; ^1H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.83 (s, 3H), 0.87-0.91 (m, 9H), 0.99 (d, J= 3.4 Hz, 1H), 1.26 (sl, 18H), 1.59-1.78 (m, 4H), 1.87-2.01 (m, 1H), 2.27-2.43 (m, 3H), 4.85-4.92 (ddd, J_1= 2.2 Hz, J_2= 3.4 Hz, J_3= 10.0 Hz, 1H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.4 (CH_3), 14.0 (CH_3), 18.8 (CH_3), 19.7 (CH_3), 22.6 (CH_2), 25.2 (CH_2), 27.2 (CH_2), 28.1 (CH_2), 29.2 (CH_2), 29.3 (CH_2), 29.5 (CH_2), 29.6 (CH_2), 31.9 (CH_2), 34.7 (CH_2), 36.9 (CH_2), 45.0 (CH), 47.8 (C), 48.8 (C), 79.6 (CH), 174.0 (CO).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl myristate (**5**): clear oil; $C_{24}H_{44}O_2$; HR-ESIMS: *m/z* Calcd for $C_{24}H_{44}O_2Na$ ($[M + Na]^+$): 387.3239, found: 387.3294; IR (ATR, cm^{-1}): 1159, 1177, 1734, 2853, 2923; ^1H and ^{13}C NMR spectral data are in accordance with data reported by Silva et al. (2016).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl palmitate (**6**): clear oil; $C_{26}H_{48}O_2$; HR-ESIMS: *m/z* Calcd for $C_{26}H_{48}O_2Na$ ($[M + Na]^+$): 415.3552, found: 415.3561; IR (ATR, cm^{-1}): 1159, 1177, 1734, 2853, 2922 cm^{-1}; ^1H and ^{13}C NMR spectral data are in accordance with data reported by Silva et al. (2016).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl stearate (**7**): clear oil; $C_{28}H_{52}O_2$; HR-ESIMS: *m/z* Calcd for $C_{28}H_{52}O_2Na$ ($[M + Na]^+$): 443.3865, found: 443.4183; IR (ATR, cm^{-1}): 1159, 1175, 1734, 2852, 2922 cm^{-1}. ^1H and ^{13}C NMR spectral data are in accordance with data reported by Silva et al. (2016).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl butanoic acid (**8**): white solid; $C_{14}H_{22}O_4$; HR-ESIMS: *m/z* Calcd for $C_{14}H_{21}O_4$ ($[M - H]^-$): 253.1440, found: 253.1428;

IR (KBr, cm^{-1}): 1018, 1160, 1182, 1328, 1386, 1714, 1738, 2854, 2882, 2928, 2988, 3448; ^{1}H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.82 (s, 3H), 0.87 (s, 3H), 0.90 (s, 3H), 1.00 (d, *J*= 3.2 Hz, 1H), 1.15-1.35 (m, 3H), 1.65-1.97 (m, 3H), 2.27-2.42 (m, 1H), 2.67 (sl, 4H), 4.89-4.93 (m, 1H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.4 (CH_3), 18.8 (CH_3), 19.7 (CH_3), 27.0 (CH_2), 28.0 (CH_2), 29.1 (CH_2), 29.2 (CH_2), 36.6 (CH_2), 44.8 (CH), 47.8 (C), 48.8 (C), 80.5 (CH), 172.3 (CO), 178.1 (COOH).

bis(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl succinate (**9**): white solid; m.p. 75-77 °C; $C_{24}H_{38}O_4$; HR-ESIMS: *m/z* Calcd for $C_{24}H_{38}O_4Na$ ($[M + Na]^+$): 413.2668, found: 413.2700; IR (KBr, cm^{-1}): 1022, 1156, 1212, 1352, 1386, 1456, 1730, 2876, 2956, 3446; ^{1}H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.83 (s, 6H), 0.87 (s, 6H), 0.90 (s, 6H), 0.93-1.02 (dd, J_1= 3.4 Hz, J_2= 10.2 Hz, 2H), 1.16-1.36 (m, 6H), 1.60-1.99 (m, 8H), 2.27-2.42 (m, 2H), 2.65 (s, 4H), 4.87-4.94 (ddd, J_1= 2.2 Hz, J_2= 3.2 Hz, J_3= 10.0 Hz, 2H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.5 (CH_3), 18.9 (CH_3), 19.7 (CH_3), 27.2 (CH_2), 28.1 (CH_2), 29.7 (CH_2), 36.7 (CH_2), 45.0 (CH), 47.8 (C), 48.8 (C), 80.3 (CH), 172.4 (CO).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl 4-Isopropyl[isopropylamine) carbonyl]amine}-4-oxobutanoate (**10**): clear oil; $C_{21}H_{36}N_2O_4$; HR-ESIMS: *m/z* Calcd for $C_{21}H_{36}N_2O_4Na$ ($[M + Na]^+$): 403.2573, found: 403.2655; IR (NaCl, cm^{-1}): 1022, 1170, 1366, 1386, 1456, 1524, 1662, 1704, 1732, 2878, 2956, 2970, 3314; ^{1}H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.82 (s, 3H), 0.87 (s, 3H), 0.90 (s, 3H), 0.95-1.02 (dd, J_1= 3.3 Hz, J_2= 10.2 Hz, 1H), 1.19 (d, *J*= 6.6 Hz, 6H), 1.38 (d, *J*= 6.6 Hz, 6H), 1.24-1.31 (m, 2H), 1.65-1.69 (m, 1H), 1.72-1.79 (m, 1H), 1.84-1.93 (m, 1H), 2.25-2.41 (m, 1H), 3.86-4.10 (oct, *J*= 7.0 Hz, 1H), 4.32-4.52 (hept, *J*= 6.8 Hz, 1H), 4.86-4.94 (ddd, J_1= 2.2 Hz, J_2= 3.3 Hz, J_3= 10.0 Hz, 2H), 7.61-7.63 (sl, 1H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.5 (CH_3), 18.8 (CH_3), 19.7 (CH_3), 20.8 (CH_3), 22.4 (CH_3), 27.2 (CH_2), 28.0

(CH_2), 29.8 (CH_2), 30.5 (CH_2), 36.6 (CH_2), 42.8 (CH), 45.0 (CH), 47.9 (C, CH), 48.9 (C), 80.5 (CH), 154.0 (CO), 172.2 (CO), 173.5 (CO).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl benzoate (**11**): clear oil; $C_{17}H_{22}O_2$; HR-ESIMS: *m/z* Calcd for $C_{17}H_{22}O_2Na$ ($[M + Na]^+$): 281.1517, found: 281.1525; IR (ATR, cm^{-1}): 710, 978, 1112, 1270, 1451, 1714, 2879, 2953 cm^{-1}; ^1H and ^{13}C NMR spectral data are in accordance with data reported by Silva et al. (2016) and by Corrêa et al. (2012).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl 4'-methoxybenzoate (**12**): clear oil; $C_{18}H_{24}O_3$; HR-ESIMS: *m/z* Calcd for $C_{18}H_{24}O_3Na$ ($[M + Na]^+$): 311.1623, found: 311.1609; IR (ATR, cm^{-1}): 770, 848, 1118, 1168, 1280, 1510, 1606, 1712, 2838, 2954 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.91 (s, 6H), 0.96 (s, 3H), 1.06-1.15 (dd, J_1= 3.5 Hz, J_2= 13.6 Hz, 1H), 1.22-1.45 (m, 2H), 1.72-1.88 (m, 2H), 2.06-2.19 (m, 1H), 2.38-2.54 (m, 1H), 3.86 (s, 3H), 5.05-5.13 (ddd, J_1= 2.2 Hz, J_2= 3.2 Hz, J_3= 10.0 Hz, 1H), 6.93 (d, J=9.0 Hz, 2H), 8.02 (d, J= 9.0 Hz, 2H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.6 (CH_3), 18.9 (CH_3), 19.8 (CH_3), 27.5 (CH_2), 28.1 (CH_2), 37.0 (CH_2), 45.1 (CH), 47.9 (C), 49.1 (C), 55.4 (CH_3), 80.2 (CH), 113.6 (CH), 123.5 (CH), 131.5 (CH), 163.3 (C), 166.6 (CO).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl 3',4'-dimethoxybenzoate (**13**): clear oil; $C_{19}H_{26}O_4$; HR-ESIMS: *m/z* Calcd for $C_{19}H_{26}O_4Na$ ($[M + Na]^+$): 341.1729, found: 341.1703; IR (Si, cm^{-1}): 763, 1025, 1177, 1224, 1290, 1453, 1514, 1601, 1710, 2878, 2954 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.92 (s, 6H), 0.97 (s, 3H), 1.08-1.16 (dd, J_1= 3.4 Hz, J_2= 13.8 Hz, 1H), 1.23-1.48 (m, 2H), 1.71-1.84 (m, 2H), 2.05-2.18 (m, 1H), 2.39-2.55 (m, 1H), 3.94 (s, 6H), 5.06-5.13 (ddd, J_1= 2.0 Hz, J_2= 3.4 Hz, J_3= 9.8 Hz, 1H), 6.90 (d, J=8.4 Hz, 2H), 7.58 (d, J=2.0 Hz, 1H), 7.69-7.73 (dd, J_1= 2.0 Hz, J_2= 8.4 Hz, 2H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.6 (CH_3), 19.0 (CH_3), 19.8

(CH_3), 27.5 (CH_2), 28.2 (CH_2), 37.0 (CH_2), 45.2 (CH), 47.9 (C), 49.2 (C), 56.1 (CH_3), 80.4 (CH), 110.5 (CH), 112.5 (CH), 123.4 (CH), 123.7 (C), 148.9 (C), 153.1 (C), 166.6 (CO).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl 3',4',5'-trimethoxybenzoate (**14**): white solid; m.p. 69-71 °C; $C_{20}H_{28}O_5$; HR-ESIMS: *m/z* Calcd for $C_{20}H_{28}O_5Na$ ([M + Na]$^+$): 371.1834, found: 371.1892; IR (ATR, cm^{-1}): 767, 873, 1122, 1228, 1333, 1415, 1586, 1708, 2836, 2952 cm^{-1}; ^{1}H and ^{13}C NMR spectral data are in accordance with data reported by Corrêa et al. (2012) and by Silva et al. (2016).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl 3',5'-dinitrobenzoate (**15**): white solid; m.p. 145-146 °C; $C_{17}H_{20}N_2O_6$; HR-ESIMS: *m/z* Calcd for $C_{17}H_{21}N_2O_6$ ([M + H]$^+$): 349.1400, found: 349.1408; IR (ATR, cm^{-1}): 729, 822, 913, 1286, 1343, 1541, 1723, 2879, 2956, 3018 cm^{-1}; ^{1}H and ^{13}C NMR spectral data are in accordance with data reported by Silva et al. (2016).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl 3',5'-dinitrosalicylate (**16**): orange solid; $C_{17}H_{20}N_2O_7$; HR-ESIMS: *m/z* Calcd for $C_{17}H_{19}N_2O_7$ ([M - H]$^-$): 363.1192, found: 363.1191; IR (KBr, cm^{-1}): 742, 806, 1086, 1178, 1262, 1338, 1454, 1546, 1622, 1682, 1710, 2884, 2958, 3098 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.96 (s, 6H), 0.99 (s, 3H), 1,14 (m, 1H), 1.37-1.55 (m, 2H), 1.83-1.89 (m, 2H), 1.98-2.09 (m, 1H), 2.48-2.60 (m, 1H), 5.23-5.28 (m, 1H), 8.97 (s, 1H), 9.03 (s, 1H), 12.93 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.6 (CH_3), 18.8 (CH_3), 19.6 (CH_3), 27.3 (CH_2), 28.0 (CH_2), 36.6 (CH_2), 44.7 (CH), 48.1 (C), 49.3 (C), 84.6 (CH), 116.2 (C), 126.5 (CH), 129.7 (CH), 137.8 (C), 138.2 (C), 159.9 (C), 168.3 (CO).

(1S,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl nicotinate (**17**): clear oil; $C_{16}H_{21}NO_2$; HR-ESIMS: *m/z* Calcd for $C_{16}H_{22}NO_2$ ([M + H]$^+$): 260.1651, found: 260.1651; IR (NaCl, cm^{-1}): 740, 1024, 1124, 1286, 1302, 1590, 1718, 2880, 2954, 3040

cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ_H (ppm): 0.93 (s, 6H), 0.98 (s, 3H), 1.09-1.18 (dd, J_1= 3.6 Hz, J_2= 13.8 Hz, 1H), 1.26-1.50 (m, 2H), 1.74-1.84 (m, 2H), 2.03-2.17 (m, 1H), 2.41-2.57 (m, 1H), 5.12-5.19 (ddd, J_1= 2.0 Hz, J_2= 3.2 Hz, J_3= 9.8 Hz, 1H), 7.37-7.44 (dd, J_1= 4.8 Hz, J_2= 8.0 Hz, 1H), 8.28-8.34 (td, J_1= 1.8 Hz, J_2= 8.0 Hz, 1H), 8.76-8.80 (dd, J_1= 1.8 Hz, J_2= 4.8 Hz, 1H), 9.25-9.26 (sl, 1H); ^{13}C NMR (50 MHz, $CDCl_3$) δ_C (ppm): 13.6 (CH_3), 18.9 (CH_3), 19.7 (CH_3), 27.4 (CH_2), 28.1 (CH_2), 36.9 (CH_2), 45.0 (CH), 48.0 (C), 49.2 (C), 81.2 (CH), 123.2 (CH), 126.8 (C), 136.9 (CH), 150.9 (CH),153.2 (CH), 165.5 (CO).

Antimicrobial activity

Borneol and its esters (**1**–**17)** were subjected to antimicrobial assay by broth microdilution method and the minimum inhibitory concentration required to inhibit the growth of 50% of microorganisms (MIC_{50}) was determined (Rodrigues et al., 2015). Two Gram-positive bacteria (*Streptococcus sanguinis* ATCC 49456 and *Staphylococcus aureus* ATCC 25923), two Gram-negative bacteria (*Escherichia coli* ATCC 25922 and *Pseudomonas aeruginosa* ATCC 27853) and the fungus *Candida albicans* ATCC 18804 were assayed.

Compounds were solubilized in DMSO to a concentration of 12.5 mg mL^{-1} and were diluted in brain heart infusion (BHI) broth to achieve a concentration of 500 μg mL^{-1}. Microbial pre-inoculum were prepared in test tubes using 3.0 mL of BHI culture medium. The tubes were then incubated in a Quimis Q-316 oven (Brazil) at 37 °C for 18 h. An amount of 500.0 μL of each pre-inoculum containing microbial cells was transferred to separate tubes containing 4.5 mL of sterile distilled water to prepare the microbial inocula. The solutions were homogenized and the turbidity compared to 0.5 of standard turbidity McFarland scale (10^8 CFU mL^{-1}). All microdilution assays were

carried out using a 96-well microplate. An amount of 100 µL of BHI culture medium was added to each well. In well 1, 100.0 µL of the sample solutions were added. The solution was homogenized, and 100.0 µL was successively transferred to the next well until eight concentrations levels were prepared (500, 250, 125, 62.5, 31.2, 15.6, 7.8 and 3.9 µg mL^{-1}). Then, 100.0 µL of inoculum of each microorganism was added to the respective wells.

Ampicillin and miconazole were used as antibacterial and antifungal standards, respectively. Bioassay of each microorganism was carried out on a different microplate. The plates were incubated in an oven at 37 °C. After 24 h, absorbance was measured on the BioTek ELx800 microplate spectrophotometer (USA) at 495 nm.

Minimum inhibitory concentrations (MICs) were calculated based on the quantity of microorganisms present after the experiments, i.e., the lowest concentration of compounds that resulted in the inhibition of 50% of growth (MIC_{50}) compared with the positive control test. The results represent the mean from at least three different determinations.

References

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Figures S1-S44

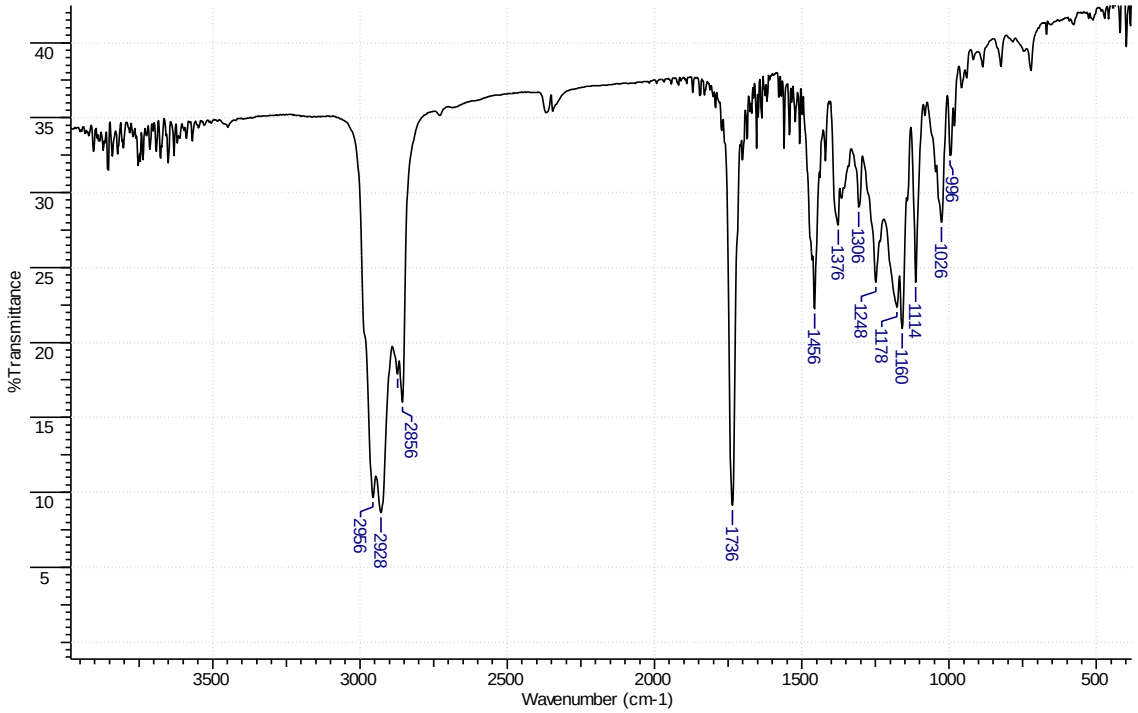

Figure S1. IR spectrum (KBr 1%) of compound **3**.

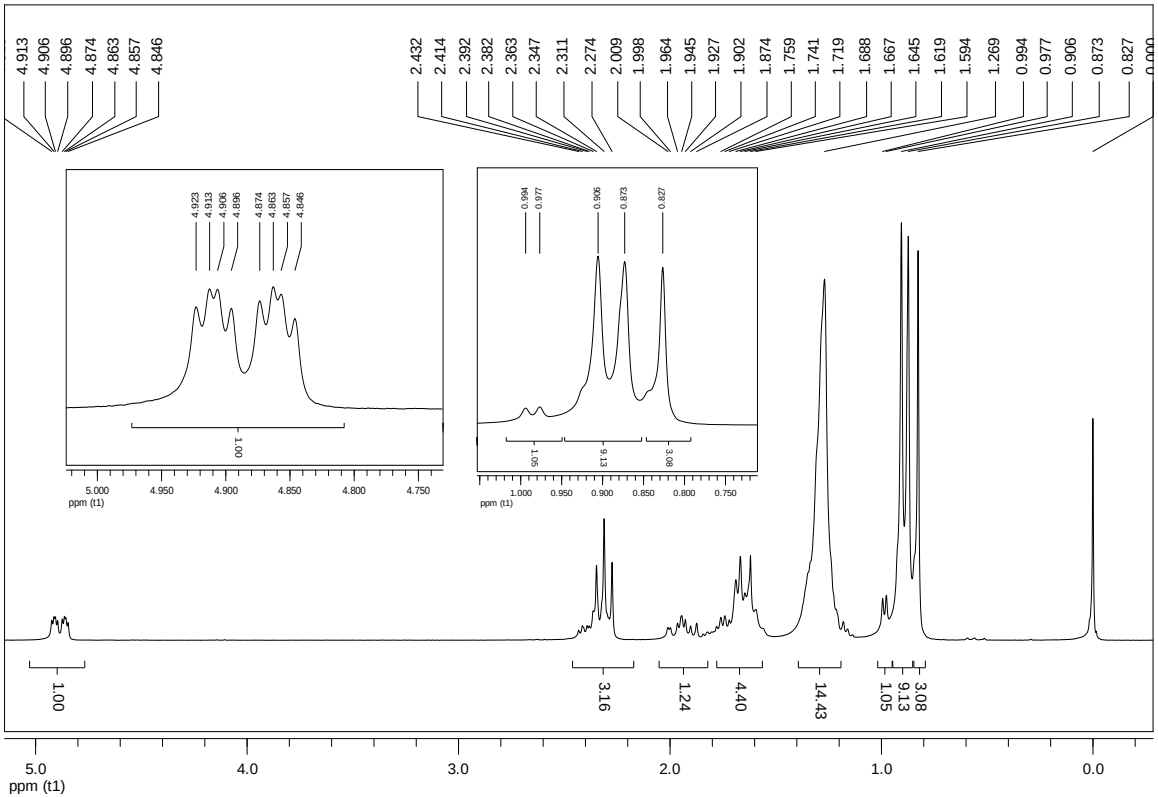

Figure S2. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **3**.

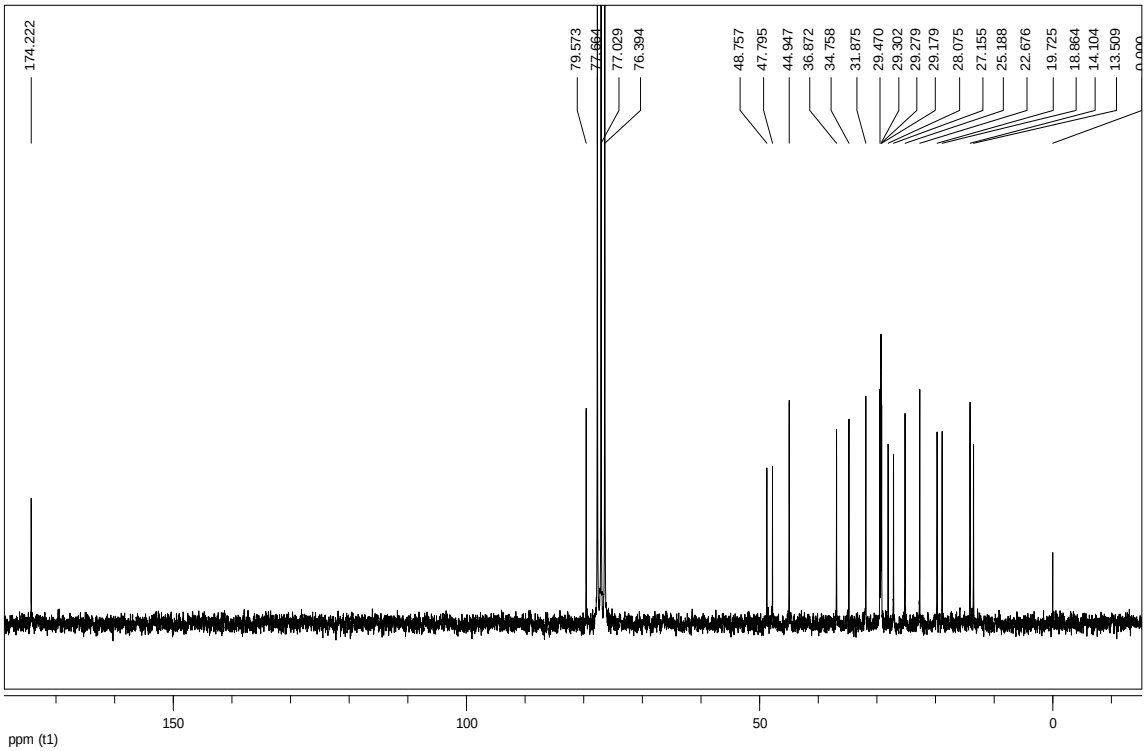

Figure S3. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **3**.

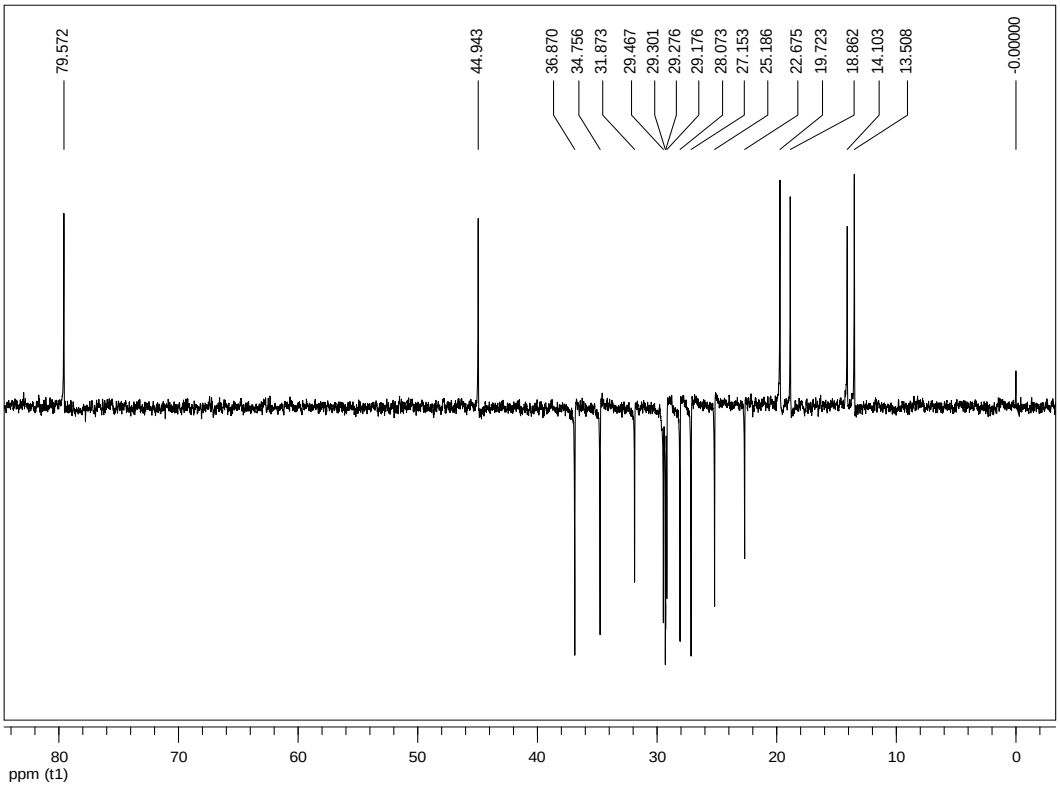

Figure S4. DEPT spectrum (50 MHz, $CDCl_3$) of compound **3**.

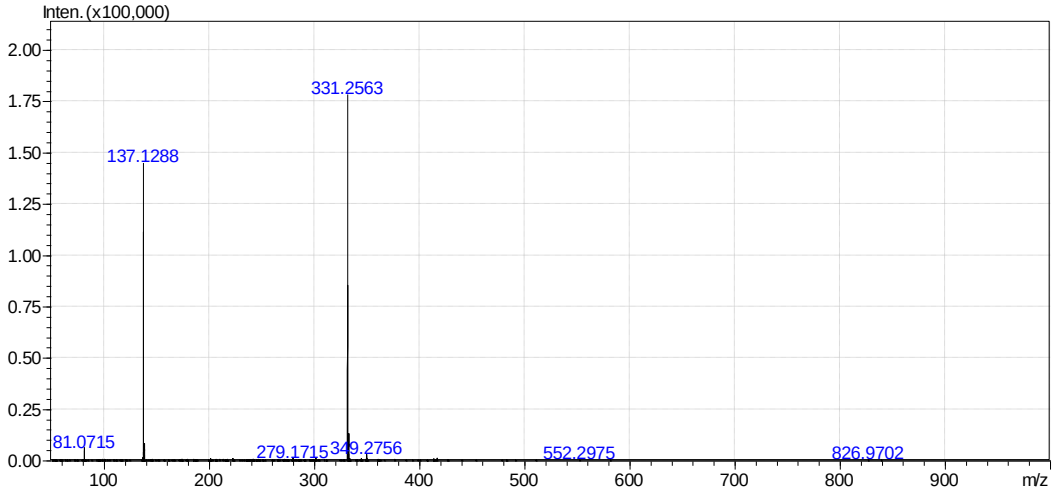

Figure S5. HR-ESIMS spectrum of compound **3**.

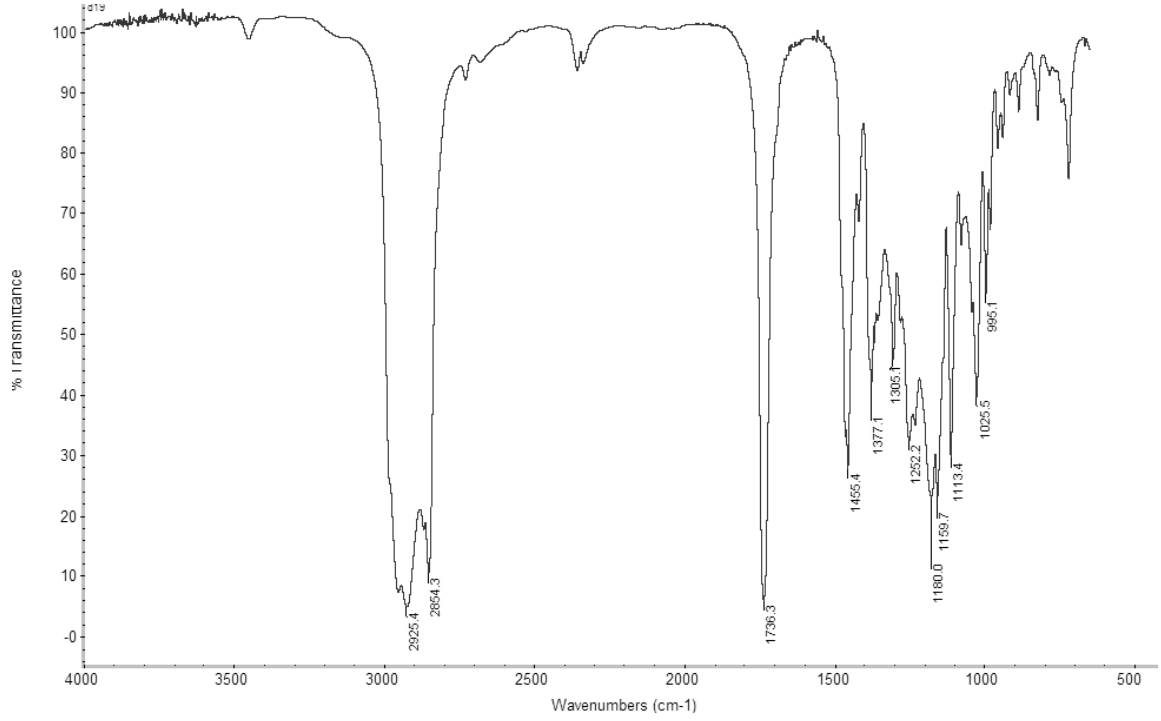

Figure S6. IR spectrum (Si) of compound **4**.

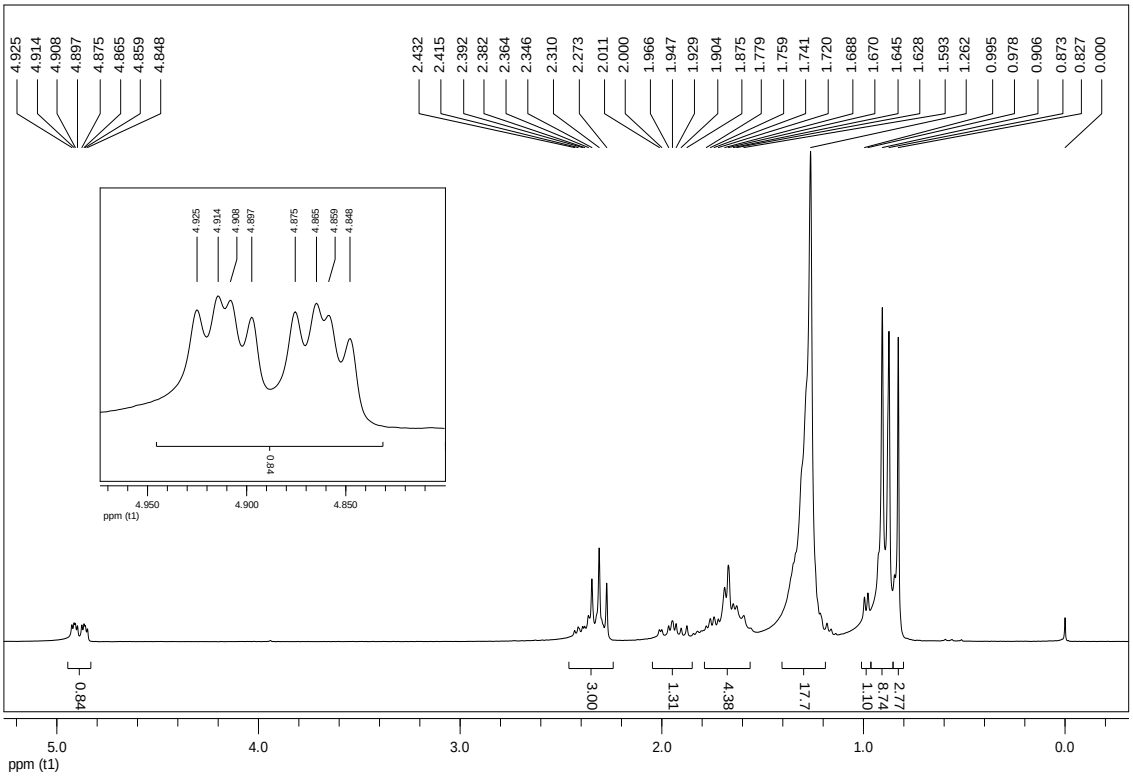

Figure S7. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **4**.

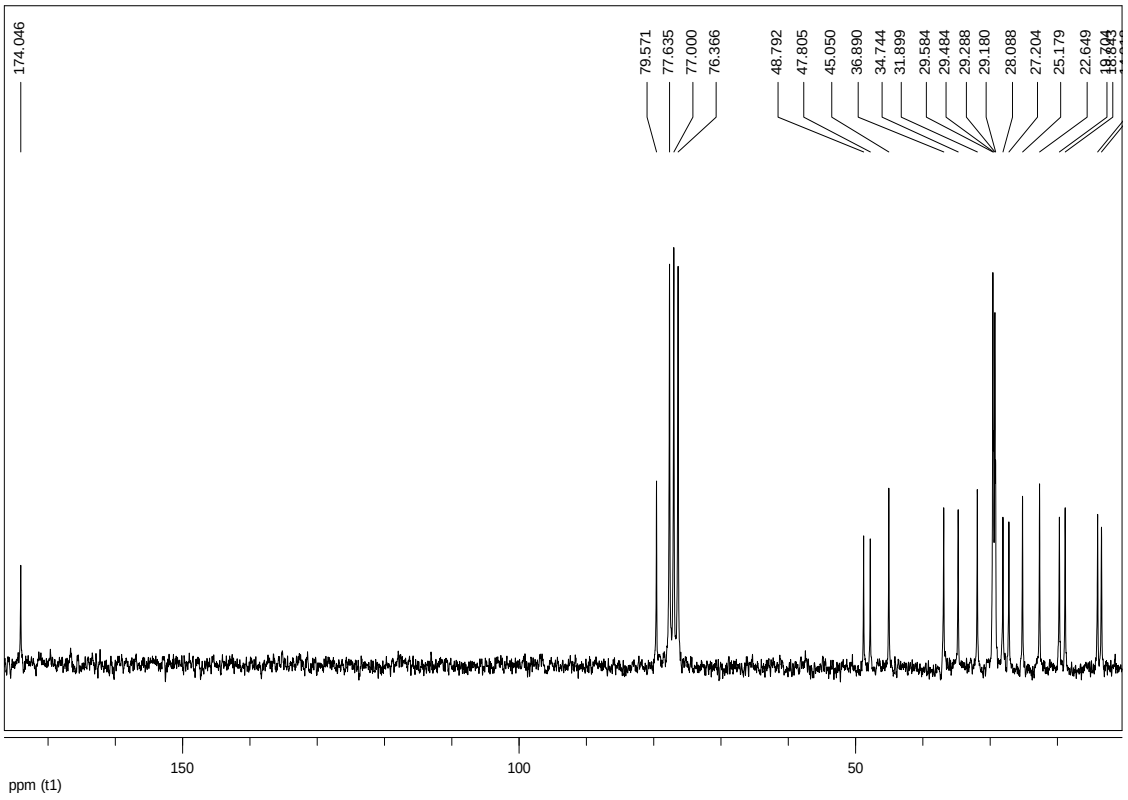

Figure S8. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **4**.

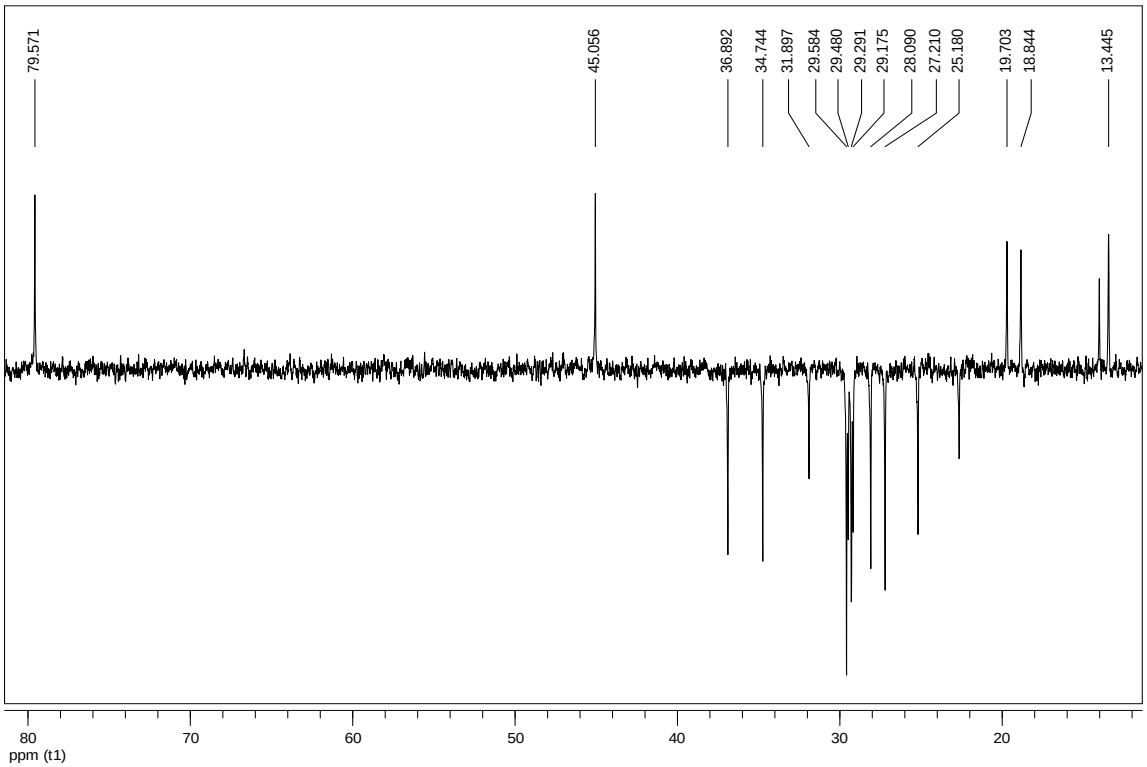

Figure S9. DEPT spectrum (50 MHz, $CDCl_3$) of compound **4**.

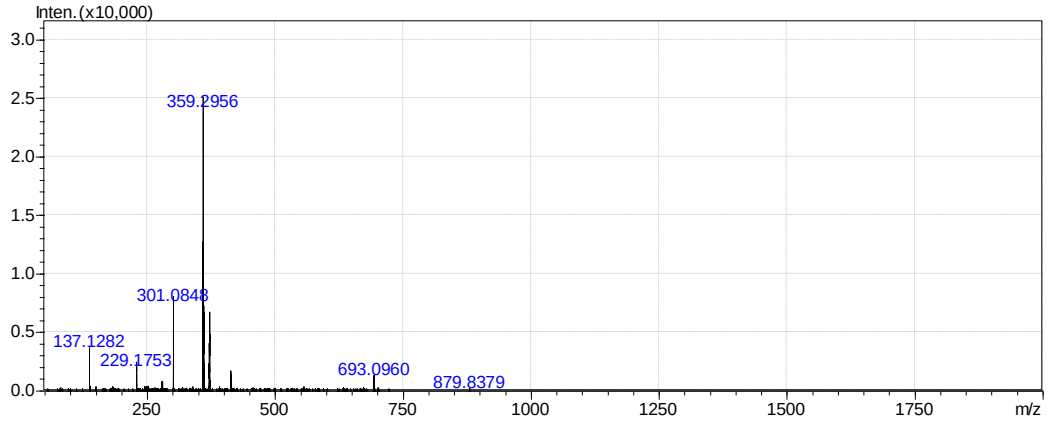

Figure S10. HR-ESIMS spectrum of compound **4.**

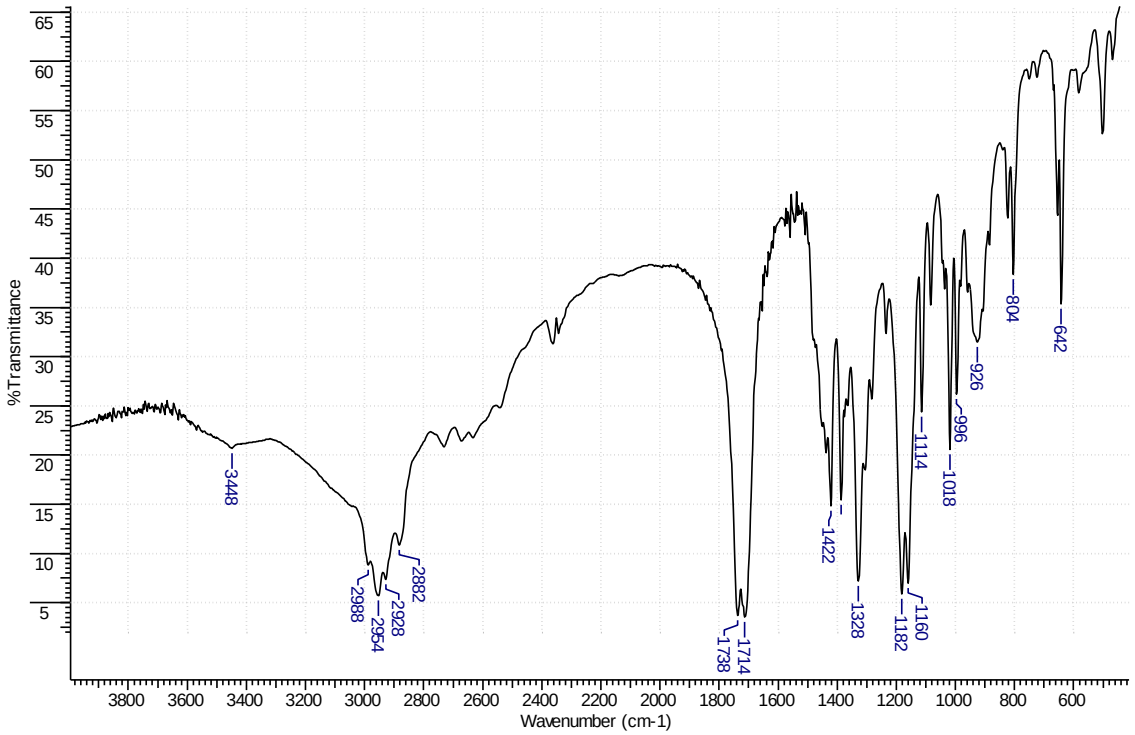

Figure S11. IR spectrum (KBr 1%) of compound **8**.

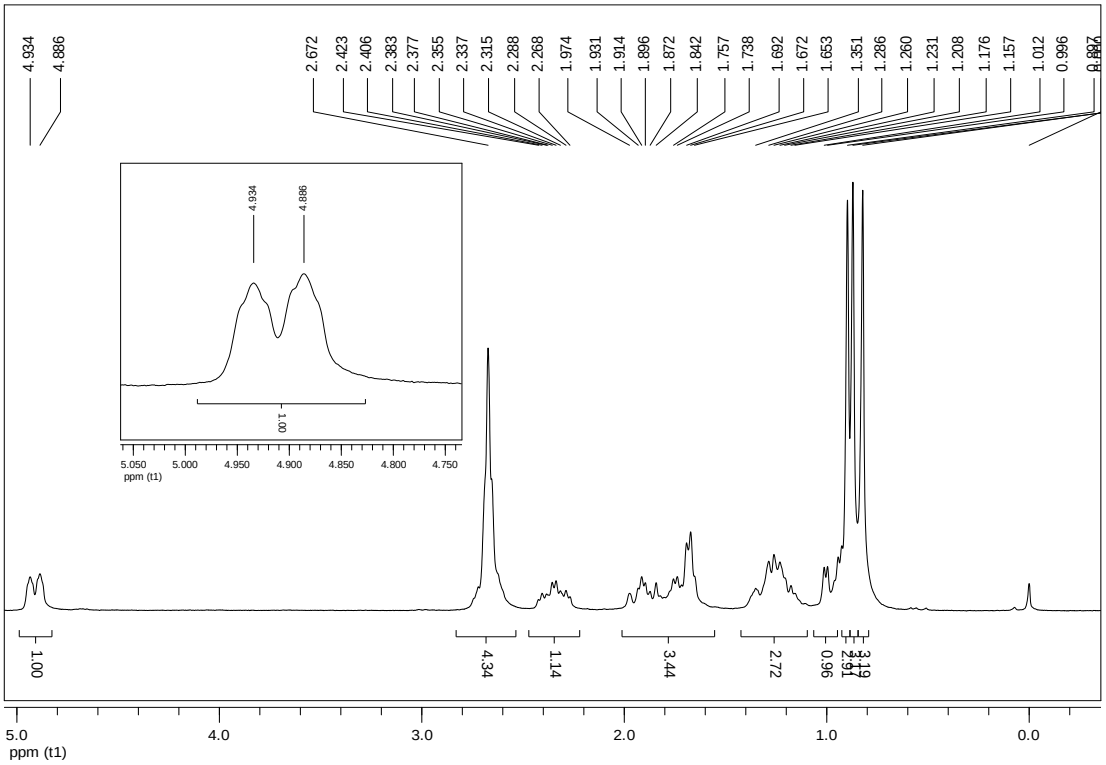

Figure S12. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **8**.

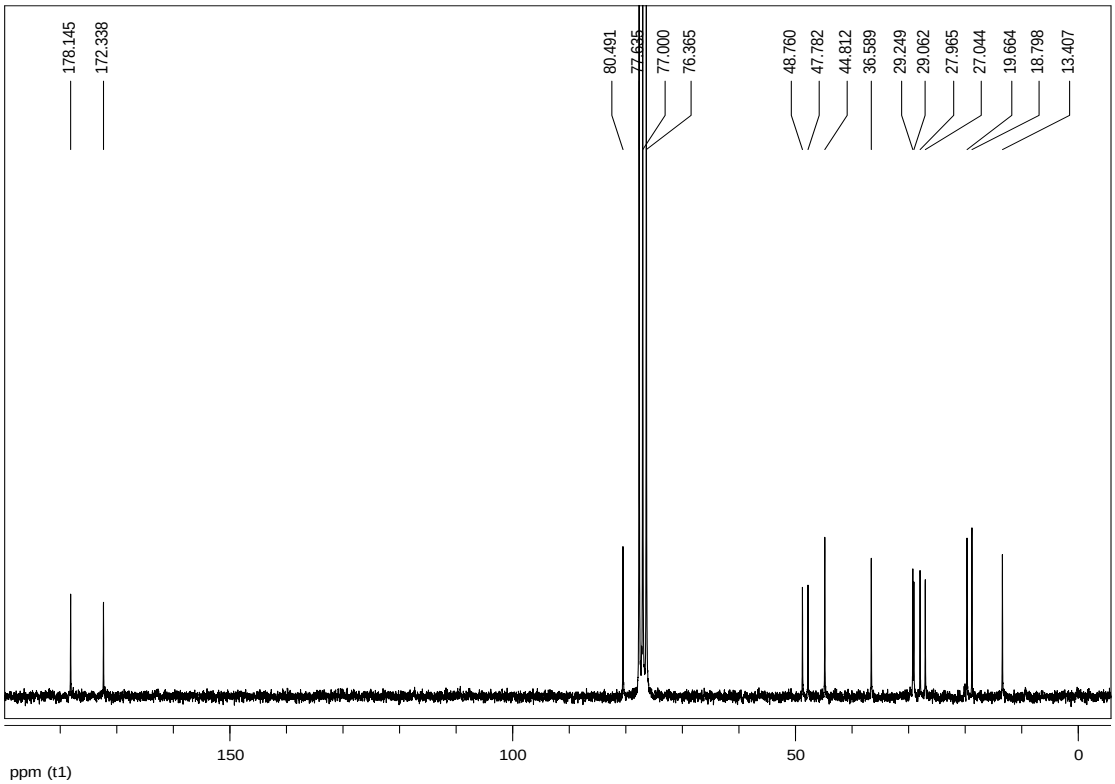

Figure S13. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **8**.

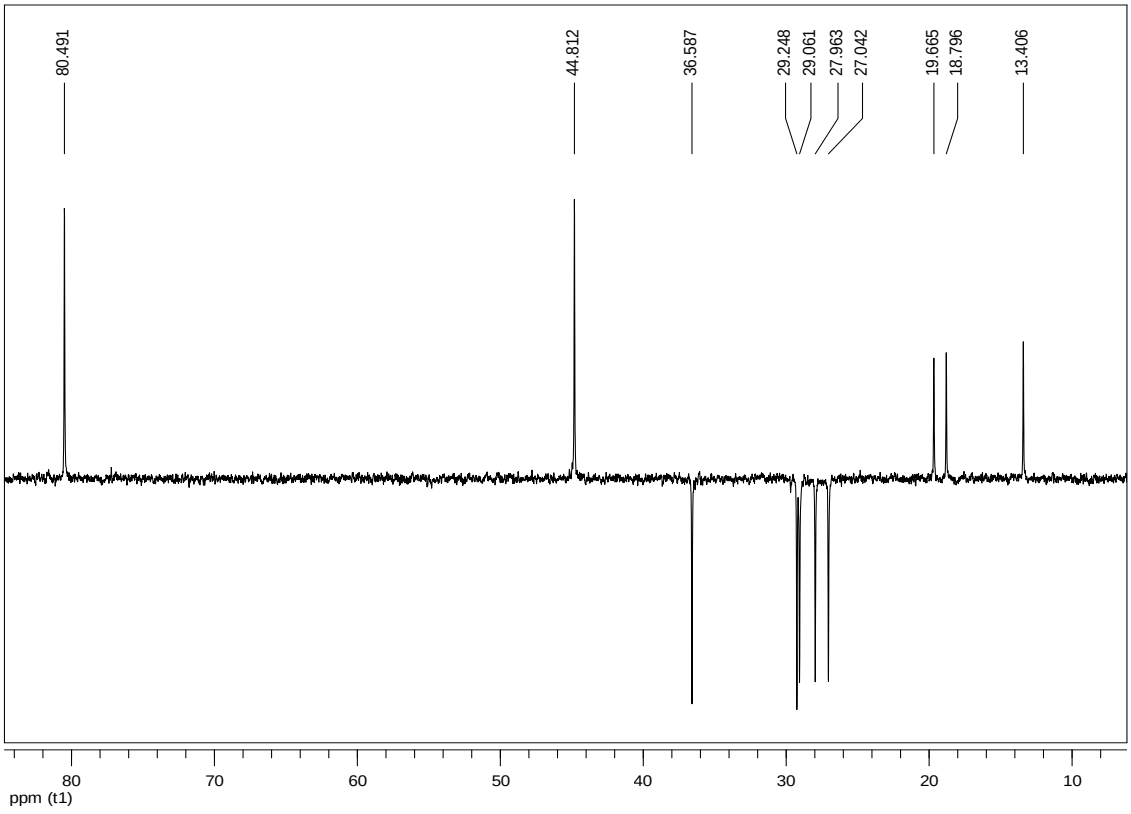

Figure S14. DEPT spectrum (50 MHz, $CDCl_3$) of compound **8**.

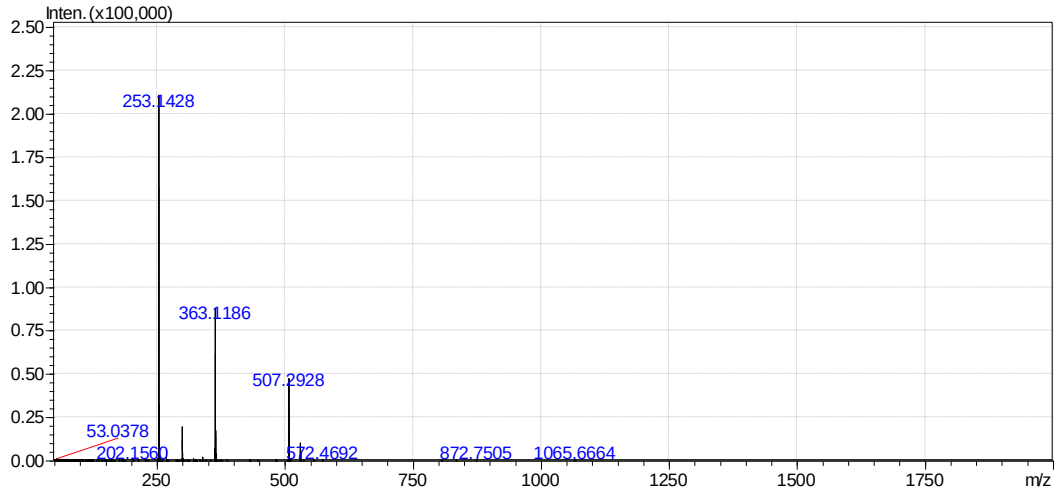

Figure S15. HR-ESIMS spectrum of compound **8.**

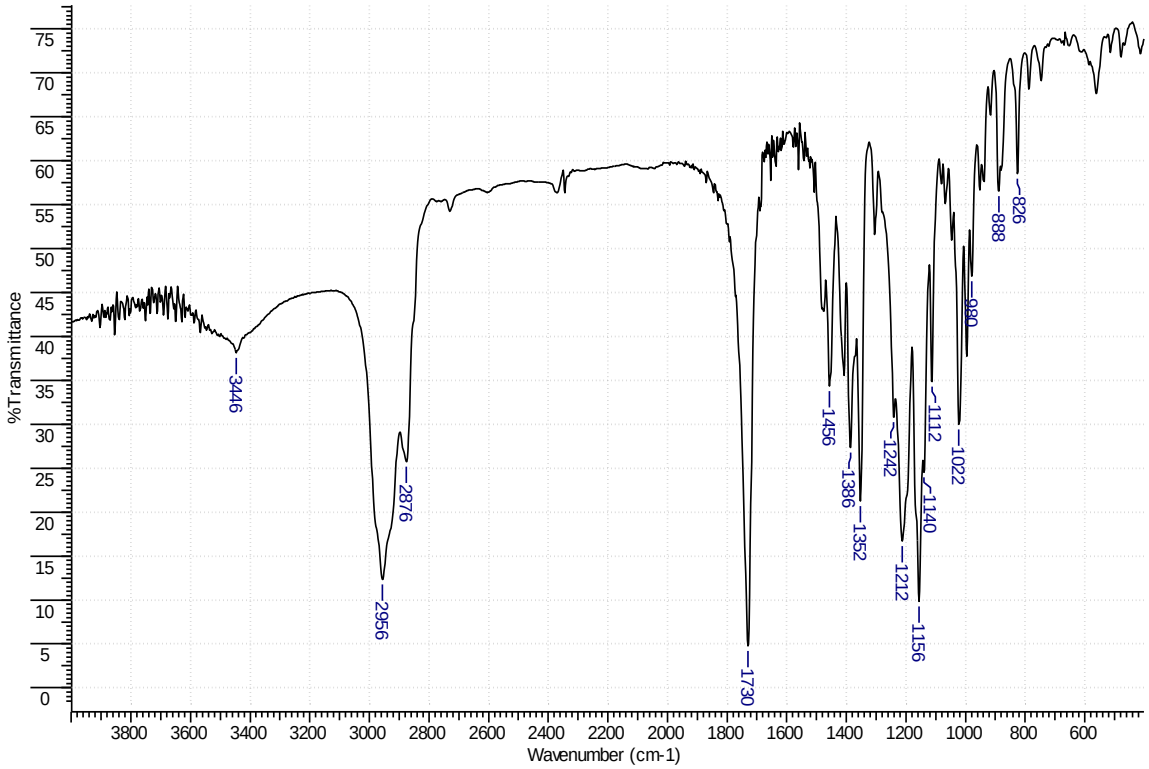

Figure S16. IR spectrum (KBr 1%) of compound **9**.

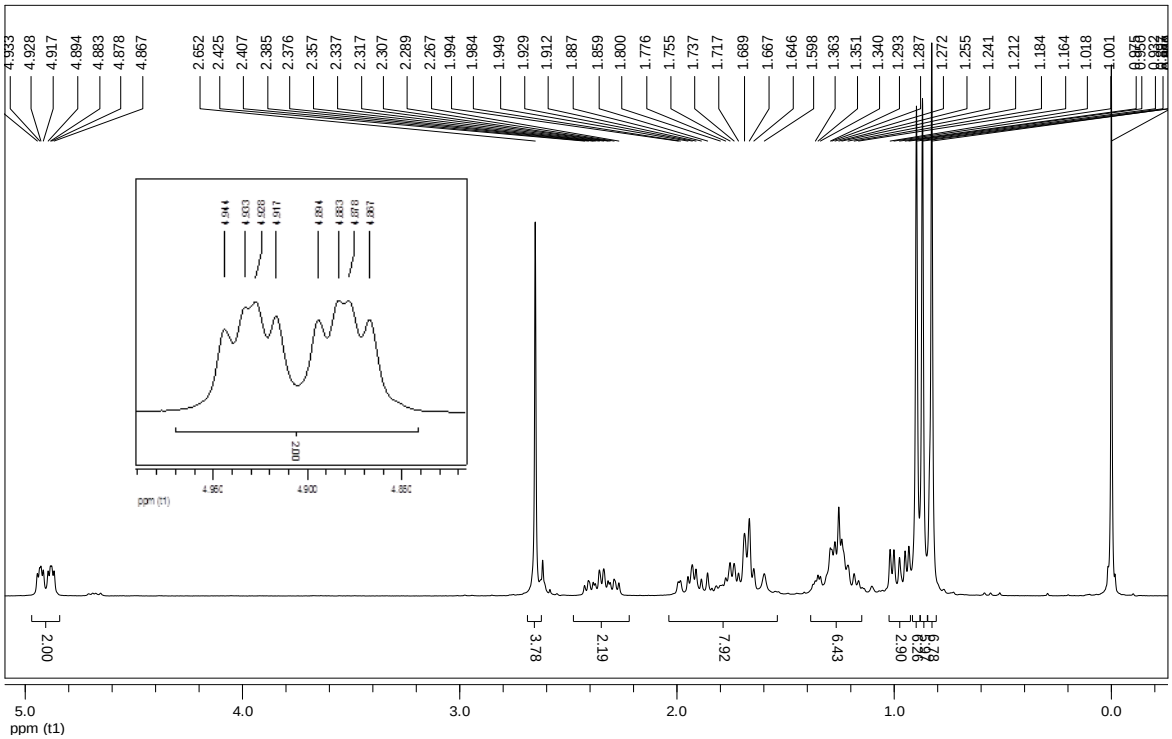

Figure S17. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **9**.

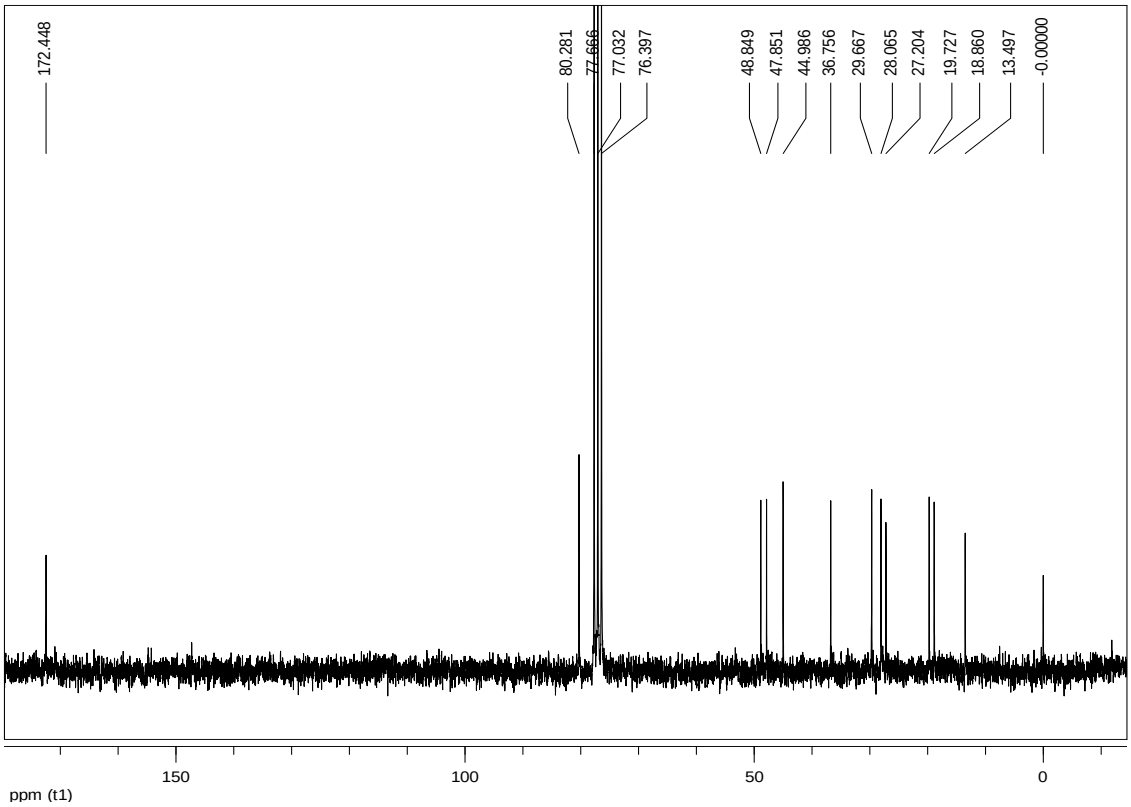

Figure S18. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **9**.

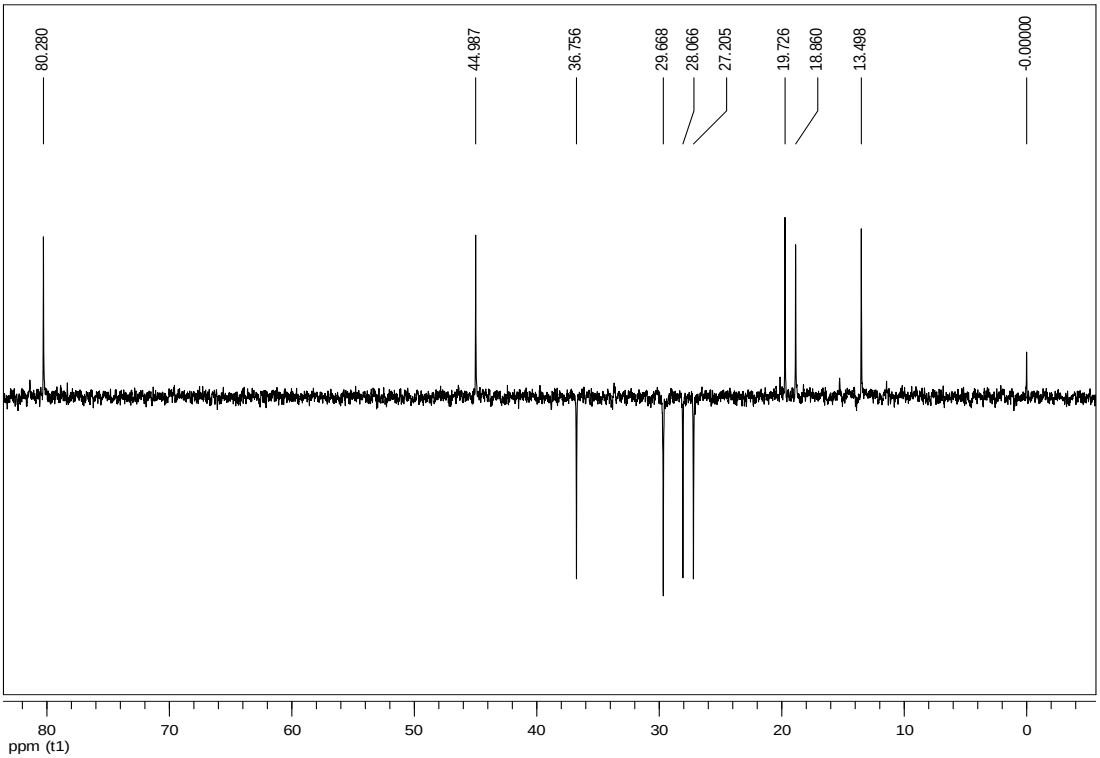

Figure S19. DEPT spectrum (50 MHz, $CDCl_3$) of compound **9**.

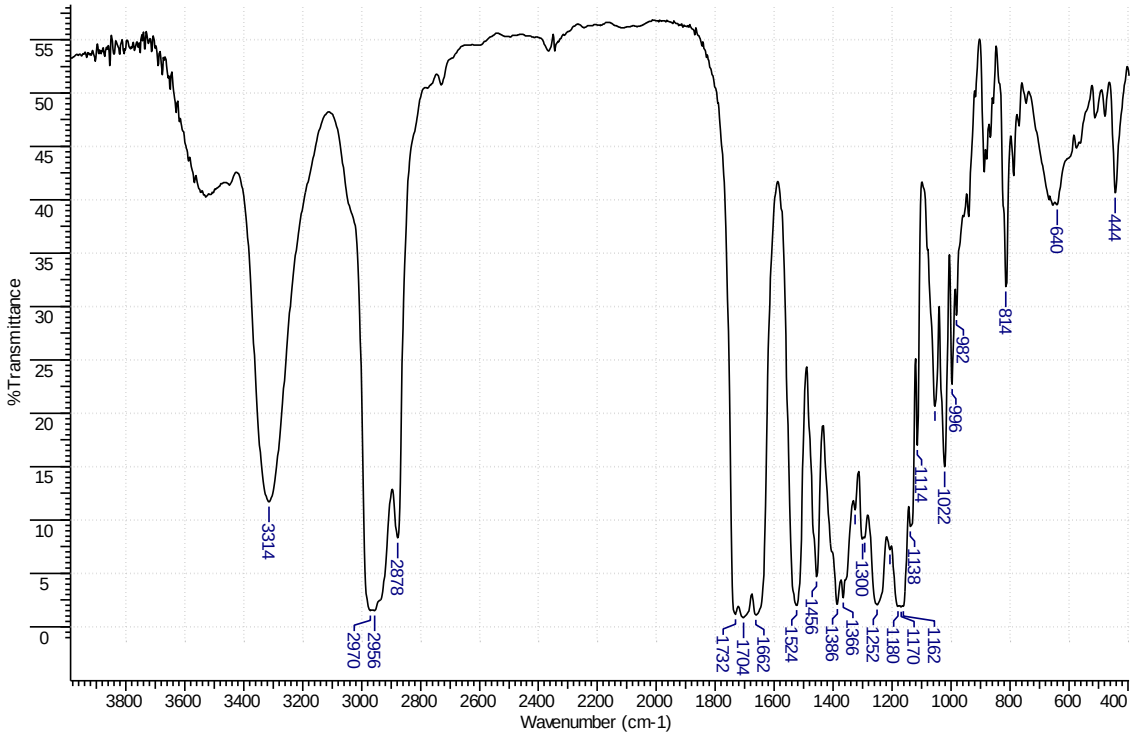

Figure S20. IR spectrum (KBr 1%) of compound **10**.

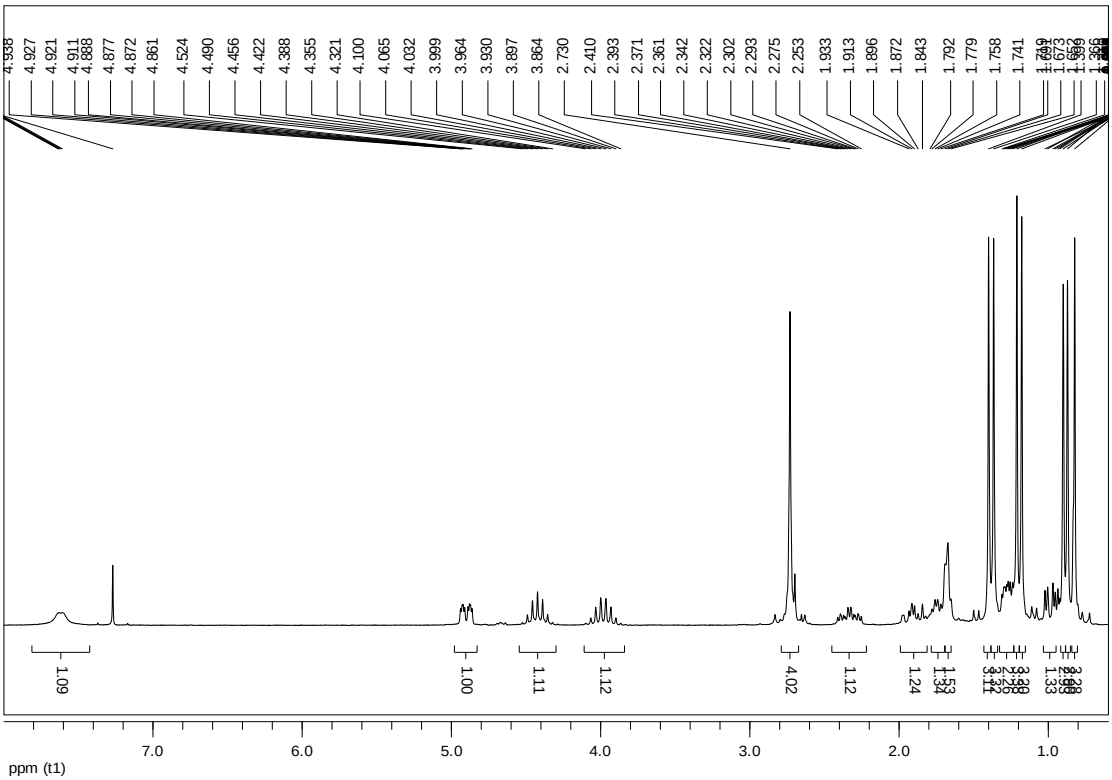

Figure S21. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **10**.

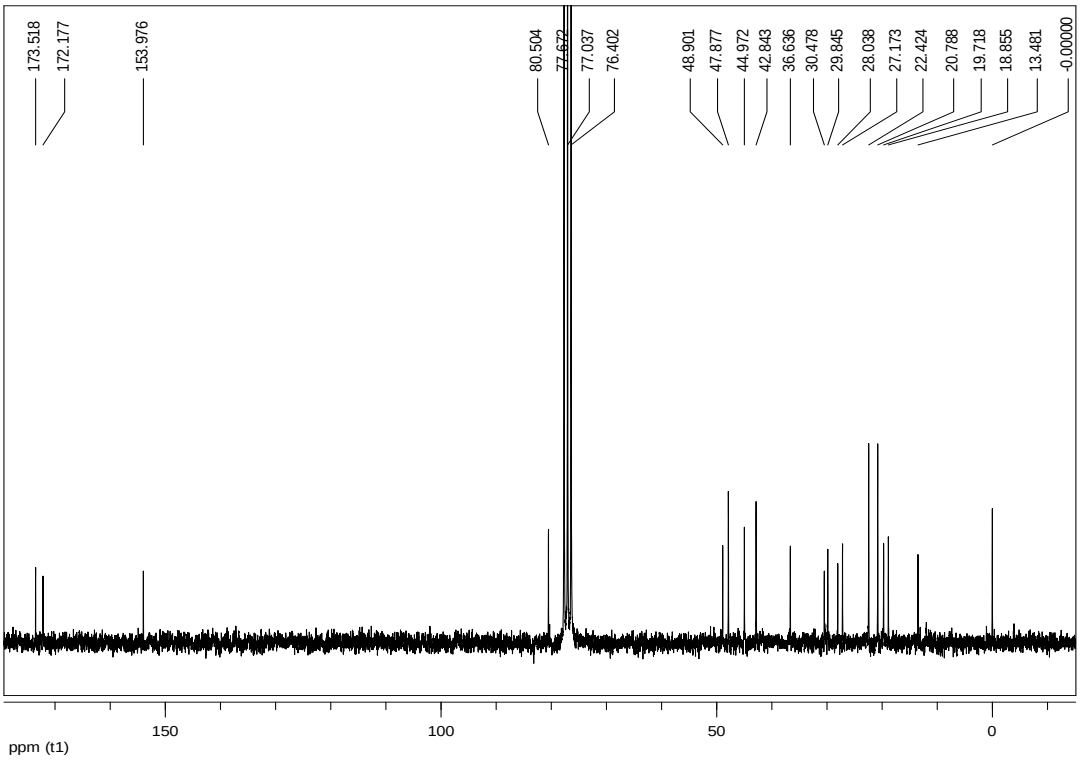

Figure S22. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **10**.

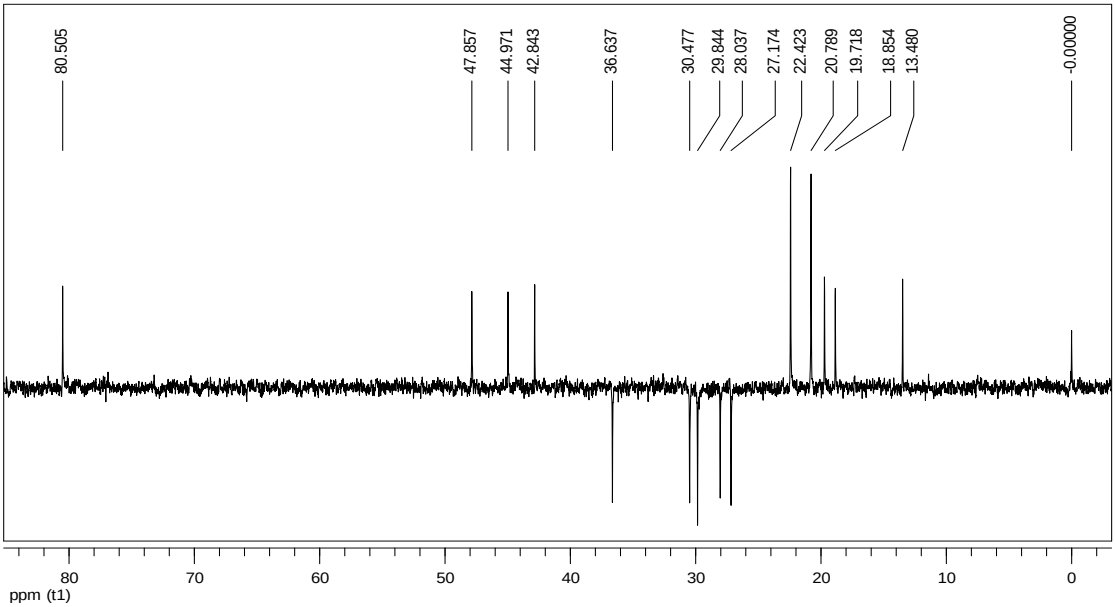

Figure S23. DEPT spectrum (50 MHz, $CDCl_3$) of compound **10**.

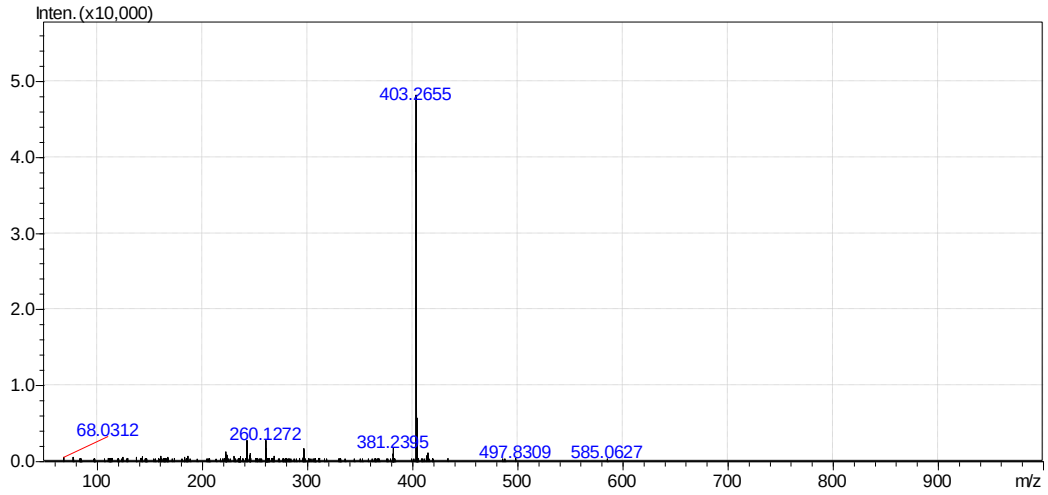

Figure S24. HR-ESIMS spectrum of compound **10.**

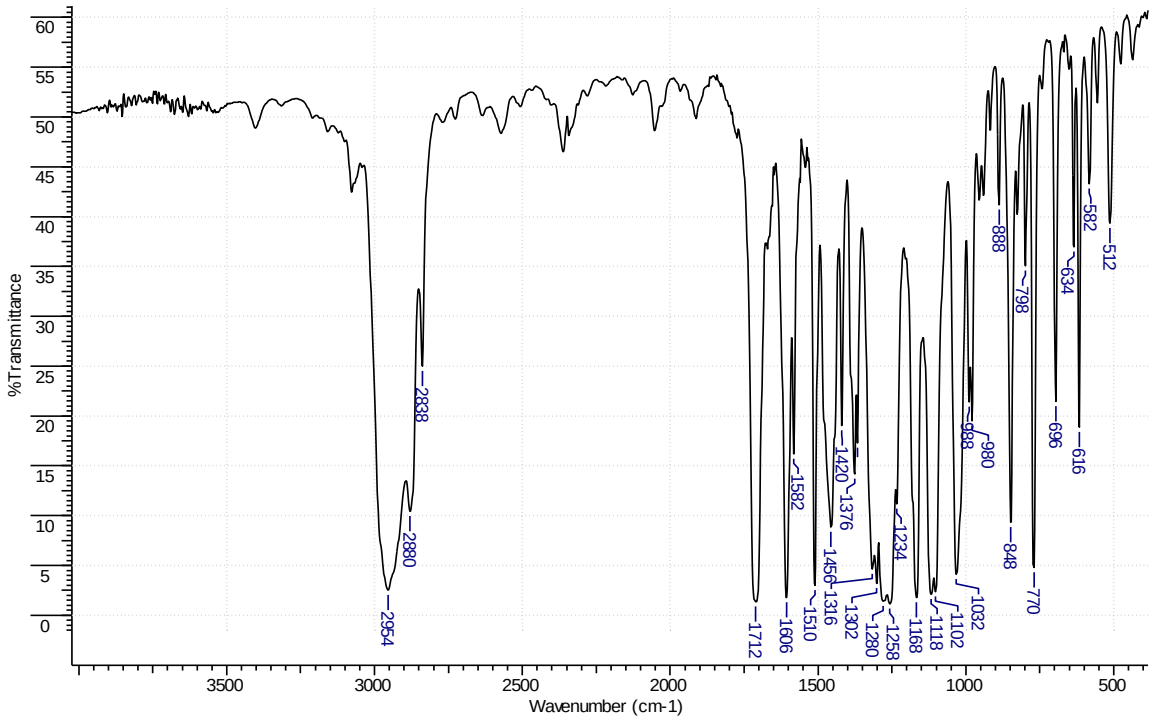

Figure S25. IR spectrum (NaCl) of compound **12**.

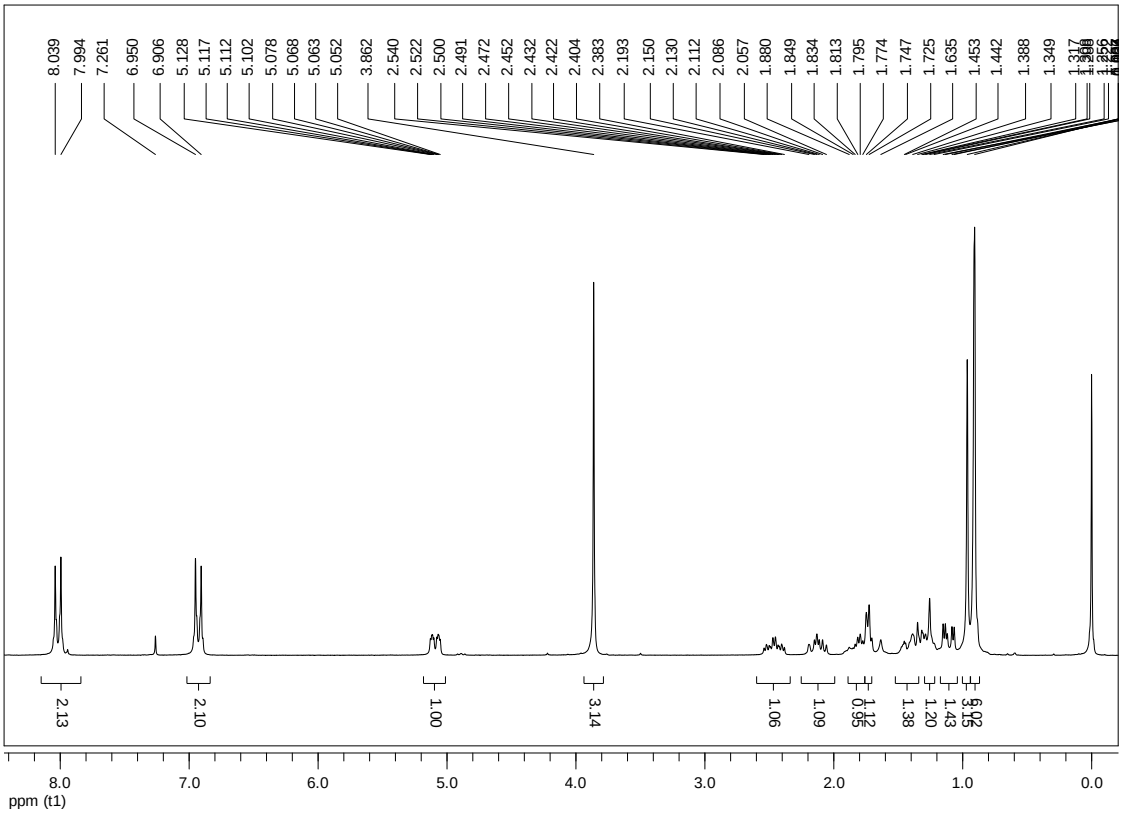

Figure S26. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **12**.

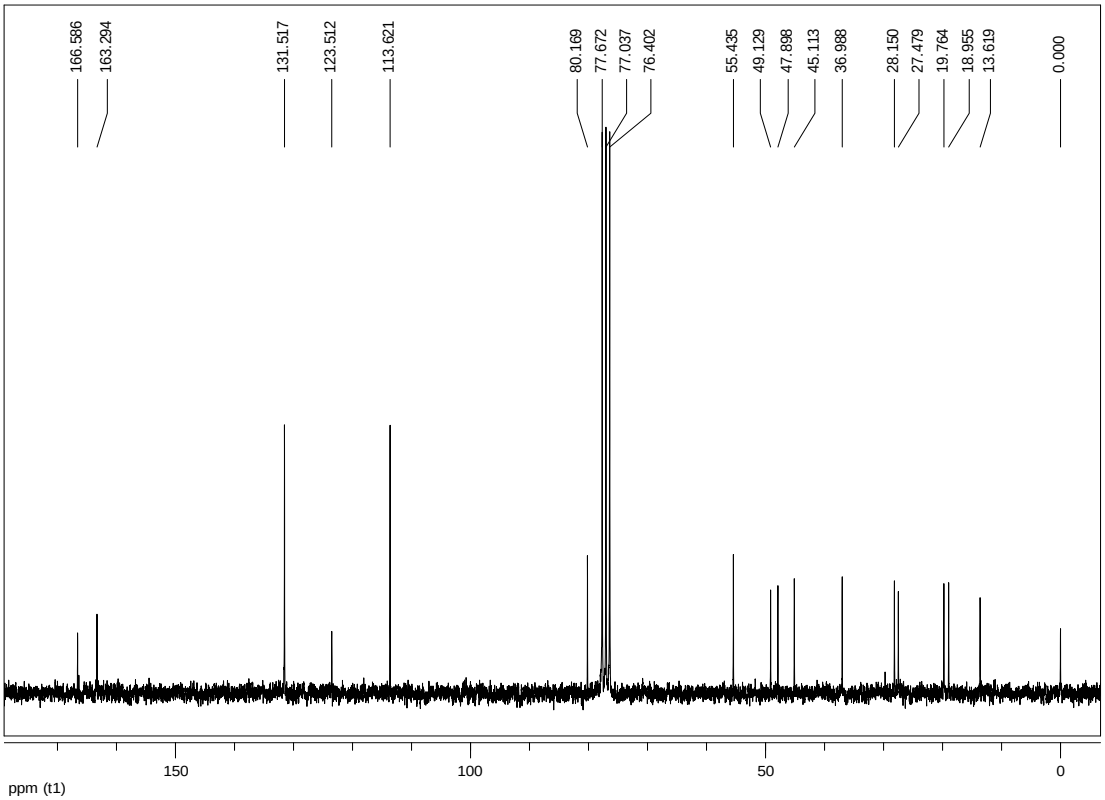

Figure S27. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **12**.

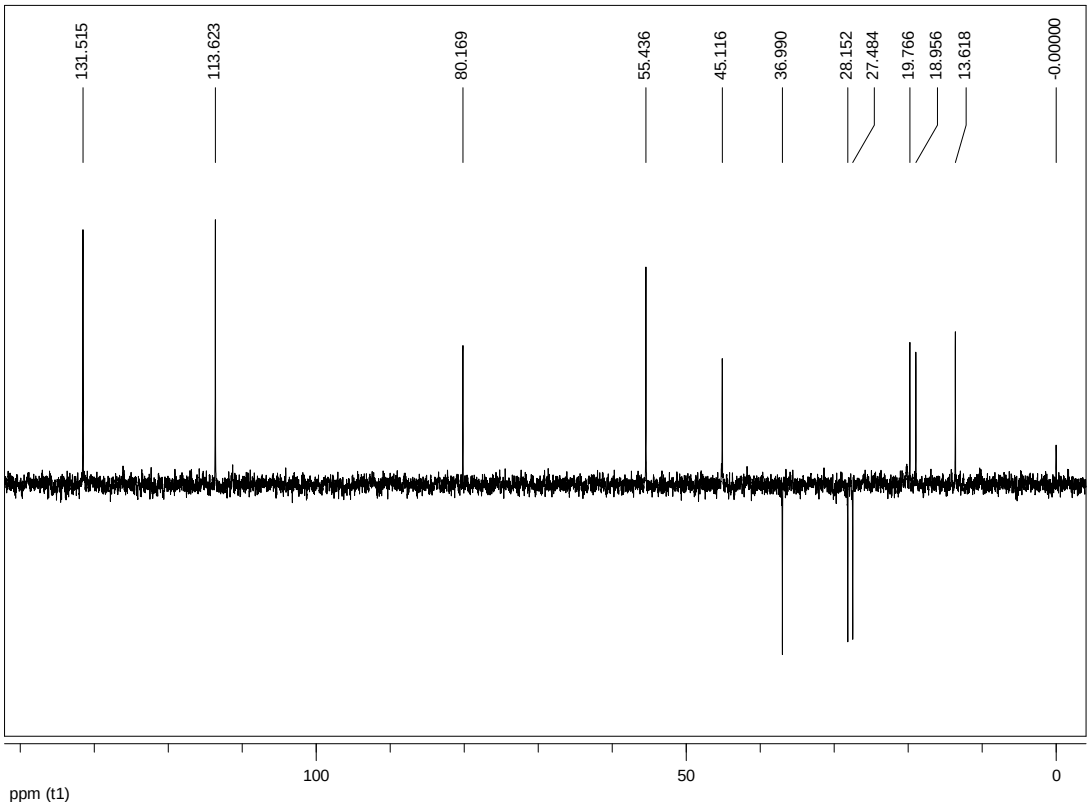

Figure S28. DEPT spectrum (50 MHz, $CDCl_3$) of compound **12**.

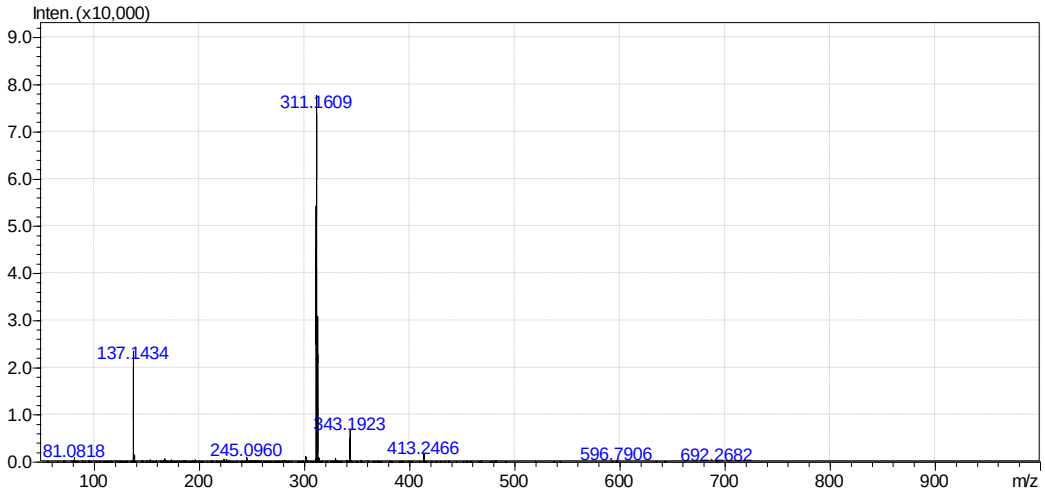

Figure S29. HR-ESIMS spectrum of compound **12.**

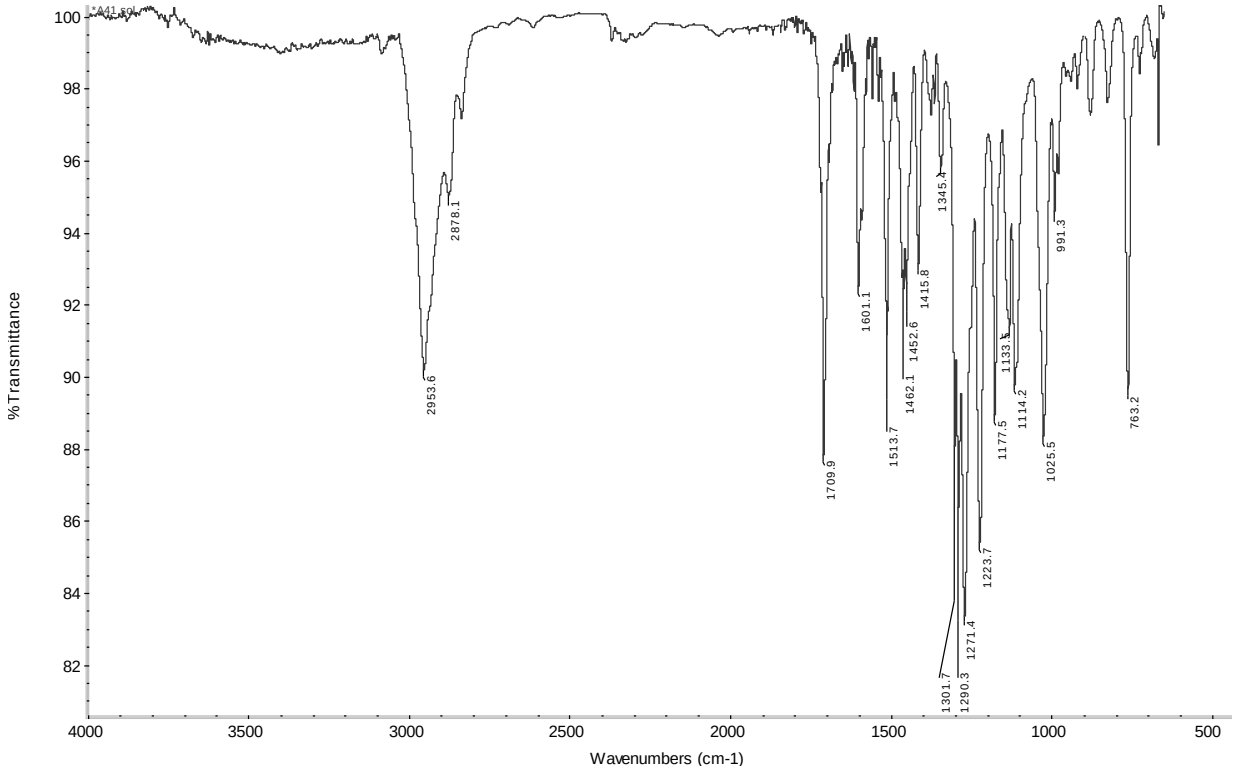

Figure S30. IR spectrum (Si) of compound **13**.

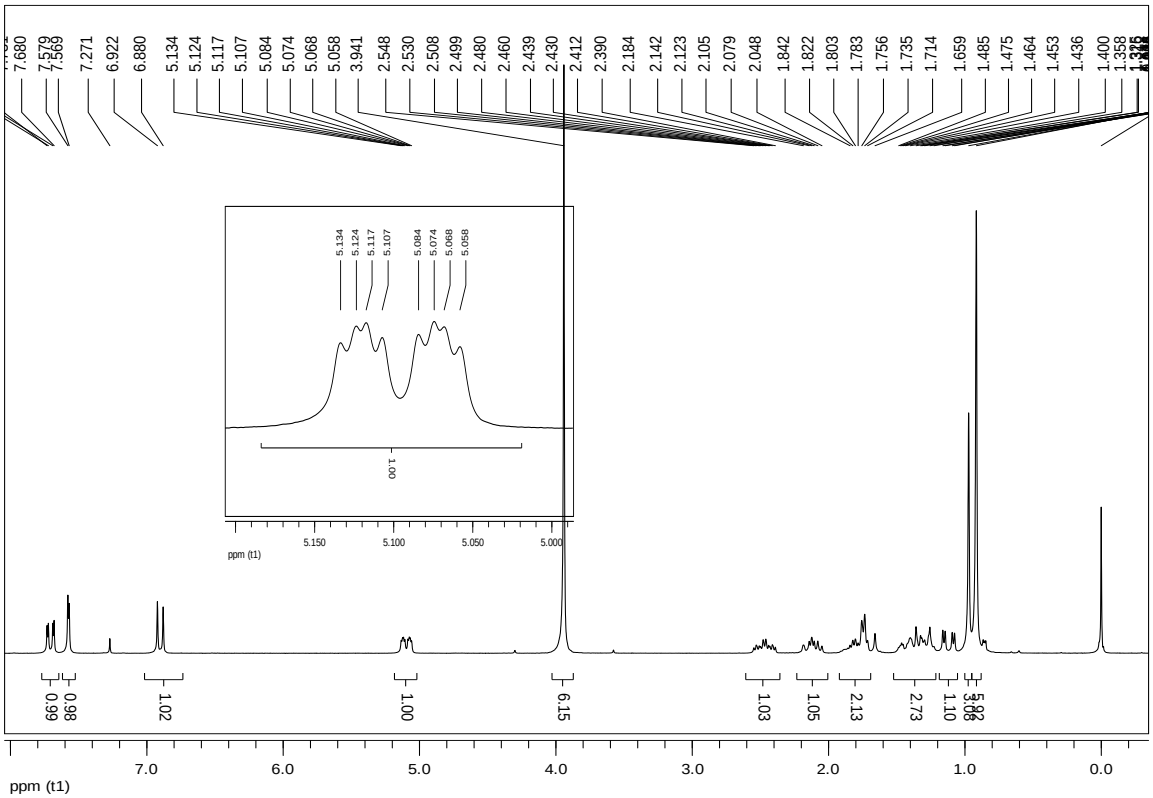

Figure S31. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **13**.

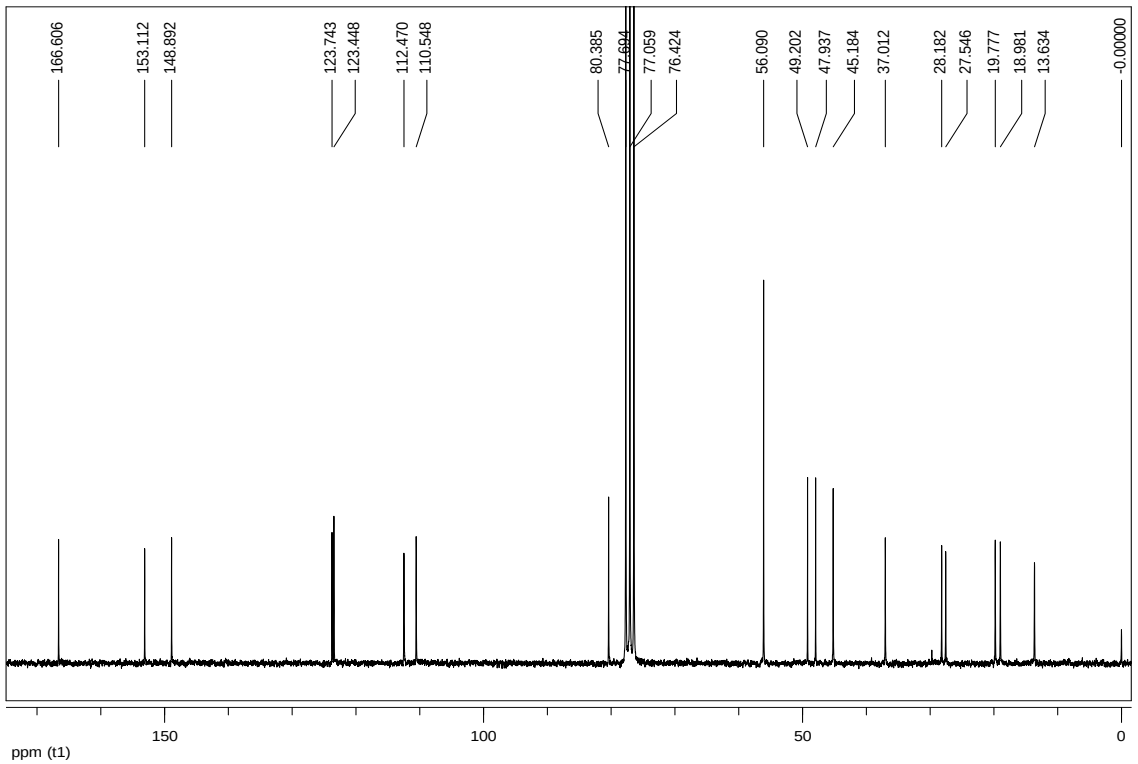

Figure S32. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **13**.

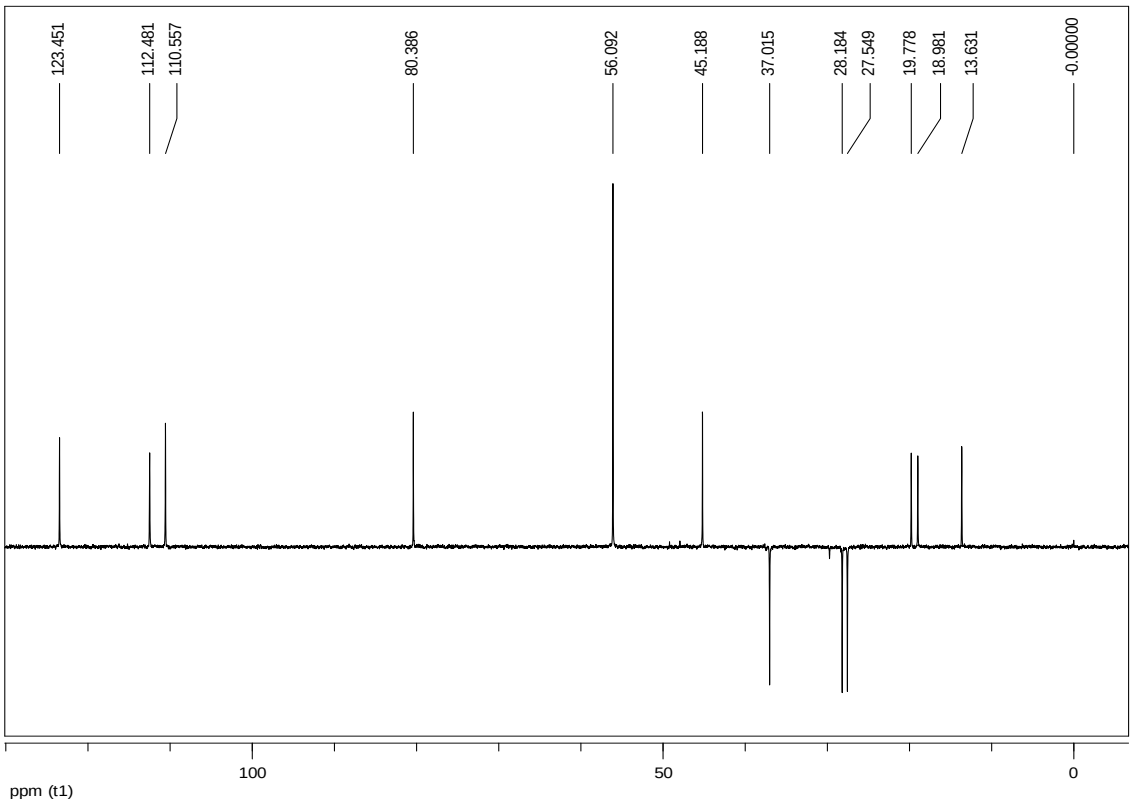

Figure S33. DEPT spectrum (50 MHz, $CDCl_3$) of compound **13**.

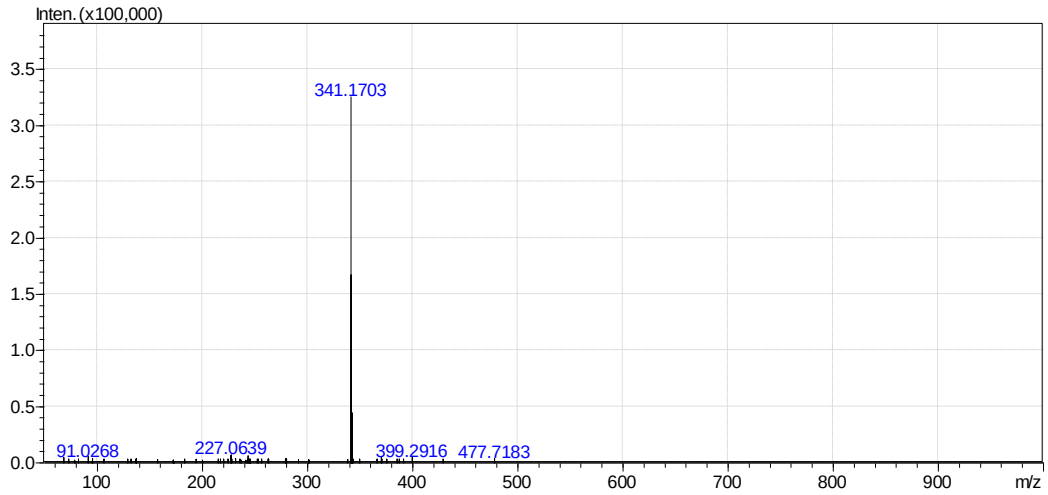

Figure S34. HR-ESIMS spectrum of compound **13.**

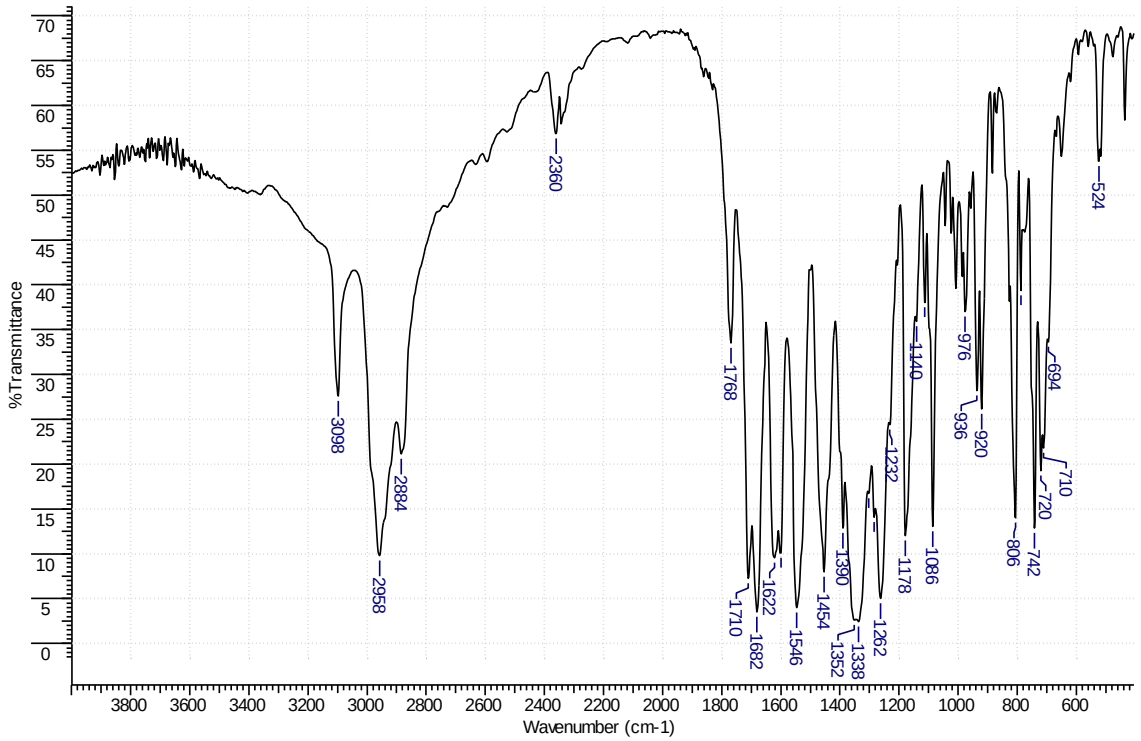

Figure S35. IR spectrum (KBr 1%) of compound **16**.

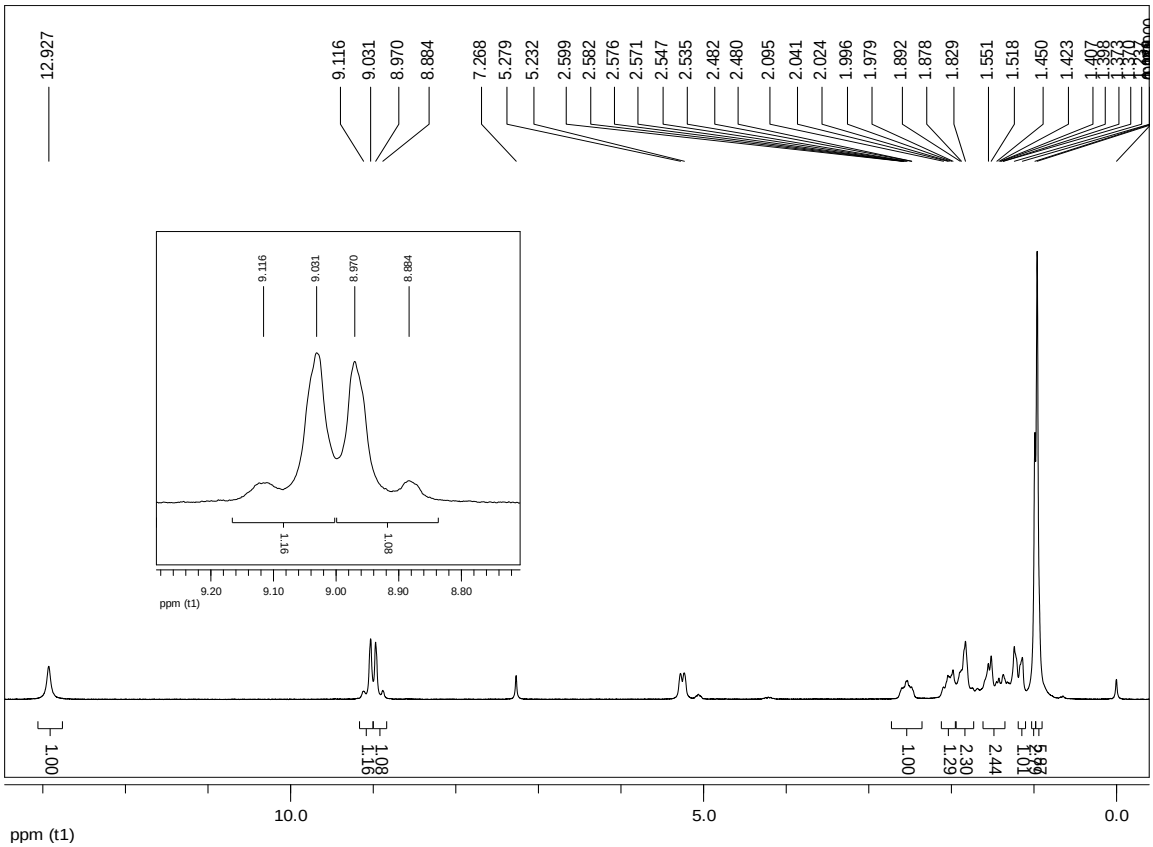

Figure S36. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **16**.

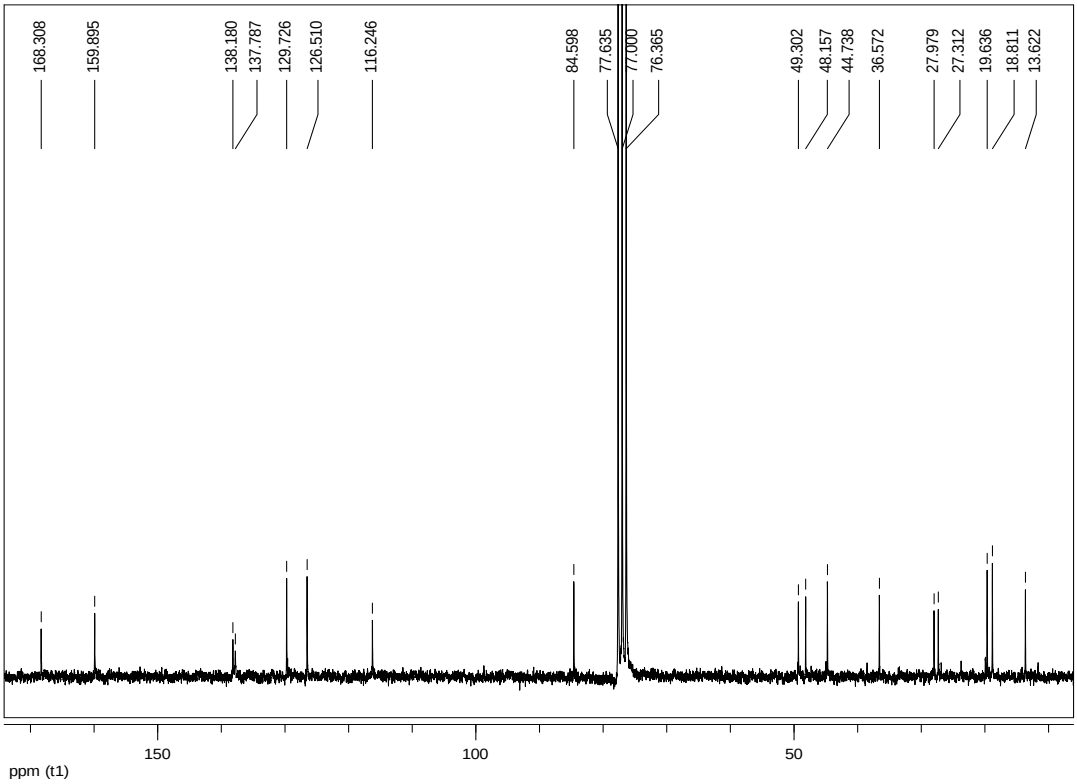

Figure S37. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **16**.

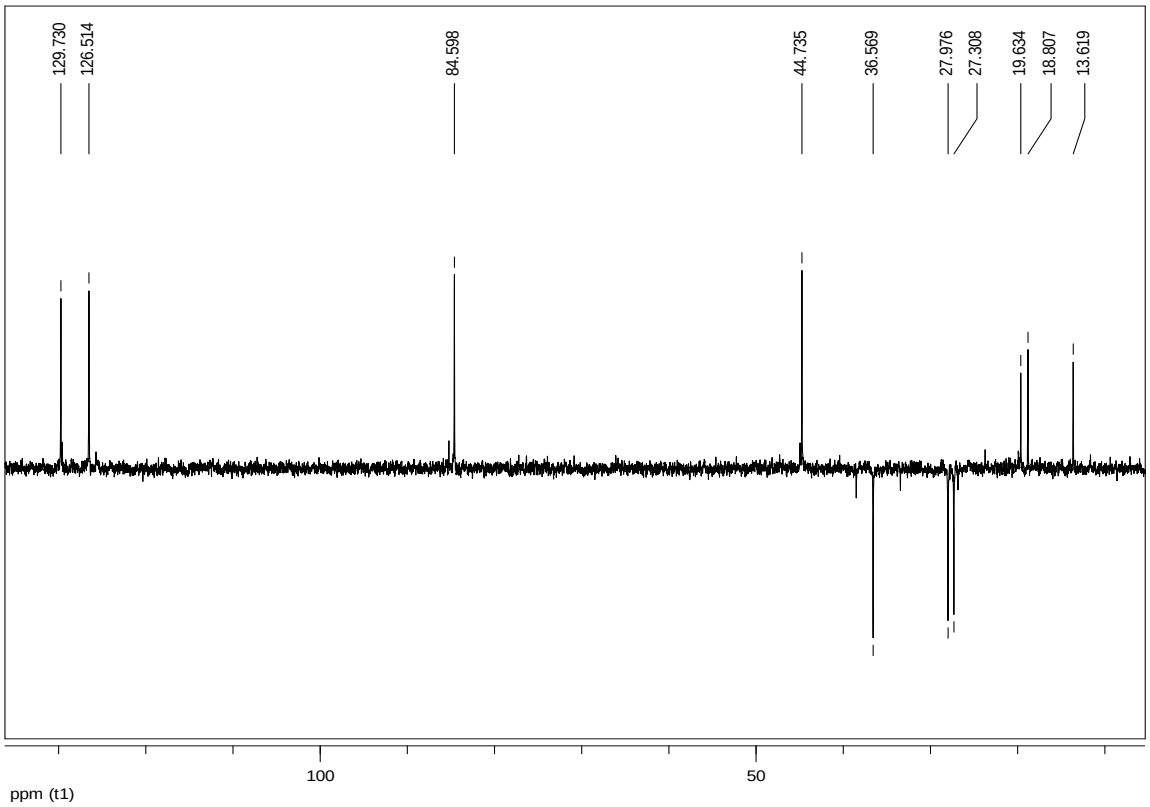

Figure S38. DEPT spectrum (50 MHz, $CDCl_3$) of compound **16**.

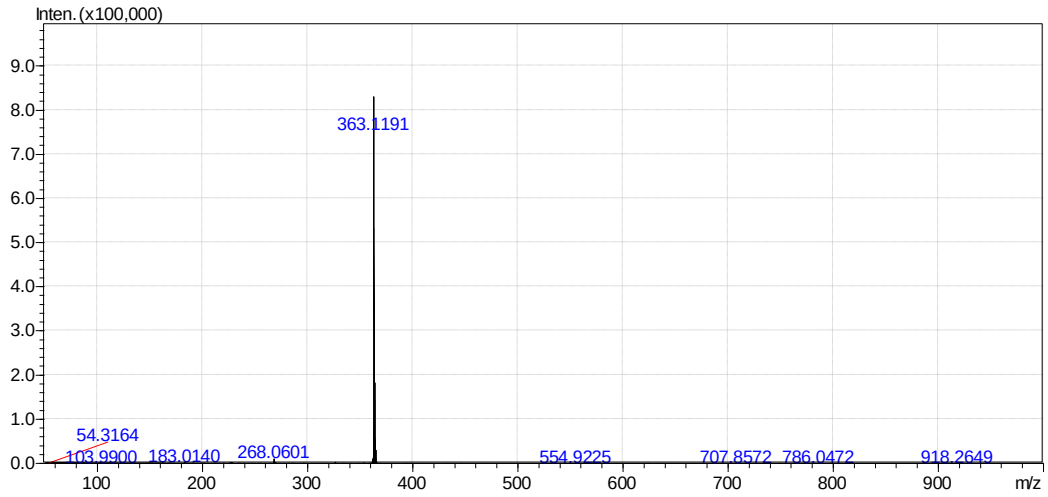

Figure S39. HR-ESIMS spectrum of compound **16.**

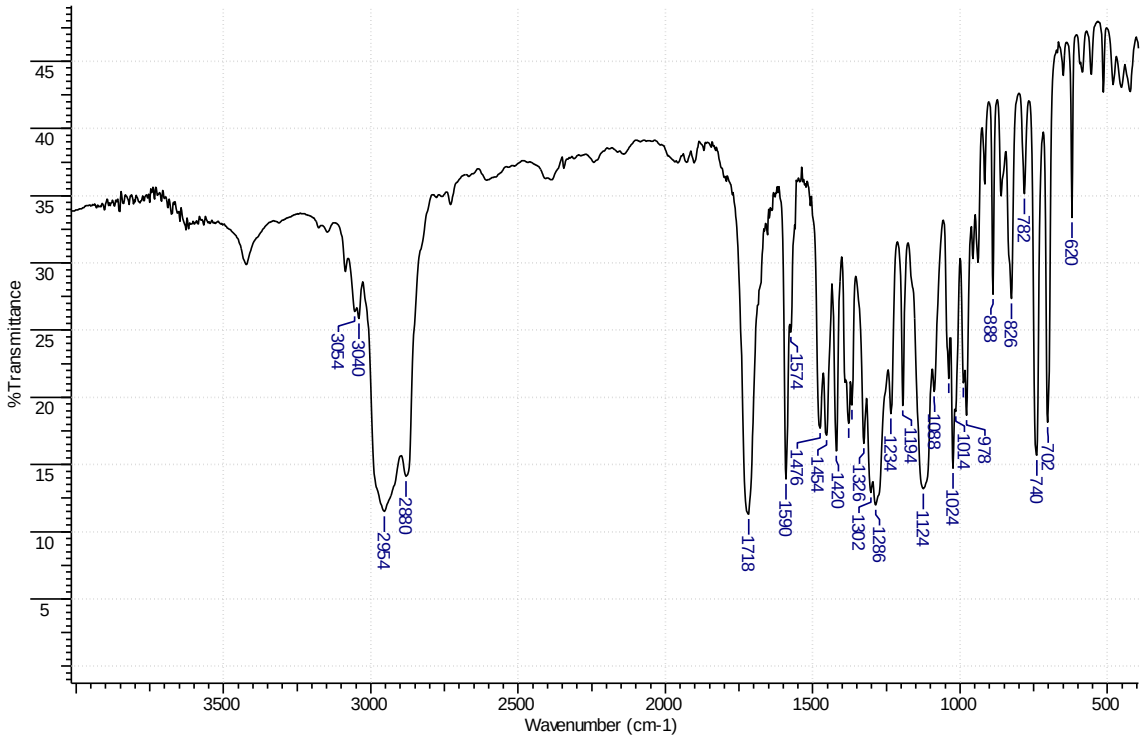

Figure S40. IR spectrum (NaCl) of compound **17**.

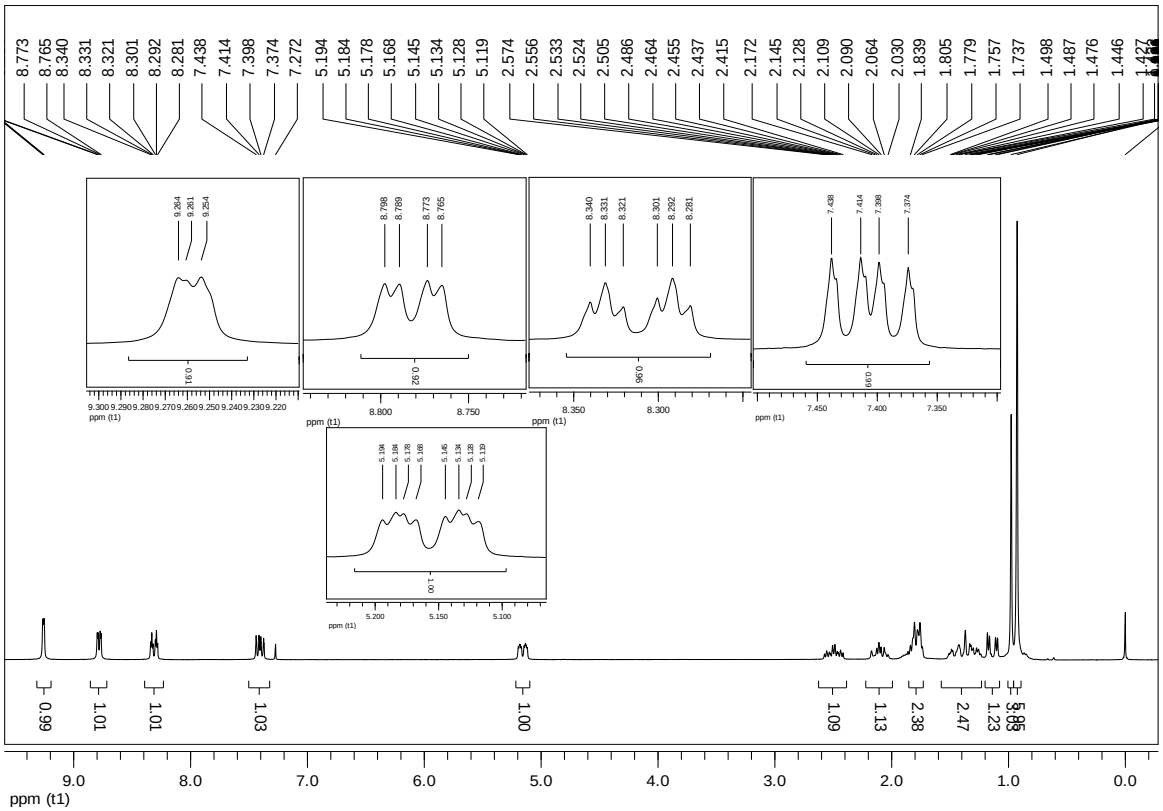

Figure S41. ^{1}H NMR spectrum (200 MHz, $CDCl_3$) of compound **17**.

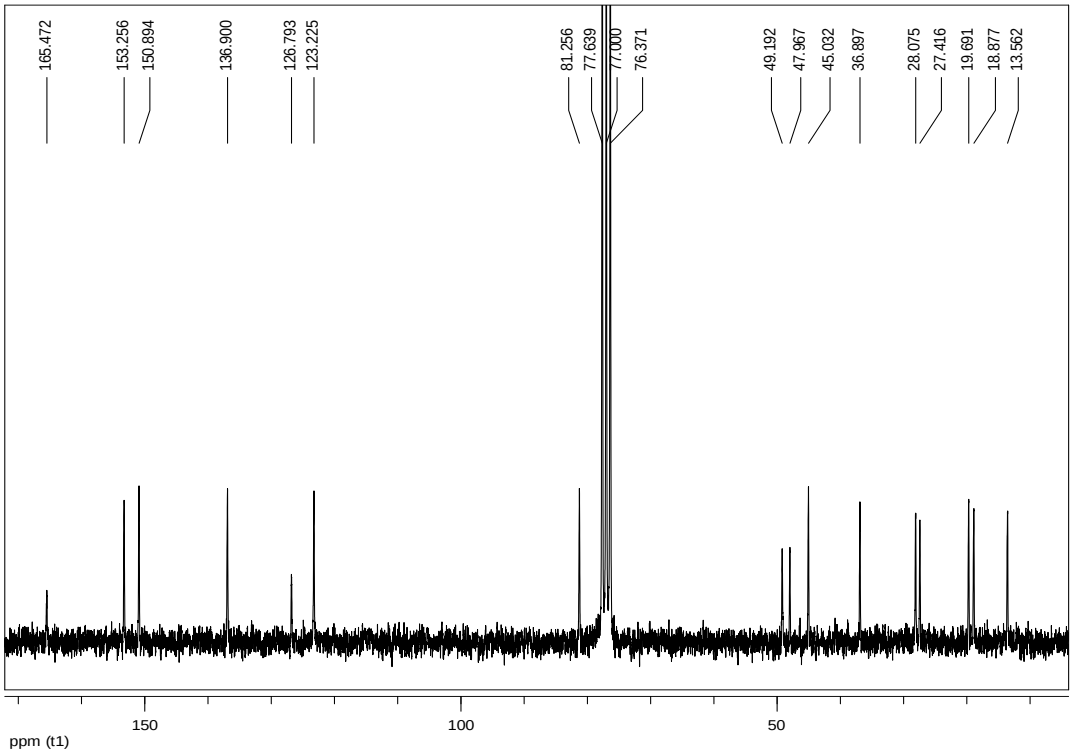

Figure S42. ^{13}C NMR spectrum (50 MHz, $CDCl_3$) of compound **17**.

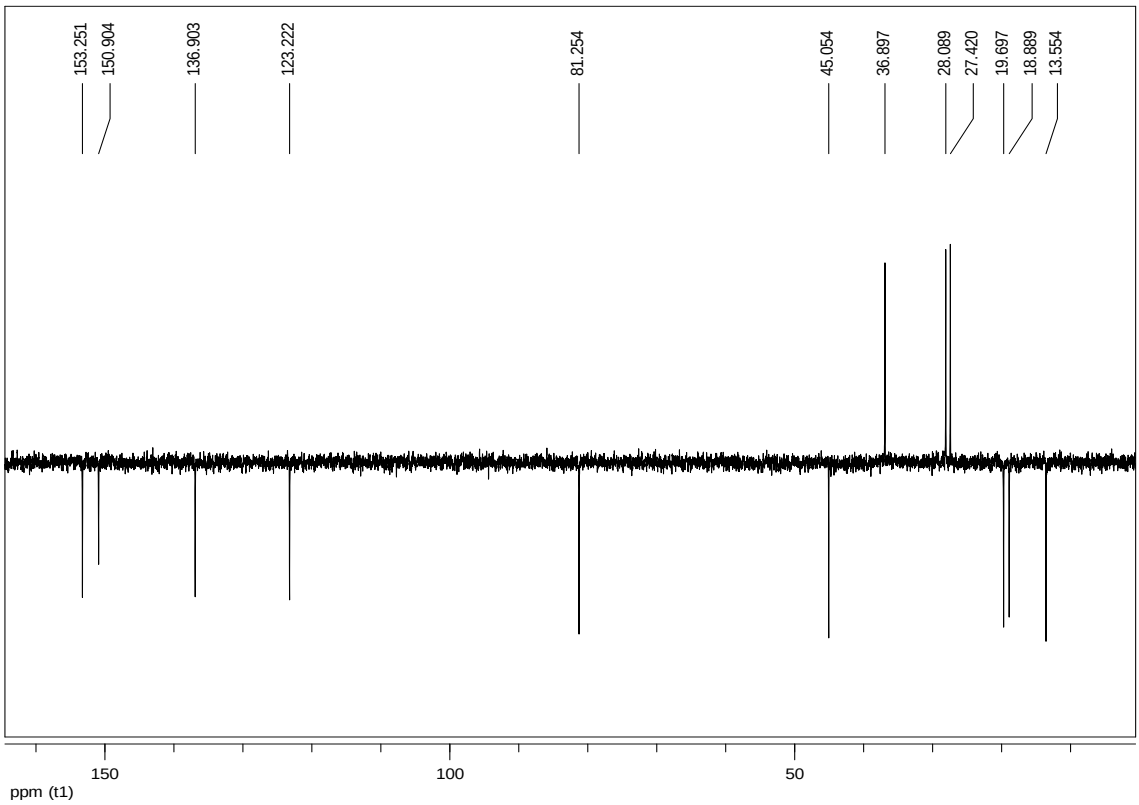

Figure S43. DEPT spectrum (50 MHz, $CDCl_3$) of compound **17**.

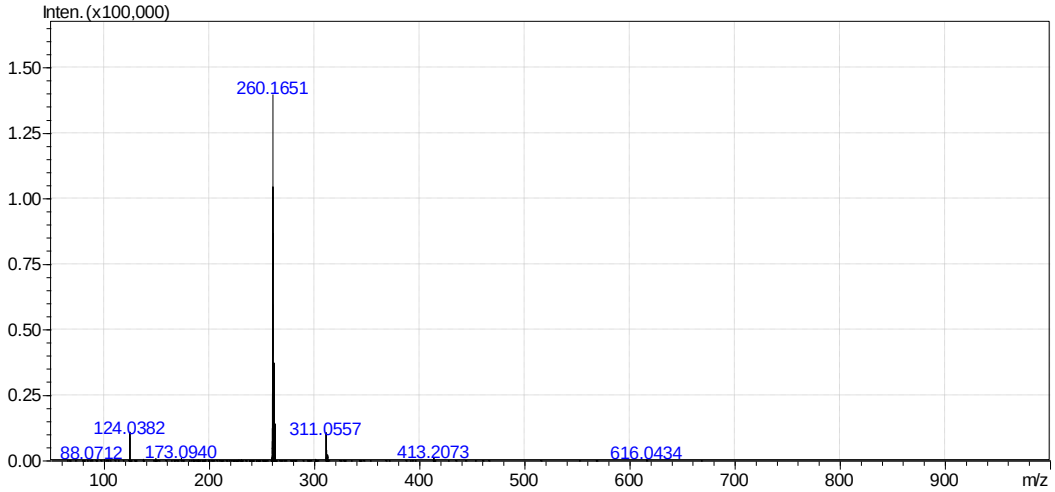

Figure S44. HR-ESIMS spectrum of compound **17.**