Supplementary Information:

Photochemical Studies on Aromatic γ,δ-epoxy Ketones: Efficient Synthesis of Benzocyclobutanones and Indanones

Yutian Shao,[†] Chao Yang [†], Weijun Gui[†] , Yang Liu[†] and Wujiong Xia*[,†, ‡]

[†]State Key Lab of Urban Water Resource and Environment, the Academy of Fundamental and Interdisciplinary Sciences, Harbin Institute of Technology, Harbin 150080

[‡]State Key Lab of Applied Organic Chemistry, Lanzhou University, Lanzhou 730000, China

E-mail: xiawj@hit.edu.cn

Contents

General and Materials

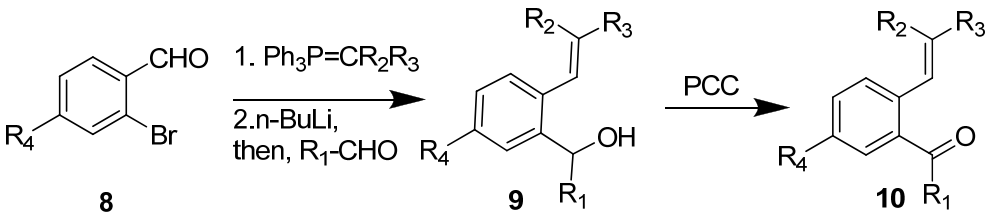
General Procedures. Reactions were carried out under an atmosphere of nitrogen and monitored by thin-layer chromatography (TLC) using UV light visualizing agent and ethanolic solution of Phosphomolybdic acid hydrate. NMR spectra were measured on Bruker AVANCE III 400M NMR in $CDCl_3$ (7.262 for ^1H, 77.01 for ^{13}C) or CD_3COCD_3 (2.05 for ^1H, 29.84 and 206.26 for ^{13}C) with tetramethylsilane as the internal reference. When peak multiplicities were reported, the following abbreviations were used: s-singlet, d-doublet, t-triplet, q-quartet,

m-multiplet, br-broadened. IR absorption spectra results were obtained on Nicolet impact 400 FT-IR instrument and using as a film on NaCl single-crystal plate (SPECTRUM100). HRMS (ESI) was recorded using Agilent 6520 accurate-Mass Q-TOF LC/MS system (1200-6520/Agilent). Low-resolution Mass spectra were obtained from GC-MS system (7890A-5975C/Agilent). Silica gel (200-300 mesh, QingDao, China) was used for column chromatography and preparative thin-layer chromatography was performed on commercial available silica gel plates (GF254, QingDao, China).

Materials. Anhydrous tetrehydrofuran (THF), benzene, diethyl ether (Et_2O) were dried with sodium (Na). Anhydrous dichloromethane (DCM) were dealt with CaH_2. Reagents were purchased at the highest commercial quality and used without further purification.

Experimental Procedures

Synthesis of Olefin-Ketone 10.



Entry	R_1/C_6H_5	R_2/C_6H_5	R_3	R_4
a	Ph	H	H	H
b	p-Me-Ph	H	H	H
c	p-CO_2Me-Ph	H	H	H
d	p-Me-Ph	H	H	Me

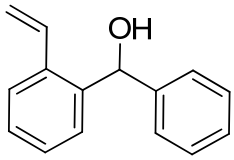
e	i-Pr	H	H	H
f	Ph	Me	H	H
g	Ph	Et	H	H
h	Ph	Ph	H	H
i	p-CO_2Me-Ph	Me	H	H
j	Ph	Me	Me	H
k	Me	Ph	H	H

General Procedure for Synthesis of Compound 9.

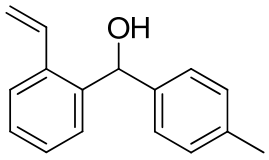
To a stirred solution of $Ph_3P^+CH_2R_2R_3Br^-$(12.0 mmol) and 80 mL of anhydrous THF was added n-BuLi (5.0 mL, 2.4 M in hexane, 12.0 mmol) dropwise at -78 ℃ under nitrogen protection[1]. After addition, the mixture was stirred at ambient temperature for one hour. The mixture was cooled to -78 ℃ again before the addition of 2-bromoaldehyde **8** (1.85 g, 10.0 mmol). The reaction was quenched with 15 mL of water at -30 ℃ when 2-bromoaldehyde couldn't be detected by TLC. Then, separated the organic layer and the water layer was extracted with petrol ether (3 × 50 mL), the combined organic phase was washed with brine (2 × 50 mL) and dried over $MgSO_4$. The solvent was diminished under vacuum to give the crude product, which was used for next step directly without further purification.

The olefin (1.0 equiv) obtained in above step was dissolved in 15 mL of anhydrous THF and cooled to -78 ℃, n-BuLi (2.4 M in hexane, 1.0 equiv) was added dropwise under nitrogen protection[2], and the mixture was stirred for two hours at the same temperature before the addition of commercial available R_1CHO (1.0 equiv, dissovled

in 3 mL of anhydrous THF) was added. After addition, the reaction was monitored with TLC until the R_1CHO was consumed completely. 5 mL of water was added to the mixture to quenched the reaction and stirred until the solid was dissolved completely. Separated the organic layer and the water phase was extracted with diethyl ether (3 × 50 mL), combined the organic solution and dried over Na_2SO_4 before evaporated *in vacuo* to remove the solvent. Then, the crude product was purified by silica gel column chromatography to give the desired alcohols **9** as colorless oil.

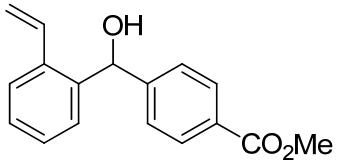


Compound 9a. Yield 74% for two steps. **IR** (neat) ν_{max} : 3408, 3063, 2959, 2871, 1714, 1626, 1454, 1017, 699 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.40-7.47 (m, 2H), 7.23-7.30 (m, 7H), 6.96 (dd, J = 17.2, 11.2 Hz, 1H), 6.06 (s, 1H), 5.57 (d, J = 17.6 Hz, 1H), 5.24 (d, J = 11.2 Hz, 1H), 2.31 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 143.1, 140.4, 136.4, 134.4, 128.5, 128.0, 127.9, 127.5, 126.9, 126.4, 116.7, 73.0. **LRMS** (EI): 209 [M-1], 192, 165, 132, 105, 91, 77, 51, 27. **HRMS** (ESI): calcd for $C_{15}H_{15}O^+$ 211.1117 $[M+H]^+$, found 211.1115.

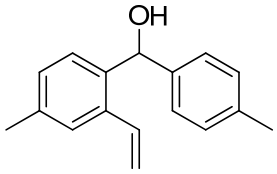


Compound 9b. Yield 82% for two steps. **IR** (neat) ν_{max}: 3435, 2978, 1647, 1513, 1268, 1017, 756 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.51 (dd, J = 8.8, 2.4 Hz, 2H), 7.31-7.36 (m, 2 H), 7.25 (d, J = 8.0 Hz, 2H), 7.17(d, J = 8.0 Hz, 2H), 7.02 (q, J = 17.2 Hz, 1H), 5.63 (dd, J = 17.2, 1.2 Hz, 1H), 5.30 (dd, J = 10.8, 1.2 Hz, 1H), 2.37 (s, 3H), 2.21 (br, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 140.5,

140.1, 137.3, 136.2, 134.3, 129.2, 128.0, 127.8, 126.9, 126.7, 126.3, 116.6, 72.9, 21.1. **LRMS** (EI): 224 [M], 205, 189, 165, 139, 115, 89, 63, 51, 28, 14. **HRMS** (ESI): calcd for $C_{16}H_{17}O^+$ 225.1274 $[M+H]^+$, found 225.1117.

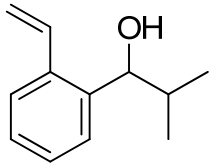


Compound 9c. Yield 77% for two steps. **IR** (neat) ν_{max}: 3445, 3063, 2952, 1713, 1612, 1435, 1104, 754 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.92 (d, J = 8.4 Hz, 2H), 7.45 (t, J = 9.2 Hz, 1H), 7.30-7.37 (m, 3H), 7.22-7.26 (m, 2H), 6.96 (dd, J = 17.4, 10.8/11.2 Hz, 1H), 6.07 (d, J = 2.0 Hz, 1H), 5.57 (dd, J = 17.2, 0.8/1.2 Hz, 1H), 5.24 (dd, J = 10.8, 0.8/1.2 Hz, 1H), 3.84 (s, 3H), 3.06 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 167.1, 148.4, 140.0, 136.4, 134.2, 129.7, 129.0, 128.2, 128.1, 127.2, 126.7, 126.5, 117.0, 72.5, 52.1. **LRMS** (EI): 267 [M-1], 250, 209, 191, 165, 149, 133, 104, 77, 59, 28. **HRMS** (ESI): calcd for $C_{17}H_{17}O_3^+$ 269.1172 $[M+H]^+$, found 269.1178.

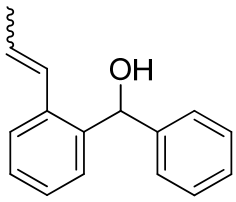


Compound 9d. Yield 77% for two steps. **IR** (neat) ν_{max}: 3367, 2956, 2860, 1901, 1728, 1613, 1456, 1179, 1039, 819 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.37 (dd, J = 8.0, 2.0 Hz, 1H), 7.28 (s, 1H), 7.19 (d, J = 8.0 Hz, 2H), 7.09 (m 3H), 6.91 (dd, J = 17.6/17.2, 11.2/10.8 Hz, 1H), 6.03 (d, J = 2.8 Hz, 1H), 5.54 (d, J = 17.6 Hz, 1H), 5.20 (d, J = 10.8 Hz, 1H), 2.33 (s, 3H), 2.31 (s, 3H), 2.24 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 140.4, 140.3, 137.8, 137.2, 134.2, 133.4, 129.2, 128.6, 126.2, 115.7, 72.8, 21.4, 21.2. **LRMS** (EI): 239 [M+1], 221, 207, 195,

160, 131, 115, 91, 77, 65, 43, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{19}O^+$ 239.1430 $[M+H]^+$, found 239.1428.

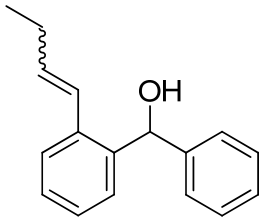


Compound 9e. Yield 55% for two steps. **IR** (neat) ν_{max} : 3400, 3063, 2960, 1625, 1468, 1226, 1004, 756cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.43-7.47 (m, 2H), 7.23-7.31 (m, 2H), 7.07 (dd, J = 17.2, 10.8 Hz, 1H), 5.60 (dd, J = 17.2, 1.2 Hz, 1H), 5.34 (dd, J = 10.8, 1.2 Hz, 1H), 4.71 (dd, J = 6.8, 3.2 Hz, 1H), 1.96-2.04 (m, 1H), 1.01 (d, J = 2.8 Hz, 3H), 0.82 (d, J = 6.8 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 141.1, 136.2, 134.6, 127.8, 127.4, 126.4, 126.2, 116.2, 76.0, 34.8, 19.6, 17.8. **LRMS** (EI): 176 [M], 158, 133, 115, 103, 91, 77, 63, 55, 39, 27, 15. **HRMS** (ESI): calcd for $C_{12}H_{17}O^+$ 177.1274 $[M+H]^+$, found 177.1270.

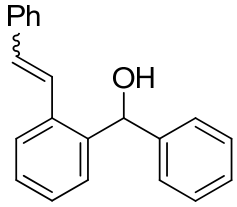


Compound 9f (*Z/E* = 1:1). Yield 73% for two steps. **IR** (neat) ν_{max}: 3391, 3062, 3028, 2912, 1646, 1449, 1176, 1011, 698 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.51（d, J = 8.8 Hz, 1H）, 7.23-7.40 (m, 8H), 6.68 (dd, J = 7.6, 1.6 Hz, 0.5H), 6.48 (dd, J = 7.2, 1.2 Hz, 0.5H), 6.11 (d, J = 3.6 Hz, 0.5H), 5.99 (d, J = 3.6 Hz, 0.5H), 6.05 (m, 0.5H), 5.85 (m, 0.5H), 2.25 (m, 1H), 1.85 (dd, J=1.6, 6.4 Hz, 1.3H), 1.63 (dd, J=1.6, 5.8 Hz, 1.6H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 143.2, 141.6, 140.0, 136.6, 135.2, 129.8, 128.8, 128.4, 128.4, 127.2, 127.2, 127.1, 126.9, 126.8, 126.8, 126.6, 126.4, 73.3, 72.9, 18.8, 14.3. **LRMS** (EI): 223 [M-1], 208, 196, 182, 167, 147, 131, 105, 97, 89, 79, 65, 43, 29, 15. **HRMS**(ESI): calcd for $C_{16}H_{15}O^-$

223.1128 $[M-H]^-$, found 223.1119.

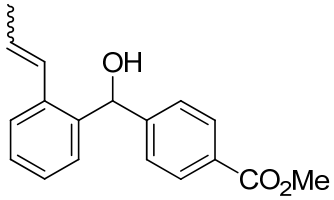


Compound 9g (*Z/E* = 5:2). Yield 70 % for two steps. **IR** (neat) ν_{max}: 3390, 3062, 3028, 2964, 1645, 1453, 1115, 1017, 698 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.57 （d, J = 7.6 Hz, 1H）, 7.44-7.46 (m, 1H), 7.29-7.38 (m, 6H), 7.20 (d, J = 7.2 Hz, 1H), 6.69 (d, J = 14.6 Hz, 0.3H), 6.47 (d, J = 11.2 Hz, 0.7H), 6.15 (s, 0.3H), 6.04 (s, 0.7H), 6.08-6.13 (m, 0.3H), 5.70-5.77 (m, 0.7H), 2.27 (s, 1H), 2.07-2.25 (m, 0.4H), 2.05-2.10 (m, 1.5H), 1.09 (t, J = 7.6 Hz, 0.8H), 0.96 (t, J = 7.6 Hz, 2.2H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 143.2, 141.5, 135.9, 135.8, 123.0, 128.4, 128.3, 127.4, 127.2, 127.2, 126.9, 126.9, 126.6, 126.3, 73.3, 21.8, 14.1. **LRMS** (EI) : 237 [M-1], 219, 189, 164, 143, 128, 103, 79, 65, 57, 39. **HRMS**(ESI): calcd for $C_{17}H_{19}O^+$ 239.1430 $[M+H]^+$, found 239.1370.

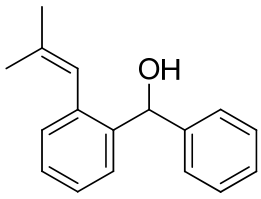


Compound 9h (*Z/E* = 3:2). Yield 76 % for two steps. **IR** (neat) ν_{max}: 3565, 3061, 2933, 1667, 1596, 1448, 1267, 1151, 700 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.56-7.58 (m, 1H), 7.28-7.41 (m, 10H), 7.15-7.17 (m, 3H), 7.03-7.05 (m, 1H), 6.68 (d, J = 6.4 Hz, 1H), 6.24 (d, J = 3.6 Hz, 0.4H), 6.10 (d, J = 3.6 Hz, 0.6H), 2.25 (d, J = 4.0 Hz, 0.4H), 2.11 (d, J = 3.6 Hz, 0.6H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 143.1, 141.5, 136.5, 136.1, 131.5, 131.3, 129.5, 129.0, 128.7, 128.6, 128.4, 128.2, 127.8, 127.7, 127.6, 127.4, 127.3, 126.8, 126.8, 126.6, 73.3. **LRMS** (EI):

286 [M], 252, 235, 207, 196, 164, 131, 125, 79, 63, 51. **HRMS**(ESI): calcd for $C_{21}H_{17}O^-$ 285.1285 $[M-H]^-$, found 285.1261.

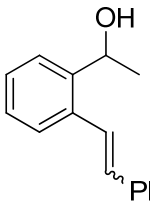


Compound 9i (*Z/E* = 2:1). Yield 74 % for two steps. **IR** (neat) ν_{max}: 3445, 3063, 3023, 2952, 1714, 1610, 1435, 1282, 1113, 762 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.98 (t, J = 8.0 Hz, 2H), 7.38-7.42 (m, 3H), 7.17-7.27 (m, 3H), 6.69 (dd, J = 1.6, 15.6 Hz, 0.4H), 6.50 (dd, J = 1.6, 11.2 Hz, 0.7 H), 6.14 (d, J = 4.0 Hz, 0.4H), 6.03 (d, J = 3.6 Hz, 0.7H), 6.04-6.08 (m, 0.3H), 5.81-5.87 (m, 0.7H), 3.89 (s, 1H), 3.88 (s, 2H), 2.64 (br, 1H), 1.85 (dd, J = 1.6, 6.8 Hz, 1H), 1.62 (dd, J = 1.6, 6.8 Hz, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 171.4, 167.1, 148.5, 141.1, 135.64, 131.8, 123.0, 129.7, 129.6, 128.1, 127.5, 127.4, 126.7, 126.7, 115.2, 72.8, 72.6, 60.5, 52.1, 21.1, 18.8, 14.3, 14.2. **LRMS** (EI): 281 [M-1], 248, 225, 206, 189, 164, 147, 117, 91, 76, 65, 59, 51, 43, 15. **HRMS**(ESI): calcd for $C_{18}H_{19}O_3^+$ 283.1329 $[M+H]^+$, found 283.1322.



Compound 9j. Yield 44 % for two step. **IR** (neat) ν_{max}: 3434, 3063, 2929, 1644, 1448, 1184, 748 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.52-7.54 (m, 1H), 7.27-7.34 (m, 7H), 7.14 (dd, J = 2.0, 6.8 Hz, 1H), 6.25 (s, 1H), 6.01 (s, 1H), 2.25 (s, 1H), 1.87 (d, J = 1.2 Hz, 3H), 1.56 (d, J = 1.2 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 141.8, 137.0, 136.8, 130.2, 128.3, 127.3, 127.2, 126.9, 126.9, 126.8, 126.1, 123.3, 100.0, 73.4, 25.8, 19.1. **LRMS** (EI): 238 [M], 220,

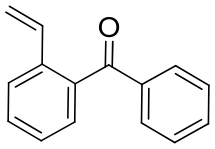
204, 190, 176, 161, 150, 142, 128, 119, 105, 90, 77, 51, 43, 31, 14. **HRMS**(ESI): calcd for $C_{17}H_{19}O^+$ 239.1430 $[M+H]^+$, found 239.1446.



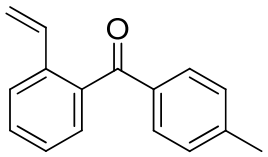
Compound 9k (*Z/E* = 1:1). Yield 82 % for two steps. **IR** (neat) ν_{max}: 3368, 3059, 3025, 2972, 2928, 2627, 1950, 1705, 1631, 1599, 1446, 1367, 1073, 761 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.24-7.58 (m, 12H), 7.13-7.14 (m, 5H), 7.05-7.07 (m, 2H), 6.97 (d, J = 16 Hz, 1H), 6.73 (d, J = 12.4 Hz, 1H), 6.63 (d, J = 12.4 Hz, 1H), 5.28 (t, J = 12.4 Hz, 1H), 5.11 (dd, J = 12.8/12.4, 6.4/6.0 Hz, 1H), 1.50 (d, J = 6.4 Hz, 3H), 1.40 (d, J = 6.4 Hz, 3H), 1.37 (d, J = 5.2 Hz, 1H), 1.18 (d, J = 6.4 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 143.6, 143.1, 137.5, 136.6, 135.2, 135.0, 131.3, 131.2, 129.3, 129.1, 128.8, 128.5, 128.2, 128.0, 127.9, 127.8, 127.6, 127.4, 127.3, 126.7, 126.2, 125.7, 125.1, 67.3, 67.1, 24.5, 24.2. **LRMS** (EI): 224 [M], 209, 191, 178, 165, 152, 139, 131, 115, 103, 91, 77, 63, 51, 43, 27, 15. **HRMS**(ESI): calcd for $C_{17}H_{19}O^+$ 225.1274 $[M+H]^+$, found 225.1270.

Synthesis of Compounds 10. [3]

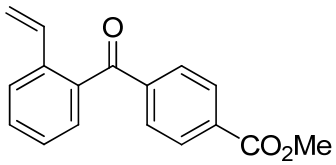
The alcohol **9** prepared above was dissolved in anhydrous CH_2Cl_2 at room temperature, a mixture of PCC (1.5 equiv) and Celite was added. The mixture was allowed to stir at room temperature for four hours and diethyl ether (20 mL) was added. The solution was then filtered through a silica gel column and rinsed with diethyl ether. The solvent was removed *in vacuo* and the residue purified by column chromatography (petrol ether/diethyl ether = 20:1) to yield compound **10** as clear oil.



Compound 10a. Yield 92 %. **IR** (neat) ν_{max} : 3062, 1703, 1667, 1448, 1265, 1152, 774 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.79 (t, J = 8.4 Hz, 2H), 7.67 (d, J = 7.6 Hz, 1H), 7.57 (d, J = 7.4 Hz, 1H), 7.42-7.49 (m, 3H), 7.32-7.35 (m, 2H), 6.77 (dd, J = 17.4, 10.2/11.2 Hz, 1H), 5.69 (dd, J = 17.2, 0.8 Hz, 1H), 5.21 (dd, J = 11.2, 0.8 Hz, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 198.2, 138.0, 137.6, 136.7, 134.3, 133.3, 130.4, 130.3, 128.6, 128.5, 127.2, 126.0, 116.2. **LRMS** (EI): 209 [M+1], 206, 191, 180, 165, 152, 139, 130, 115, 102, 89, 77, 51, 27. **HRMS** (ESI): calcd for $C_{15}H_{13}O^+$ 209.0961 $[M+H]^+$, found 209.0961.

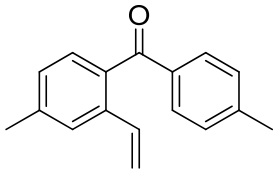


Compound 10b. Yield 91 %. **IR** (neat) ν_{max} : 3060, 2933, 1726, 1651, 1447, 1278, 1074, 702 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.69-7.74 (m, 3H), 7.50 (m, 1H), 7.35 (d, J = 4.4 Hz, 2H), 7.26-7.29 (m, 2H), 6.78 (q, J = 17.6 Hz, 1H), 5.73 (dd, J = 17.2, 0.4/0.8 Hz, 1H), 5.25 (dd, J = 11.2, 0.4 Hz, 1H), 2.45 (s, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.9, 144.3, 138.3, 136.5, 135.1, 134.3, 130.5, 130.1, 129.2, 128.3, 127.1, 125.9, 116.4, 21.7. **LRMS** (EI): 223 [M+1], 208, 193, 165, 151, 134, 119, 105, 91, 77, 51, 28, 14. **HRMS** (ESI): calcd for $C_{16}H_{15}O^+$ 223.1117 $[M+H]^+$, found 223.1112.

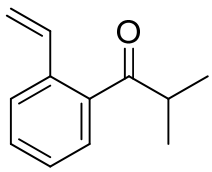


Compound 10c. Yield 95 %. **IR** (neat) ν_{max} : 3064, 2953, 1732, 1652, 1435, 1285, 1108, 770 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.09 (t, J = 8.4 Hz, 2H), 7.84 (t, J = 8.4 Hz, 2H), 7.67 (d, J = 8.0 Hz, 1H), 7.50 (q, J = 8.4 Hz,

1H), 7.34 (d, J = 4.0 Hz, 2H), 6.77 (q, J = 8.6 Hz, 1H), 5.68 (d, J = 8.8 Hz, 1H), 5.22 (d, J = 10.8 Hz, 1H), 3.93 (s, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.4, 166.2, 141.0, 137.2, 137.0, 134.2, 133.9, 130.9, 129.7, 128.8, 127.3, 126.3, 117.1, 52.5. **LRMS** (EI): 266 [M], 251, 235, 207, 178, 163, 131, 103, 77, 51, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{15}O_3^+$ 267.1016 $[M+H]^+$, found 267.1011.

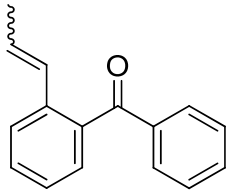


Compound 10d. Yield 93 %. **IR** (neat) ν_{max}: 2958, 2930, 2857, 1683, 1607, 1456, 1267, 1180, 1014, 826. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.70 (d, J = 8.0 Hz, 2H), 7.56 (d, J = 8.0 Hz, 1H), 7.25 (m, 3H), 7.12 (s, 1H), 6.69 (dd, J = 17.2/17.6, 10.8/11.2 Hz, 1H), 5.64 (d, J = 17.2 Hz, 1H), 5.15 (d, J = 10.8 Hz, 1H), 2.41 (s, 3H), 2.36 (s, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 198.2, 144.3, 138.3, 137.2, 135.1, 134.1, 133.6, 131.0, 130.5, 129.2, 128.7, 125.7, 115.5, 21.8, 21.1. **LRMS** (EI): 236 [M], 221, 193, 178, 144, 115, 91, 77, 65, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{17}O^+$ 237.1274 $[M+H]^+$, found 237.1270.

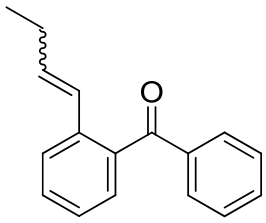


Compound 10e. Yield 87 %. **IR** (neat) ν_{max}: 3088, 2971, 2328, 1770, 1693, 1466, 756 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.57 (d, J = 8.0 Hz, 1H), 7.40-7.46 (m , 2H), 7.31 (t, J = 7.6 Hz, 1H), 6.93 (dd, J = 17.6/17.2, 11.2/10.8 Hz, 1H), 5.65 (d, J = 17.2 Hz, 1H), 5.31 (d, J = 10.8 Hz, 1H), 3.31 (m , 1H), 1.16 (d, 6.8 Hz, 6H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 209.7, 138.5, 136.9, 135.2, 130.6, 127.4, 127.2, 126.9, 116.6, 39.4, 18.5. **LRMS** (EI): 174 [M], 131, 103, 77, 63, 51, 43,

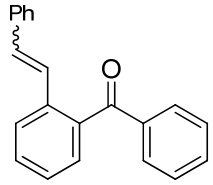
28, 14. **HRMS** (ESI): calcd for $C_{12}H_{15}O^+$ 175.1117 $[M+H]^+$, found 175.1112.



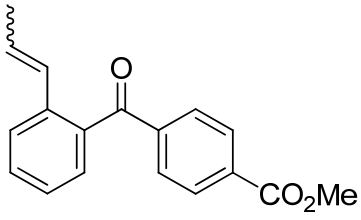
Compound 10f (*Z/E* = 1:1). Yield 90 %. **IR** (neat) ν_{max}: 3061, 2965, 2874, 1667, 1449, 1286, 1151, 929, 701 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.78-7.84 (m, 2H), 7.57-7.63 (m, 2H), 7.31-7.53 (m, 5H), 6.51 (dd, J = 1.2, 7.6 Hz, 0.5H), 6.43 (dd, J = 1.2, 7.6 Hz, 0.5H), 6.16-6.25 (m, 0.5H), 5.65-5.74 (m, 0.5H),1.80 (dd, J = 1.6, 6.4 Hz, 1.7H), 1.75 (dd, J = 1.2, 7.2 Hz, 1.4H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 198.5, 198.4, 138.8, 137.8, 137.7, 137.3, 137.0, 136.3, 133.2, 133.1, 130.3, 130.1, 129.9, 129.9, 128.9, 128.5, 128.4, 128.3, 128.1, 126.3, 126.1, 126.1, 18.7, 14.5. **LRMS** (EI): 221[M-1], 207, 178, 115, 77, 51, 28, 15. **HRMS**(ESI) calced for $C_{16}H_{15}O^+$ 223.1117 $[M+H]^+$, found 223.1112.



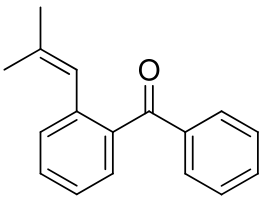
Compound 10g (*Z/E* = 4:1). Yield 87 %. **IR** (neat) ν_{max}: 2926, 2855, 1769, 1624, 1449, 1293, 1176, 931, 770 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.78-7.81 (m, 2H), 7.56-7.60 (m, 1H), 7.42-7.49 (m, 4H), 7.36-7.38 (m, 2H), 6.47 (d, J = 15.6 Hz, 0.2H), 6.38 (d, J = 11.6 Hz, 0.8H), 6.17-6.24 (m, 0.2H), 5.53-5.60 (m, 0.8H), 2.15-2.19 (m, 2H), 1.00 (t, J = 7.2 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 198.4, 190.6, 138.8, 137.7, 136.5, 135.9, 133.1, 130.1, 129.9, 129.8, 128.46, 128.3, 126.4, 126.4, 126.3, 126.2, 126.1, 26.2, 21.9, 14.1. **LRMS** (EI): 236 [M], 220, 193, 164, 151, 139, 115, 91, 77, 63, 51, 39, 27, 18. **HRMS**(ESI): calced for $C_{17}H_{17}O^+$ 237.1274 $[M+H]^+$, found 237.1254.



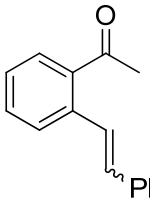
Compound 10h (*Z/E* = 3:2). Yield 92 %.**IR** (neat) ν_{max}: 3025, 2961, 1964, 1738, 1667, 1447, 1277, 1152, 701 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.88 (d, J = 8.4 Hz, 2H), 7.80 (d, J = 7.2 Hz, 2H), 7.44-7.60 (m, 5H), 7.28-7.36 (m, 2H), 7.14-7.18 (m, 3H), 6.66 (d, J = 12.4 Hz, 1H), 6.54 (d, J = 12.0 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 198.3, 197.8, 138.6, 137.7, 137.0, 136.6, 133.3, 133.0, 132.5, 131.4, 131.3, 130.6, 130.3, 130.3, 130.1, 129.1, 128.6, 128.5, 128.5, 128.4, 128.3, 128.2, 127.9, 127.2, 126.9, 126.8, 126.7, 126.0, 125.9. **LRMS** (EI): 284 [M], 265, 252, 239, 225, 206, 194, 178, 165, 151, 142, 126, 115, 105, 91, 77, 63, 28, 14. **HRMS**(ESI): calced for $C_{21}H_{17}O^+$ 285.1274 $[M+H]^+$, found 285.1277.



Compound 10i (*Z/E* = 3:1). Yield 87 %. **IR** (neat) ν_{max}: 3062, 2953, 2549, 1943, 1731, 1668, 1435, 1107, 728 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 8.11 (t, J = 8.4 Hz, 2H), 7.78-7.85 (m, 2H), 7.35-7.60 (m, 4H), 6.47 (dd, J = 1.6, 15.6 Hz, 0.2H), 6.37 (dd, J = 1.6, 11.6 Hz, 0.8H), 6.11-6.20 (m, 0.3H), 5.60-5.68 (m, 0.7H), 3.95 (s, 3H), 1.75 (dd, J = 1.6, 6.4 Hz, 0.8H), 1.69 (dd, J = 1.6, 6.8 Hz, 2.2H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 197.8, 166.3, 166.3, 141.2, 141.2, 138.1, 137.3, 136.6, 133.8, 130.8, 130.4, 130.1, 130.0, 129.8, 129.6, 129.5, 128.8, 128.7, 128.3, 128.1, 126.6, 126.4, 128.3, 52.5, 18.7, 14.5. **LRMS** (EI): 281 [M+1], 264, 249, 232, 221, 202, 193, 163, 135, 117, 89, 76, 65, 50, 39, 28, 15. **HRMS**(ESI): calced for $C_{18}H_{17}O_3^+$ 281.1172 $[M+H]^+$, found 281.1169.

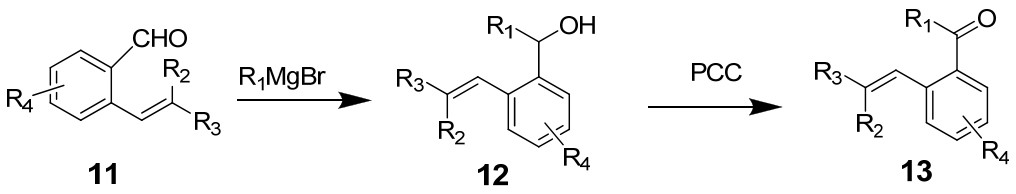


Compound 10j. Yield 74 %. **IR** (neat) ν_{max}: 2967, 1664, 1448, 1263, 929, 702 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.77 (d, J = 7.2 Hz, 2H), 7.59 (t, J = 7.2 Hz, 1H), 7.42-7.49 (m, 5H), 7.29-7.33 (m, 1H), 6.16 (s, 1H), 1.68 (s, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 198.77, 132.86, 130.18, 129.92, 129.88, 128.33, 128.22, 125.91, 123.51, 104.24, 25.97, 19.40. **LRMS** (EI): 236 [M], 220, 201, 192, 178, 165, 138, 129, 114, 105, 91, 77, 51, 41, 32, 28, 14. **HRMS**(ESI): calced for $C_{17}H_{17}O^+$ 237.1274 $[M+H]^+$, found 237.1275.



Compound 10k(*Z/E* = 1:3). Yield 90 %. **IR** (neat) ν_{max}: 3059, 3023, 2925, 1949, 1682, 1596, 1494, 1355, 1249, 957, 760cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.66-7.70 (m, 3H), 7.46-7.54 (m, 3H), 7.24-7.37 (m, 5H), 6.96-7.14 (m, 3H), 6.91 (d, J = 12.0 Hz, 0.4 H), 6.64 (d, J = 12.4 Hz, 0.38 H), 2.60 (s, 3H), 2.53 (s, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 202.2, 201.0, 137.8, 137.6, 137.5, 137.4, 137.3, 136.7, 131.7, 131.7, 131.2, 130.5, 130.1, 139.4, 129.3, 129.2, 129.1, 128.7, 128.1, 127.9, 127.6, 127.5, 127.4, 127.3, 127.1, 126.9, 30.0, 29.3. **LRMS** (EI): 222 [M], 207, 189, 178, 165, 152, 145, 131, 115, 103, 88, 76, 63, 51, 43, 28, 15. **HRMS**(ESI): calced for $C_{16}H_{15}O^+$ 223.1117 $[M+H]^+$, found 223.1120.

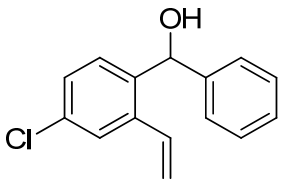
General Procedure for Synthesis of Olefin-Ketone 13. [3]



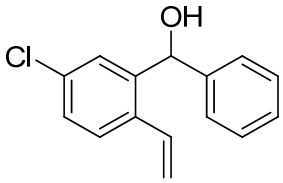
Entry	R_1/C_6H_5	R_2	R_3	R_4
a	Ph	H	H	*meta*-Cl (relative to C=O)
b	Ph	H	H	*para*-Cl
c	p-CO_2Me-Ph	H	H	*meta*-Cl
d	p-CO_2Me-Ph	H	H	*para*-Cl
e	Ph	Me	H	*meta*-Cl
f	Ph	Me	H	*para*-Cl
g	p-CO_2Me-Ph	Me	H	*para*-Cl

Synthesis of Compound 12.

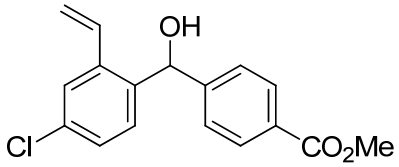
The aldehyde **11** was dissolved in anhydrous THF and cooled to 0 ℃, freshly prepared Grigard reagent R_1MgBr (1.5 equiv) was diluted with THF and added dropwise. After addition, the mixture was stirred for another one hour before quenched with 10 mL of saturated NH_4Cl aqueous solution, then extracted with ethyl acetate (3 × 50 mL), washed with brine (50 mL), dried over $MgSO_4$ and the solvent was diminished under vacuum and the residue was purified by silica gel column chromatography to yield alcohol **12**.



Compound 12a. Yield 91 %. **IR** (neat) ν_{max}: 3350, 2928, 2857, 1754, 1625, 1452, 1192, 1018, 733 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.38-7.43 (m, 2H), 7.23-7.35 (m, 6H), 6.88 (dd, J = 17.2, 10.8 Hz,1 H), 6.01 (s, 1H), 5.68 (dd, J = 17.2, 0.8 Hz, 1H), 5.29 (dd, J = 10.8, 0.4/0.8 Hz, 1H), 2.42 (br, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 142.6, 138.8, 137.9, 133.7, 133.2, 128.6, 128.4, 127.9, 127.8, 126.9, 126.3, 117.9, 72.6. **LRMS** (EI): 244 [M], 226, 213, 191, 179, 165, 149, 138, 125, 115, 102, 91, 77, 65, 51, 29, 27. **HRMS**(ESI): calced for $C_{15}H_{14}ClO^+$ 245.0728 $[M+H]^+$, found 245.0730.

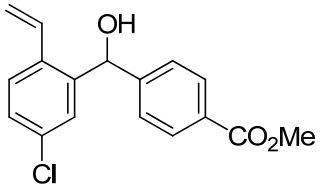


Compound 12b. Yield 90 %. **IR** (neat) ν_{max}: 3030, 2925, 2893, 1762, 1625, 1592, 1452, 1172, 987, 699 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.52 (d, J = 2.4 Hz, 1H), 7.38 (dd, J = 8.0 Hz, 1H), 7.22-7.34 (m, 6 H), 6.83 (dd, J = 17.2, 10.8 Hz, 1H), 6.02 (s, 1H), 5.55 (dd, J = 17.2, 1.2 Hz, 1H), 5.26 (dd, J = 11.2/10.8, 1.2/0.8 Hz, 1H), 2.39 (br, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 142.3, 142.0, 134.6, 133.9, 133.2, 128.7, 128.5, 127.9, 127.7, 127.0, 126.8, 117.2, 72.7. **LRMS** (EI): 244 [M], 226, 194, 178, 152, 131, 115, 103, 91, 77, 63, 51, 39, 28, 14. **HRMS**(ESI): calced for $C_{15}H_{14}ClO^+$ 245.0728 $[M+H]^+$, found 245.0730.

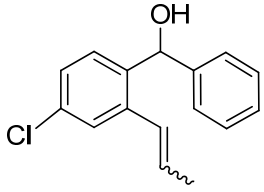


Compound 12c. Yield 86 %. **IR** (neat) ν_{max}: 3441, 2925, 2854, 1935, 1724, 1610, 1437, 1281, 1114, 879 cm^{-1}. **^{1}H NMR** (400 MHz,

$CDCl_3$, ppm): δ 7.99 (d, J = 8.4 Hz, 2H), 7.46 (d, J = 2.0 Hz, 1H), 7.39 (d, J = 8.4 Hz, 2H), 7.33 (d, J = 8.4 Hz, 2H), 7.26 (m, 2H), 6.92 (dd, J = 17.2, 10.8 Hz, 1H), 6.11 (s, 1H), 5.62 (d, J = 17.6 Hz, 1H), 5.33 (d, J = 10.8 Hz, 1H), 3.91 (s, 3H), 2.30 (br, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 163.4, 147.6, 138.1, 134.1, 133.0, 129.9, 129.6, 128.7, 128.1, 126.6, 126.6, 124.5, 118.4, 72.3, 52.2. **LRMS** (EI): 302 [M], 284, 243, 225, 207, 178, 149, 103, 77, 59, 28, 15. **HRMS**(ESI): calced for $C_{15}H_{14}ClO^+$ 303.0782 $[M+H]^+$, found 303.0730.

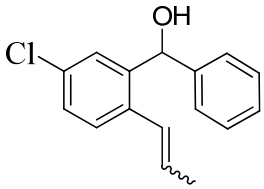


Compound 12d. Yield 86 %. **IR** (neat) ν_{max}: 3394, 2953, 2854, 2078, 1929, 1720, 1609, 1436, 1283, 1115, 1017, 773 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 8.00 (d, J = 8.4 Hz, 2H), 7.95 (d, J = 8.8 Hz, 1H), 7.40-7.44 (m, 4H), 6.89 (dd, J = 17.2/16.8, 11.2/10.8 Hz, 1H), 6.11 (s, 1H), 5.58 (d, J = 17.2 Hz, 1H), 5.30 (d, J = 10.8 Hz, 1H), 3.91 (s, 3H), 2.33 (br, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 166.8, 146.0, 141.5, 133.0, 131.9, 129.9, 129.6, 128.3, 128.0, 127.1, 126.7, 117.7, 115.2, 72.3, 52.2. **LRMS** (EI): 303 [M+1], 269, 253, 232, 219, 207, 194, 179, 163, 137, 120, 105, 91, 77, 59, 43, 28, 15. **HRMS**(ESI): calced for $C_{15}H_{14}ClO^+$ 303.0782 $[M+H]^+$, found 303.0730.

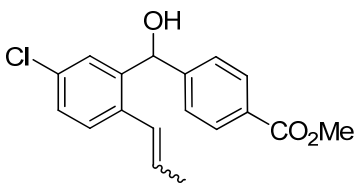


Compound 12e (*Z/E* = 3:2). Yield 87 %. **IR** (neat) ν_{max}: 3364, 3063, 2913, 1650, 1592, 1472, 1170, 699 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.50 (d, J = 8.4 Hz, 1H), 7.42 (d, J = 7.6 Hz, 1H), 7.25-7.36 (m, 5H), 7.14-7.25 (m,

1H), 6.59 (dd, *J* = 1.6, 15.6 Hz, 0.4H), 6.38 (d, *J* = 11.6 Hz, 0.6H), 6.05 (s, 0.4H), 5.93 (s, 0.6H), 6.04-6.11 (m, 0.4H), 5.79-5.87 (m, 0.6H), 2.17 (s, 1H), 1.85 (dd, *J* = 1.6, 5.6 Hz, 1H), 1.62 (dd, *J* = 1.6, 6.8 Hz, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 148.0, 142.8, 140.1, 137.2, 132.8, 130.1, 129.5, 129.4, 128.5, 128.5, 128.3, 128.2, 127.8, 127.7, 127.7, 127.2, 127.2, 127.1, 127.0, 126.9, 126.8, 126.8, 126.4, 125.8, 72.8, 72.5, 18.7, 14.3. **LRMS** (EI): 258 [M], 240, 228, 214, 204, 193, 178, 152, 127, 115, 105, 91, 77, 63, 43, 14. **HRMS**(ESI): calced for $C_{16}H_{16}ClO^+$ 259.0884 $[M+H]^+$, found 259.0880.



Compound 12f (*Z/E* = 4:1). Yield 87 %. **IR** (neat) ν_{max}: 3417, 3062, 2964, 1645, 1448, 1024, 699 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.63 (d, *J* = 2.4 Hz, 1H), 7.25-7.44 (m, 6H), 7.13 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 1.2, 15.6 Hz, 0.2H), 6.38 (d, *J* = 11.6 Hz, 0.8H), 6.07-6.08 (m, 0.2H), 5.83-5.87 (m, 0.8H), 5.96 (d, *J* = 4.0 Hz, 1H), 2.29 (d, *J* = 4.0 Hz, 1H), 1.87 (dd, *J* = 1.6, 6.8 Hz, 0.5H), 1.63 (dd, *J* = 1.6, 7.2 Hz, 2.6H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 143.4, 142.4, 133.8, 133.1, 129.0, 128.5, 127.8, 127.2, 127.2, 127.0, 126.5, 115.3, 73.0, 14.2. **LRMS** (EI): 258 [M], 240, 228, 214, 204, 193, 178, 152, 127, 115, 105, 91, 77, 63, 43, 14. **HRMS**(ESI): calced for $C_{16}H_{16}ClO^+$ 259.0884 $[M+H]^+$, found 259.0880.

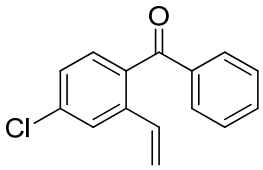


Compound 12g(*Z/E* = 2:1). Yield 89 %. **IR** (neat) ν_{max}: 3062, 2953, 2850, 1715, 1682, 1435, 1271, 1106, 731 cm^{-1}. **^{1}H NMR** (400 MHz,

$CDCl_3$, ppm): δ 787-7.93 (m, 2H), 7.02-7.43 (m, 5H), 7.04 (d, J = 8.4 Hz, 0.4H), 6.79 (dd, J = 2.0, 6.8 Hz, 0.6H), 6.44-6.50 (m, 0.4H), 5.75-5.80 (m, 0.6H), 6.29-6.32 (m, 0.4H), 5.91-5.99 (m, 0.7H), 3.83 (s, 2H), 3.81 (s, 1H), 2.24 (br, 1H), 1.51 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 171.3, 167.0, 166.9, 160.3, 147.9, 139.6, 137.3, 131.9, 129.8, 129.7, 129.7, 129.6, 127.4, 126.8, 126.7, 125.2, 72.4, 60.5, 52.1, 21.0, 14.2. **LRMS** (EI): 315 [M-1], 287, 273, 259, 239, 228, 212, 198, 178, 163, 146, 131, 115, 77, 57, 43, 28, 14. **HRMS**(ESI): calced for $C_{18}H_{18}ClO_3^+$ 317.0939 $[M+H]^+$, found 317.0934.

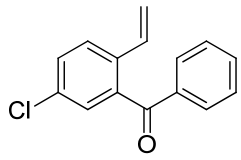
Synthesis of Compounds 13.

The alcohol **12** prepared above was dissolved in anhydrous CH_2Cl_2 at room temperature, a mixture of PCC (1.5 equiv) and Celite was added. The mixture was allowed to stir at room temperature for four hours and diethyl ether (20 mL) was added. The solution was then filtered through a silica gel column and rinsed with diethyl ether. The solvent was removed *in vacuo* and the residue purified by column chromatography (petrol ether/diethyl ether = 20:1) to give the desired products **13**.

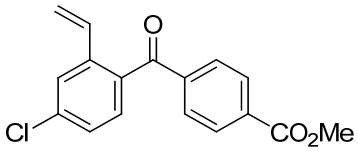


Compound 13a. Yield 85 %. **IR** (neat) ν_{max}: 2928, 2856, 1774, 1666, 1588, 1448, 1282, 927, 709 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.78 (d, J = 8.0 Hz, 2H), 7.58-7.65 (m, 2H), 7.46 (t, J = 7.8 Hz, 2H), 7.31 (m, 1H), 6.73 (dd, J = 17.6/17.2, 11.2/10.8 Hz, 1H), 5.72 (d, J = 17.2 Hz, 1H), 5.28 (d, J = 11.2 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 197.1, 138.7, 137.3, 136.7, 136.1, 133.6, 133.2, 130.3, 130.1, 128.6, 127.2, 126.1, 118.0. **LRMS** (EI): 243 [M+1], 221, 207, 193, 178,

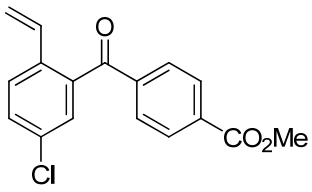
165, 144, 115, 102, 91, 77, 65, 51, 39, 27, 15. **HRMS**(ESI): calced for $C_{15}H_{12}ClO^+$ 243.0571 $[M+H]^+$, found 243.0565.



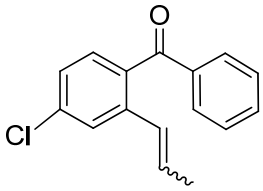
Compound 13b. Yield 85 %. **IR** (neat) ν_{max}: 3086, 2926, 1667, 1449, 1285, 928, 708 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.80 (d, J = 7.2 Hz, 2H), 7.58-7.62 (m, 2H), 7.42-7.48 (m, 3H), 7.32 (s, 1H), 6.71 (dd, J = 11.2/10.8, 17.6 Hz, 1H), 5.70 (d, J = 17.6 Hz, 1H), 5.25 (d, J = 11.2 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 196.6, 139.3, 136.9, 135.0, 133.7, 133.2, 133.1, 130.4, 130.3, 128.7, 128.2, 127.4, 117.2. **LRMS** (EI): 241 [M-1], 224, 208, 189, 175, 136, 126, 103, 89, 76, 63, 51, 39, 27, 14. **HRMS**(ESI): calced for $C_{15}H_{12}ClO^+$ 243.0571 $[M+H]^+$, found 243.0565.



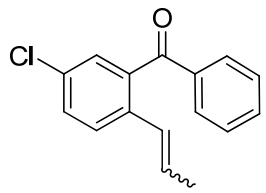
Compound 13c. Yield 85 %. **IR** (neat) ν_{max}: 2952, 2850, 1937, 1726, 1668, 1436, 1279, 1107, 931, 725 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 8.11 (d, J = 8.4 Hz, 2H), 7.82 (d, J = 8.4 Hz, 2H), 7.65 (d, J = 1.6 Hz, 1H), 7.25-7.35 (m, 2H), 6.73 (dd, J = 17.6/17.2, 11.2/10.8 Hz, 1H), 5.71 (d, J = 17.2 Hz, 1H), 5.30 (d, J = 10.8 Hz, 1H), 4.00 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 196.4, 166.1, 140.7, 139.0, 137.2, 135.4, 134.2, 133.2, 130.4, 130.0, 129.8, 127.4, 126.4, 118.4, 52.6. **LRMS** (EI): 300 [M], 285, 269, 243, 212, 178, 165, 135, 120, 102, 88, 76, 50, 28, 15. **HRMS**(ESI): calced for $C_{17}H_{14}ClO_3^+$ 301.0626 $[M+H]^+$, found 301.0630.



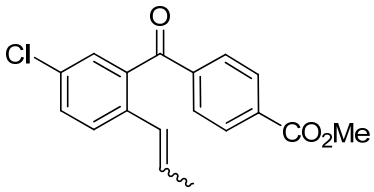
Compound 13d. Yield 87 %. **IR** (neat) ν_{max}: 2952, 2850, 1944, 1727, 1673, 1436, 1280, 1108, 947, 736 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 8.12 (d, J = 8.4 Hz, 2H), 7.83 (d, J = 8.4 Hz, 2H), 7.61 (d, J = 8.4 Hz, 1H), 7.47 (dd, J = 8.4, 2.0 Hz, 1H), 7.32 (d, J = 2.0 Hz, 1H), 6.66 (dd, J = 17.6/17.2, 11.2/10.8 Hz, 1H), 5.68 (d, J = 17.6 Hz, 1H), 5.30 (d, J = 10.8 Hz, 1H), 4.00 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 196.1, 166.1, 140.3, 138.6, 135.3, 134.3, 133.3, 133.0, 130.9, 129.8, 128.4, 127.7, 117.7, 52.6. **LRMS** (EI): 300 [M], 285, 269, 241, 212, 178, 163, 137, 102, 76, 50, 28, 15. **HRMS**(ESI): calced for $C_{17}H_{14}ClO_3^+$ 301.0626 $[M+H]^+$, found 301.0630.



Compound 13e (*Z/E* = 3:2). Yield 85 %. **IR** (neat) ν_{max}: 3061, 2937, 1730, 1668, 1449, 1279, 950, 696 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.64-7.71 (m, 2H), 7.47-7.49 (m, 2H), 7.34-7.39 (m, 2H), 7.23-7.27 (m, 1H), 7.15-7.17 (m, 1H), 6.36 (dd, J = 1.6, 15.6 Hz, 0.4H), 6.26 (dd, J = 1.6, 11.6 Hz, 0.6H), 6.08-6.14 (m, 0.4H), 5.57-5.65 (m, 0.6H), 1.68 (dd, J = 1.6, 6.4 Hz, 1H), 1.74 (dd, J = 1.6, 7.2 Hz, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 197.2, 138.3, 137.4, 137.1, 135.9, 133.3, 130.2, 130.1, 130.0, 130.0, 129.9, 129.8, 129.5, 128.5, 128.5, 128.4, 128.3, 127.0, 126.5, 18.3, 14.5. **LRMS** (EI): 255 [M-1], 240, 227, 219, 212, 202, 190, 177, 164, 151, 136, 125, 115, 105, 99, 89, 77, 63, 51. **HRMS**(ESI): calced for $C_{16}H_{14}ClO^+$ 257.0728 $[M+H]^+$, found 257.0712.

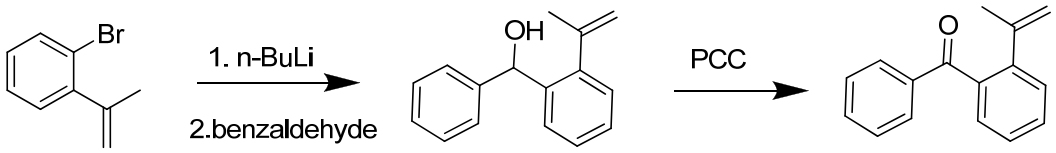


Compound 13f (*Z/E* = 4:1). Yield 87 %. **IR** (neat) ν_{max}: 3061, 2934, 1775, 1667, 1447, 1280, 925, 707 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.77-7.79 (m, 2H), 7.63 (t, J = 7.6 Hz, 1H) 7.41-7.49 (m, 4H), 7.29-7.35 (m, 1H), 6.41 (dd, J = 1.6, 15.6 Hz, 0.2H), 6.33 (dd, J = 1.6, 11.6 Hz, 0.8H), 6.17-6.22 (m, 0.2H), 5.68-5.73 (m, 0.8H), 1.78 (dd, J = 1.6, 6.4 Hz, 0.4H), 1.74 (dd, J = 1.6, 7.2 Hz, 2.6H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 196.8, 140.3, 137.0, 134.6, 133.5, 132.4, 131.3, 130.0, 129.9, 129.6, 129.2, 128.6, 128.1, 126.9, 18.6, 14.5. **LRMS** (EI): 255 [M-1], 240, 227, 219, 212, 202, 190, 177, 164, 151, 136, 125, 115, 105, 99, 89, 77, 63, 51. **HRMS**(ESI): calced for $C_{16}H_{14}ClO^+$ 257.0728 $[M+H]^+$, found 257.0712.



Compound 13g (*Z/E* = 5:1). Yield 89 %. **IR** (neat) ν_{max}: 3062, 2953, 1943, 1715, 1682, 1435, 1271, 1106, 731 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm):δ 8.07-8.13 (m, 2H), 7.76-7.85 (m, 2H), 7.26-7.58 (m, 3H), 6.15-6.43 (m, 1H), 5.62-5.72 (m, 1H), 3.95 (s, 3H), 1.72-1.77 (m, 0.5H), 1.66-1.70 (m, 2.5H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 196.6, 166.2, 140.9, 138.5, 136.6, 136.4, 133.9, 131.4, 130.4, 130.2, 130.0, 129.7, 129.6, 128.7, 128.4, 128.1, 127.0, 126.9 126.7, 52.5, 18.7, 14.5. **LRMS** (EI): 313 [M-1], 294, 278, 264, 249, 233, 219, 202, 177, 164, 151, 145, 135, 117, 91, 76, 59, 39, 28, 15. **HRMS**(ESI): calced for $C_{18}H_{16}ClO_3^+$ 315.0782 $[M+H]^+$, found 315.0772.

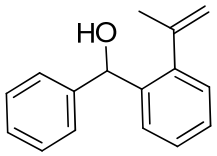
Synthesis of compounds 16.



14 **15** **16**

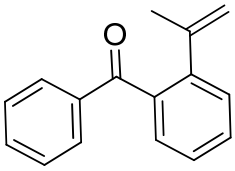
A flame-dried, round-bottomed flask was charged with compound **14**[4] (1.0 g, 5.07 mmol) and 30 mL of anhydrous THF, the mixture was cooled to -78 ℃, n-BuLi (2.1 mL, 2.4 M in hexane, 5.07 mmol) was added dropwise within 10 minutes. After addition, the solution was stirred for 2 hours at the same temperature. Commercial available benzaldehyde (0.56 g, 5.3 mmol) was diluted with 5 mL of anhydrous THF and added into the solution. The reaction was quenched with 20 mL of water before no starting material remaining by TLC analysis. The mixture was extracted with diethyl ether (3 × 50 mL), the combined organic phase was washed with 40 mL of brine, dried over $MgSO_4$ and chromatographed on a silica gel to give 1.0 g of alcohol **15** as clear oil.

The alcohol **15** (0.9 g, 4.02 mmol) prepared above was oxided in 25 mL of anhydrous CH_2Cl_2 with a mixture of PCC (1.29 g, 6.03 mmol) and Celite (1.29 g) at room temperature. Upon completion, 5 mL of diethyl ether was added to diluted the mixture before removed the solvent under vacuum. Then, the residue was purified through a silica gel column eluting with petrol ether/ethyl acetate (20:1) to give 0.84 g of products **16** as colorless oil.



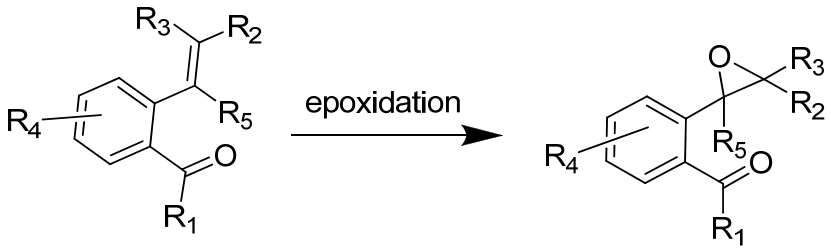
Compound 15. Yield 88 %. **IR** (neat) ν_{max}: 3401, 3013, 2934, 1699,

1640, 1451, 1182, 1015, 762 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.43 (t, J = 8.0 Hz, 1H), 7.21-7.34 (m, 7H), 7.12-7.14 (m, 1H), 6.12 (s, 1H), 5.22 (s, 1H), 4.84 (s, 1H), 1.98 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 144.9, 144.1, 143.1, 140.2, 128.5, 128.3, 128.1, 127.4, 127.4, 127.3, 127.2, 126.8, 125.9, 115.9, 72.5, 25.6. **LRMS** (EI): 223 [M-1], 205, 198, 178, 165, 152, 133, 115, 105, 91, 77, 63, 51, 39, 27. **HRMS**(ESI): calced for $C_{16}H_{17}O^+$ 223.1128 $[M+H]^+$, found 223.1119.



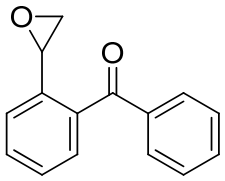
Compound 16. Yield 94 %. **IR** (neat) ν_{max}: 3062, 2965, 1796, 1661, 1597, 1449, 1284, 1152, 710 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$, ppm): δ 7.72-7.74 (m, 2H), 7.53 (t, J = 7.2 Hz, 1H), 7.32-7.48 (m, 6H), 4.95 (s, 1H), 4.85 (s, 1H), 1.94 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$, ppm): δ 198.8, 143.9, 142.9, 138.3, 137.9, 132.9, 130.0, 129.9, 128.4, 128.3, 127.9, 126.8, 117.4, 23.7. **LRMS** (EI): 220 [M-2], 203, 173, 145, 115, 91, 77, 51, 43, 27. **HRMS**(ESI): calced for $C_{16}H_{15}O^+$ 223.1117 $[M+H]^+$, found 223.1125.

General Procedure of Synthesis of Epoxy Ketones. [5]

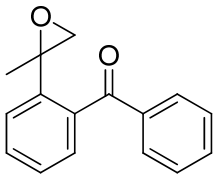


To round-bottomed flask was added olefin prepared above, acetone (20.0 equiv), acetonitrile (1.0 mL/20 mg of substrate), water (1.0 mL/20 mg of substrate), $NaHCO_3$ (20.0 equiv), 18-crown-6 (0.01 equiv), the mixture was cooled to 0℃, Oxone (4.0

equiv) was dissolved in water and added slowly. After addition, the reaction was stirred at the same temperature until no starting material could be detected by TLC. 30 mL of methylene chloride was added to dilute the mixture, separated the organic layer, the water layer was extracted with methylene chloride (2 × 40 mL), combined the organic phase and washed with saturated $NaHCO_3$ aqueous solution (2×40 mL), brine (2×40 mL), dried over Na_2SO_4. Removed the solvent *in vacuo* and the residue was purified through a flash column chromatography using petral/ethyl acetate (10:1) to give colorless oil.

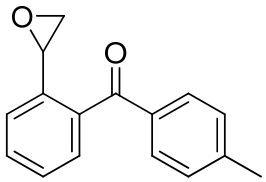


Compound 1a. Yield 64 %. **IR** (neat) v_{max}: 2927, 1634, 1365, 1231, 1112, 701 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.84 (d, J = 7.6 Hz, 2H), 7.36-7.65 (m, 6H), 7.17-7.24 (m, 1H), 4.10 (dd, J = 3.6, 2.8 Hz, 1H), 3.12 (t, J = 4.8 Hz, 1H), 2.72 (dd, J = 5.6, 2.4 Hz, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.3, 138.2, 137.7, 137.6, 133.3, 131.3, 130.3, 129.4, 128.8, 128.5, 128.2, 127.0, 124.9, 51.6, 50.8. **LRMS** (EI): 203 [M-1], 209, 193, 181, 165, 152, 105, 77, 53, 28. **HRMS** (ESI): calcd for $C_{15}H_{13}O_2^+$ 225.0910 $[M+H]^+$, found 225.0912.

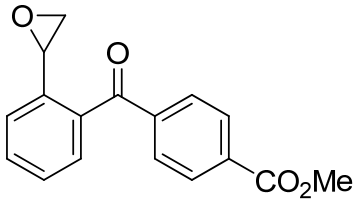


Compound 1b. Yield 70 %. **IR** (neat) v_{max}: 3060, 2965, 2928, 1667, 1597, 1448, 1267, 929, 705 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.78 (d, J = 8.4 Hz, 2H), 7.64-7.68 (m, 2H), 7.52-7.59 (m, 3H), 7.40-7.44 (m, 1H), 7.33 (d, J =7.8 Hz, 1H), 2.77 (d, J = 5.2 Hz, 1H), 2.61 (d, J = 5.2 Hz, 1H), 1.60 (s, 3H). **^{13}C NMR**

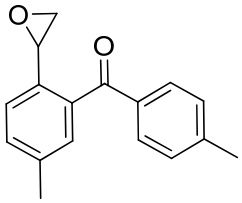
($CDCl_3$, 100 MHz, ppm): δ 196.9, 141.3, 137.9, 137.4, 133.1, 130.2, 129.8, 128.5, 128.1, 127.9, 126.9, 57.5, 54.9, 23.8. **LRMS** (EI): 238 [M], 208, 178, 165, 151, 131, 105, 77, 43, 27. **HRMS** (ESI): calcd for $C_{16}H_{15}O_2^+$ 239.1067 $[M+H]^+$, found 239.1070.



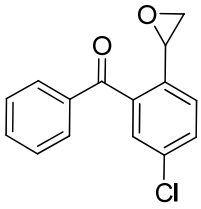
Compound 1c. Yield 61 %. **IR** (neat) ν_{max}: 2850, 1644, 1455, 1260, 1055, 760 cm^{-1}. ^1H NMR ($CDCl_3$, 400 MHz, ppm): δ 7.55 (d, J = 8.4 Hz, 2H), 7.41-7.45 (m, 1H), 7.21-7.32 (m, 5H), 3.80 (dd, J = 4.0, 2.8 Hz, 1H), 2.86 (dd, J = 5.6, 4.0 Hz, 1H), 2.53 (dd, J = 5.6, 2.4 Hz, 1H), 2.29 (s, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.0, 145.1, 139.4, 138.6, 136.2, 131.7, 131.0, 130.1, 129.5, 128.0, 125.6, 51.5, 50.9, 21.6. **LRMS** (EI): 238 [M], 222, 194, 165, 147, 119, 91, 76, 65, 43, 28, 15. **HRMS** (ESI): calcd for $C_{16}H_{15}O_2^+$ 239.1067 $[M+H]^+$, found 239.1070.



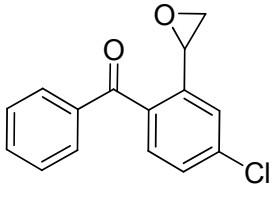
Compound 1d. Yield 60 %. **IR** (neat) ν_{max}: 2953, 1723, 1436, 1281, 1113, 764 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.01 (d, J = 8.0 Hz, 2H), 7.75 (d, J = 8.4 Hz, 2H), 7.32 (m, 3H), 3.80 (s, 3H), 2.88 (dd, J = 5.6/5.2, 4.4/4.0 Hz, 1H), 2.53 (dd, J = 5.6/6.0, 2.4/2.8 Hz, 1H), 1.91 (m, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 196.9, 166.6, 142.3, 139.3, 138.2, 134.8, 132.3, 130.8, 130.4, 130.2, 128.2, 126.0, 52.8, 51.6, 51.1. **LRMS** (EI): 283 [M+1], 257, 239, 222, 207, 193, 165, 151, 112, 90, 74, 45, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{15}O_4^+$ 283.0965 $[M+H]^+$, found 283.0972.



Compound 1e. Yield 62 %. **IR** (neat) ν_{max}: 3030, 2955, 2930, 1720, 1607, 1556, 1267, 1179, 1010, 839 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.72 (d, J = 8.0 Hz, 2H), 7.37-7.40 (m, 3H), 7.29 (d, J = 8.0 Hz, 1H), 7.23 (s, 1H), 3.90 (dd, J = 3.6/4.0, 2.4/2.8 Hz, 1H), 2.98 (dd, J = 5.6, 4.4 Hz, 1H), 2.66 (dd, J = 6.0/5.6, 2.8/2.4 Hz, 1H), 2.45 (s, 3H), 2.38 (s, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 196.3, 144.1, 138.6, 137.0, 135.3, 134.7, 131.3, 130.1, 129.2, 129.0, 124.7, 50.5, 49.9, 20.7, 20.1. **LRMS** (EI): 252, 234, 209, 191, 165, 147, 119, 91, 77, 65, 43, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{17}O_2^+$ 253.1223 $[M+H]^+$, found 253.1220.

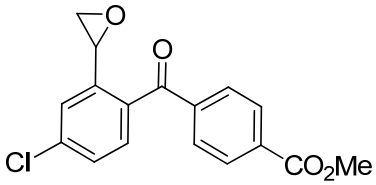


Compound 1f. Yield 63 %. **IR** (neat) ν_{max}: 2961, 2849, 1712, 1663, 1448, 1261, 1021, 840 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.82-7.85 (m, 2H), 7.75 (t, J = 7.6 Hz, 1H), 7.58-7.64 (m, 3H), 7.44-7.47 (m, 2H), 3.94 (dd, J = 2.4, 4.0 Hz, 1H), 3.02 (dd, J = 4.4, 5.6 Hz, 1H), 2.71 (dd, J = 2.4, 5.6 Hz, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 196.0, 137.5, 134.5, 131.7, 130.8, 129.7, 129.1, 127.8, 51.5, 50.6. **LRMS** (EI): 257 [M-1], 241, 221, 197, 181, 165, 135, 119, 91, 73, 57, 28, 14. **HRMS** (ESI): calcd for $C_{15}H_{12}ClO_2^+$ 259.0520 $[M+H]^+$, found 259.0527.

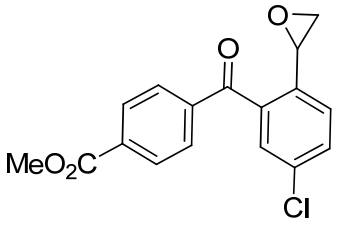


Compound 1g. Yield 66 %. **IR** (neat) ν_{max}: 3050, 2900, 1720, 1662, 1440, 1247, 980, 717 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.82-7.85 (m,

2H), 7.75 (t, *J* = 7.6 Hz, 1H), 7.58-7.64 (m, 3H), 7.44-7.47 (m, 2H), 3.94 (dd, *J* = 2.4, 4.0 Hz, 1H), 3.02 (dd, *J* = 4.4, 5.6 Hz, 1H), 2.71 (dd, *J* = 2.4, 5.6 Hz, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 196.01, 137.51, 134.55, 131.68, 130.81, 129.66, 129.14, 127.81, 51.54, 50.59. **LRMS** (EI): 258 [M], 243, 202, 181, 165, 152, 105, 91, 77, 53, 43, 28, 14. **HRMS** (ESI): calcd for $C_{15}H_{12}ClO_2^+$ 259.0520 $[M+H]^+$, found 259.0527.

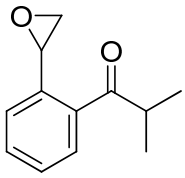


Compound 1h. Yield 59 %. **IR** (neat) ν_{max}: 2953, 2846, 1942, 1726, 1666, 1405, 1281, 1107, 931, 715 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.02 (d, *J* = 8.4 Hz, 2H), 7.78 (d, *J* = 8.4 Hz, 2H), 7.36-7.40 (m, 2H), 7.31 (d, *J* = 2.0 Hz, 1H), 3.92 (dd, *J* = 4.4/4.0, 2.8/2.4 Hz, 1H), 3.81 (s, 3H), 2.92 (dd, *J* = 5.6, 4.4 Hz, 1H), 2.59 (dd, *J* = 5.6, 2.4 Hz, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 196.0, 166.5, 142.1, 142.0, 138.2, 136.7, 134.9, 132.2, 130.8, 130.4, 128.3, 126.0, 52.8, 51.7, 50.8. **LRMS** (EI): 317 [M+1], 301, 285, 257, 214, 181, 163, 135, 103, 76, 59, 43, 28, 15. **HRMS** (ESI): calcd for $C_{17}H_{14}ClO_4^+$ 317.0575 $[M+H]^+$, found 317.0570.

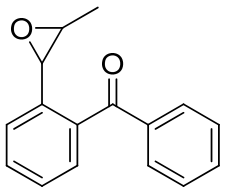


Compound 1i. Yield 62 %. **IR** (neat) ν_{max}: 2923, 2857, 1720, 1650, 1449, 1210, 1110, 911, 723 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.03 (d, *J* = 8.4 Hz, 2H), 7.79 (d, *J* = 8.4 Hz, 2H), 7.50 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.34 (m, 2H), 3.83 (dd, *J* = 4.0, 2.4 Hz, 1H), 3.81 (s, 3H), 2.88 (dd, *J* = 10.0/9.2, 5.6/4.8 Hz, 1H), 2.54 (dd, *J* = 5.6/5.2, 2.8/2.4 Hz, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ

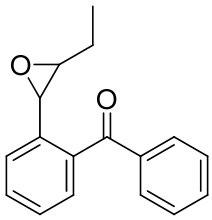
195.6, 166.5, 141.6, 140.1, 137.9, 135.2, 132.1, 130.8, 130.5, 129.5, 128.1, 126.0, 52.8, 51.6, 50.7. **LRMS** (EI): 316 [M], 286, 255, 227, 199, 163, 135, 113, 89, 72, 59, 43, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{14}ClO_4^+$ 317.0575 $[M+H]^+$, found 317.0570.



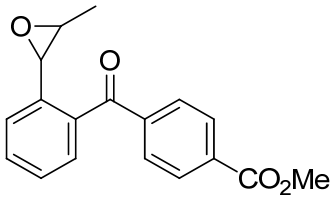
Compound I'. Yield 45 %. **IR** (neat) ν_{max}: 2916, 1790, 1694, 1610, 1461, 1276, 1066, 768 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.88 (t, J = 7.4 Hz, 1H), 7.55 (d, J = 7.6 Hz, 1H), 7.45 (d, J = 7.2, 1H), 7.37 (t, J = 7.4 Hz, 1H), 4.10 (dd, 3.6, 2.8 Hz ,1H), 3.21 (q, J = 5.6, 4.8 Hz, 1H), 3.12 (t, J = 4.8 Hz, 1H), 2.72 (dd, J = 4.6, 2.4 Hz, 1H), 1.27 (d, J = 8.0 Hz, 6H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.3, 138.2, 133.3, 131.3, 129.4, 127.0, 124.9, 51.6, 50.8, 33.1, 18.1. **LRMS** (EI): 190 [M], 172, 147, 128, 107, 91, 77, 65, 43, 28, 14. **HRMS** (ESI): calcd for $C_{12}H_{15}O_2^+$ $[M+H]^+$ 191.1067, found 191.1064.



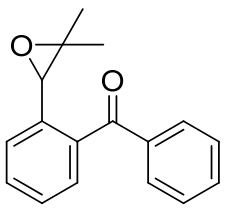
Compound 3a. Yield 67 %. **IR** (neat) ν_{max}: 2927, 2052, 1651, 1448, 1269, 928, 700 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.82 (d, J = 7.2 Hz, 2H), 7.61-7.64 (m, 1H), 7.45-7.56 (m, 4H), 7.34-7.38 (m, 2H), 3.75 (d, J = 2.0 Hz, 1H), 2.91-2.96 (m, 1H), 1.36 (d, J = 4.8 Hz, 3H) . **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.5, 138.3, 137.9, 137.3, 133.2, 131.4, 129.4, 128.6, 128.5, 128.0, 125.8, 125.0, 59.5, 58.0, 17.7. **LRMS (EI)**: 239 [M+1], 226, 209, 194, 164, 150, 126, 97, 77, 63, 43, 32, 28, 14. **HRMS (ESI)**: calcd for $C_{16}H_{15}O_2^+$ 239.1067 $[M+H]^+$, found 239.1070.



Compound 3b. Yield 67 %. **IR** (neat) v_{max}: 2970, 1878, 1658, 1442, 1112, 930, 700 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.82 (d, J = 7.2 Hz, 2H), 7.70 (t, J = 7.2 Hz, 1H), 7.56-7.60 (m, 3H), 7.43-7.46 (m, 3H), 3.74 (d, J = 2.0 Hz, 1H), 2.82 (m, 1H), 1.52-1.59 (m, 2H), 0.93 (t, J = 7.6 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 184.8, 139.1, 138.8, 134.1, 133.3, 131.9, 130.7, 129.7, 129.5, 127.8, 126.5, 125.7, 100.9, 56.9, 25.8, 9.6. **LRMS** (EI): 251 [M-1], 222, 209, 192, 164, 152, 115, 95, 77, 63, 39, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{17}O_2^+$ 253.1223 $[M+H]^+$, found 253.1220.

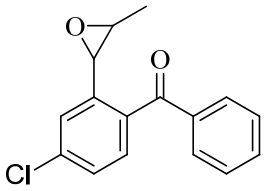


Compound 3c. Yield 67 %. **IR** (neat) v_{max}: 3020, 2960, 1715, 1660, 1278, 1105, 700 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.03 (d, J =8.4 Hz, 2H), 7.76 (d, J = 8.4 Hz, 2H), 7.45-7.49 (m, 1H), 7.29-7.35 (m, 3H), 3.80 (s, 3H), 3.54, (d, J = 2.0 Hz, 2H), 1.90-1.93 (m, 1H), 1.09 (d, J = 5.2 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.0, 166.6, 142.4, 139.3, 137.9, 134.7, 132.4, 130.7, 130.4, 130.1, 128.0, 125.9, 59.6, 58.3, 52.8, 17.8. **LRMS** (EI): 297 [M+1], 280, 251, 236, 209, 181, 165, 138, 123, 105, 77, 50, 28, 14. **HRMS** (ESI): calcd for $C_{18}H_{17}O_4^+$ 297.1121 $[M+H]^+$, found 297.1092.

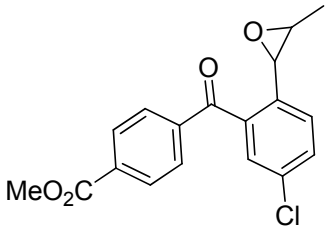


Compound 3d. Yield 57 %. **IR** (neat) v_{max}: 3060, 2968, 2860,

1660, 1447, 1067, 928, 702 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.78-7.81 (m, 2H), 7.64-7.72 (m, 1H), 7.56-7.62 (m, 3H), 7.47-7.51 (m, 3H), 3.86 (s, 1H), 1.24 (s, 3H), 0.99 (s, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.7, 139.0, 138.3, 138.0, 133.9, 133.6, 130.9, 130.1, 129.6, 129.5, 129.5, 129.1, 128.2, 127.9, 127.7, 64.2, 61.8, 24.4, 18.5. **LRMS** (EI): 252 [M], 237, 208, 180, 164, 152, 128, 105, 91, 78, 65, 43, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{17}O_2^+$ 253.1223 $[M+H]^+$, found 253.1224.

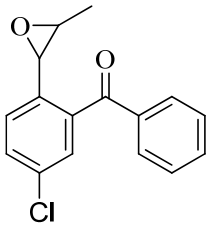


Compound 3e. Yield 57 %. **IR** (neat) ν_{max}: 2950, 2890, 1651, 1448, 1281, 927, 702 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.79-7.81 (m, 2H), 7.70-7.72 (m, 1H), 7.63-7.66 (m, 1H), 7.57-7.61 (m, 3H), 7.48-7.50 (m, 1H), 4.04 (d, J = 4.0 Hz, 1H), 3.21 (m, 1H), 0.98 (d, J = 6.4 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 196.2, 140.5, 138.1, 135.4, 134.5, 133.3, 131.2, 130.7, 130.3, 129.7, 129.7, 129.4, 56.7, 55.8, 13.2. **LRMS** (EI): 272 [M], 256, 211, 189, 164, 113, 77, 60, 39, 28, 14. **HRMS** (ESI): calcd for $C_{16}H_{14}ClO_2^+$ 273.0677 $[M+H]^+$, found 273.0673.

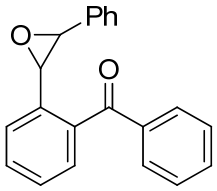


Compound 3f. Yield 59 %. **IR** (neat) ν_{max}: 2994, 2954, 1726, 1664, 1436, 1279, 1107, 729 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.00-8.03 (m, 2H), 7.73-7.77 (m, 2H), 7.36-7.40 (m, 3H), 4.02 (d, J = 4.8 Hz, 1H), 3.80 (s, 3H), 3.16 (m, 1H), 0.74 (d, J = 6.8 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 195.9, 166.5, 142.1, 140.0, 134.9, 133.5, 132.5, 131.6, 130.8, 130.7, 130.5, 130.4, 130.3, 128.6, 127.9, 69.5, 56.9, 52.8, 19.4. **LRMS** (EI): 329 [M-1], 312, 285,

253, 217, 188, 175, 163, 109, 94, 76, 59, 44, 28, 14. **HRMS** (ESI): calcd for $C_{18}H_{16}ClO_4^+$ 331.0732 $[M+H]^+$, found 331.0744.

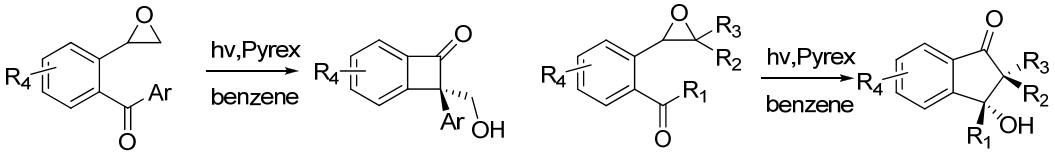


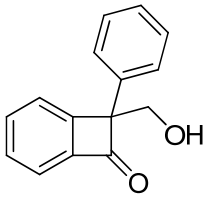
Compound 3g. Yield 56 %. **IR** (neat) ν_{max} : 2960, 2900, 1634, 1259, 1100, 790 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.80-7.83 (m, 2H), 7.67-7.74 (m, 1H), 7.58-7.61 (m, 3H), 7.49 (s, 2H), 3.67 (d, J = 1.6 Hz, 1H), 2.95 (m, 1H), 1.24 (d, J = 4.8 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 196.5, 141.6, 138.6, 137.7, 137.2, 134.2, 133.3, 131.8, 130.7, 130.6, 129.6, 129.3, 128.0, 125.7, 59.9, 57.8, 17.7. **LRMS** (EI): 272 [M], 256, 211, 189, 164, 113, 77, 60, 39, 28, 14. **HRMS** (ESI): calcd for $C_{16}H_{14}ClO_2^+$ 273.0677 $[M+H]^+$, found 273.0663.



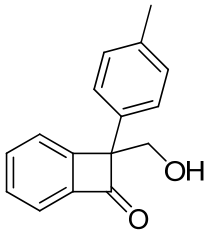
Compound II'. Yield 67 %. **IR** (neat) ν_{max} : 2926, 1726, 1449, 1280, 1019, 699 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.79 (d, J = 7.2 Hz, 2H), 7.61-7.62 (m, 4H), 7.32-7.59 (m, 8H), 4.10 (d, J = 1.6 Hz, 1H), 3.82 (d, J = 2.0 Hz, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 197.2, 137.7, 137.6, 137.5, 136.6, 133.1, 131.1, 130.1, 129.4, 128.5, 128.4, 128.3, 127.2, 125.8, 125.1,63.1, 60.6. **LRMS** (EI): 301 [M+1], 283, 269, 255, 233, 213, 178, 150, 128, 105, 91, 77, 51, 39, 28, 14. **HRMS** (ESI): calcd for $C_{21}H_{17}O_2^+$ 301.1223 $[M+H]^+$, found 301.1233.

Irradiation of epoxy ketone in benzene. [6]

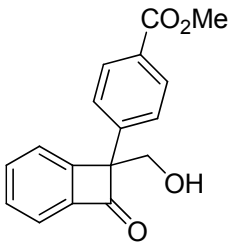




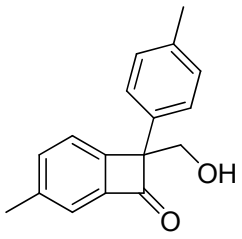
Compound 2a. Yield 73 %. **IR** (neat) ν_{max}: 3417, 2065, 1633, 1364, 1233, 1046, 750 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.67 (d, J = 8.0 Hz, 1H), 7.54 (t, J = 7.4 Hz, 1H), 7.39 (t, J = 7.4 Hz, 1H), 7.32 (d, J = 7.8 Hz, 1H), 7.17-7.25 (m, 5H), 5.21 (br, 1H), 3.05 (s, 2H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 203.7, 145.3, 138.9, 135.8, 129.5, 128.5, 127.4, 125.3, 125.1, 123.2, 78.4, 56.1. **LRMS** (EI): 224 [M], 207, 195, 178, 165, 152, 133, 118, 105, 91, 77, 65, 51, 39, 28, 14. **HRMS** (ESI): calcd for $C_{15}H_{13}ClO_2^+$ 225.0910 $[M+H]^+$, found 225.0912.



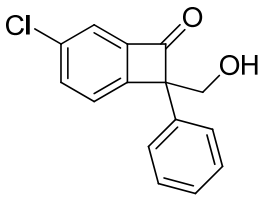
Compound 2c. Yield 72.7 %. **IR** (neat) ν_{max}: 3440, 2926, 1750, 1658, 1262, 1074, 747 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.90 (t, J = 8.8 Hz, 1H), 7.76 (dd, J = 8.8, 4.4/5.2 Hz, 2H), 7.58-7.67 (m, 2H), 7.38 (dd, J = 7.2, 1.2 Hz, 1H), 7.09 (t, J = 8.8 Hz, 2H), 4.31 (t, J = 13.6 Hz, 1H), 4.12 (dd, J = 14.4, 7.2 Hz, 1H), 2.54 (s, 3H), 2.04 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 203.4, 158.3, 142.3, 137.2, 136.0, 135.7, 129.5, 129.2, 128.7, 125.1, 125.0, 123.2, 78.5, 56.2, 21.0. **LRMS** (EI): 238 [M], 222, 209, 181, 165, 147, 119, 104, 91, 76, 65, 43, 28, 14. **HRMS** (ESI): calcd for $C_{16}H_{15}ClO_2^+$ 239.1067 $[M+H]^+$, found 239.1070.



Compound 2d. Yield 66 %. **IR** (neat) ν_{max} : 3445, 2925, 1776, 1607, 1436, 1283, 1112, 765 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.03 (d, J = 8.4 Hz, 1H), 7.85 (d, J = 7.6 Hz, 1H), 7.70 (q, J = 7.4 Hz, 1H), 7.57 (t, J = 7.4 Hz, 1H), 7.40-7.47 (m, 3H), 3.94 (s, 3H), 2.70 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 202.8, 166.7, 157.7, 150.2, 136.0, 135.9, 129.9, 129.9, 129.3, 25.2, 125.1, 123.4, 78.5, 56.0, 52.2. **LRMS** (EI): 282 [M], 251, 222, 195, 165, 133, 105, 76, 59, 29, 15. **HRMS** (ESI): calcd for $C_{17}H_{15}O_4^+$ 283.0965 $[M+H]^+$, found 283.0969.

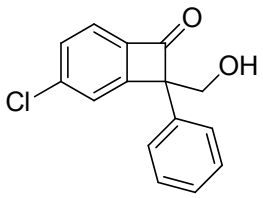


Compound 2e. Yield 67 %. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.72 (d, J = 8.0 Hz, 1H), 7.33 (t, J = 8.0 Hz, 1H), 7.17-7.26 (m, 5H), 3.18 (s, 3H), 2.46 (br, 1H), 2.44 (s, 3H), 2.37 (s, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 206.9, 147.1, 142.5, 138.2, 137.2, 130.8, 129.2, 128.8, 125.2, 125.0, 123.1, 78.4, 56.4, 30.9, 29.7. **LRMS** (EI): 252 [M], 234, 209, 192, 165, 147, 132, 119, 105, 91, 77, 65, 51, 39, 28, 15. **HRMS** (ESI): calcd for $C_{17}H_{17}O_2^+$ 253.1223 $[M+H]^+$, found 253.1220.

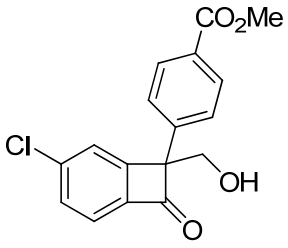


Compound 2f. Yield 62 %. **IR** (neat) ν_{max} : 3386, 2925, 2854, 1713, 1594, 1449, 1232, 1045, 701 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.73 (d, J = 8.0 Hz, 1H), 7.49 (dd, J = 1.2, 7.6 Hz, 1H), 7.32-7.42 (m, 6H), 3.19 (s, 2H),

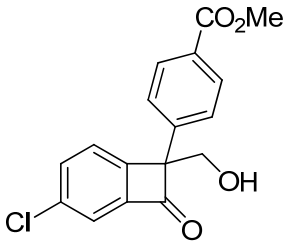
3.04-3.06 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 202.0, 159.7, 144.6, 142.2, 134.2, 130.3, 128.7, 127.7, 125.6, 124.9, 124.5, 78.2, 56.2. **LRMS** (EI): 259 [M+1], 240, 227, 211, 198, 182, 168, 139, 115, 103, 77, 65, 51, 28, 14. **HRMS** (ESI): calcd for $C_{15}H_{12}ClO_2^+$ 259.0520 $[M+H]^+$, found 259.0517.



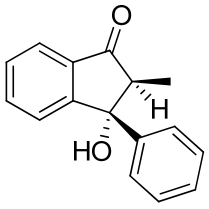
Compound 2g. Yield 63 %. **IR** (neat) ν_{max}: 2979, 2848, 1634, 1359, 1240, 1052, 740 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.73 (d, J = 8.0 Hz, 1H), 7.49 (dd, J = 1.2, 7.6 Hz, 1H), 7.32-7.42 (m, 6H), 3.19 (s, 2H), 3.05 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 202.0, 159.7, 144.6, 142.2, 134.2, 130.3, 128.7, 127.7, 125.6, 124.9, 124.5, 78.2, 56.2. **LRMS** (EI): 258[M], 240, 229, 212, 194, 178, 167, 152, 138, 105, 91, 77, 63, 51, 39, 28, 14. **HRMS** (ESI): calcd for $C_{15}H_{12}ClO_2^+$ 259.0520 $[M+H]^+$, found 259.0517.



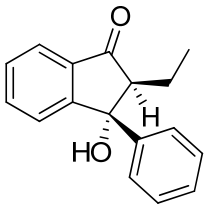
Compound 2h. Yield 46 %. **IR** (neat) ν_{max}: 3444, 2954, 2855, 1936, 1726, 1610, 1436, 1281, 1108, 777 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.03 (d, J = 8.4 Hz, 1H), 7.85 (d, J = 7.6 Hz, 1H), 7.70 (q, J = 7.4 Hz, 1H), 7.57 (t, J = 7.4 Hz, 1H), 7.40-7.47 (m, 3H), 3.91 (s, 3H), 3.20 (s, 2H), 2.70 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 202.8, 166.7, 157.7, 150.2, 136.0, 135.9, 129.9, 129.9, 129.3, 25.2, 125.1, 123.4, 78.5, 56.0, 52.2. **LRMS** (EI): 316 [M], 285, 257, 229, 194, 167, 149, 111, 91, 75, 59, 28, 15. **HRMS** (ESI): calcd for $C_{17}H_{14}ClO_4^+$ 317.0575 $[M+H]^+$, found 317.0570.



Compound 2i. Yield 44 %. **IR** (neat) ν_{max}: 3420, 2920, 2857, 1933, 1720, 1654, 1444, 1280, 1109, 709 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.03 (d, J = 7.8 Hz, 2H), 7.58 (d, J = 7.8 Hz, 2H), 7.44-7.48 (m, 3H), 3.94 (s, 3H), 3.22 (s, 2H), 2.04 (br, 1H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 202.7, 166.7, 150.1, 136.0, 130.0, 129.9, 129.1, 128.7, 125.2, 125.2, 123.4, 78.5, 56.0, 52.2. **LRMS** (EI): 316 [M], 279, 242, 227, 199, 169, 123, 95, 76, 58, 43, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{14}ClO_4^+$ 317.0575 $[M+H]^+$, found 317.0570. **HRMS** (ESI): calcd for $C_{17}H_{14}ClO_4^+$ 317.0575 $[M+H]^+$, found 317.0570.

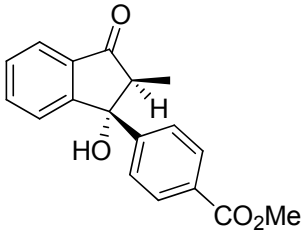


Compound 4a. Yield 62 %. **IR** (neat) ν_{max}: 3444, 3061, 2932, 1714, 1464, 1227, 702 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.83 (d, J = 7.6 Hz, 1H), 7.67 (t, J = 7.2 Hz, 1H), 7.54 (t, J = 7.2 Hz, 1H), 7.32-7.45 (m, 6H), 2.94 (q, J = 7.2 Hz, 1H), 2.26 (br, 1H), 1.31 (d, J = 7.2 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 206.3, 157.3, 144.5, 135.5, 129.7, 128.4, 127.5, 125.5, 125.3, 123.5, 80.0, 57.6, 29.7, 8.4. **LRMS** (EI): 237 [M-1], 208, 189, 181, 160, 143, 105, 91, 76, 51, 43, 27. **HRMS** (ESI): calcd for $C_{16}H_{15}O_2^+$ 239.1067 $[M+H]^+$, found 239.1070.

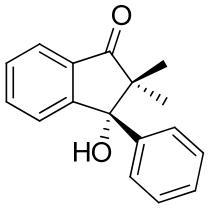


Compound 4b. Yield 61 %. **IR** (neat) ν_{max}: 3444, 2926, 2855, 1715,

1463, 1175, 701 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.85 (d, J = 7.6 Hz, 1H), 7.67 (t, J = 7.6 Hz, 1H),7.54 (t, J = 7.2 Hz, 1H), 7.29-7.44 (m, 6H), 2.87 (dd, J = 6.4, 6.0 Hz, 1H), 2.16 (br, 1H), 1.95-2.03 (m, 1H), 1.83-1.90 (m, 1H), 1.05 (t, J = 7.2 Hz, 3H),. **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 205.9, 157.7, 145.4, 135.6, 135.5, 129.7, 128.4, 127.3, 125.4, 125.2, 123.3, 100.0, 80.1, 63.7, 19.2, 12.8. **LRMS** (EI): 252 [M], 237, 223, 209, 195, 181, 152, 128, 105, 91, 77, 51, 28, 14. **HRMS** (ESI): calcd for $C_{17}H_{17}O_2^+$ 253.1223 $[M+H]^+$, found 253.1220.

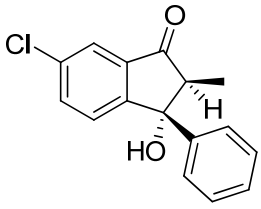


Compound 4c. Yield 84 %. **IR** (neat) ν_{max} : 2979, 2848, 1634, 1359, 1240, 1052, 740 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.02 (d, J = 8.8 Hz, 2H), 7.81 (d, J = 7.6 Hz, 1H), 7.62-7.66 (m, 1H), 7.47-7.54 (m, 3H), 7.32 (d, J = 7.6 Hz, 1H), 3.91 (s, 3H), 2.90 (q, J = 7.6 Hz, 1H), 2.54 (br, 1H), 1.29 (d, J = 7.6 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 205.8, 166.8, 156.8, 149.7, 135.7, 130.0, 129.7, 125.7, 125.3, 123.7, 79.9, 57.6, 52.2, 8.3. **LRMS** (EI): 297 [M+1], 263, 236, 209, 189, 177, 151, 143, 133, 115, 104, 89, 76, 59, 50, 27, 15. **HRMS** (ESI): calcd for $C_{18}H_{17}O_4^+$ 297.1121 $[M+H]^+$, found 297.1092.

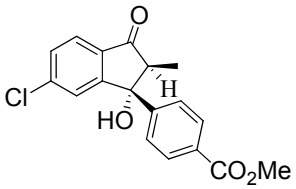


Compound 4d. Yield 80 %. **IR** (neat) ν_{max} : 2979, 2848, 1634, 1359, 1240, 1052, 740 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.88 (d, J = 7.6 Hz, 1H), 7.73 (t, J = 7.6 Hz, 1H), 7.54-7.59 (m, 2H), 7.29-7.37 (m, 3H), 7.23-7.25 (m, 2H),

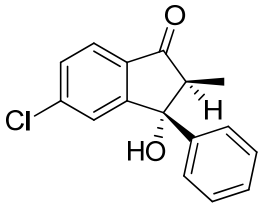
2.52 (br, 1H), 1.33 (s, 3H), 0.73 (s, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 208.9, 155.6, 142.43, 135.4, 134.8, 129.6, 128.0, 127.5, 126.8, 125.4, 123.9, 83.5, 56.1, 23.4, 20.5. **LRMS** (EI): 251 [M-1], 239, 208, 194, 174, 151, 139, 129, 115, 91, 76, 63, 51, 41, 27. **HRMS** (ESI): calcd for $C_{17}H_{17}O_2^+$ 253.1223 $[M+H]^+$, found 253.1220.



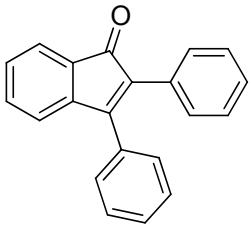
Compound 4e. Yield 62.5 %. **IR** (neat) ν_{max}: 2979, 2848, 1634, 1359, 1240, 1052, 740 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.79 (d, J = 8.0 Hz, 1H), 7.53 (d, J = 8.0 Hz, 1H), 7.37-7.43 (m, 6H), 2.98 (q, J = 7.2 Hz, 1H), 2.27 (br, 1H), 1.32 (d, J = 8.2 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 204.7, 158.7, 143.7, 141.8, 133.8, 130.5, 128.6, 127.7, 125.7, 125.4, 124.8, 79.7, 57.0, 8.4. **LRMS** (EI): 272 [M], 259, 244, 226, 218, 208, 197, 164, 151, 138, 131, 115, 105, 78, 55, 39, 27. **HRMS** (ESI): calcd for $C_{16}H_{14}ClO_2^+$ 273.0677 $[M+H]^+$, found 273.0673.



Compound 4f. Yield 66 %. **IR** (neat) ν_{max}: 2979, 2848, 1634, 1359, 1240, 1052, 740 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 8.03 (dd, J = 4.4, 8.4 Hz, 2H), 7.68-7.70 (m, 1H), 7.59 (dd, J = 2.0, 6.0 Hz, 1H), 7.46-7.49 (m, 2H), 7.25-7.29 (m, 1H), 3.90 (s, 3H), 2.96 (br, 1H), 2.93 (q, J = 7.2 Hz, 1H), 1.28 (d, J = 7.2 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 204.6, 166.8, 154.91, 149.0, 142.0, 135.6, 133.8 130.6, 129.8, 126.8, 125.7, 124.8, 79.5, 58.0, 52.3, 8.2. **LRMS** (EI): 330 [M], 318, 297, 270, 242, 225, 207, 188, 166, 149, 115, 103, 95, 89, 77, 59, 43, 28, 15. **HRMS** (ESI): calcd for $C_{18}H_{16}ClO_4^+$ 331.0732 $[M+H]^+$, found 331.0744.



Compound 4g. Yield 62.5 %. **IR** (neat) ν_{max}: 2979, 2848, 1634, 1359, 1240, 1052, 740 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.77 (d, J = 1.6 Hz, 1H), 7.62 (dd, J = 6.0, 2.0 Hz, 1H), 7.42 (d, J = 4.4 Hz, 4H), 7.31-7.38 (m, 2H), 2.97 (q, J = 7.2 Hz, 1H), 2.39 (br, 1H), 1.32 (d, J = 7.2 Hz, 3H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 205.0, 155.4, 143.9, 137.0, 136.2, 135.5, 128.6, 127.7, 126.8, 125.4, 123.4, 79.6, 58.0, 8.3. **LRMS** (EI): 273 [M+1], 268, 256, 243, 226, 208, 193, 165, 152, 138, 115, 105, 91, 83, 78, 67, 55, 43, 28, 14. **HRMS** (ESI): calcd for $C_{16}H_{14}ClO_2^+$ 273.0677 $[M+H]^+$, found 273.0673.



Compound Ⅱ. Yield 60 %. **IR** (neat) ν_{max}: 2979, 2848, 1634, 1359, 1240, 1052, 740 cm^{-1}. **^{1}H NMR** ($CDCl_3$, 400 MHz, ppm): δ 7.59 (d, J = 7.2 Hz, 2H), 7.31-7.42 (m, 8H), 7.29 (d, J = 6.4 Hz, 2H), 7.16 (d, J = 7.2 Hz, 2H). **^{13}C NMR** ($CDCl_3$, 100 MHz, ppm): δ 196.5, 155.3, 145.3, 133.4, 130.8, 130.8, 130.0, 129.3, 129.0, 128.8, 128.5, 128.1, 127.4, 123.0, 121.8. **LRMS** (EI): 281 [M-1], 252, 225, 200, 176, 150, 126, 99, 77, 51, 22. **HRMS** (ESI): calcd for $C_{21}H_{15}O^+$ 283.1117 $[M+H]^+$, found 283.1122.

Reference

[1] Elba, D. R., Néstor, M. C. *Synthesis*, 1996, 693-694.

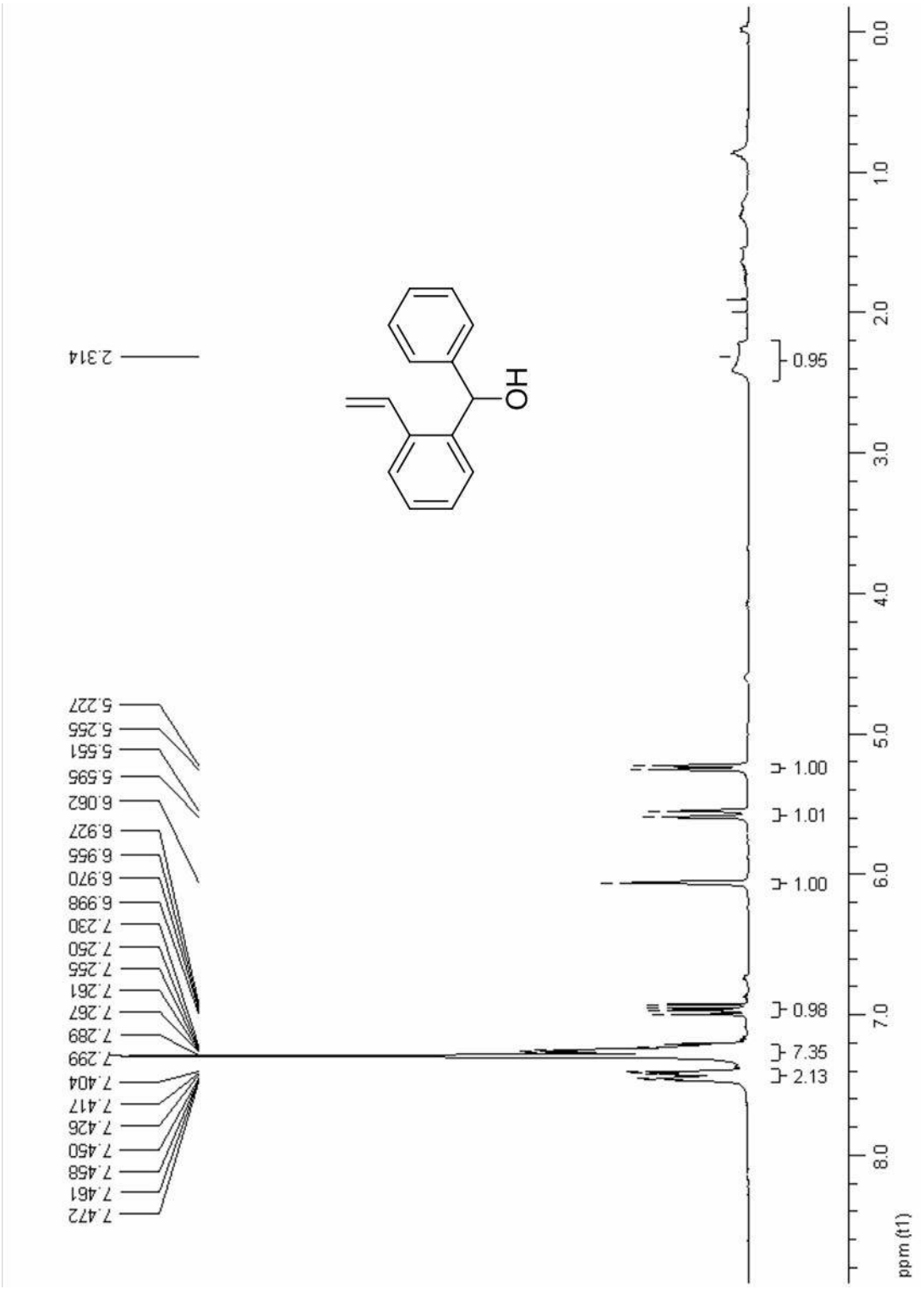
[2] Bailey, E. R., Punzalan, E. R. *J. Org. Chem.*, 1990, 55, 5404-5406.

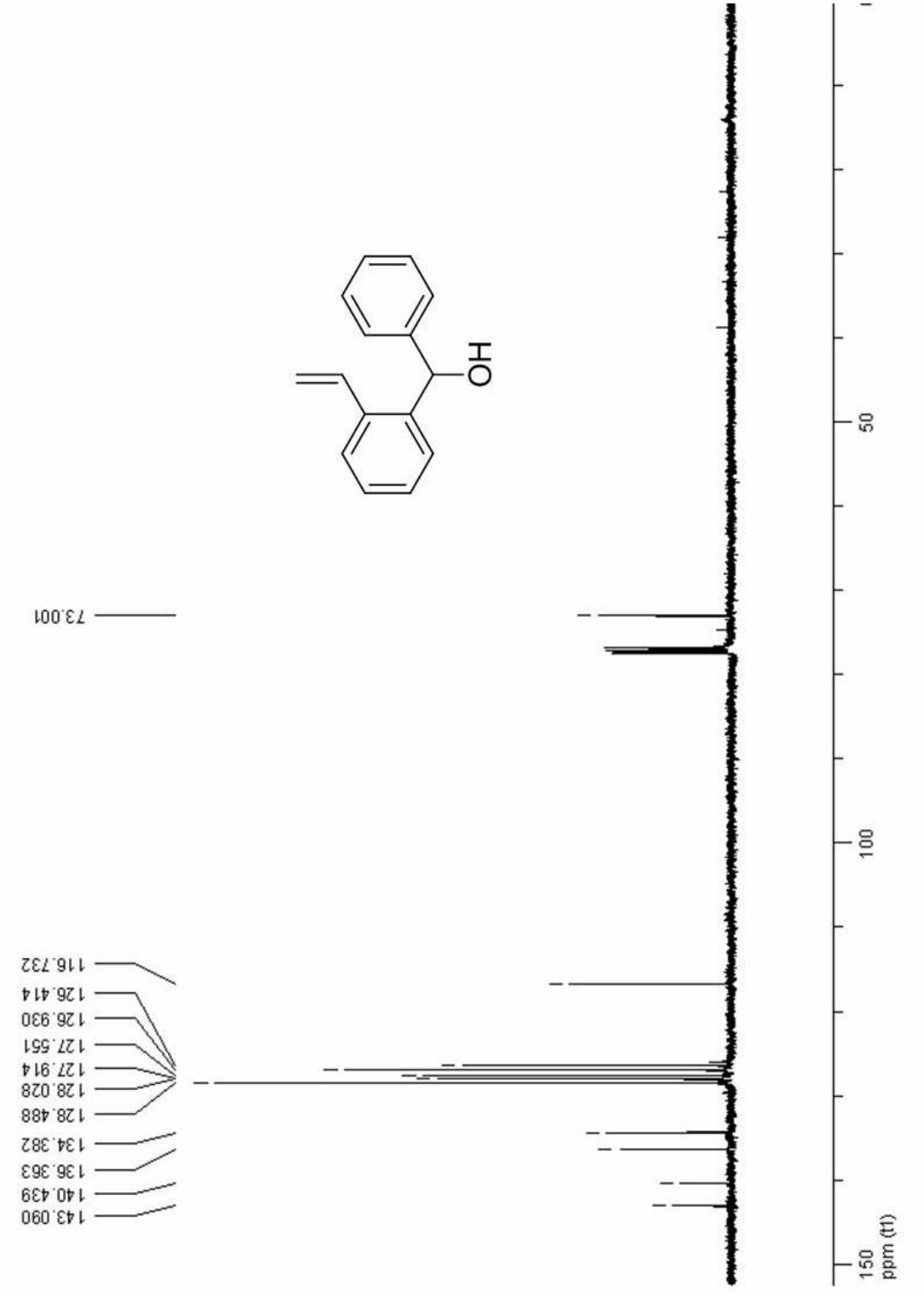
[3] Xia, W. J., Yang, C., Scheffer, J. R. *J. Am. Chem. Soc.*, 2005, 127, 2725-2730.

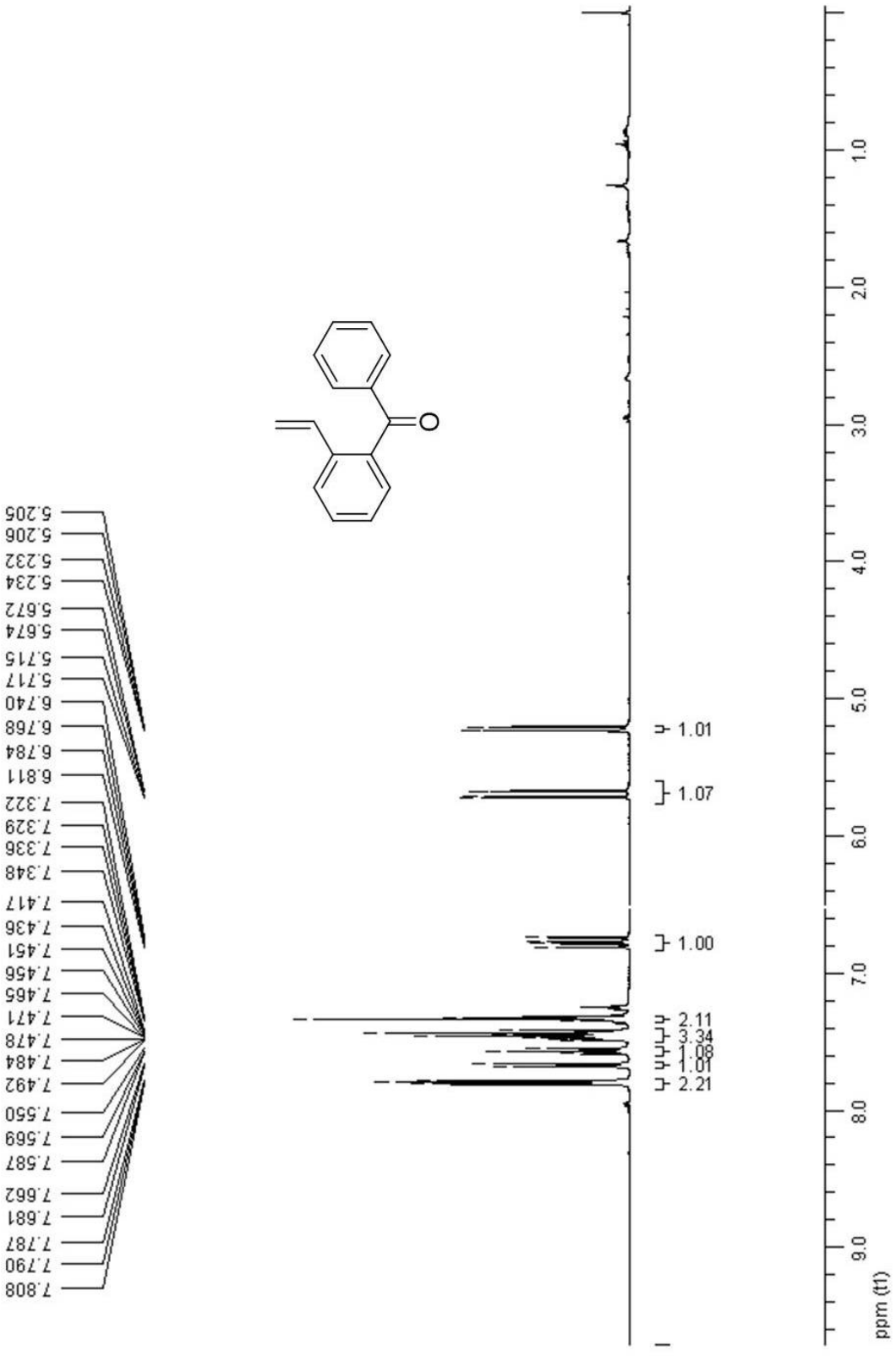
[4] Fleming, I., Woolias, M . *J. Chem. Soc. Perkin Trans 1*, 1979, 829-837.

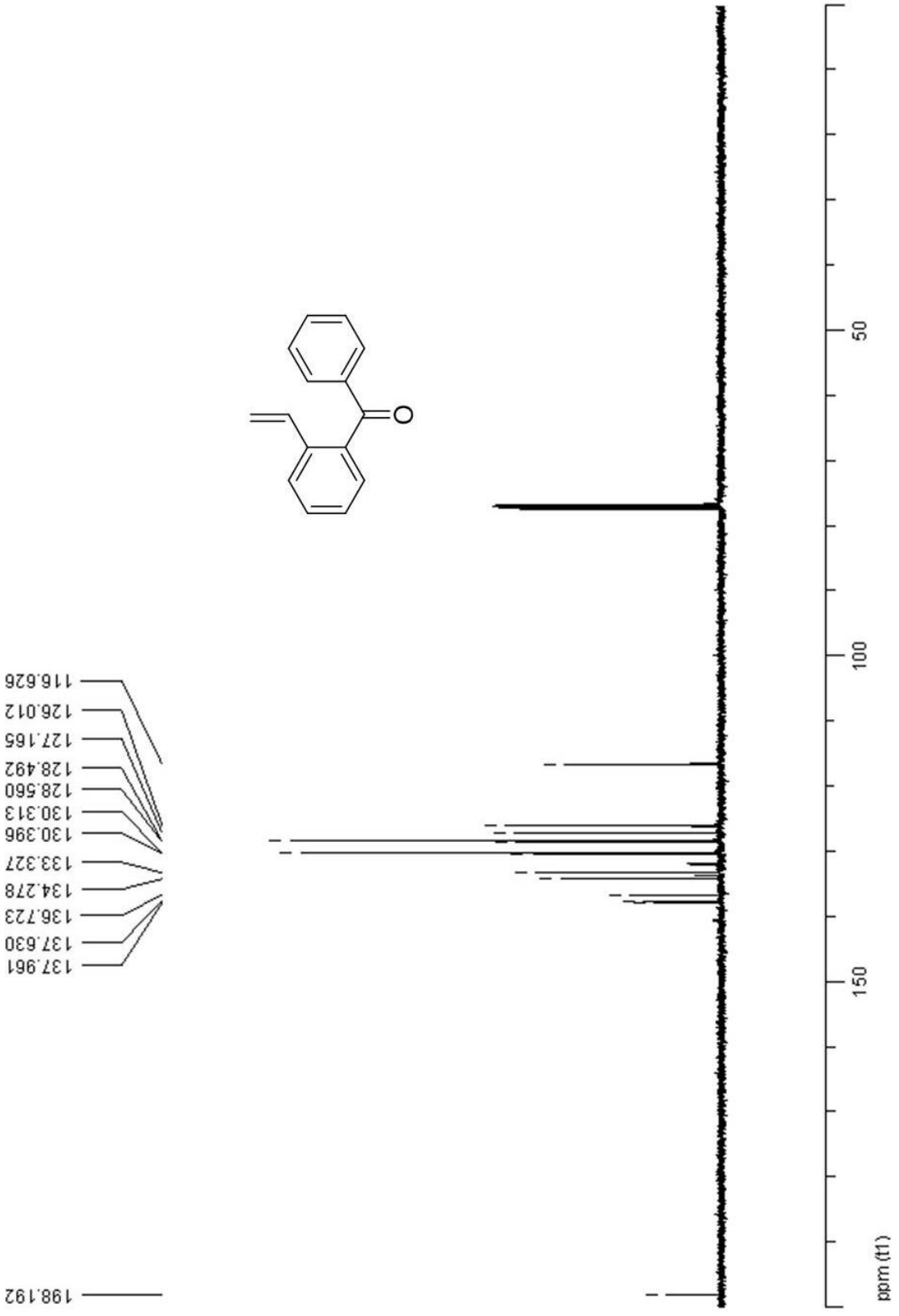
[5] Wang, Z. X., Shu, L. H., Shi, Y. *Org. Syn.*, 2003, 80, 9-17.

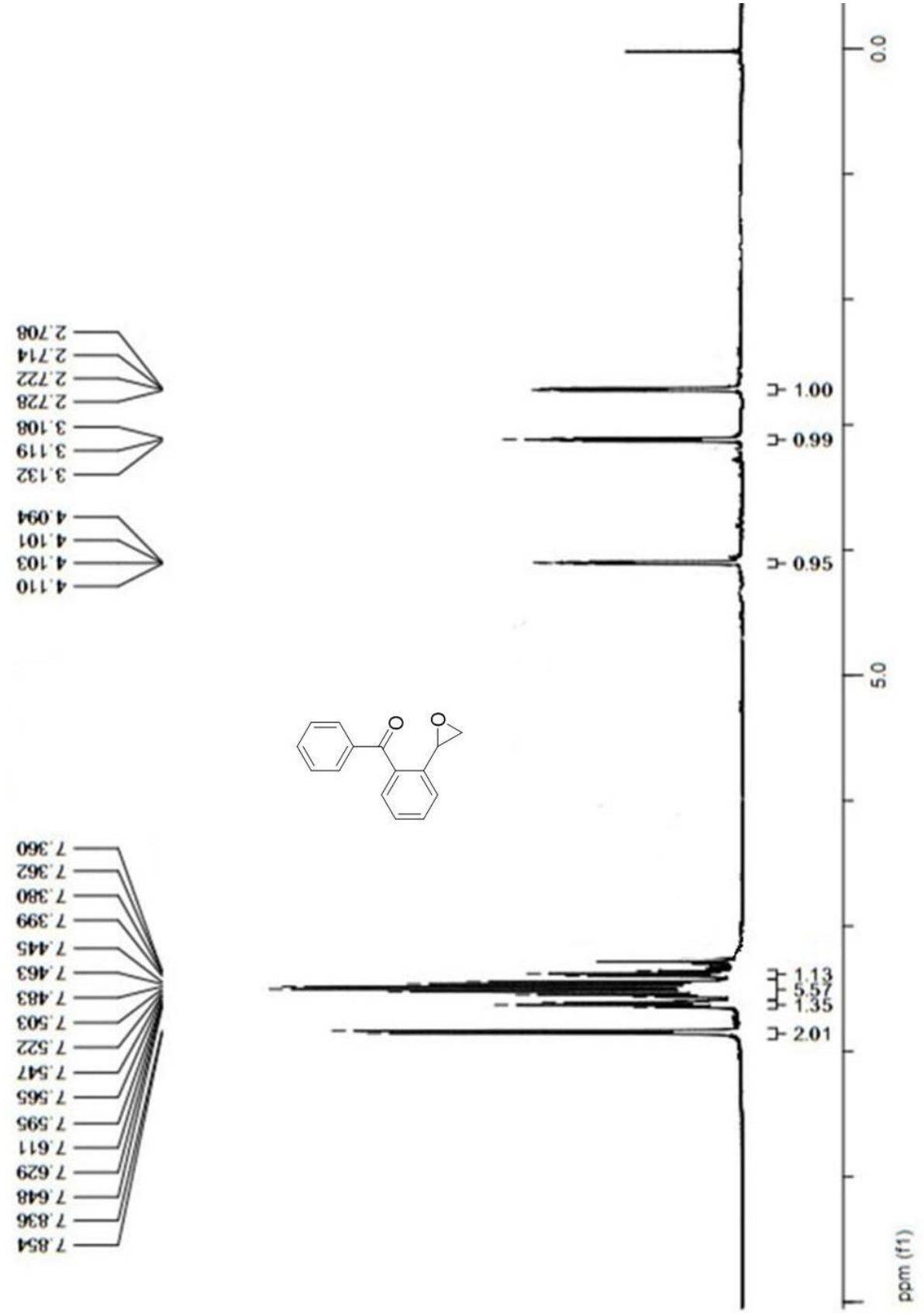
[6] Xia, W. J., Shao, Y. T., Gui, W. J. *Chem. Commun.*, 2011, 47, 11098-11100.

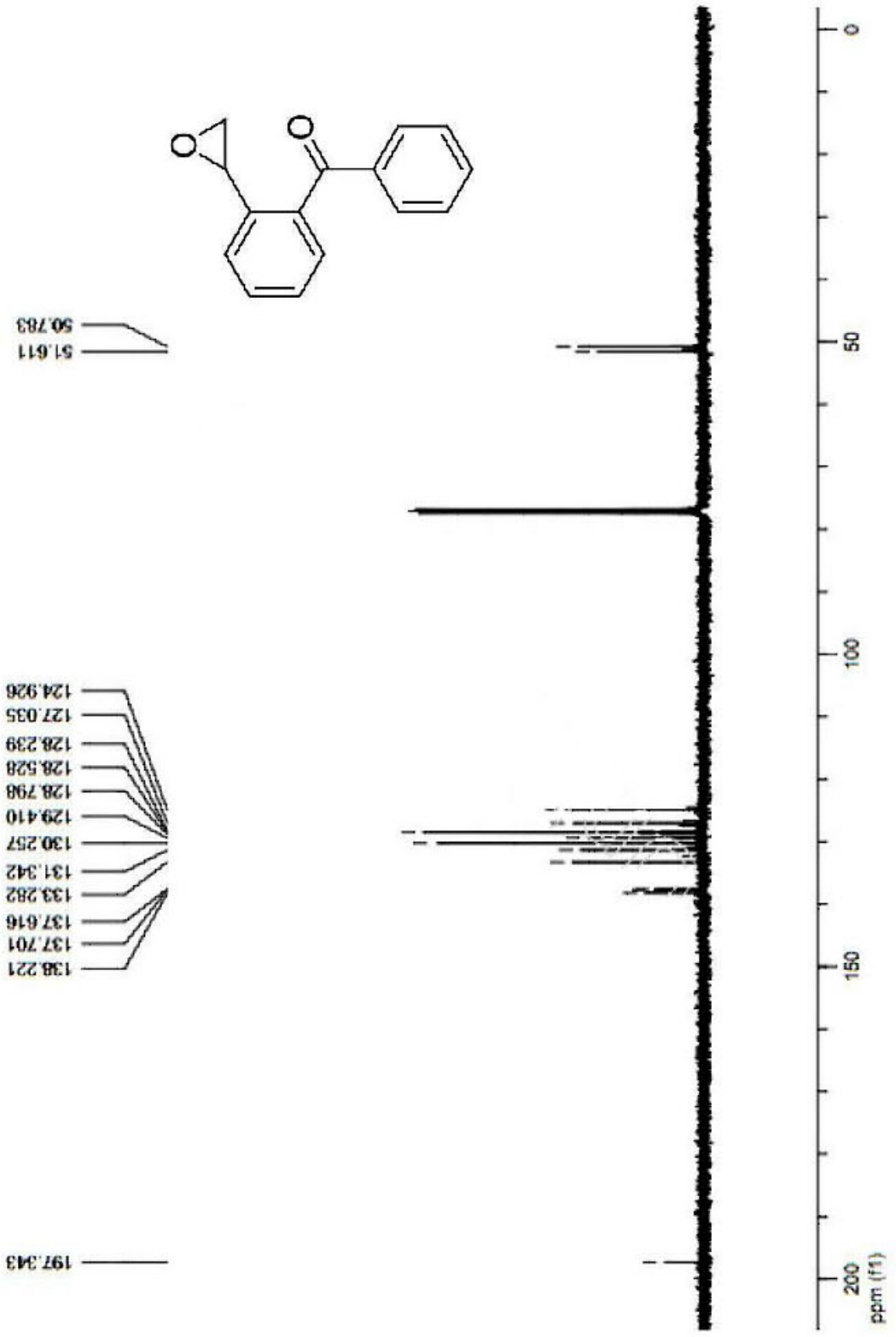

OH
2.314
5.227
5.255
5.551
5.595
6.062
6.927
6.955
6.970
6.998
7.230
7.250
7.255
7.261
7.267
7.289
7.299
7.404
7.417
7.426
7.450
7.458
7.461
7.472
0.95
1.00
1.01
1.00
0.98
7.35
2.13
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

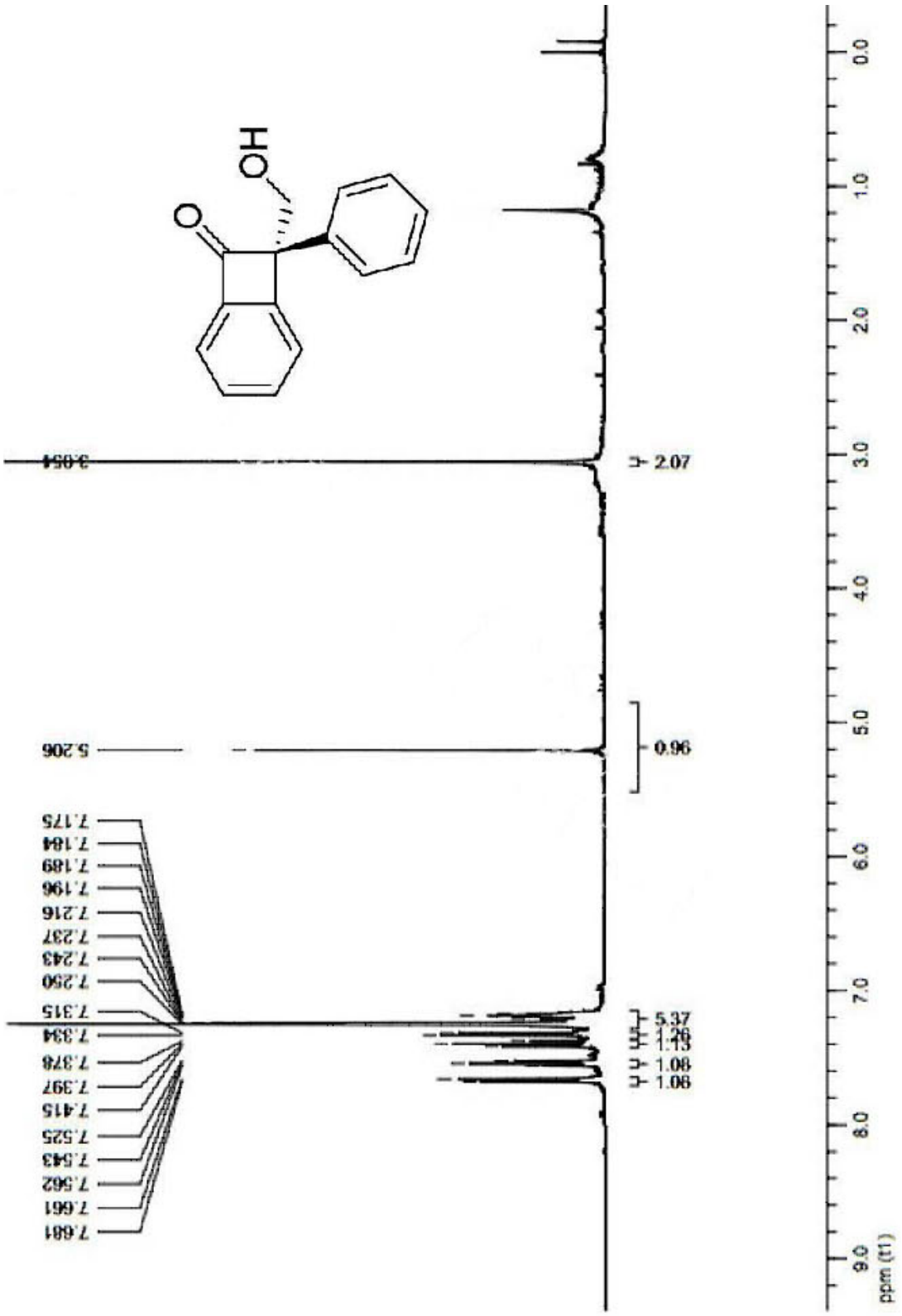

OH
73.001
116.732
126.414
126.930
127.551
127.914
128.028
128.488
134.382
136.363
140.439
143.090
50
100
150
ppm (t1)

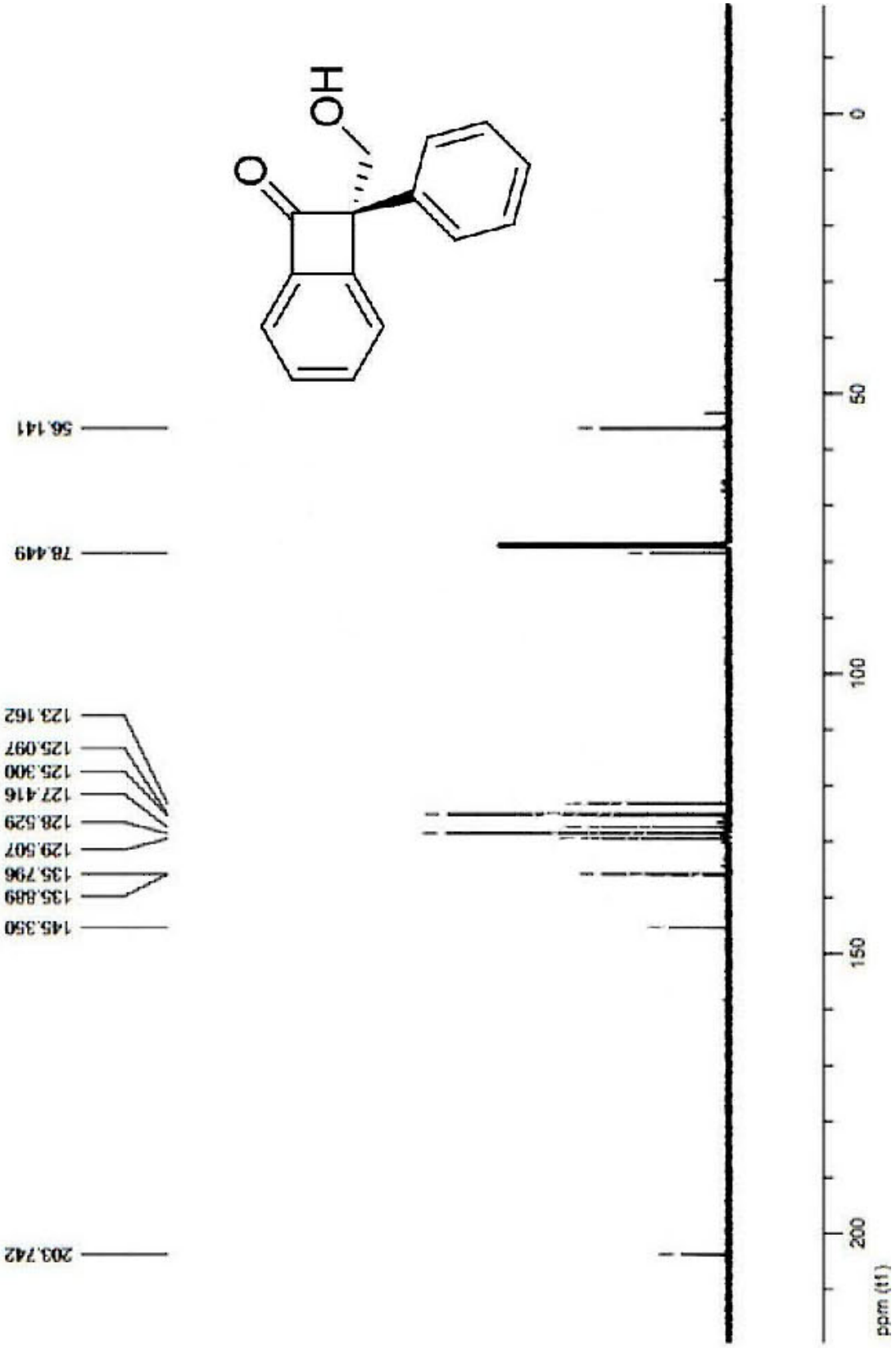

5.205
5.206
5.232
5.234
5.672
5.674
5.715
5.717
6.740
6.768
6.784
6.811
7.322
7.329
7.336
7.348
7.417
7.436
7.451
7.456
7.465
7.471
7.478
7.484
7.492
7.550
7.569
7.587
7.662
7.681
7.787
7.790
7.808
1.01
1.07
1.00
2.11
3.34
1.08
1.01
2.21
ppm (t1)

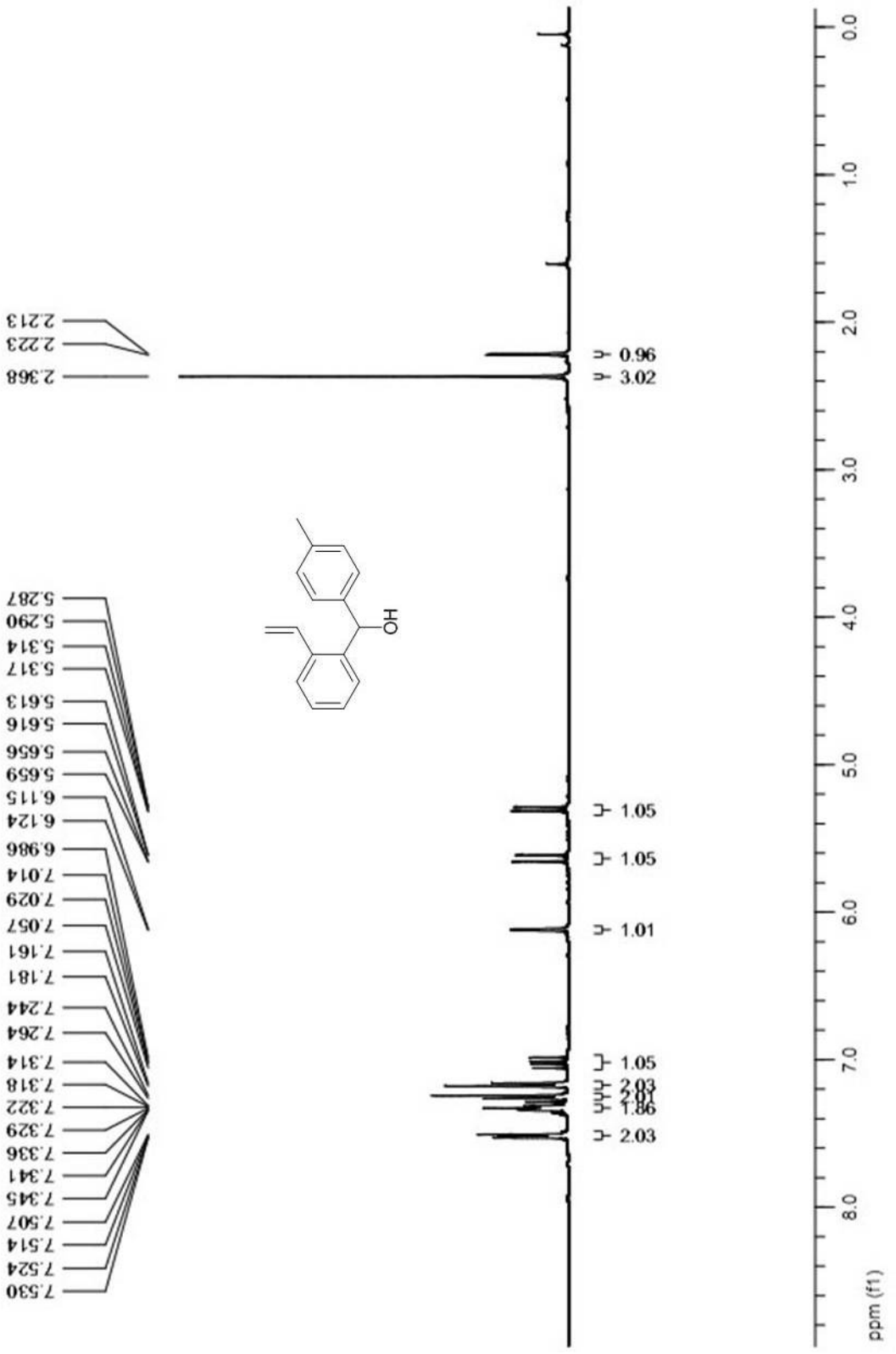

198.192
137.961
137.630
136.723
134.278
133.327
130.396
130.313
128.560
128.492
127.165
126.012
116.626
O
50
100
150
ppm (t1)

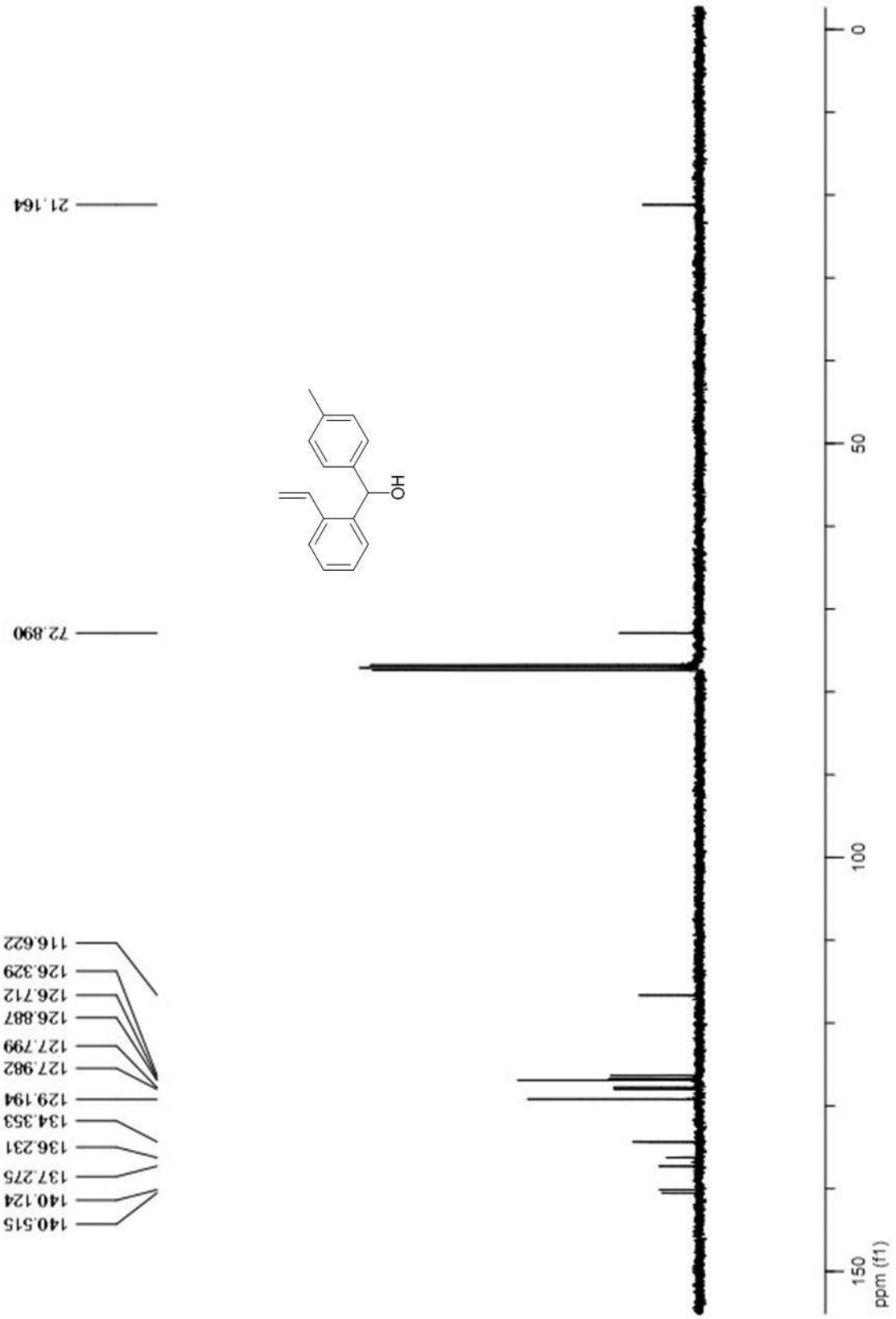

2.708
2.714
2.722
2.728
3.108
3.119
3.132
4.094
4.101
4.103
4.110
7.360
7.362
7.380
7.399
7.445
7.463
7.483
7.503
7.522
7.547
7.565
7.595
7.611
7.629
7.648
7.836
7.854
1.00
0.99
0.95
1.13
5.57
1.35
2.01
0.0
5.0
ppm (f1)

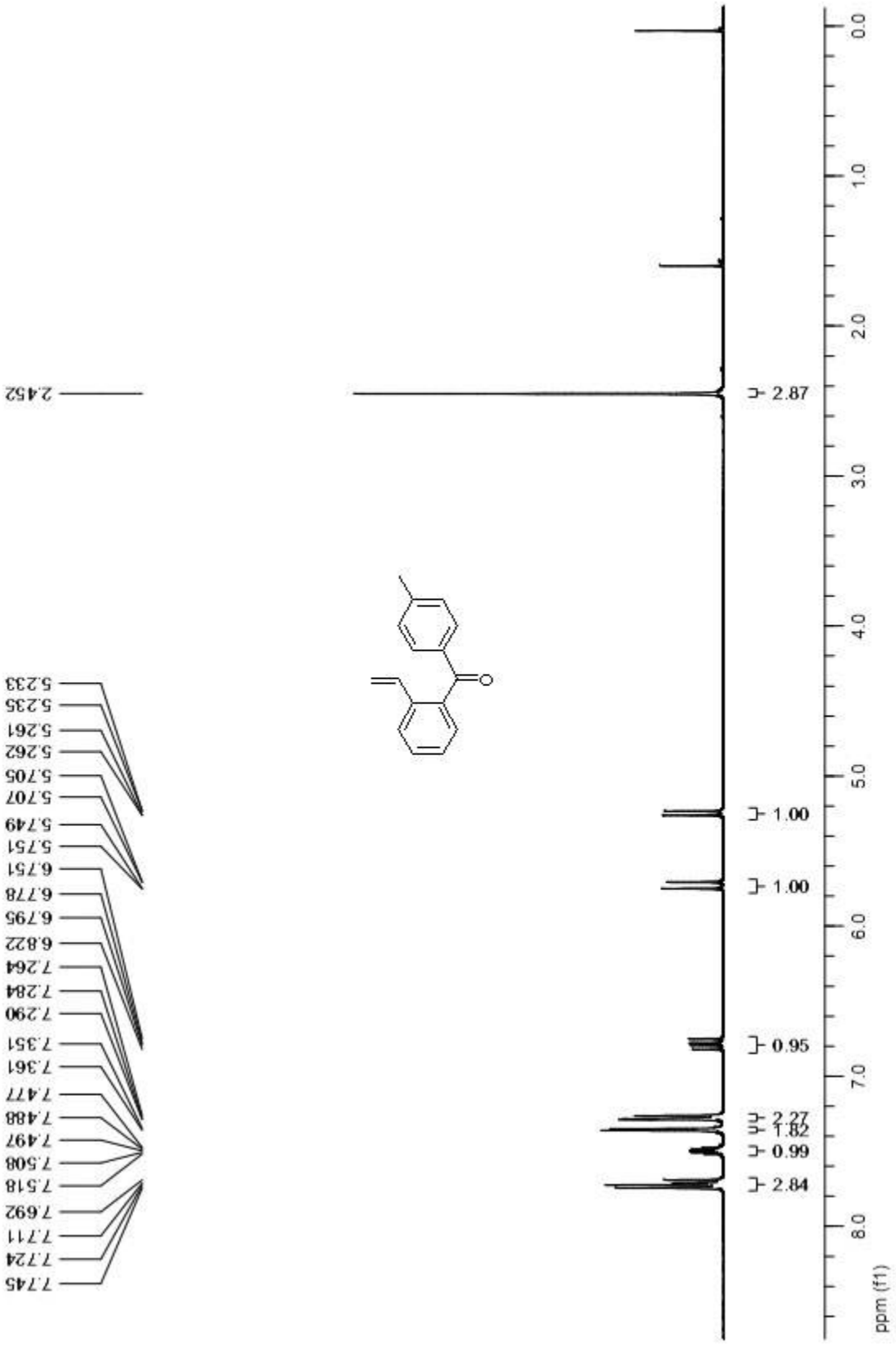

O
O
50.783
51.611
124.926
127.035
128.239
128.528
128.798
129.410
130.257
131.342
133.282
137.616
137.701
138.221
197.343
0
50
100
150
200
ppm (f1)

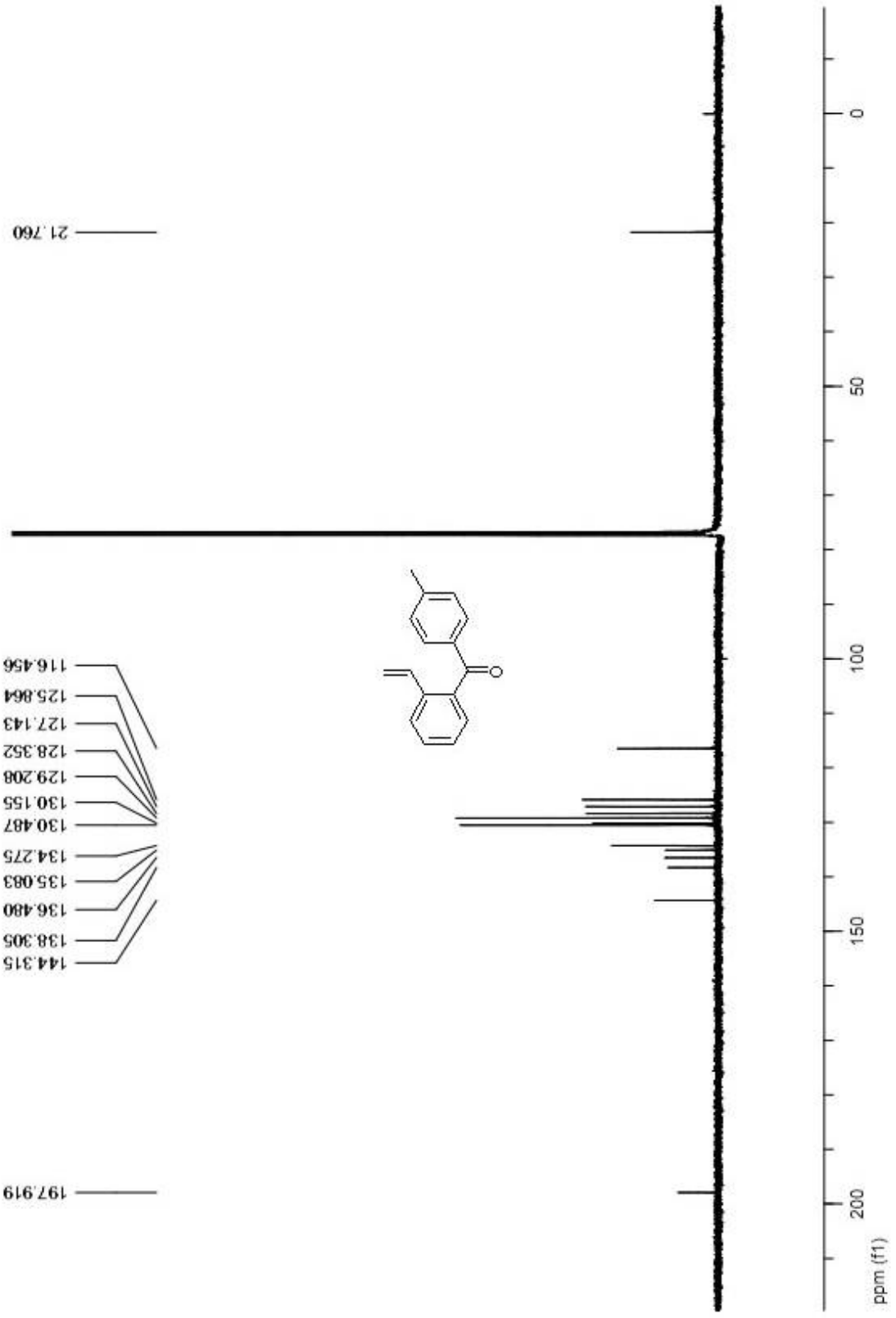

OH
O
3.854
5.206
7.175
7.184
7.189
7.196
7.216
7.237
7.243
7.250
7.315
7.334
7.378
7.397
7.415
7.525
7.543
7.562
7.661
7.681
2.07
0.96
5.37
1.26
1.13
1.08
1.06
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

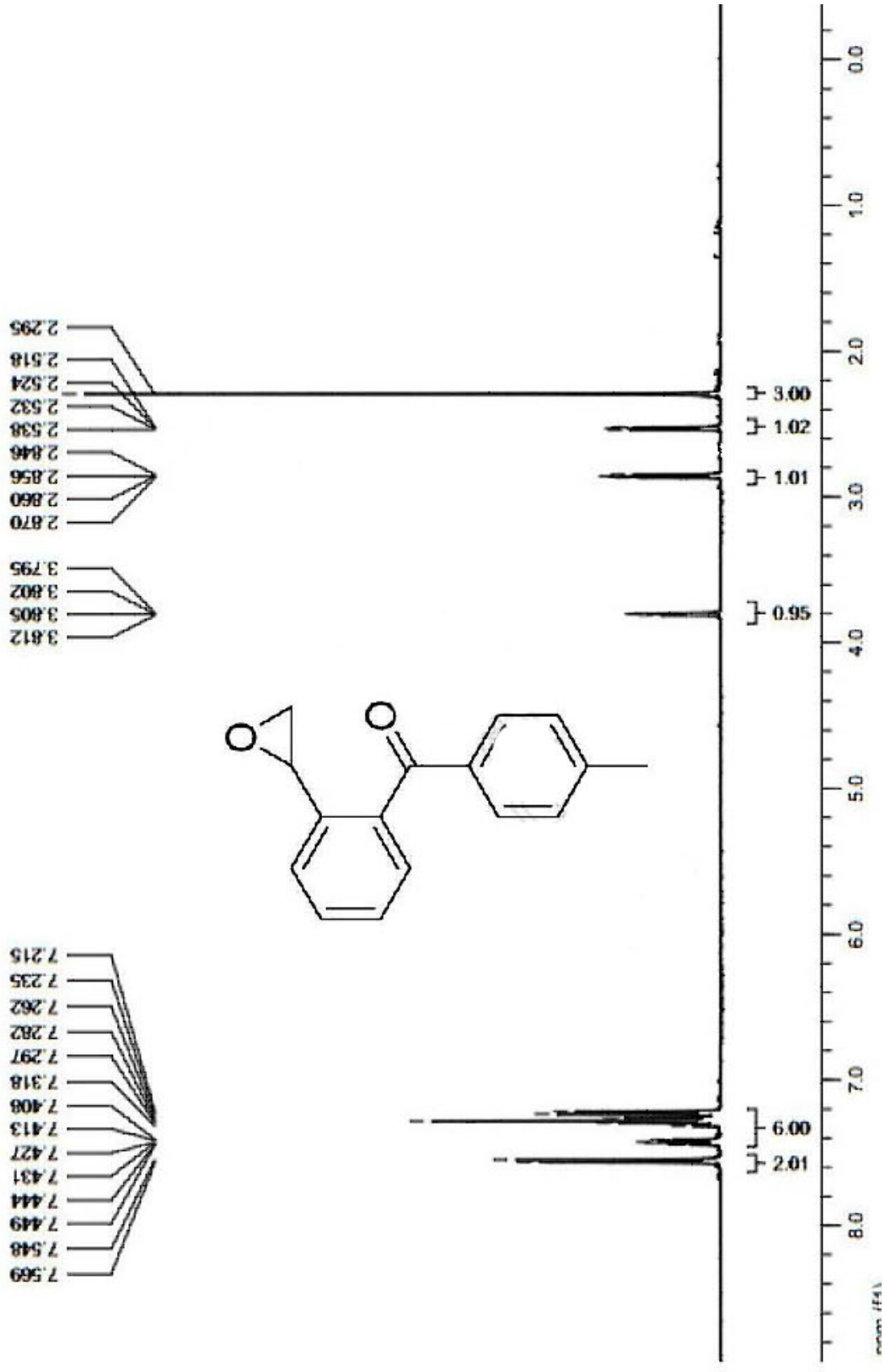

OH
O
56.141
78.449
123.162
125.097
125.300
127.416
128.529
129.507
135.796
135.889
145.350
203.742
0
50
100
150
200
ppm (t1)

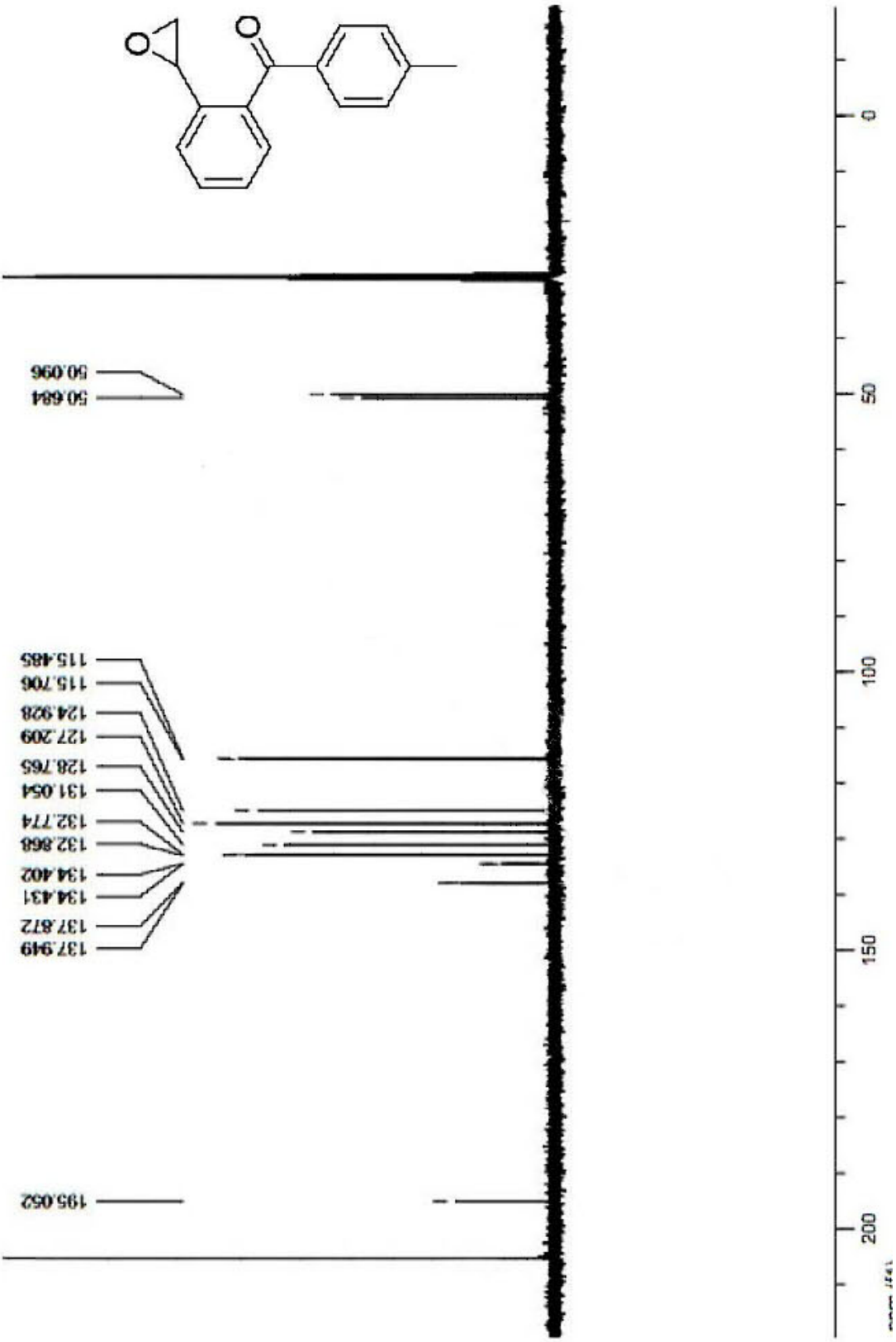

2.213
2.223
2.368
5.287
5.290
5.314
5.317
5.613
5.616
5.656
5.659
6.115
6.124
6.986
7.014
7.029
7.057
7.161
7.181
7.244
7.264
7.314
7.318
7.322
7.329
7.336
7.341
7.345
7.507
7.514
7.524
7.530
OH
0.96
3.02
1.05
1.05
1.01
1.05
2.03
2.01
1.86
2.03
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (f1)

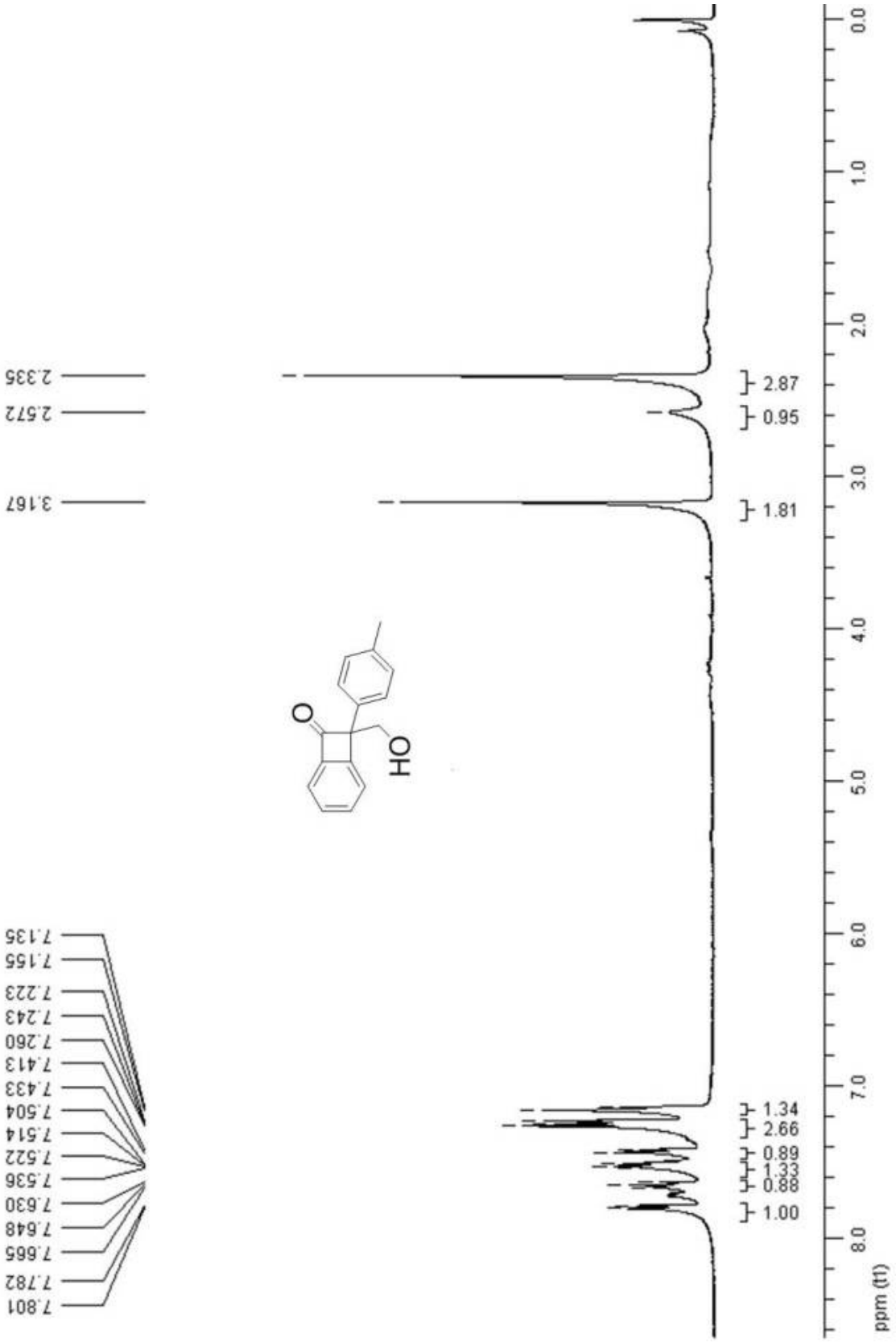

21.164
72.890
OH
116.622
126.329
126.712
126.887
127.799
127.982
129.194
134.353
136.231
137.275
140.124
140.515
0
50
100
150
ppm (f1)

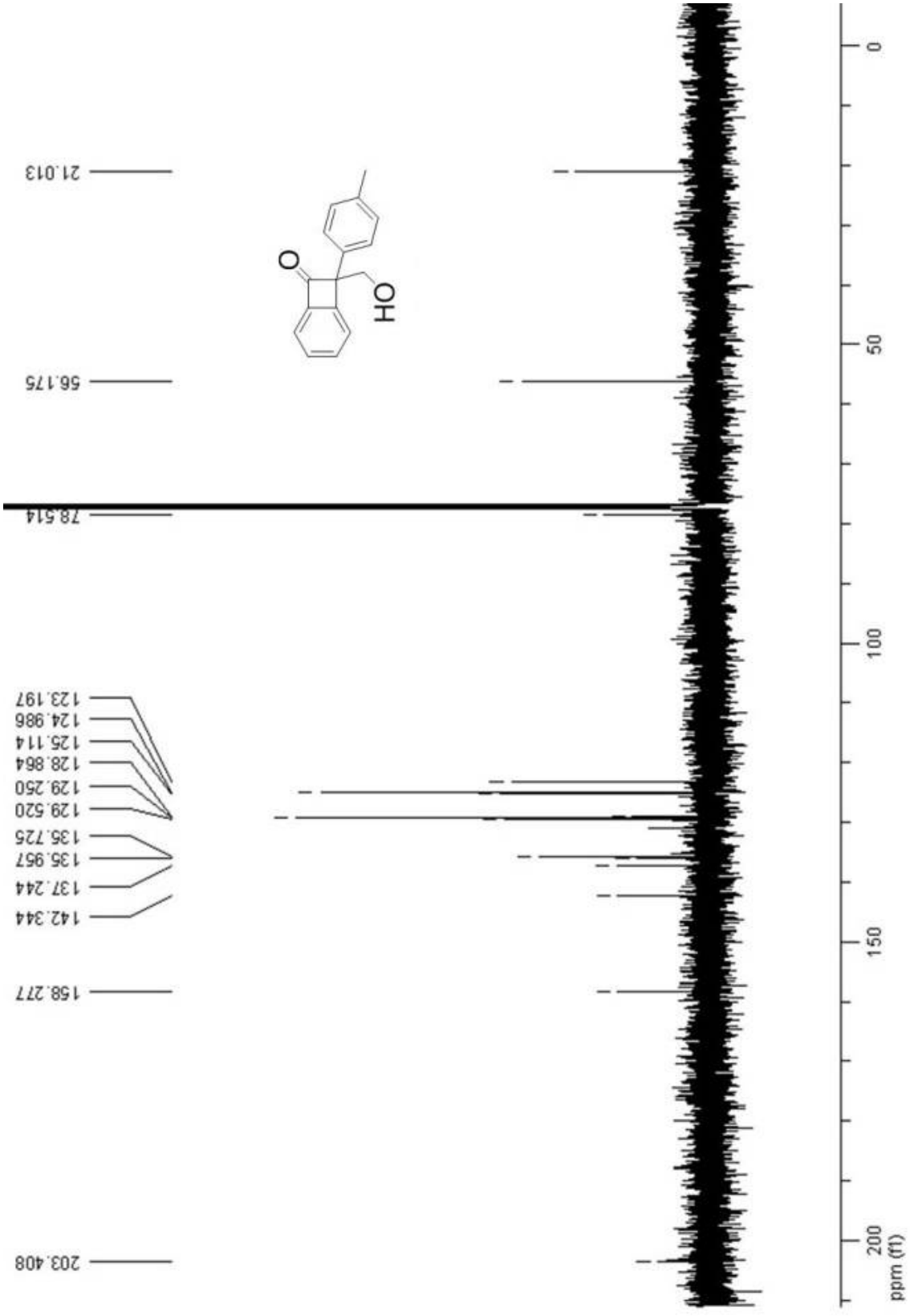

2.452
5.233
5.235
5.261
5.262
5.705
5.707
5.749
5.751
6.751
6.778
6.795
6.822
7.264
7.284
7.290
7.351
7.361
7.477
7.488
7.497
7.508
7.518
7.692
7.711
7.724
7.745
2.87
1.00
1.00
0.95
2.27
1.82
0.99
2.84
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (f1)

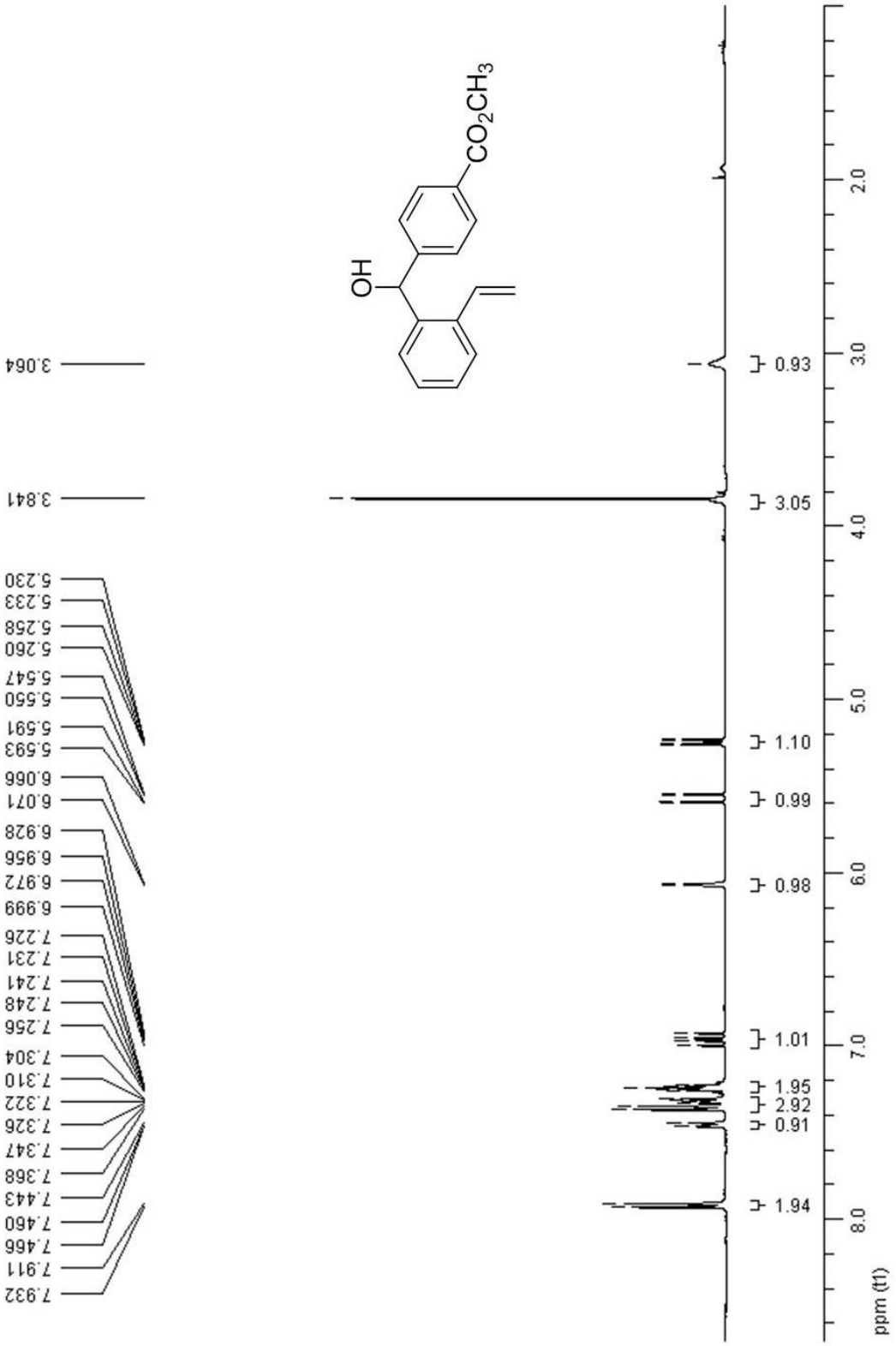

21.760
116.456
125.864
127.143
128.352
129.208
130.155
130.487
134.275
135.083
136.480
138.305
144.315
197.919
0
50
100
150
200
ppm (f1)

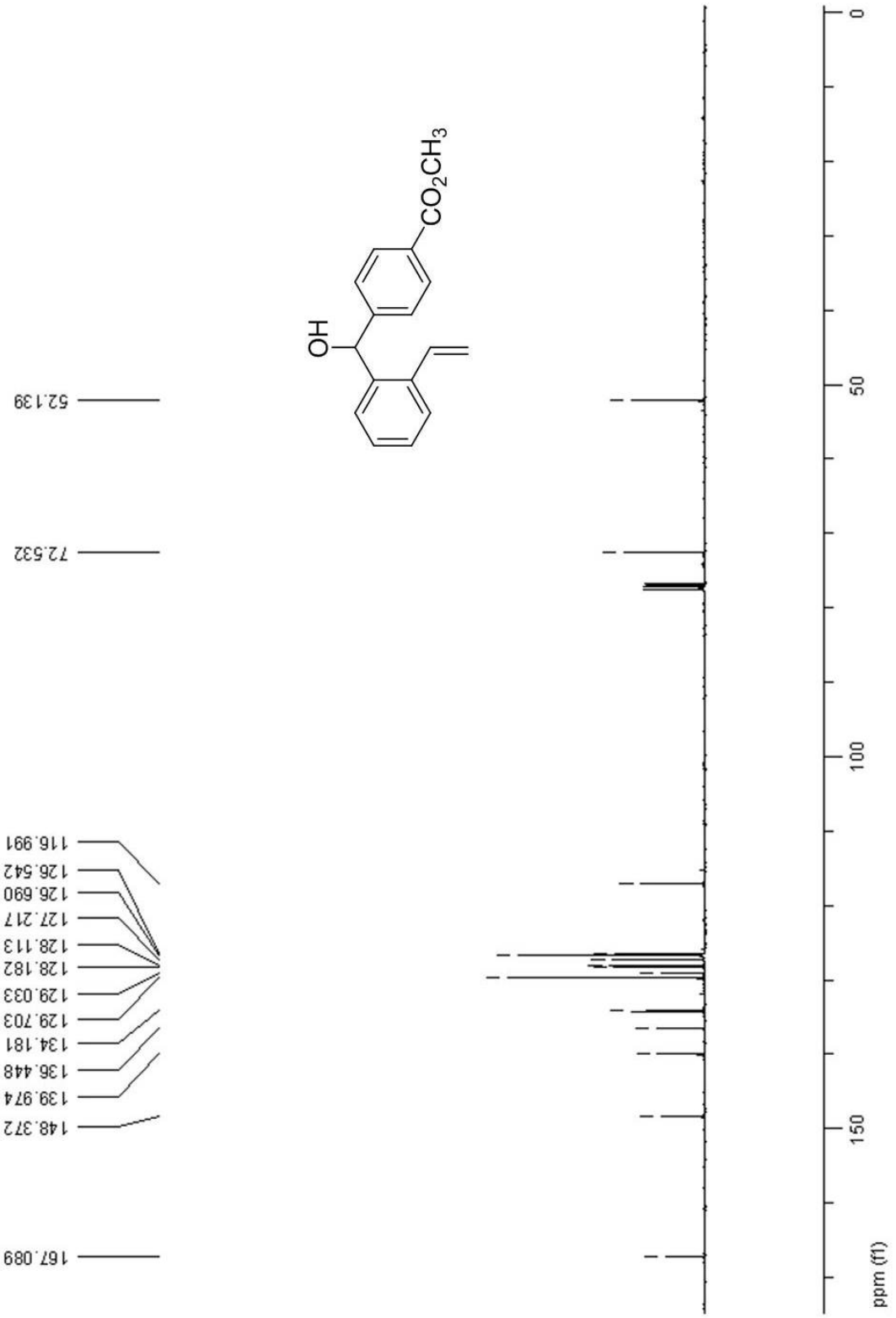

2.295
2.518
2.524
2.532
2.538
2.846
2.856
2.860
2.870
3.795
3.802
3.805
3.812
7.215
7.235
7.262
7.282
7.297
7.318
7.408
7.413
7.427
7.431
7.444
7.449
7.548
7.569
3.00
1.02
1.01
0.95
6.00
2.01
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

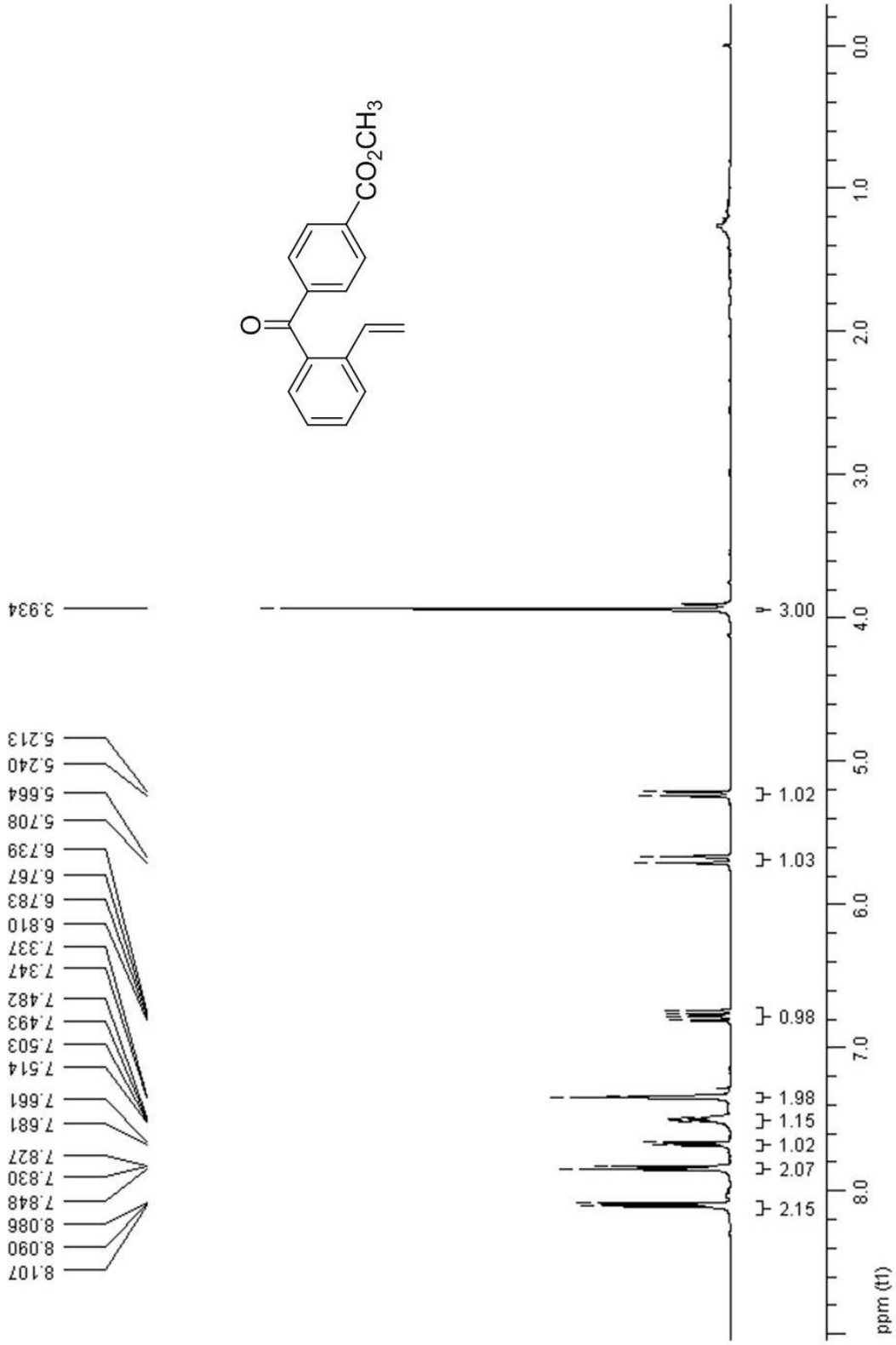

50.684
50.096
115.485
115.706
124.928
127.209
128.765
131.054
132.774
132.868
134.402
134.431
137.872
137.949
195.062
0
50
100
150
200

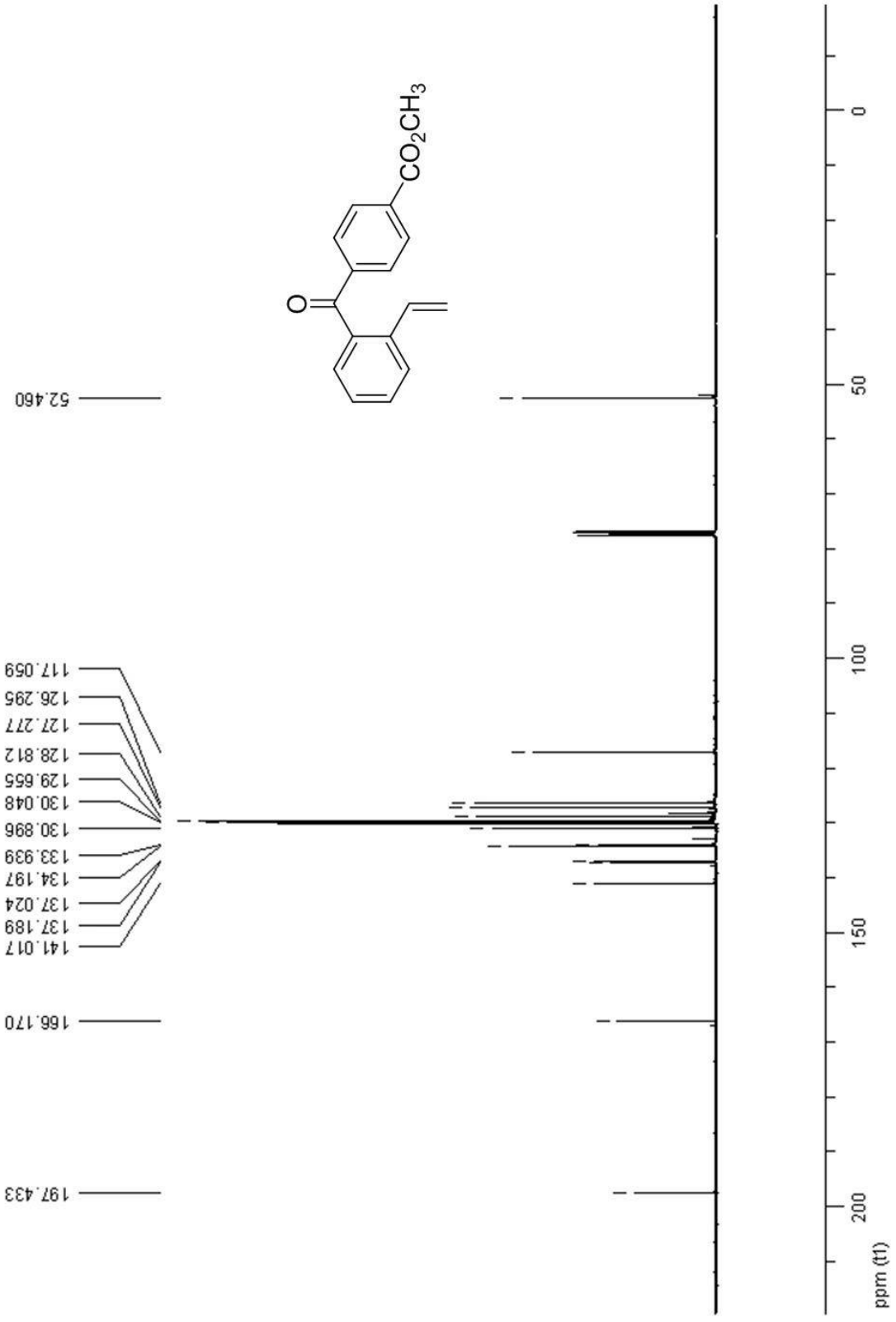

2.335
2.572
3.167
7.135
7.155
7.223
7.243
7.260
7.413
7.433
7.504
7.514
7.522
7.536
7.630
7.648
7.665
7.782
7.801
O
HO
2.87
0.95
1.81
1.34
2.66
0.89
1.33
0.88
1.00
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (f1)

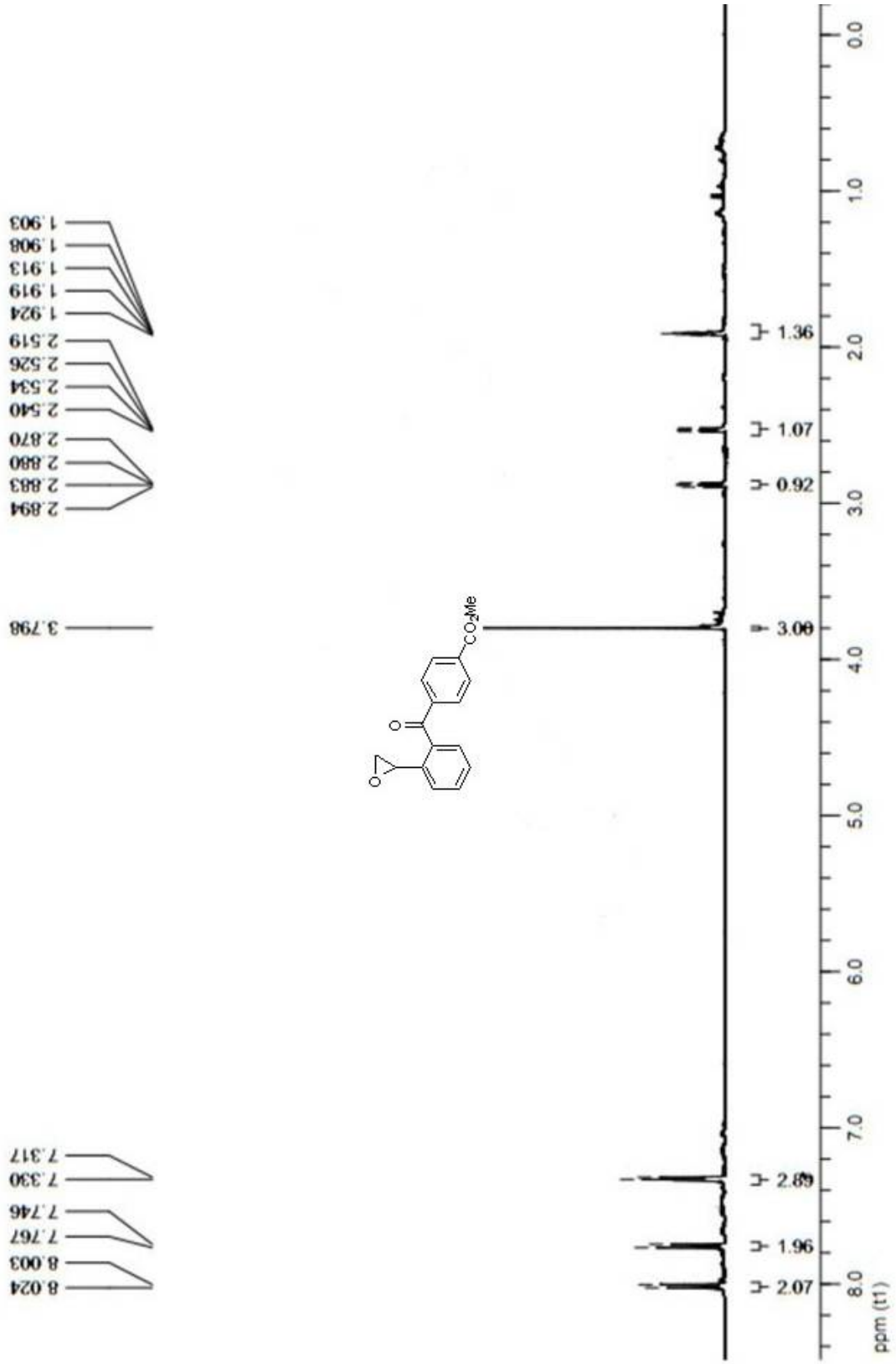

21.013
56.175
78.514
123.197
124.986
125.114
128.864
129.250
129.520
135.725
135.967
137.244
142.344
158.277
203.408
O
OH
0
50
100
150
200
ppm (f1)

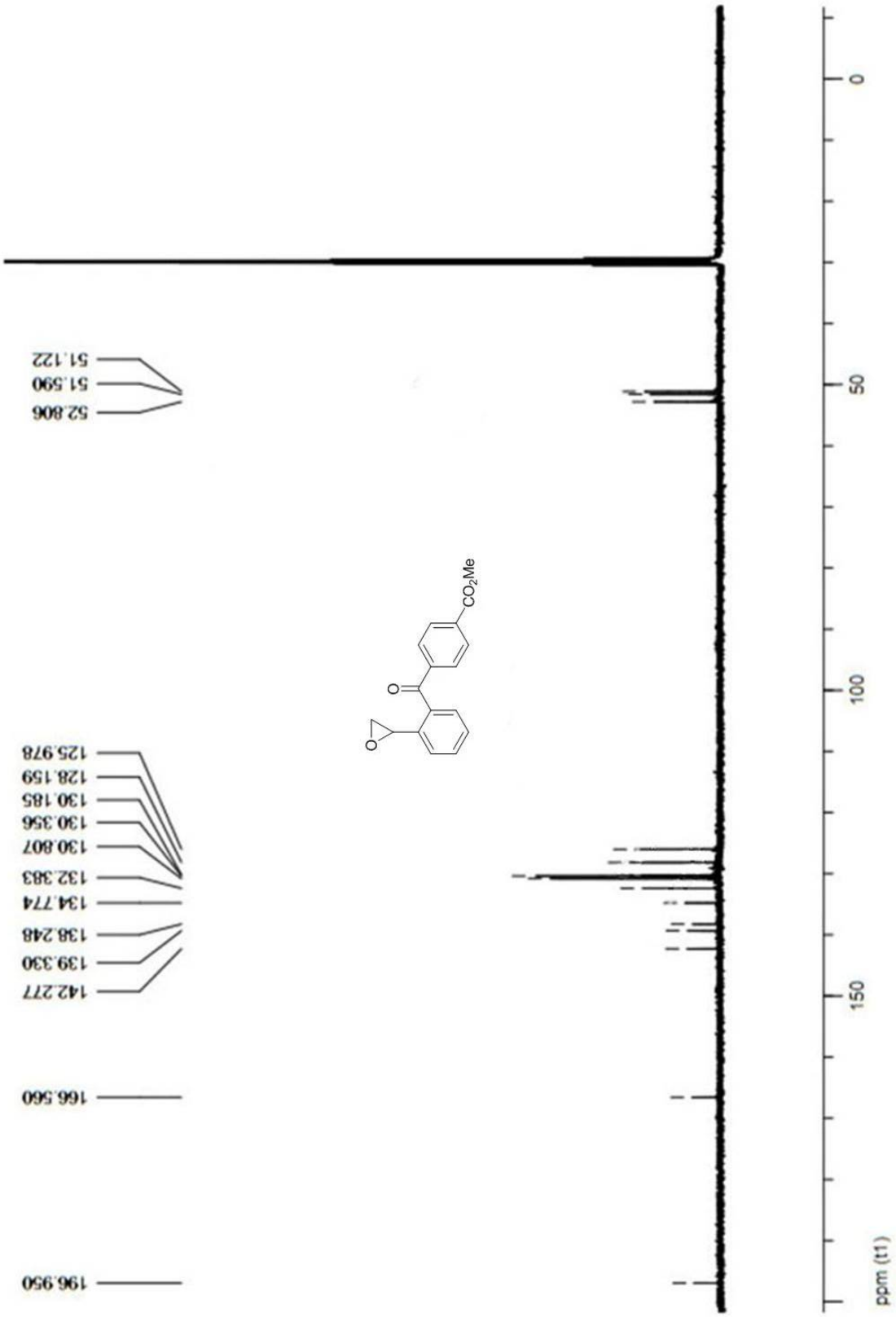

OH
CO_2CH_3
3.064
3.841
5.230
5.233
5.258
5.260
5.547
5.550
5.591
5.593
6.066
6.071
6.928
6.956
6.972
6.999
7.226
7.231
7.241
7.248
7.256
7.304
7.310
7.322
7.326
7.347
7.368
7.443
7.460
7.466
7.911
7.932
0.93
3.05
1.10
0.99
0.98
1.01
1.95
2.92
0.91
1.94
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

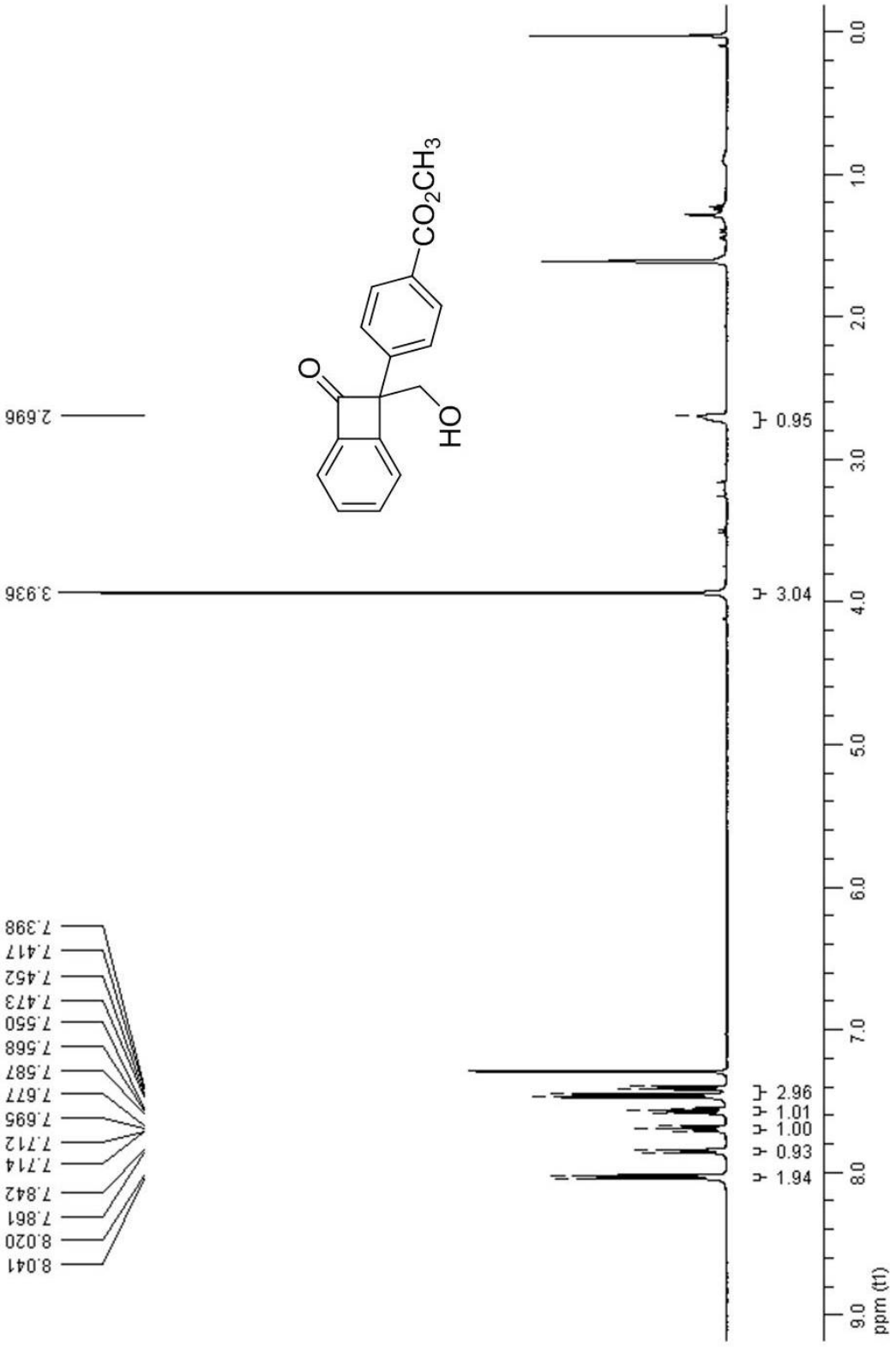

OH
CO_2CH_3
52.139
72.532
116.991
126.542
126.690
127.217
128.113
128.182
129.033
129.703
134.181
136.448
139.974
148.372
167.089
0
50
100
150
ppm (f1)

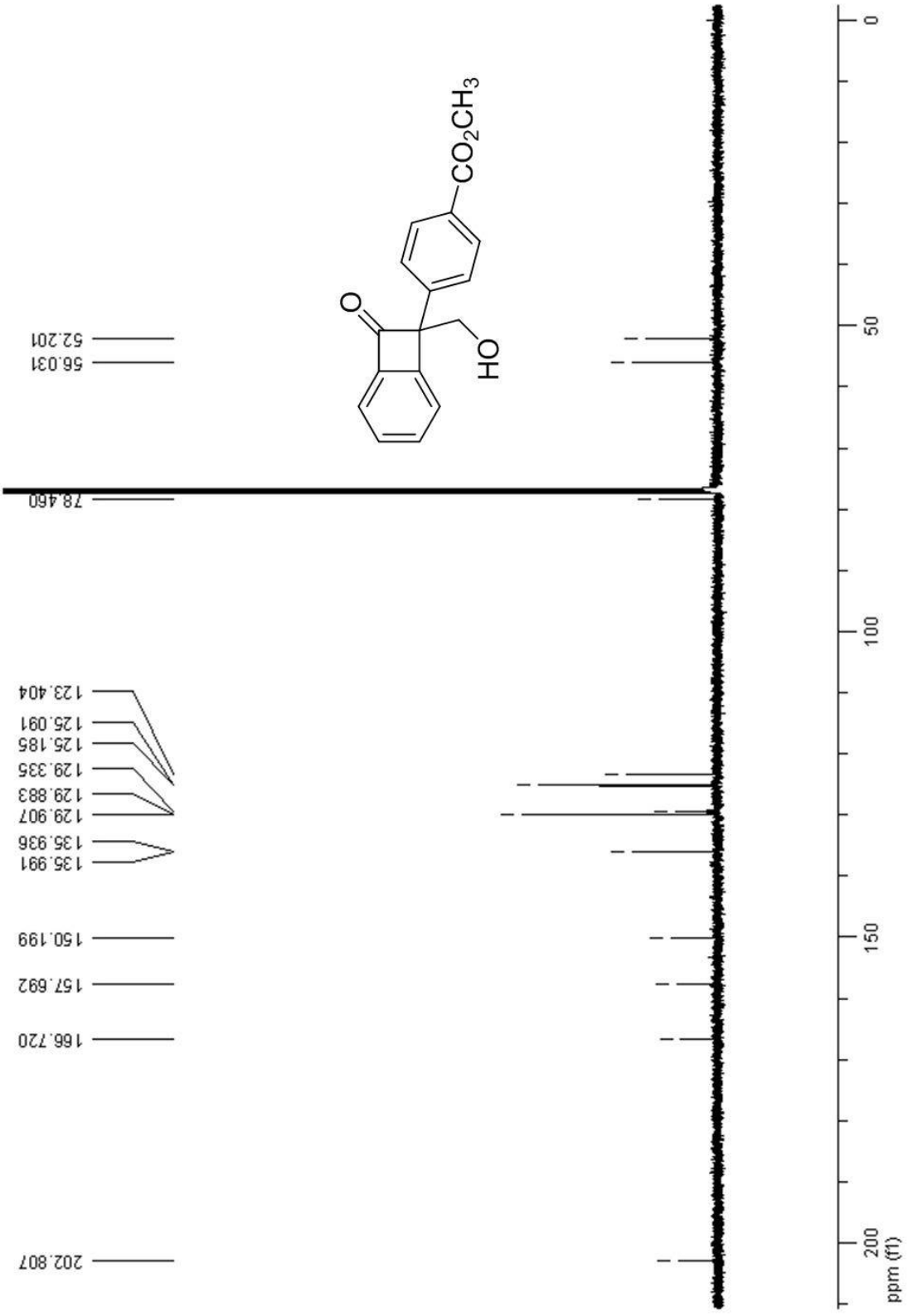

CO2CH3
O
3.934
5.213
5.240
5.664
5.708
6.739
6.767
6.783
6.810
7.337
7.347
7.482
7.493
7.503
7.514
7.661
7.681
7.827
7.830
7.848
8.086
8.090
8.107
3.00
1.02
1.03
0.98
1.98
1.15
1.02
2.07
2.15
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

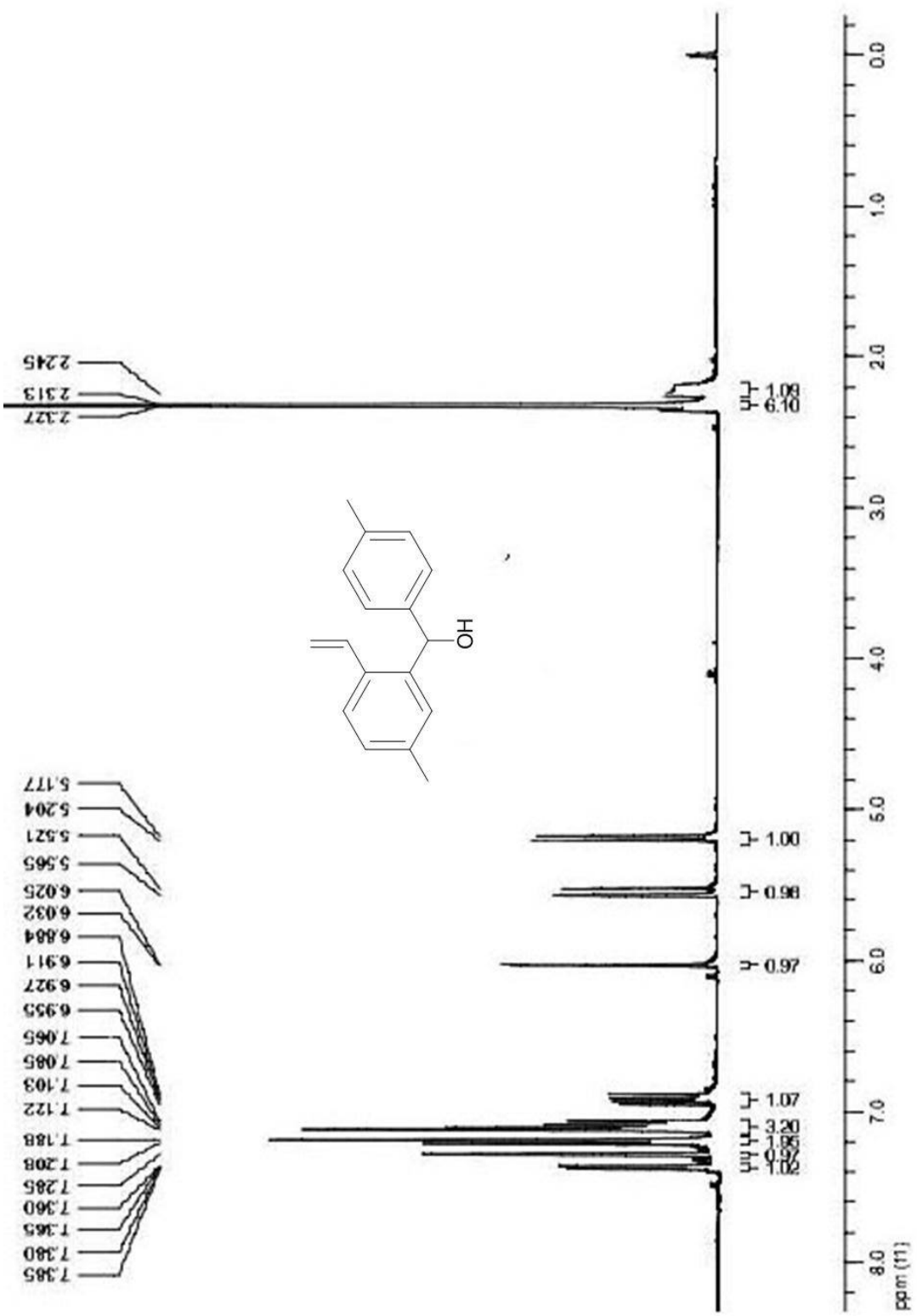

O
CO_2CH_3
52.460
117.059
126.295
127.277
128.812
129.655
130.048
130.896
133.939
134.197
137.024
137.189
141.017
166.170
197.433
0
50
100
150
200
ppm (t1)

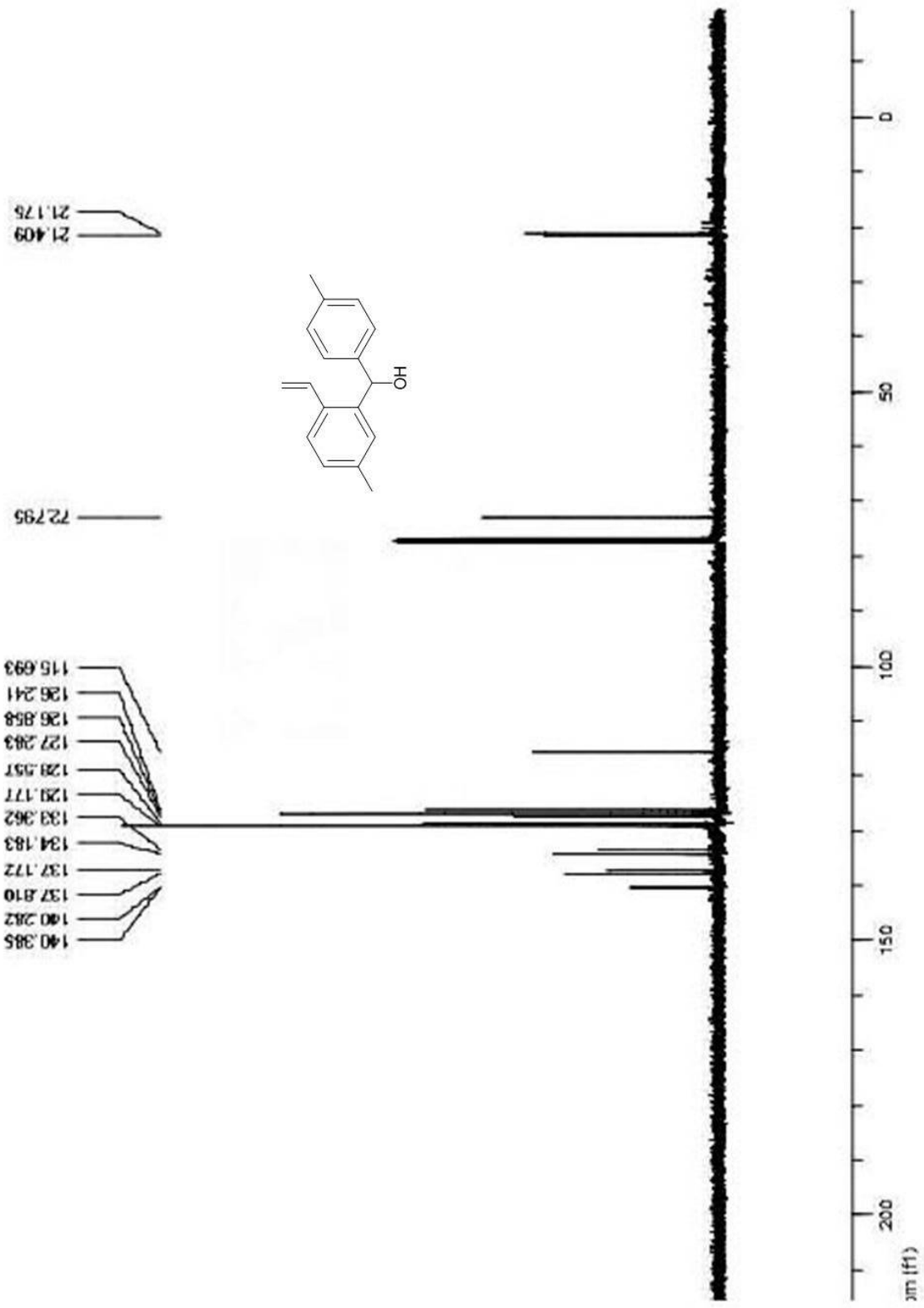

1.903
1.908
1.913
1.919
1.924
2.519
2.526
2.534
2.540
2.870
2.880
2.883
2.894
3.798
7.317
7.330
7.746
7.767
8.003
8.024
CO2Me
1.36
1.07
0.92
3.00
2.89
1.96
2.07
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

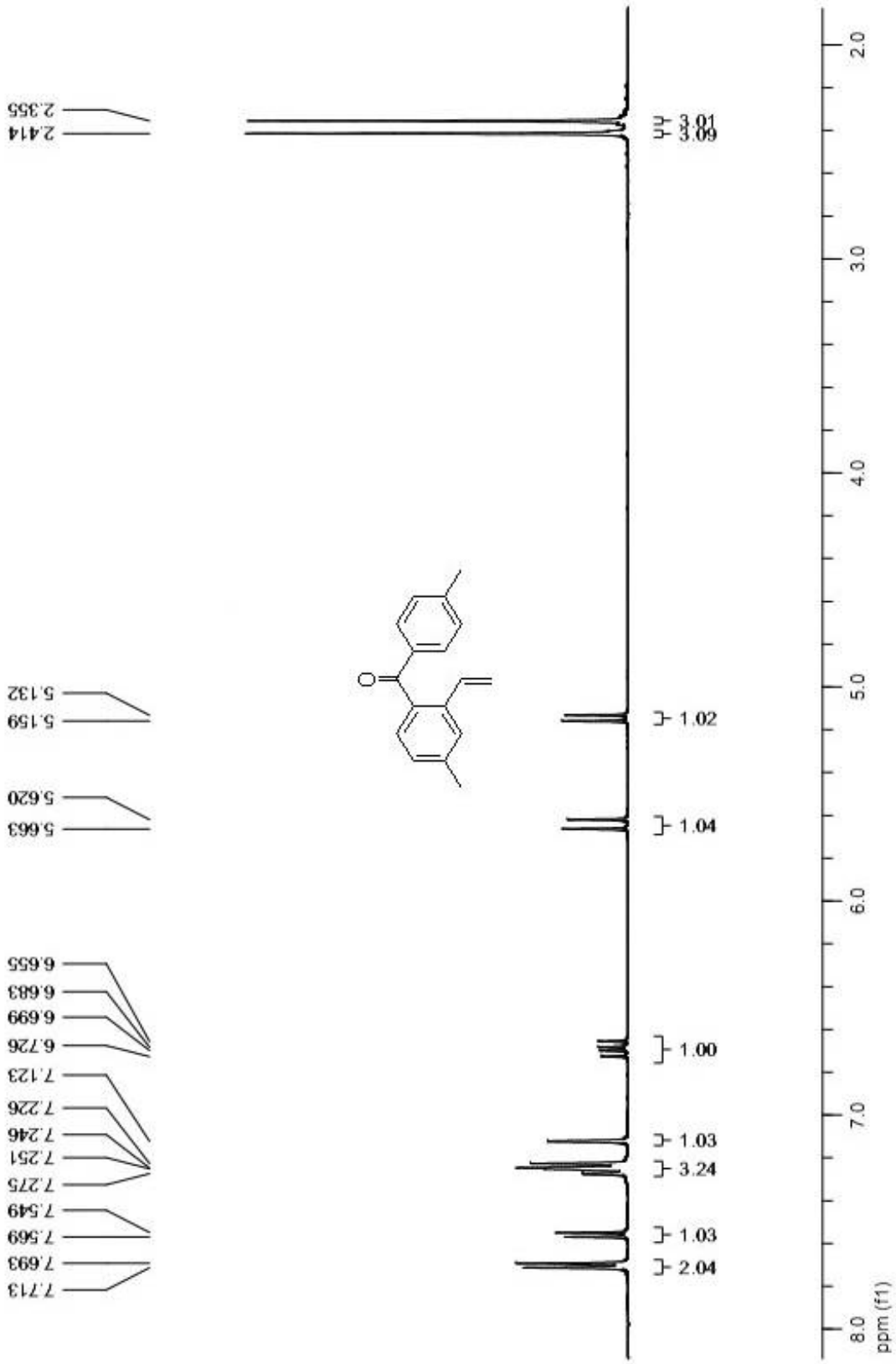

51.122
51.590
52.806
125.978
128.159
130.185
130.356
130.807
132.383
134.774
138.248
139.330
142.277
166.560
196.950
CO2Me
O
O
0
50
100
150
ppm (t1)

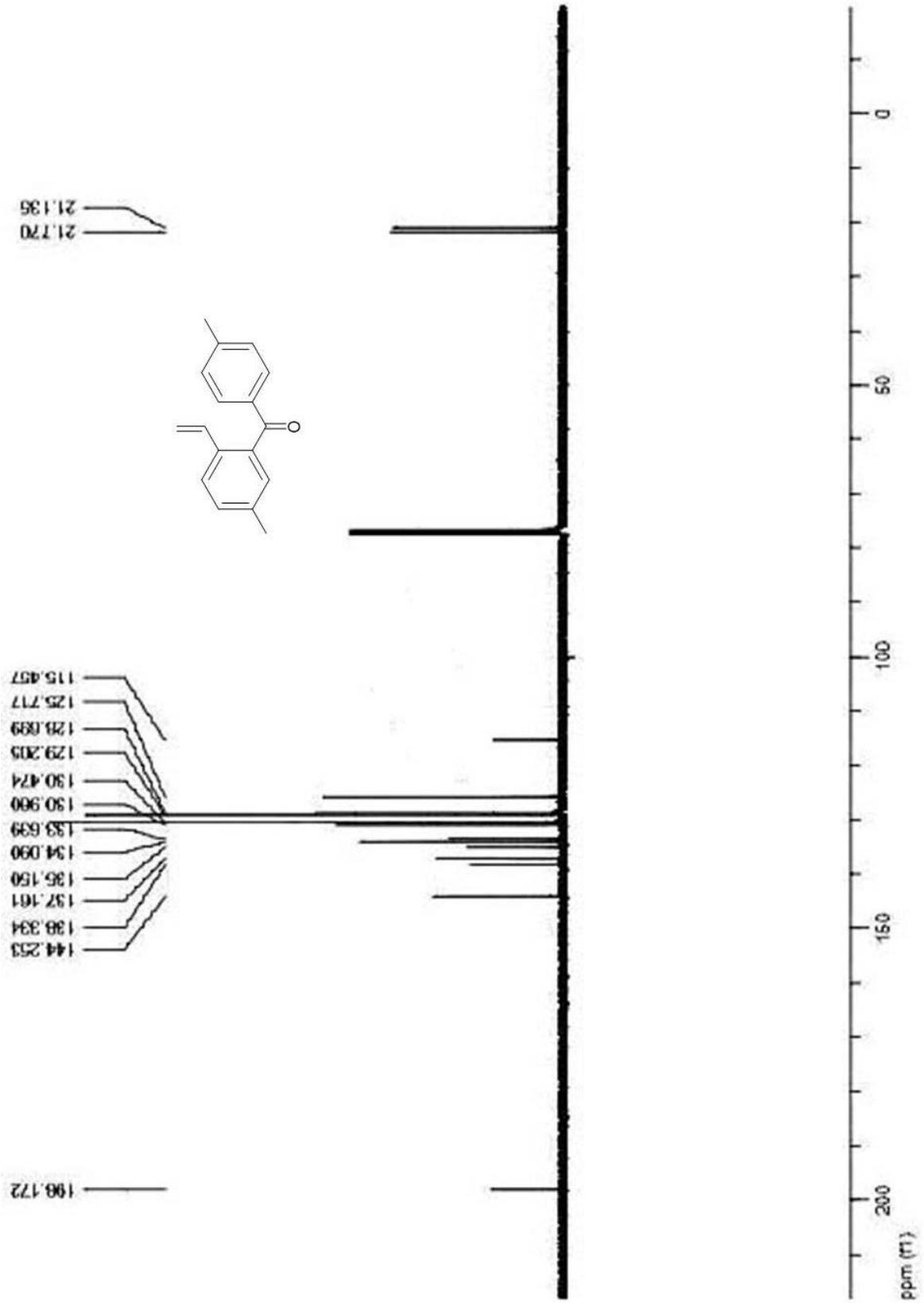

2.696
3.936
7.398
7.417
7.452
7.473
7.550
7.568
7.587
7.677
7.695
7.712
7.714
7.842
7.861
8.020
8.041
0.95
3.04
2.96
1.01
1.00
0.93
1.94
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (f1)
O
HO
CO2CH3

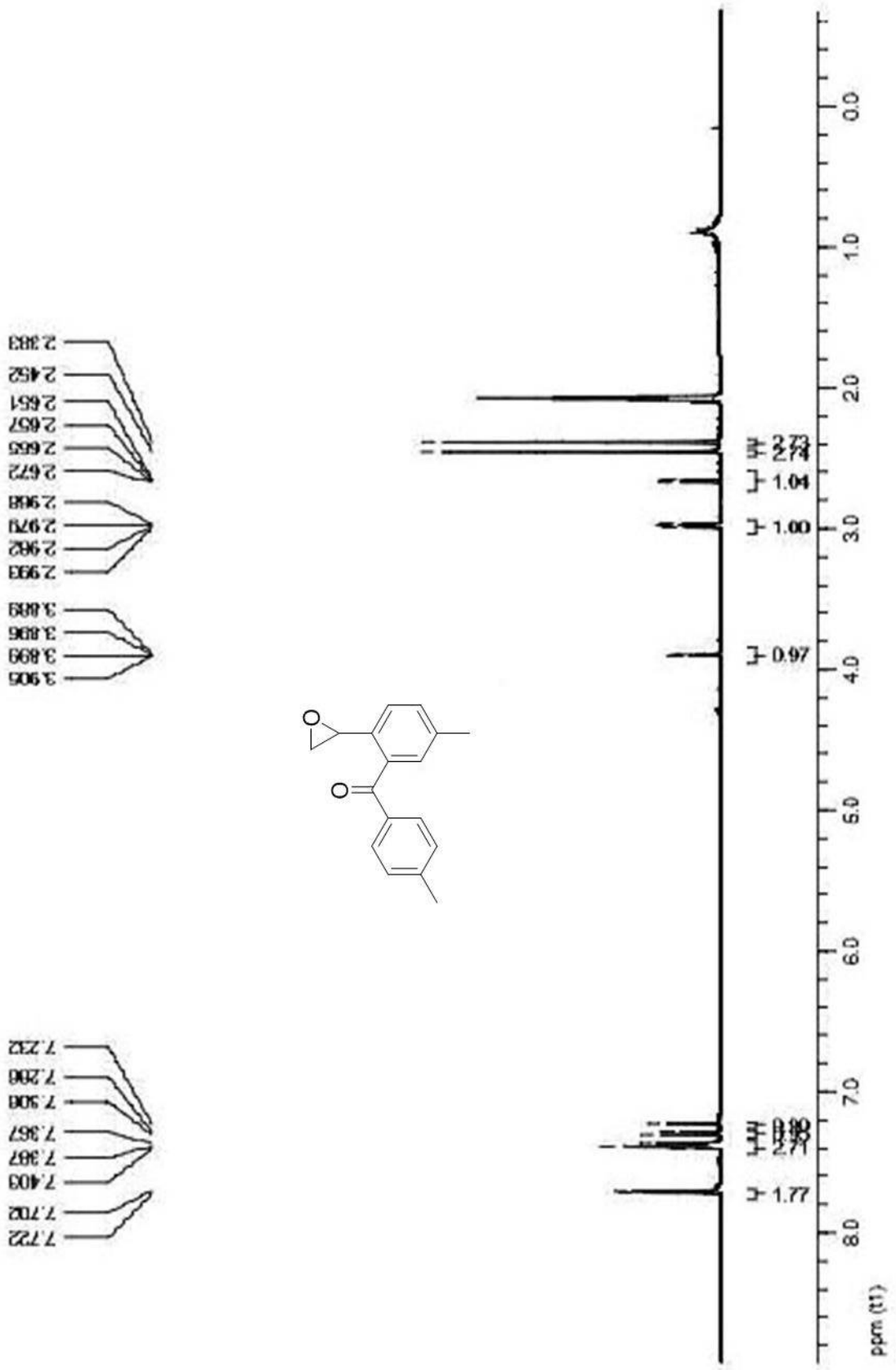

52.201
56.031
78.460
123.404
125.091
125.185
129.335
129.883
129.907
135.936
135.991
150.199
157.692
166.720
202.807
O
HO
CO_2CH_3
0
50
100
150
200
ppm (f1)

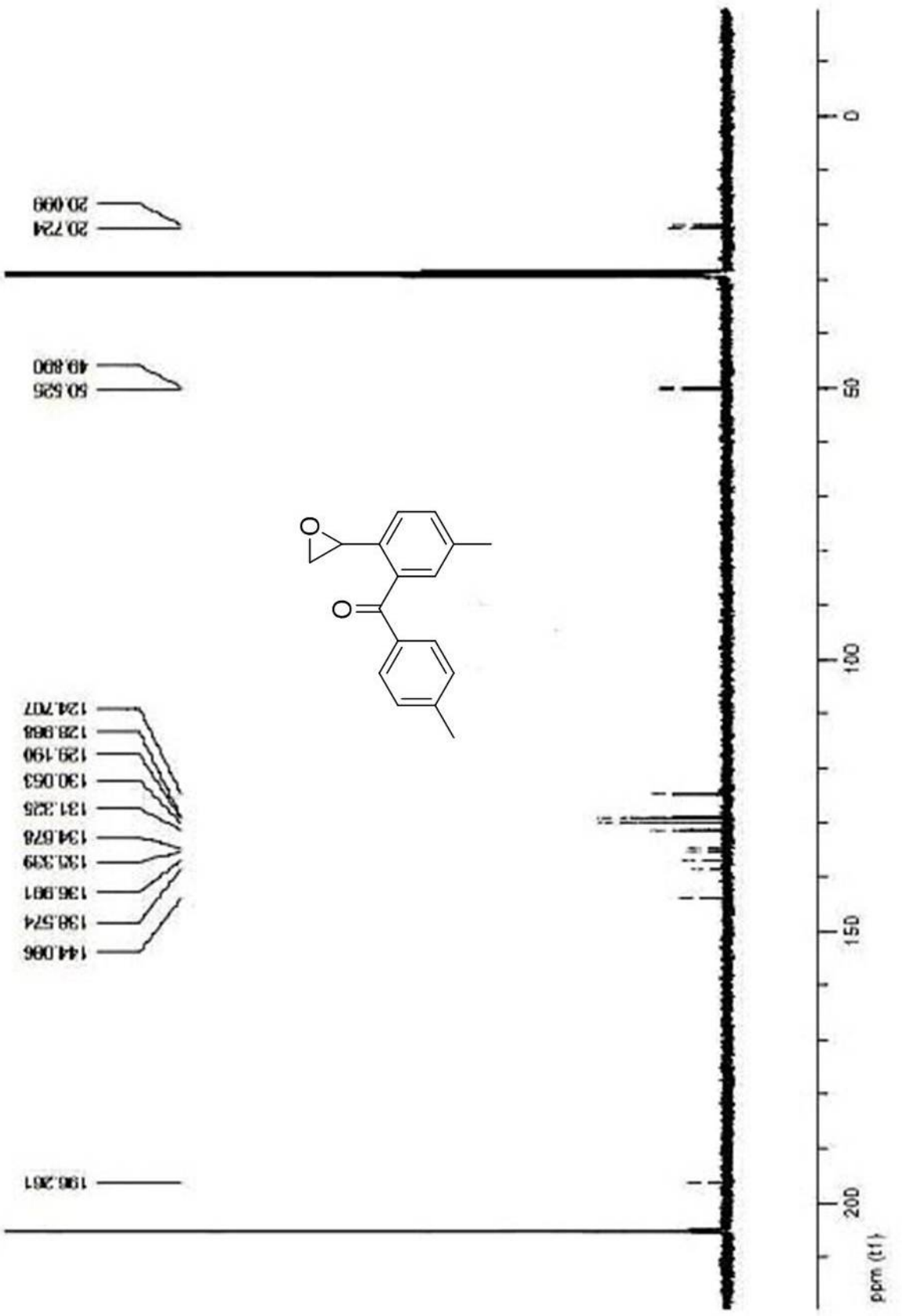

2.245
2.313
2.327
5.177
5.204
5.521
5.565
6.025
6.032
6.864
6.911
6.927
6.955
7.065
7.085
7.103
7.122
7.188
7.208
7.285
7.360
7.365
7.380
7.385
OH
1.09
6.10
1.00
0.98
0.97
1.07
3.20
1.86
0.97
1.02
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

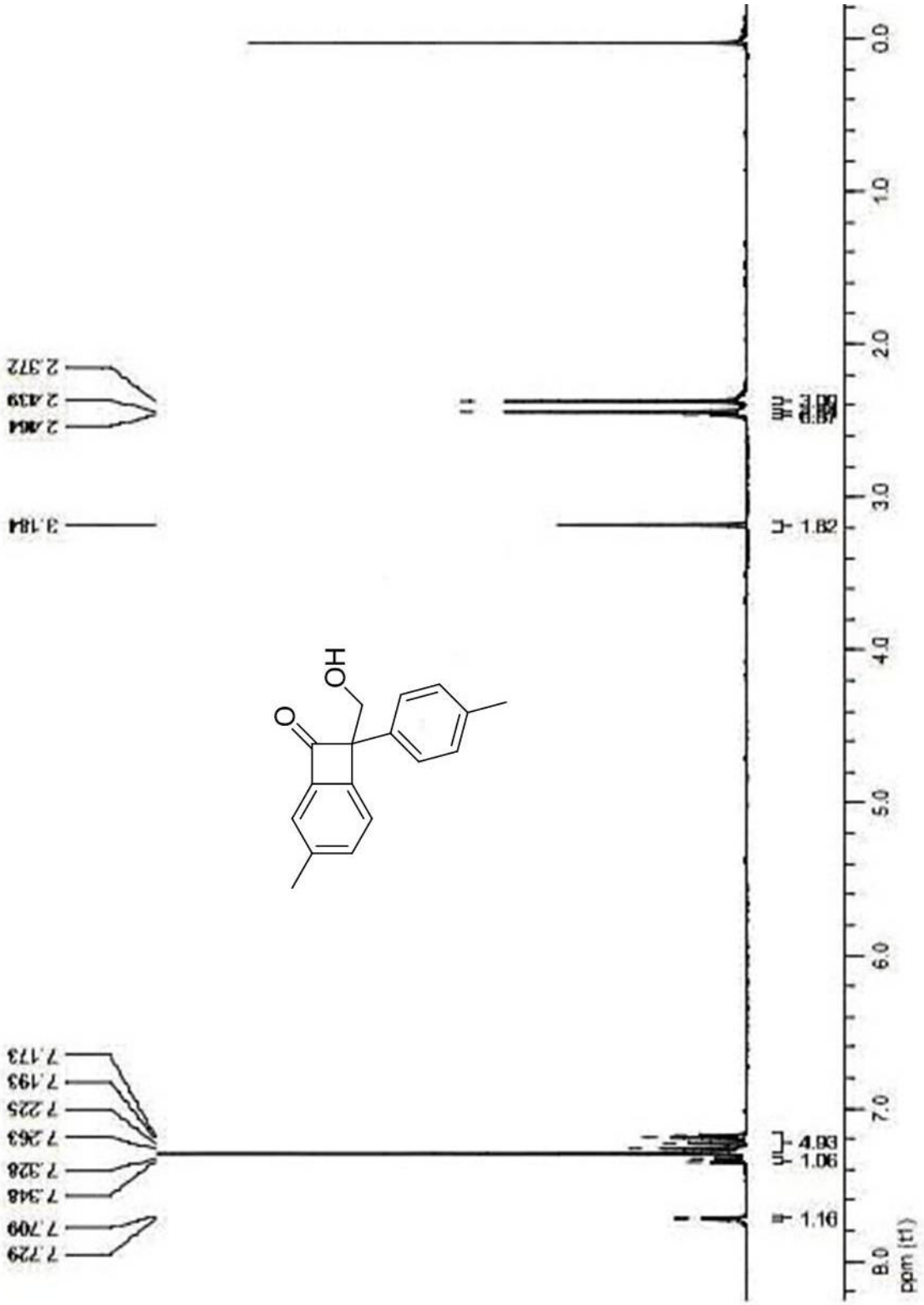

21.176
21.409
72.795
115.693
126.241
126.858
127.283
128.057
129.177
133.362
134.183
137.172
137.810
140.282
140.385
OH
0
50
100
150
200

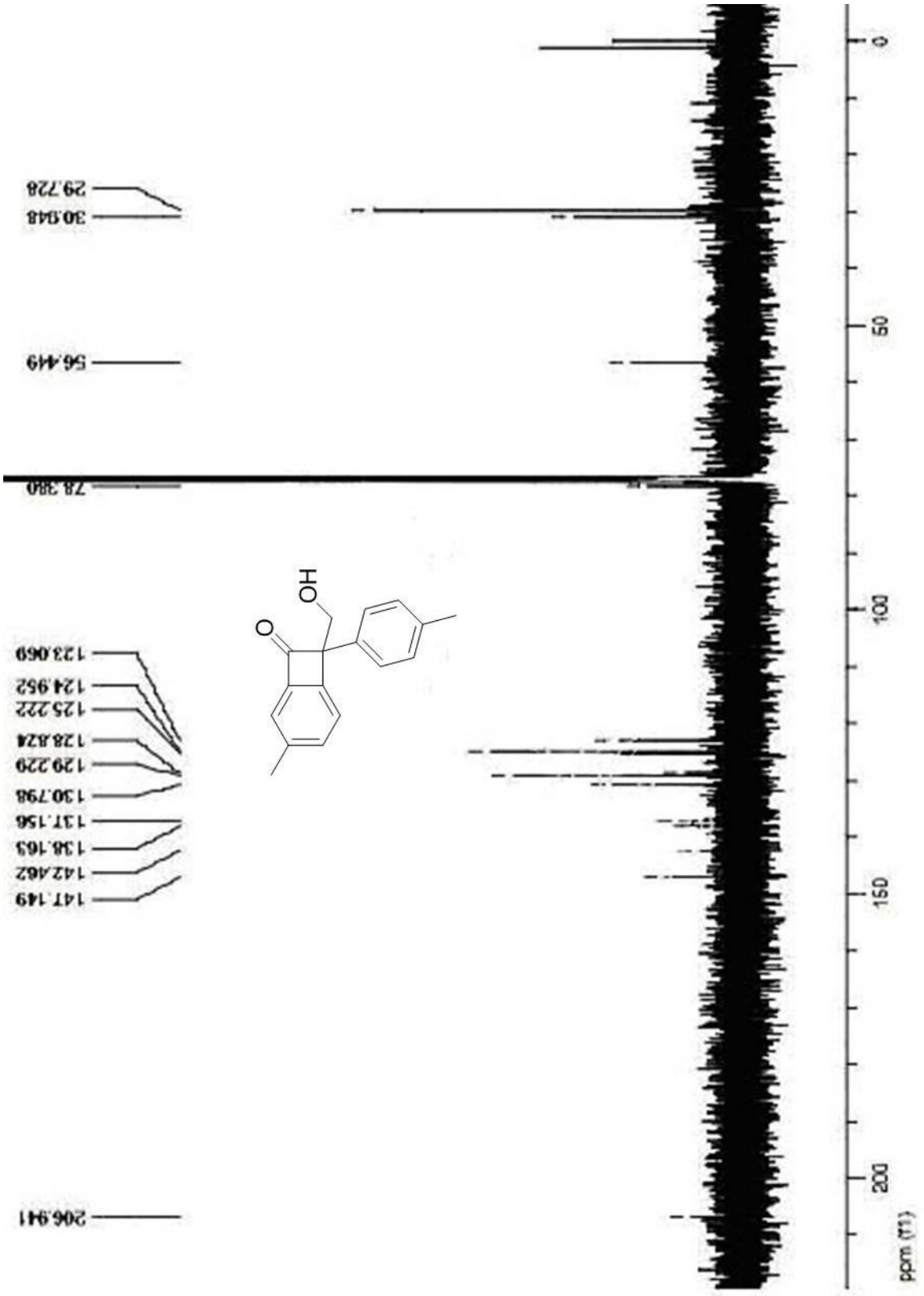

2.355
2.414
5.132
5.159
5.620
5.663
6.655
6.683
6.699
6.726
7.123
7.226
7.246
7.251
7.275
7.549
7.569
7.693
7.713
3.01
3.09
1.02
1.04
1.00
1.03
3.24
1.03
2.04
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (f1)

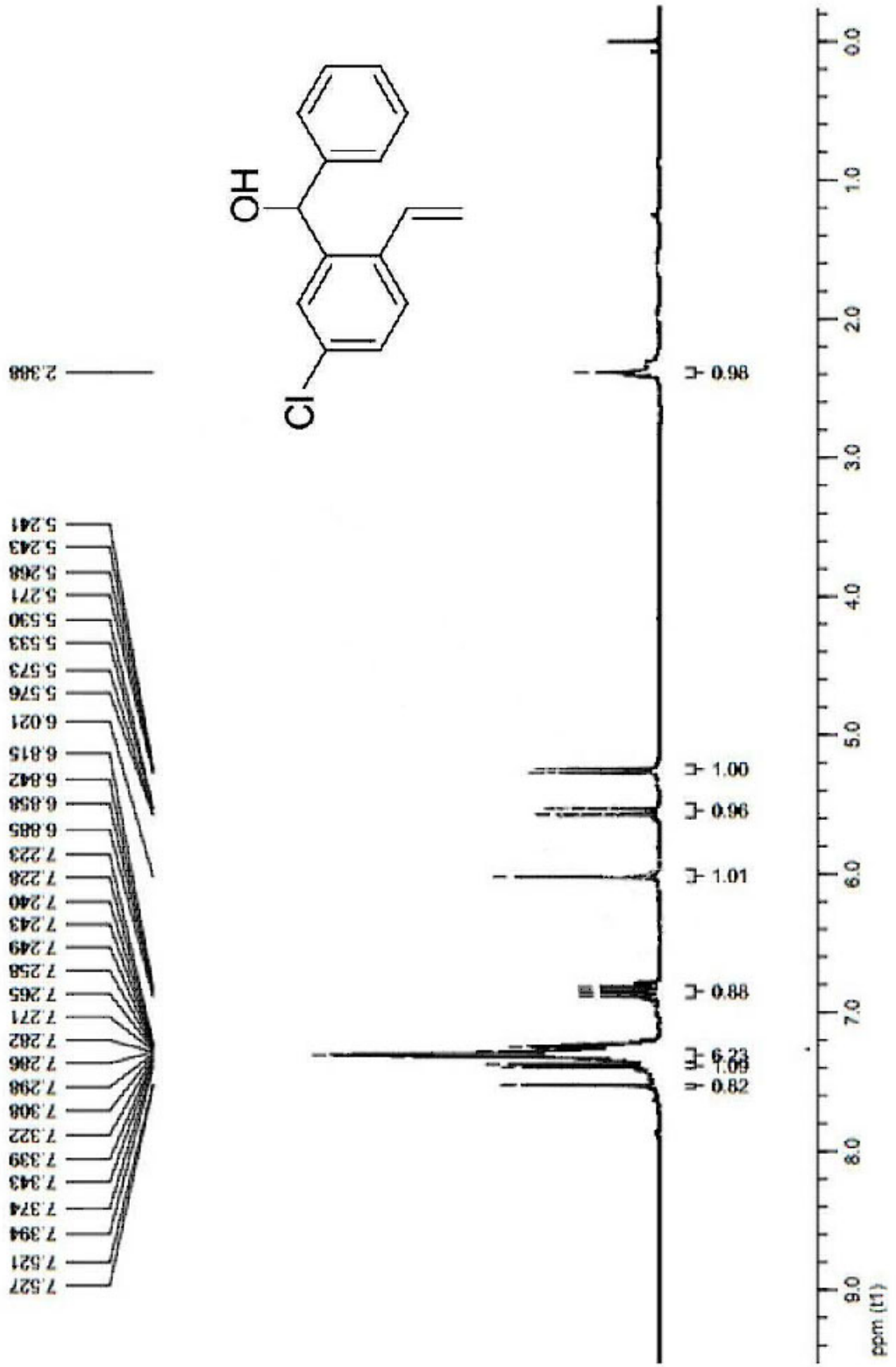

21.136
21.770
115.457
125.717
128.099
129.305
130.474
130.960
133.699
134.090
135.150
137.161
138.334
144.253
198.172
O
0
50
100
150
200
ppm (f1)

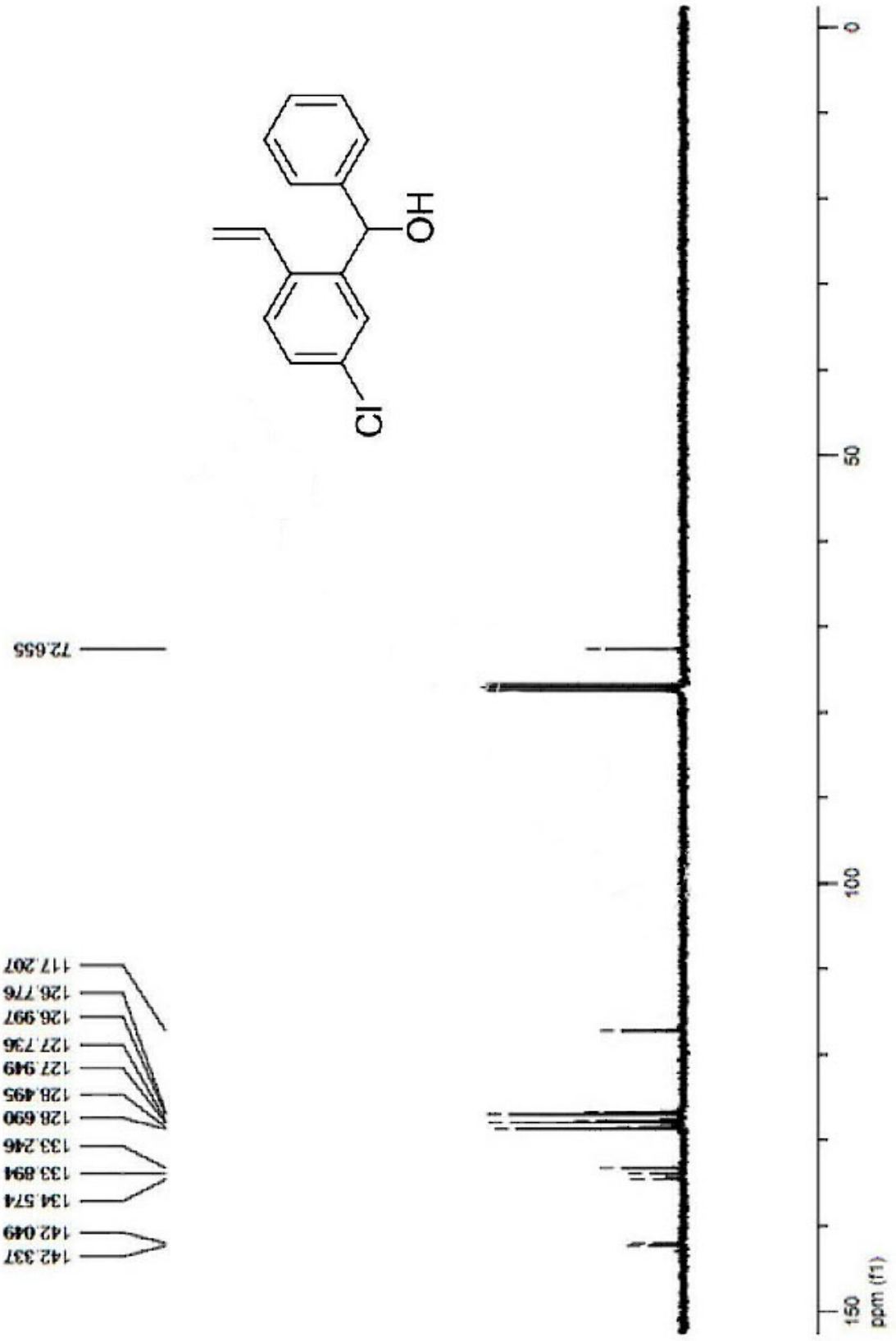


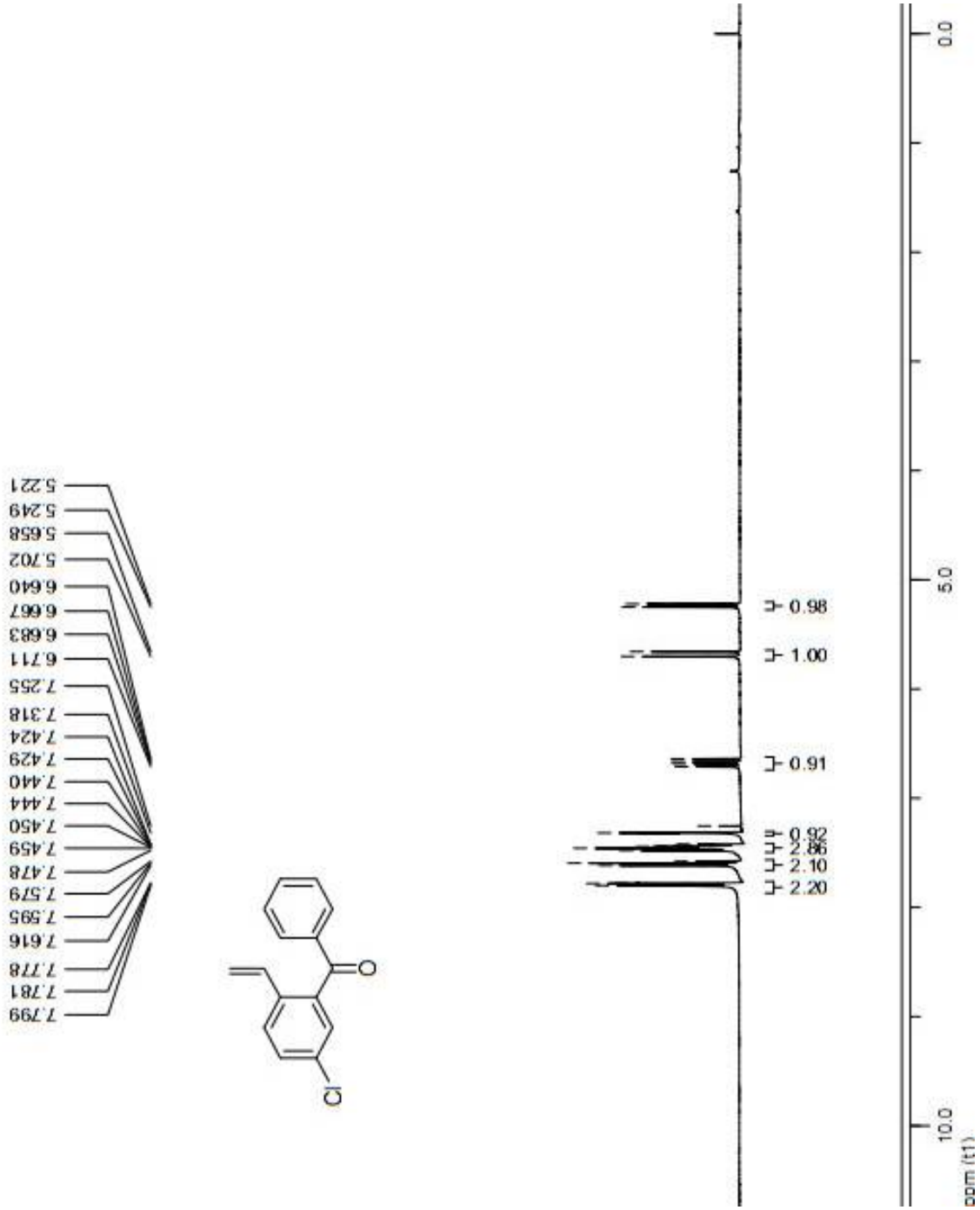

20.099
20.724
49.800
50.525
124.707
128.868
129.190
130.053
131.325
134.678
137.339
138.574
144.086
196.261
0
50
100
150
200
ppm (t1)

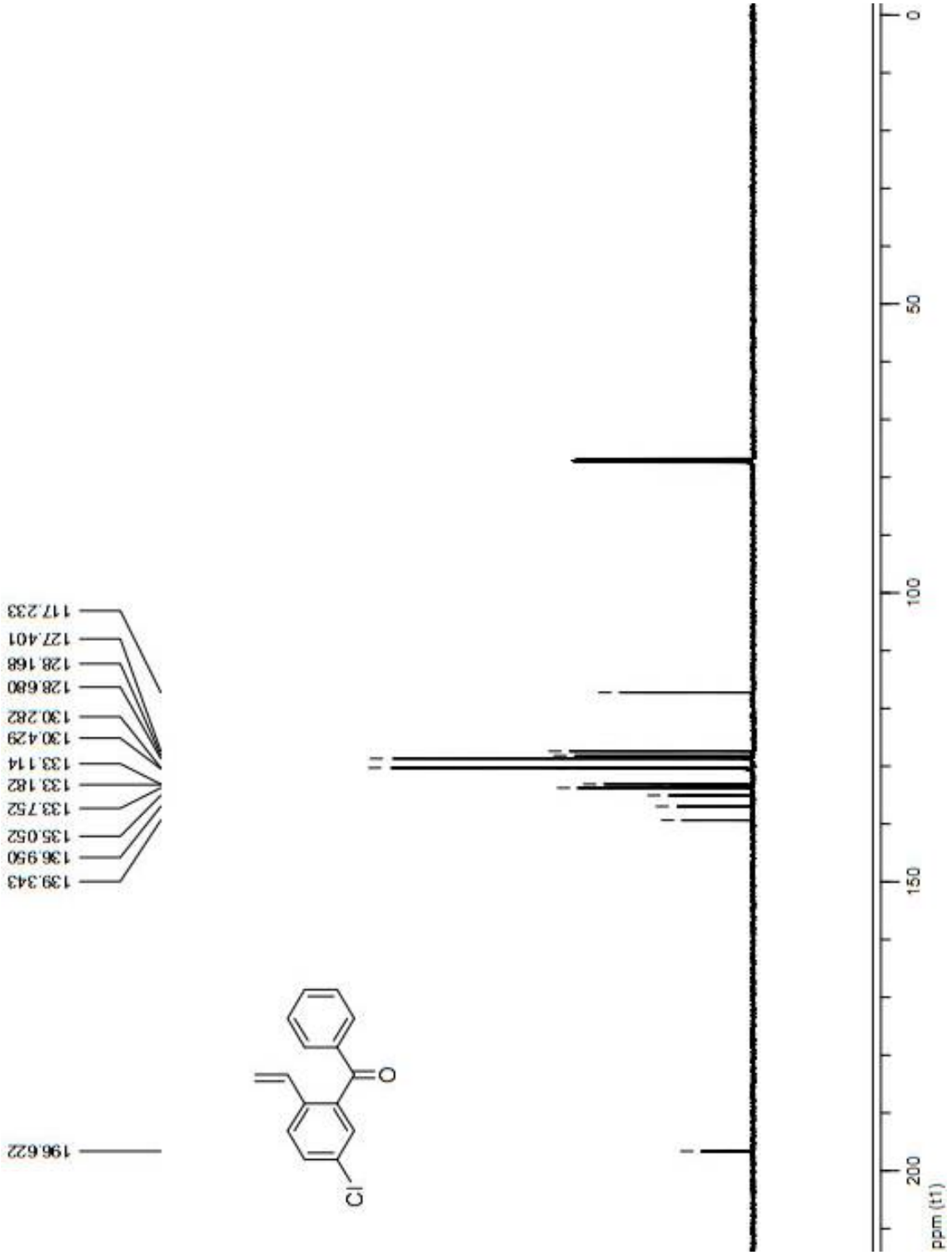

OH
O
7.173
7.193
7.225
7.263
7.328
7.348
7.709
7.729
3.184
2.372
2.439
2.464
1.82
4.93
1.06
1.16
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

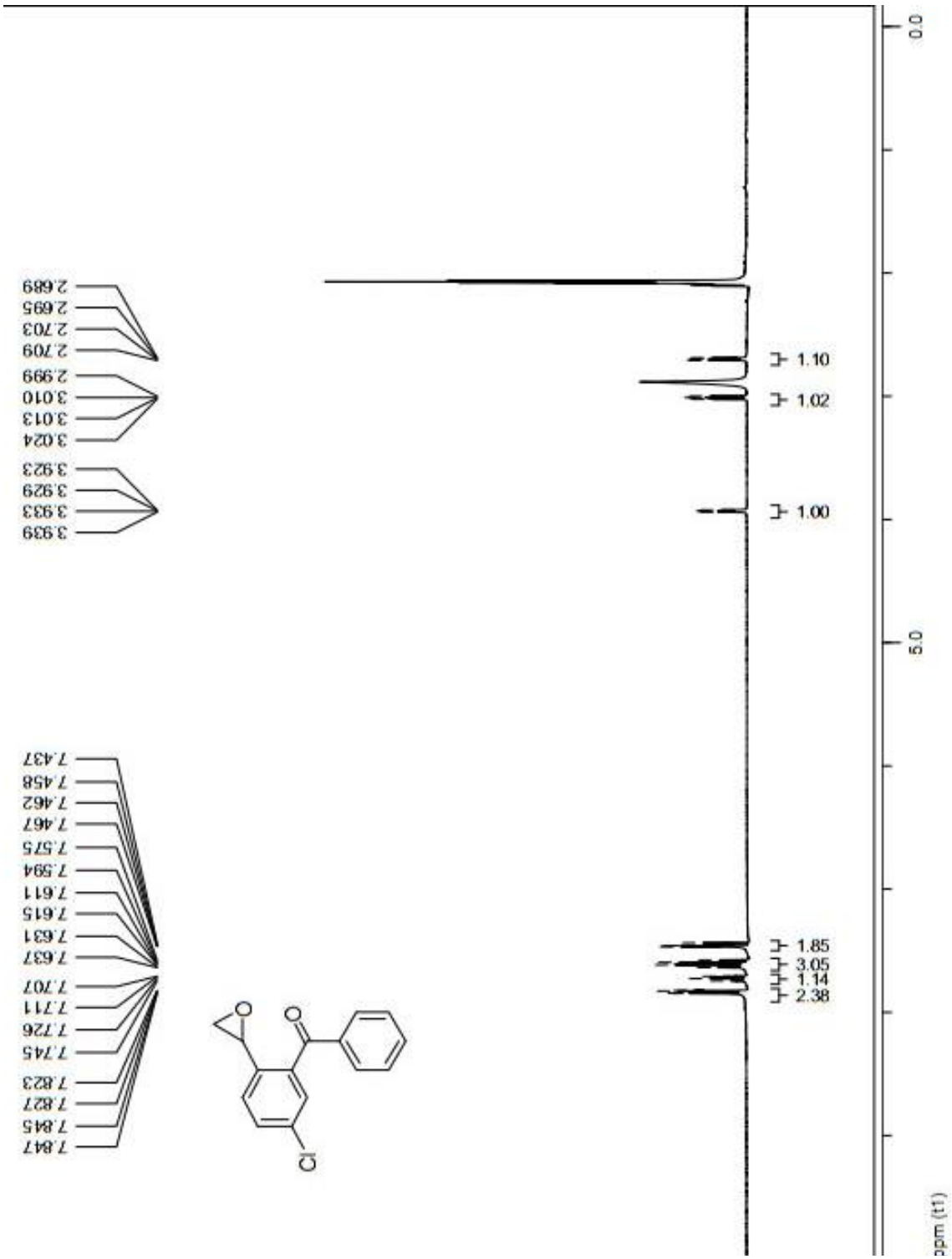

29.728
30.948
56.449
78.380
123.069
124.952
125.222
128.824
129.229
130.798
137.156
138.163
142.462
147.149
206.941
OH
O
0
50
100
150
200
ppm (f1)

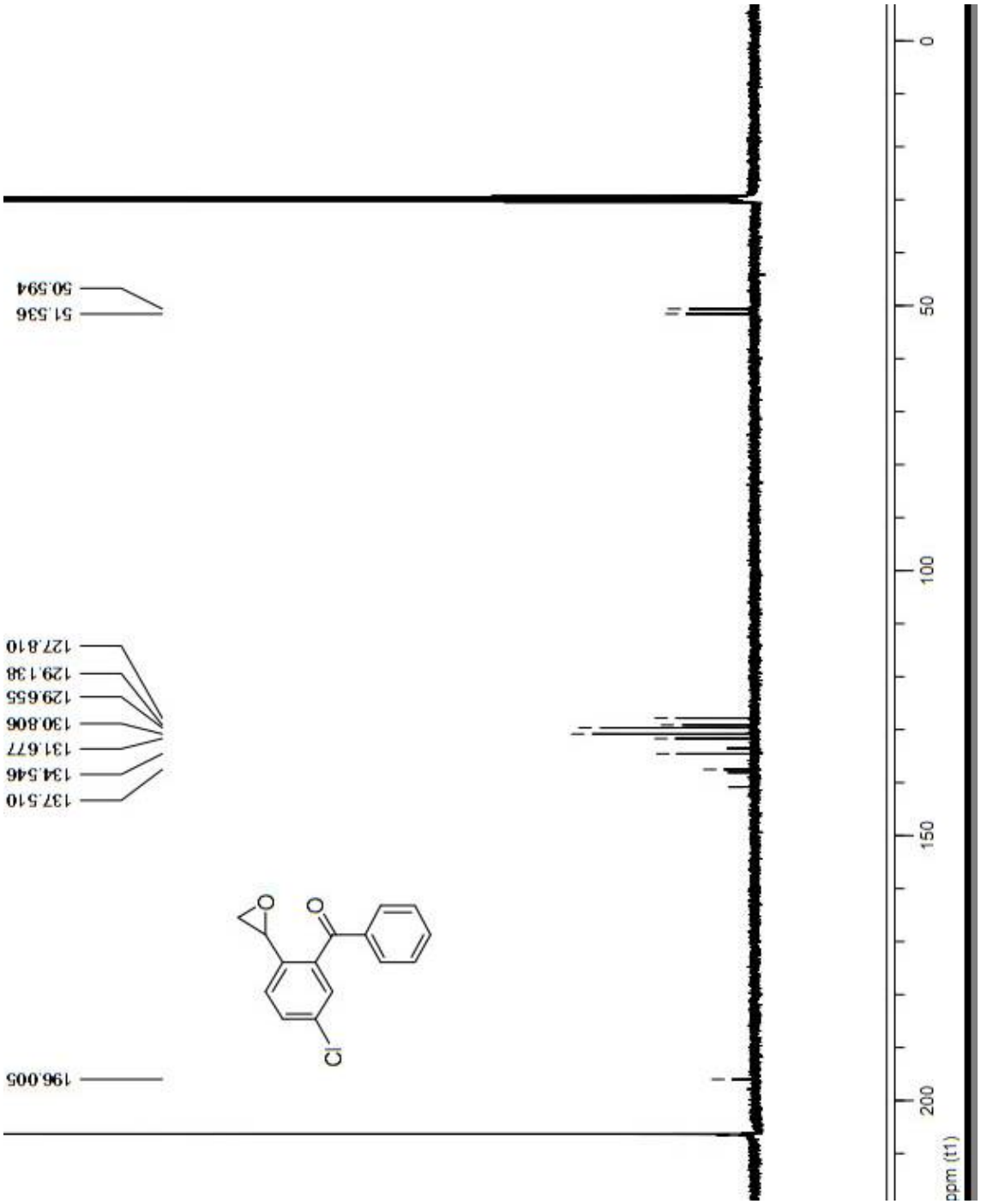

OH
Cl
2.388
5.241
5.243
5.268
5.271
5.530
5.533
5.573
5.576
6.021
6.815
6.842
6.858
6.885
7.223
7.228
7.240
7.243
7.249
7.258
7.265
7.271
7.282
7.286
7.298
7.308
7.322
7.339
7.343
7.374
7.394
7.521
7.527
0.98
1.00
0.96
1.01
0.88
6.23
1.09
0.82
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

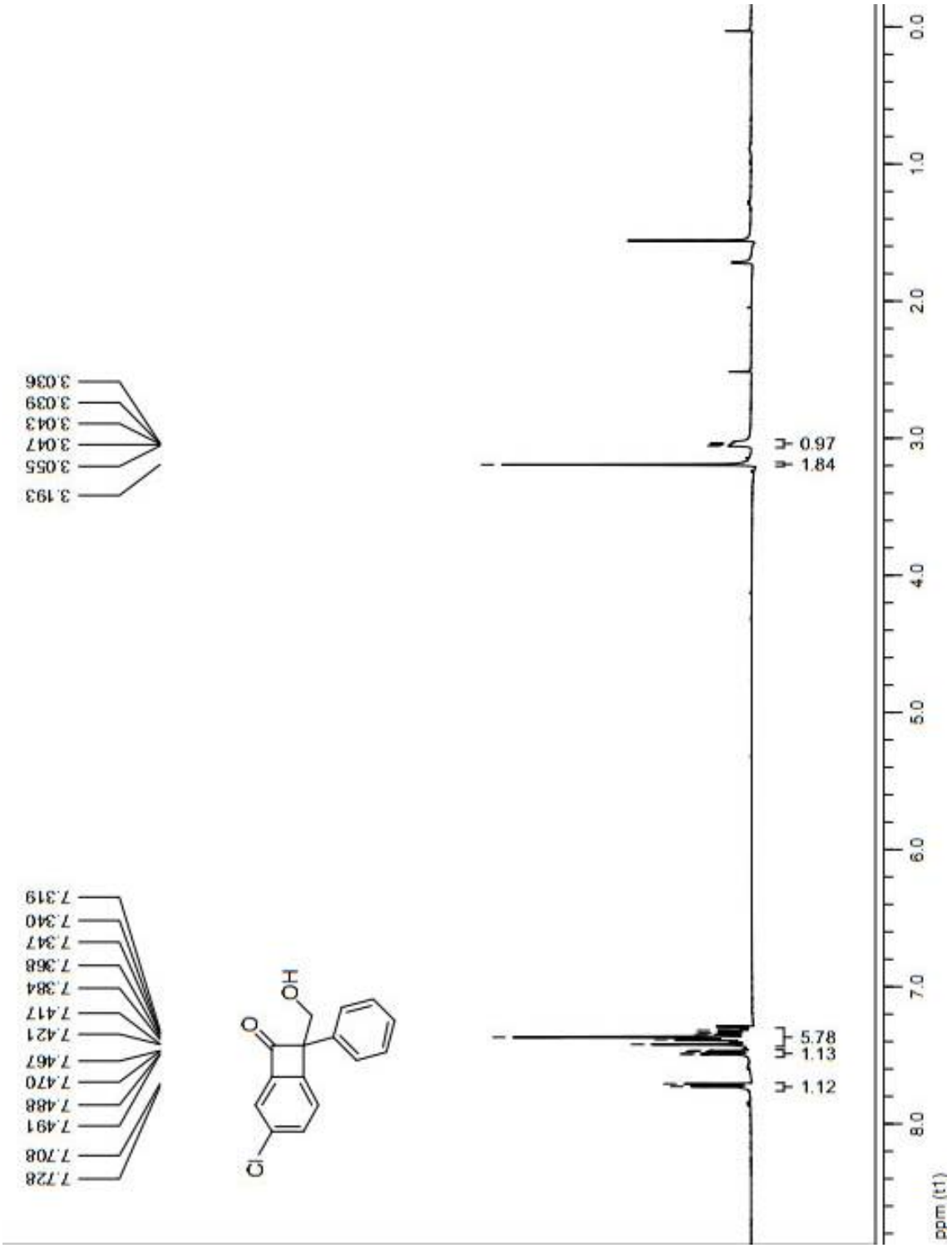

OH
Cl
72.655
117.207
126.776
126.997
127.736
127.949
128.495
128.690
133.246
133.894
134.574
142.049
142.337
0
50
100
150
ppm (f1)

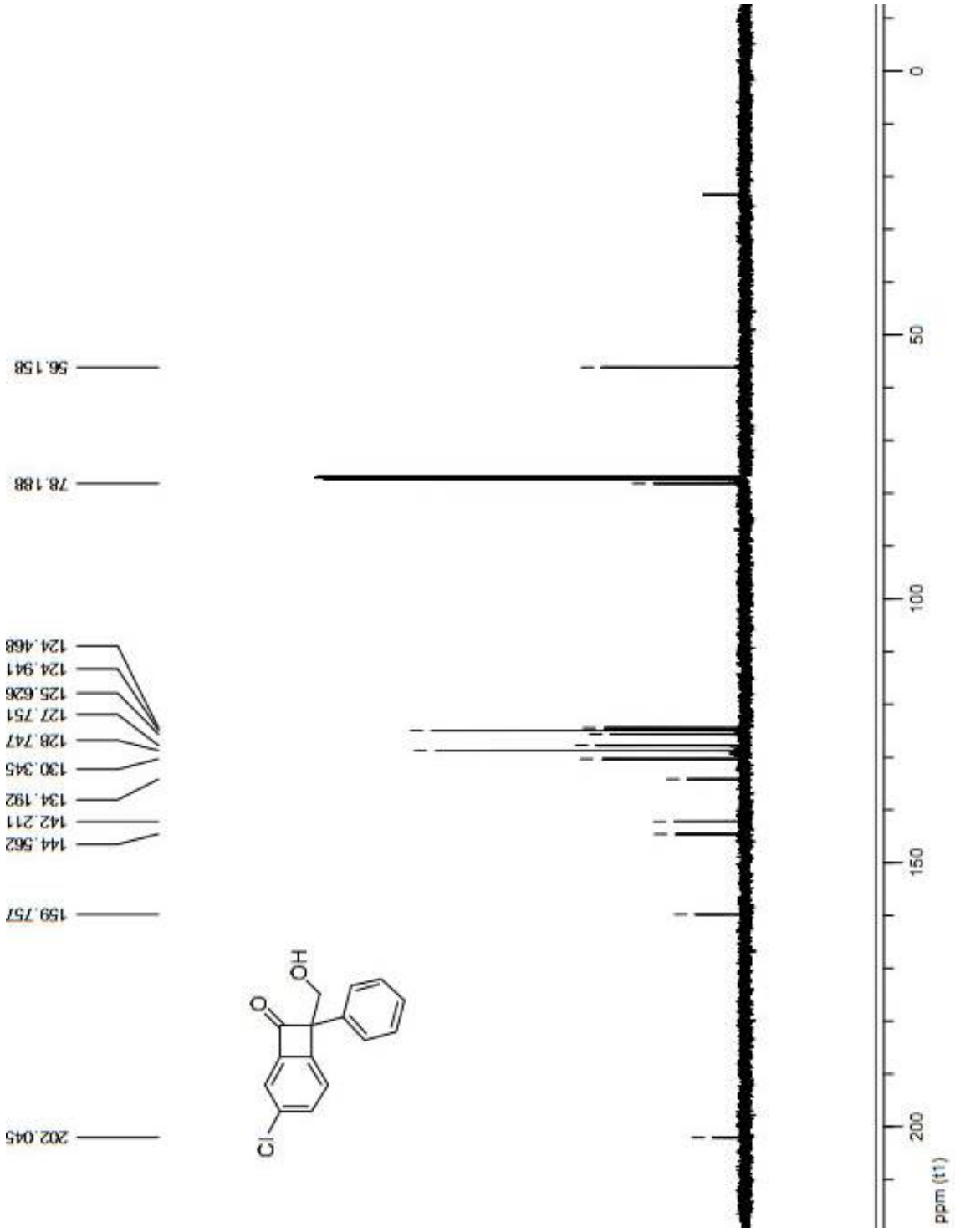

5.221
5.249
5.658
5.702
6.640
6.667
6.683
6.711
7.255
7.318
7.424
7.429
7.440
7.444
7.450
7.459
7.478
7.579
7.595
7.616
7.778
7.781
7.799
O
Cl
0.98
1.00
0.91
0.92
2.86
2.10
2.20
0.0
5.0
10.0
ppm (t1)

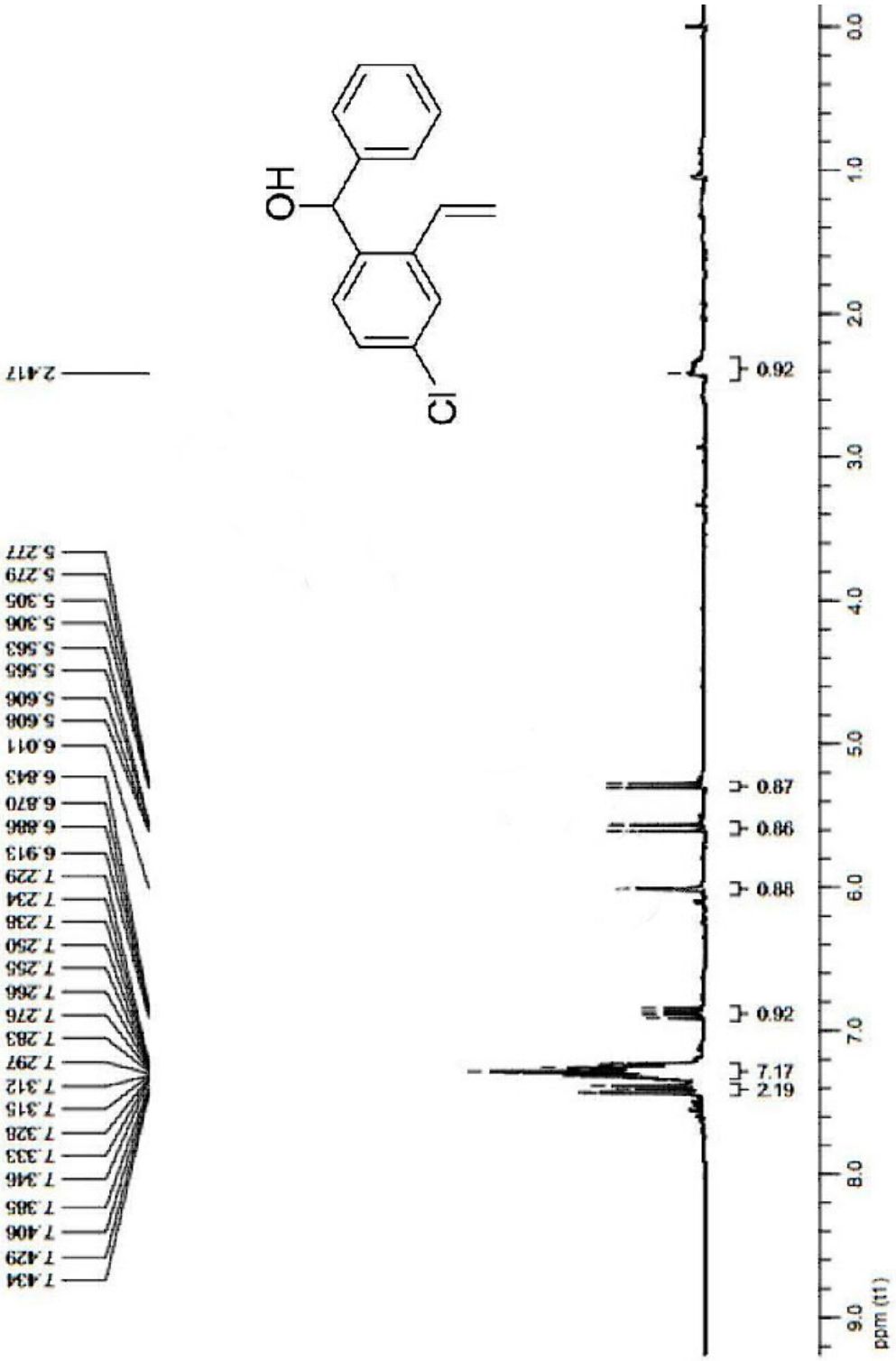

117.233
127.401
128.168
128.680
130.282
130.429
133.114
133.182
133.752
135.052
136.950
139.343
196.622
O
Cl
0
50
100
150
200
ppm (t1)

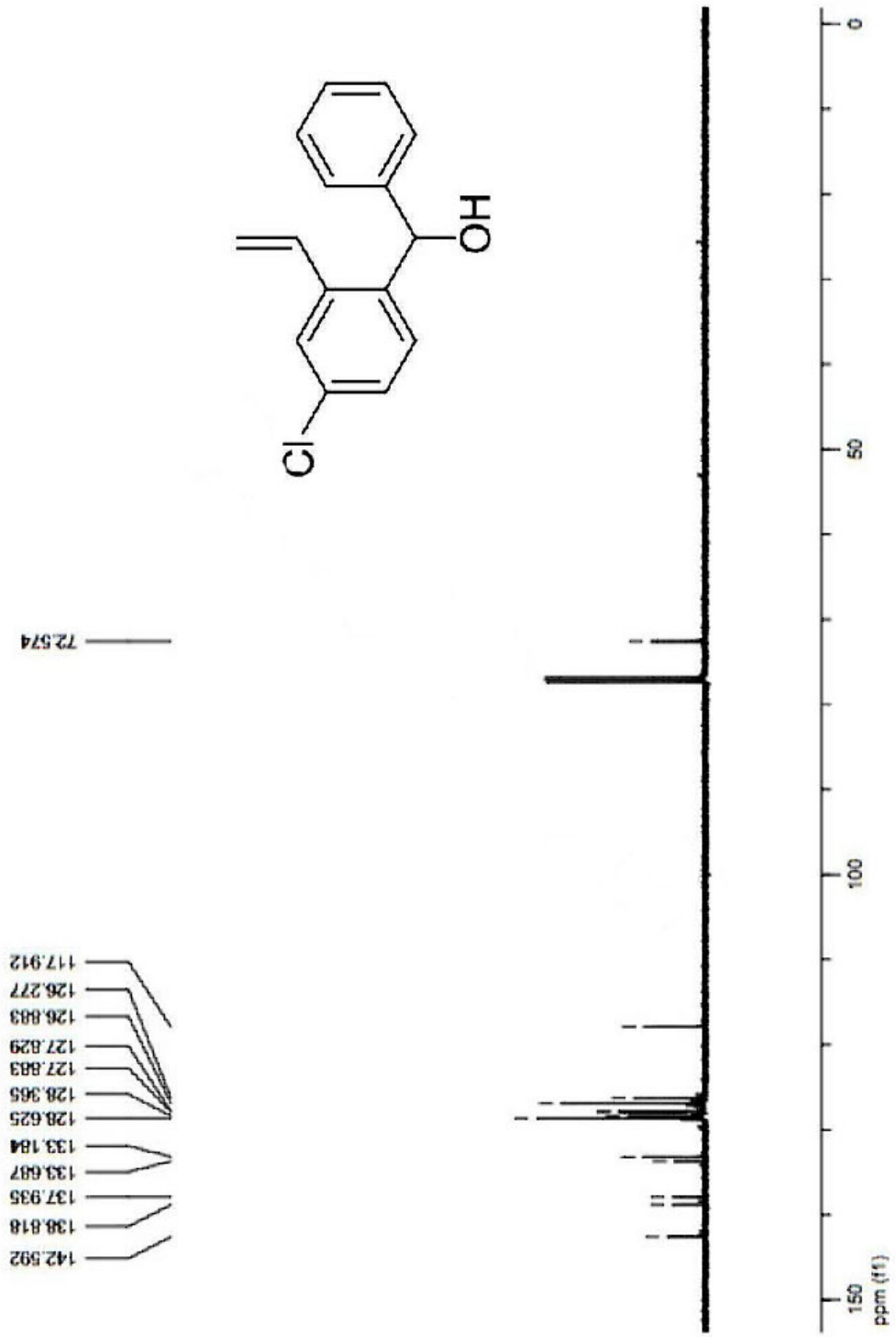


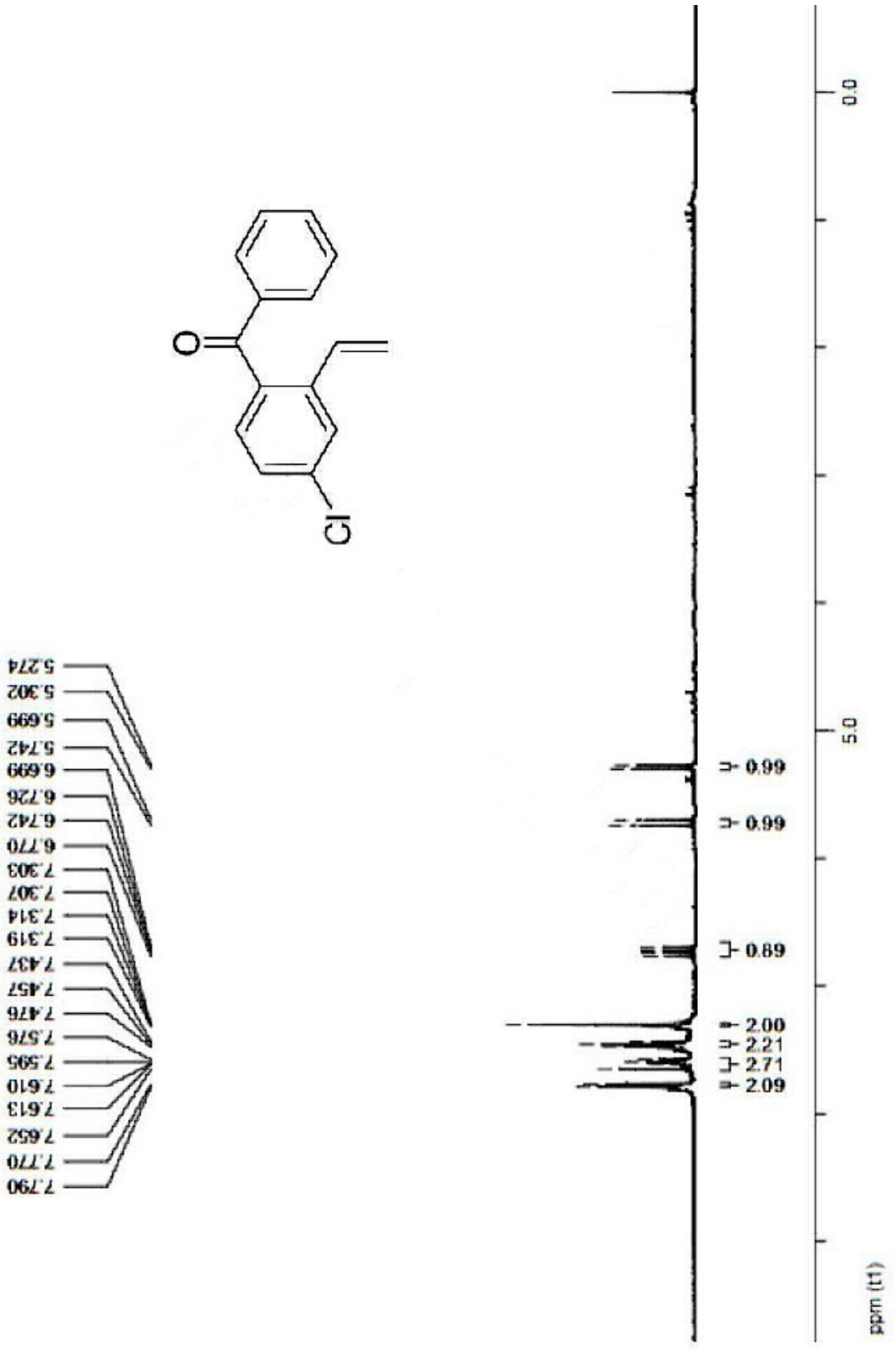

50.594
51.536
127.810
129.138
129.655
130.806
131.677
134.546
137.510
196.005
Cl
O
O
0
50
100
150
200
ppm (t1)

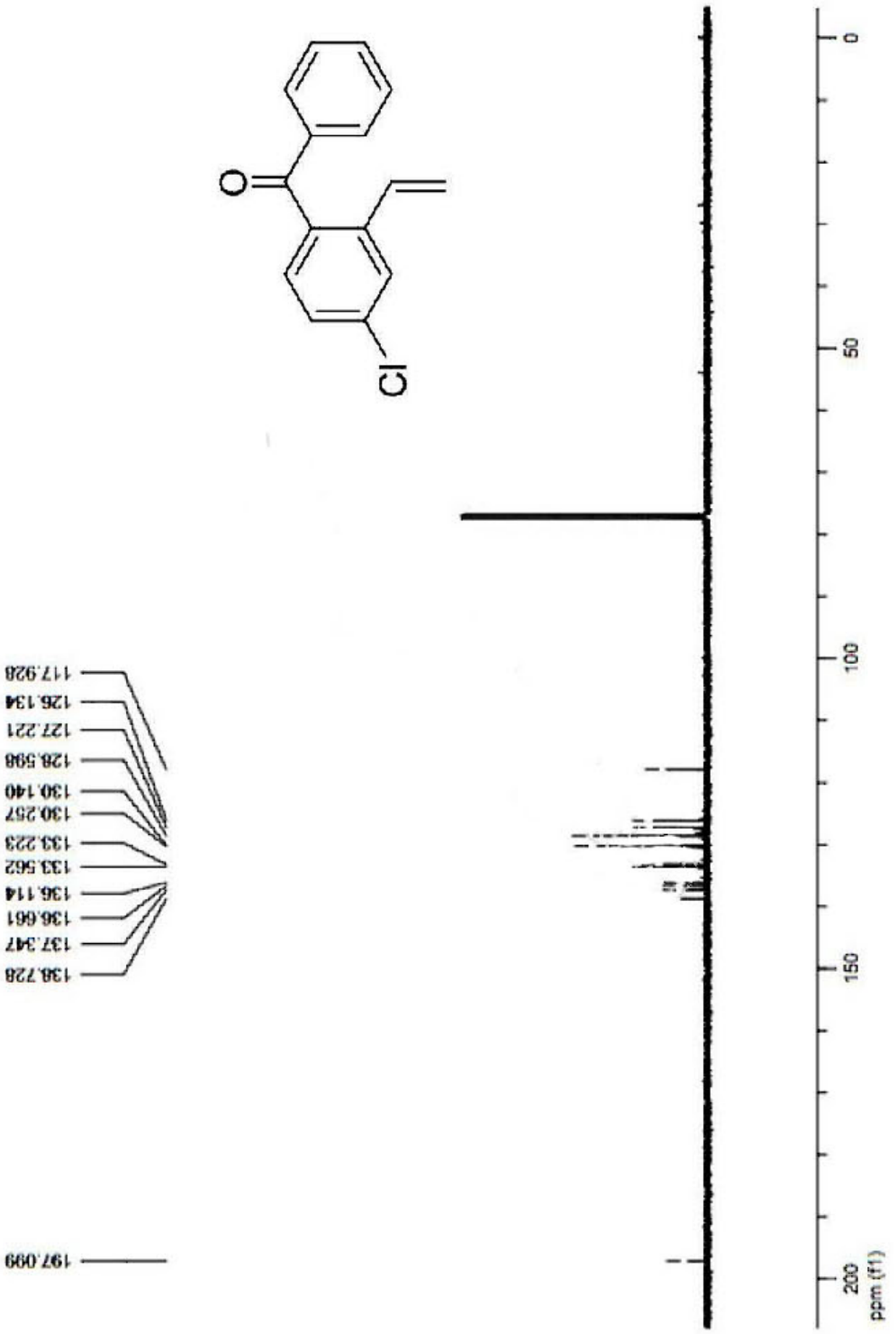

7.728
7.708
7.491
7.488
7.470
7.467
7.421
7.417
7.384
7.368
7.347
7.340
7.319
3.193
3.055
3.047
3.043
3.039
3.036
0.97
1.84
5.78
1.13
1.12
OH
O
Cl
ppm (t1)

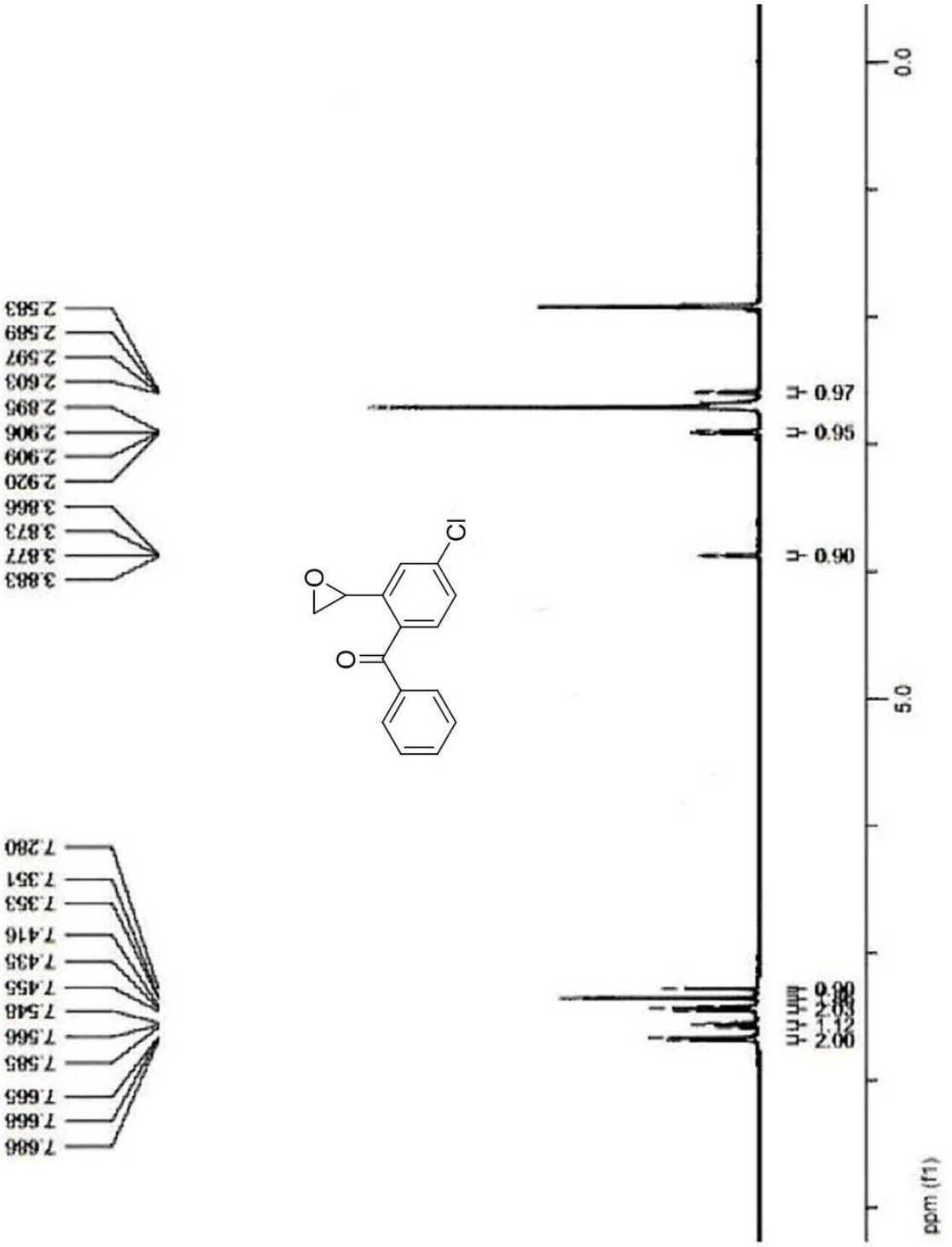

56.158
78.188
124.468
124.941
125.626
127.751
128.747
130.345
134.192
142.211
144.562
159.757
202.045
OH
O
Cl
0
50
100
150
200
ppm (t1)

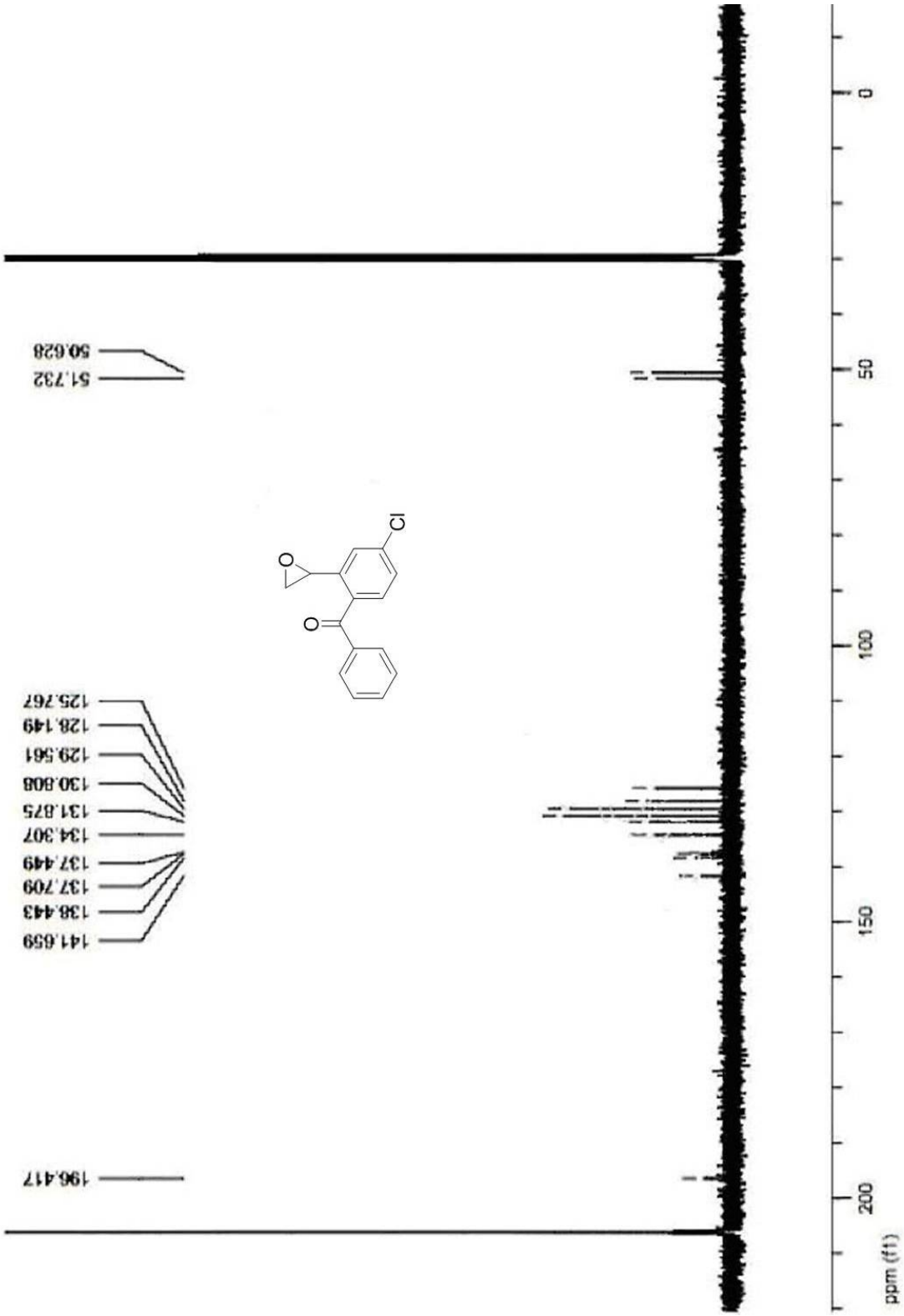


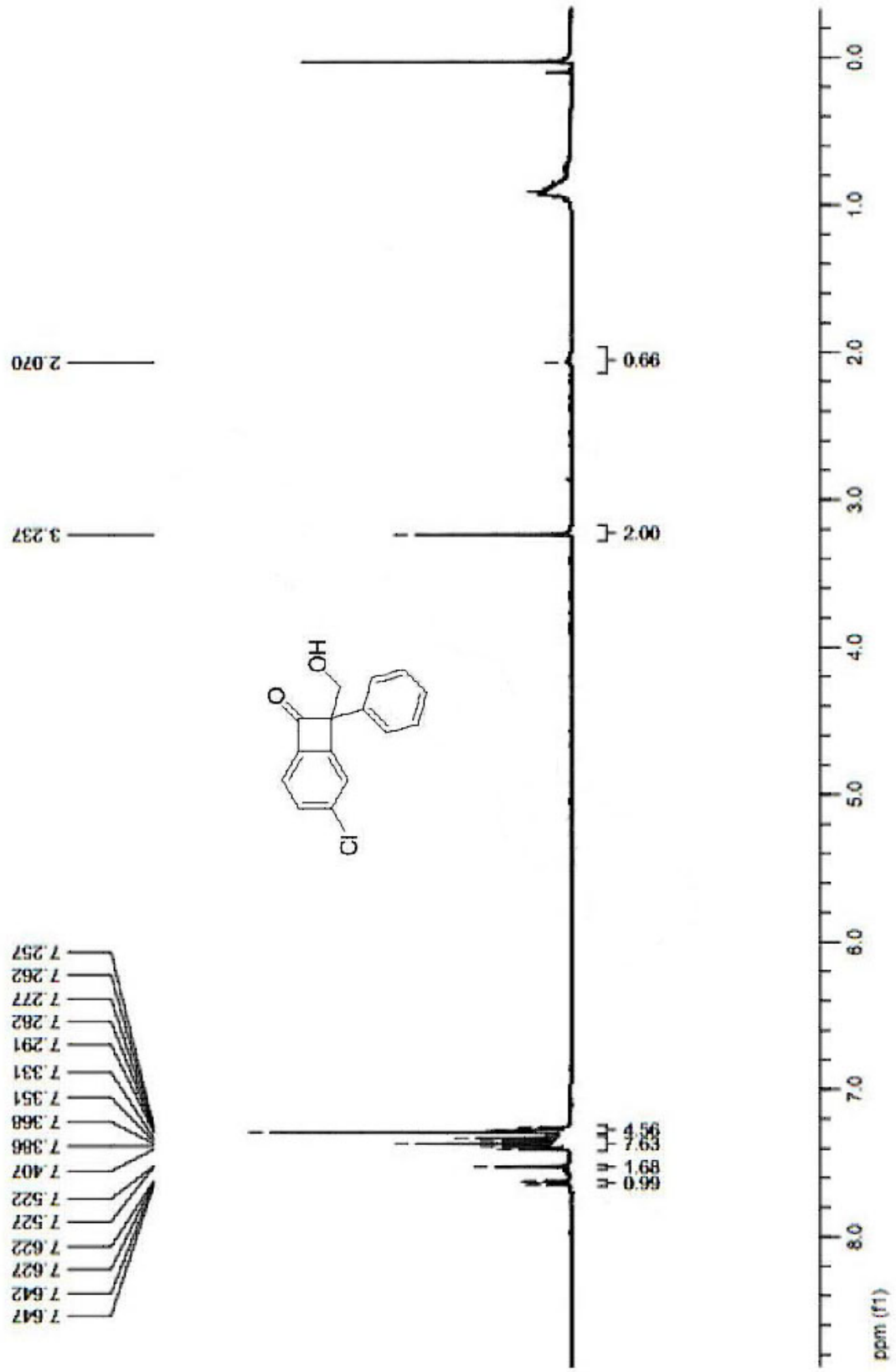

OH
Cl
72.574
117.912
126.277
126.883
127.829
127.883
128.365
128.625
133.184
133.687
137.935
138.818
142.592
0
50
100
150
ppm (f1)

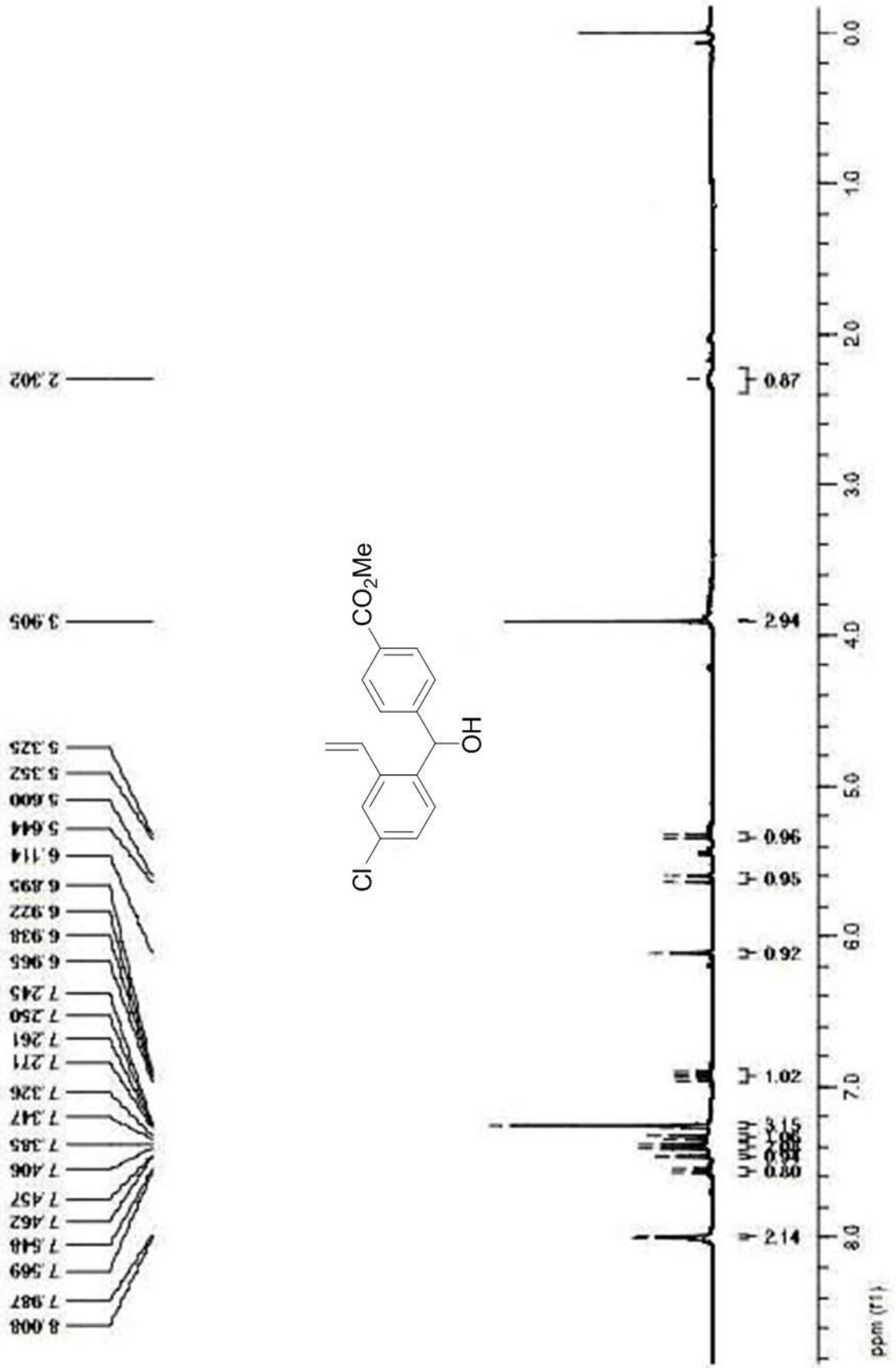

O
Cl
5.274
5.302
5.699
5.742
6.699
6.726
6.742
6.770
7.303
7.307
7.314
7.319
7.437
7.457
7.476
7.576
7.595
7.610
7.613
7.652
7.770
7.790
0.99
0.99
0.89
2.00
2.21
2.71
2.09
0.0
5.0
ppm (t1)

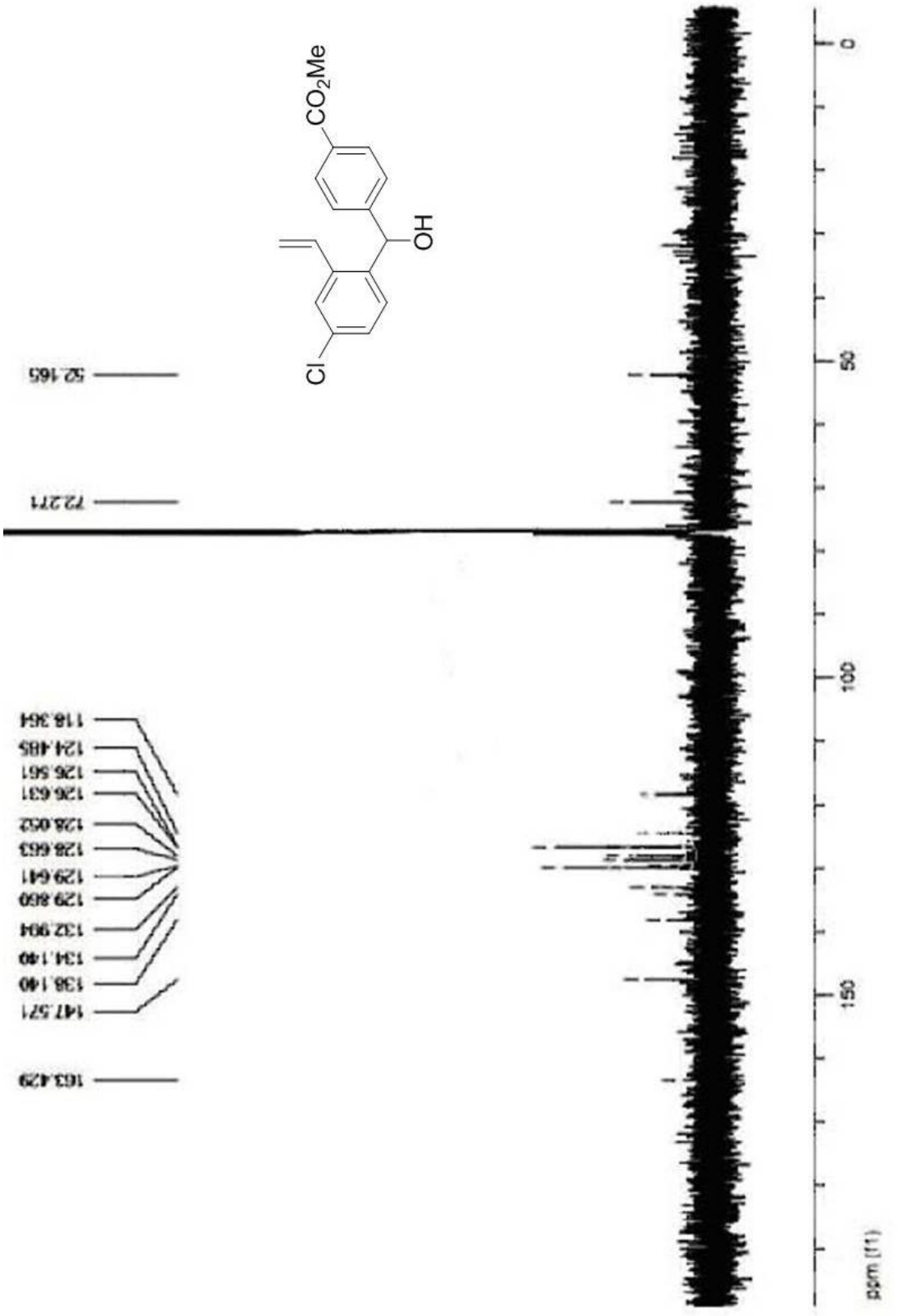

O
Cl
117.920
126.134
127.221
128.598
130.140
130.257
133.223
133.562
136.114
136.661
137.347
138.728
197.099
0
50
100
150
200
ppm (f1)

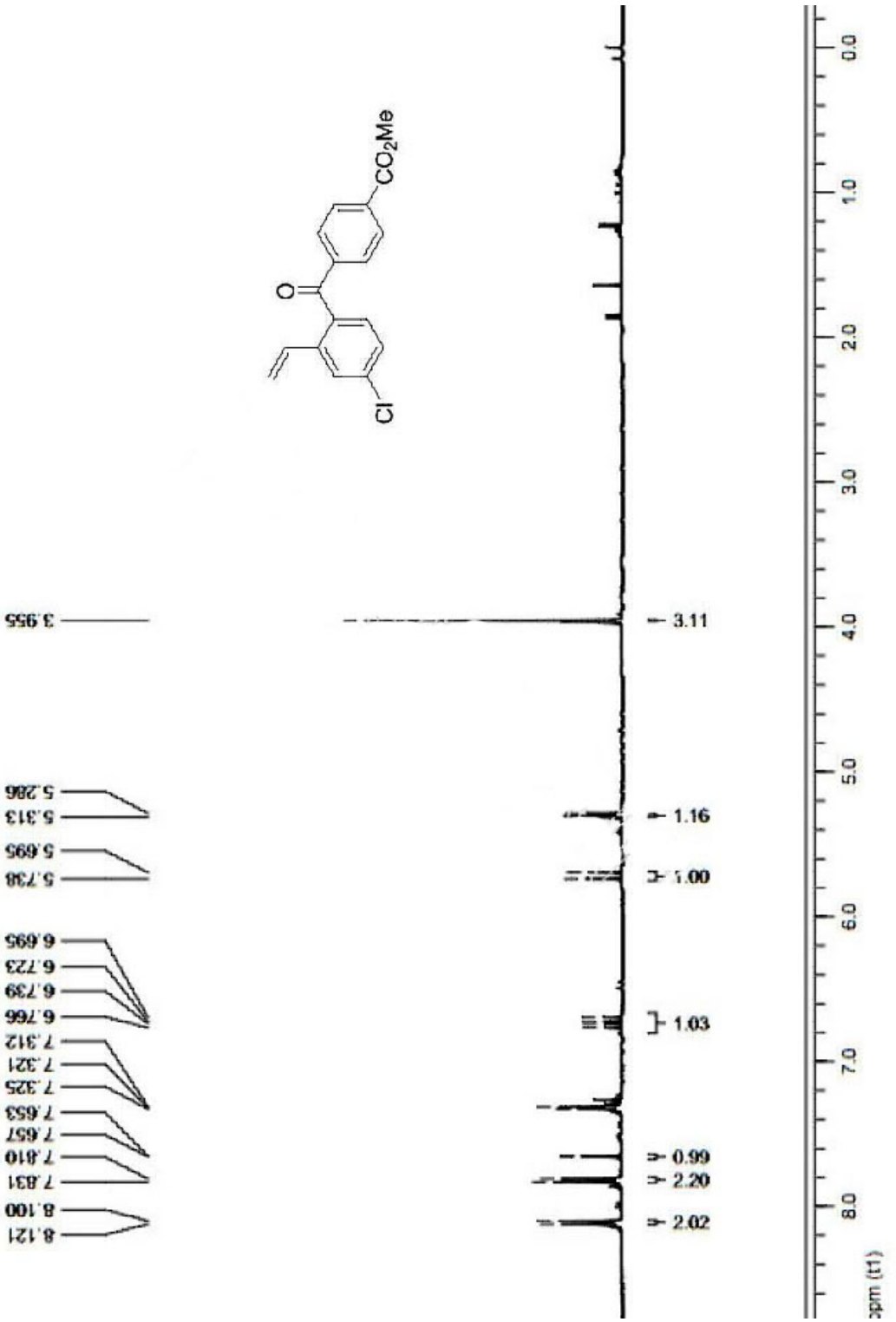

2.583
2.589
2.597
2.603
2.895
2.906
2.909
2.920
3.866
3.873
3.877
3.883
7.280
7.351
7.353
7.416
7.435
7.455
7.548
7.566
7.585
7.665
7.668
7.686
Cl
O
O
0.97
0.95
0.90
2.00
0.0
5.0
ppm (f1)

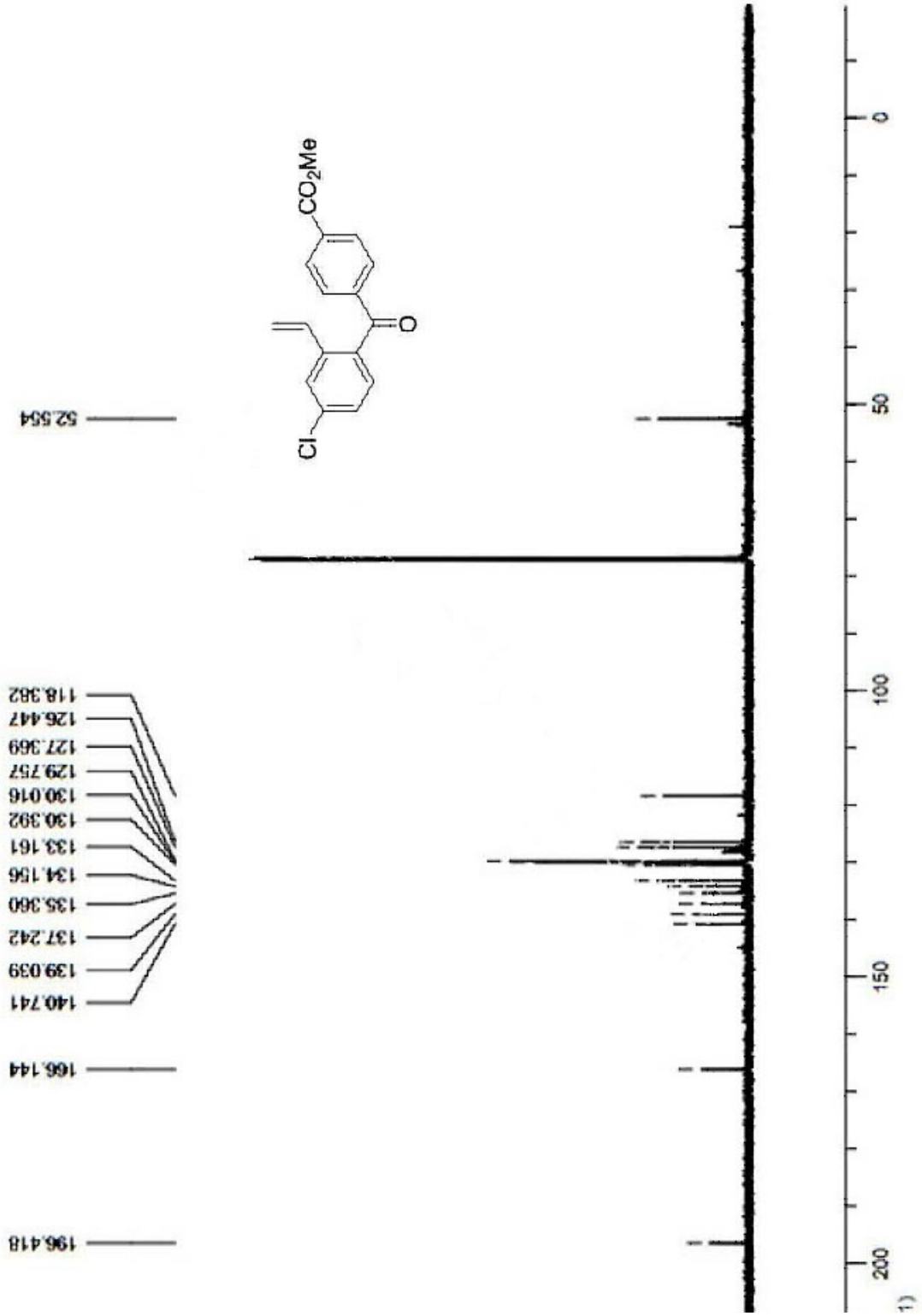

196.417
141.659
138.443
137.709
137.449
134.307
131.875
130.808
129.561
128.149
125.767
51.732
50.628
Cl
O
O
0
50
100
150
200
ppm (f1)

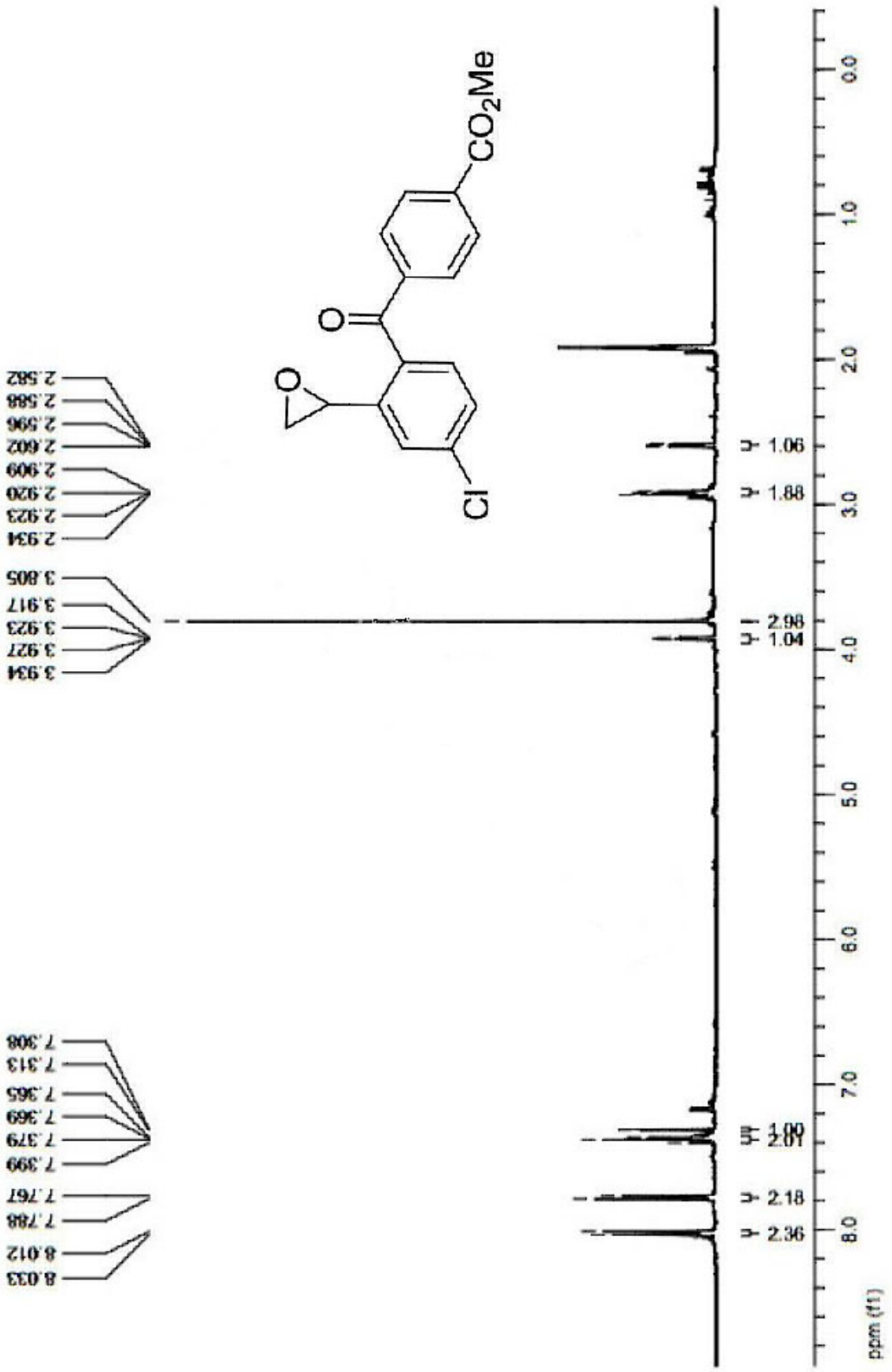

2.070
3.237
7.257
7.262
7.277
7.282
7.291
7.331
7.351
7.368
7.386
7.407
7.522
7.527
7.622
7.627
7.642
7.647
0.66
2.00
4.56
7.63
1.68
0.99
OH
O
Cl
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (f1)

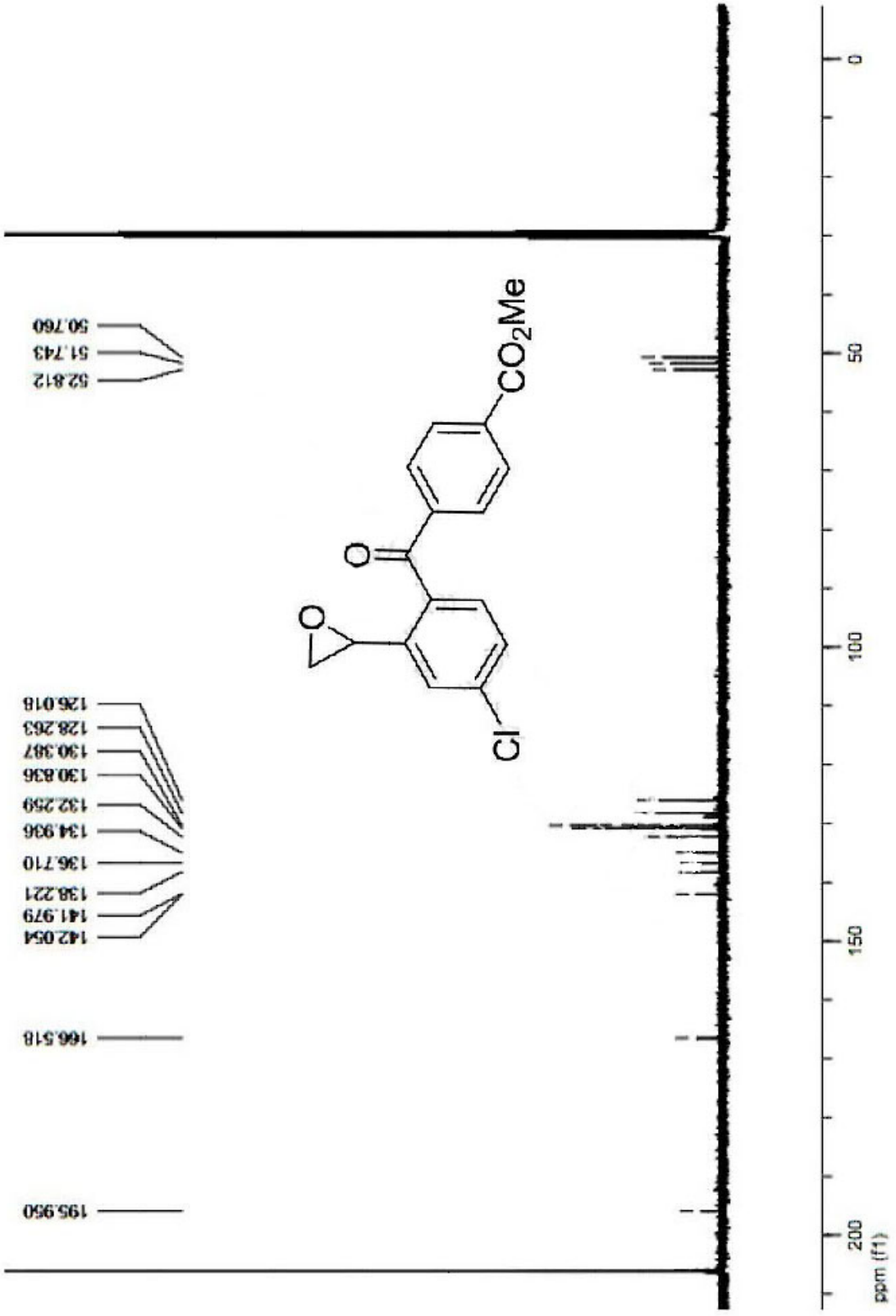

2.302
3.905
5.325
5.352
5.600
5.644
6.114
6.895
6.922
6.938
6.965
7.245
7.250
7.261
7.271
7.326
7.347
7.385
7.406
7.457
7.462
7.548
7.569
7.987
8.008
CO2Me
OH
Cl
0.87
2.94
0.96
0.95
0.92
1.02
3.15
0.80
2.14
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (f1)

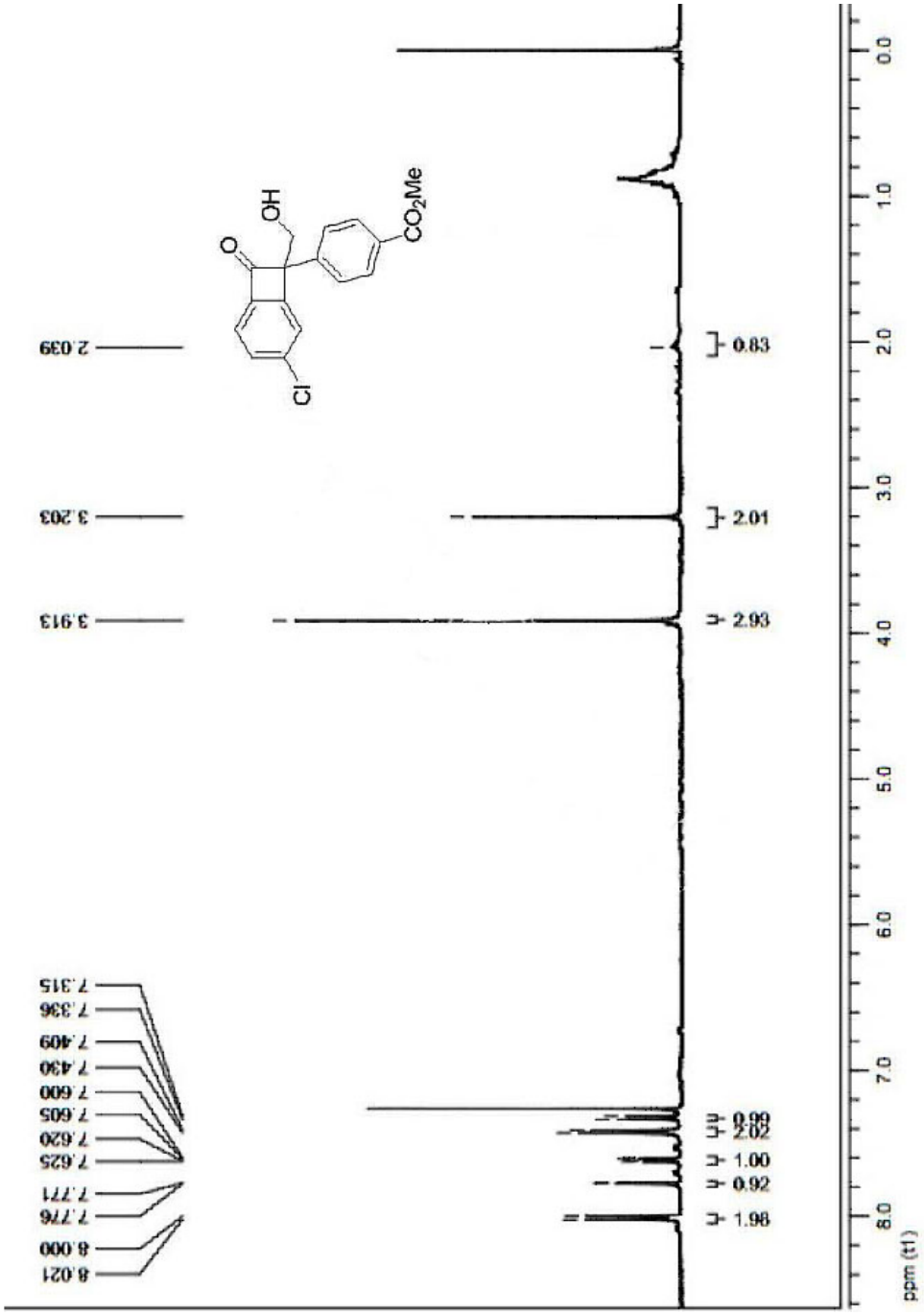

CO2Me
OH
Cl
52.165
72.271
118.364
124.485
126.561
126.631
128.052
128.663
129.641
129.860
132.904
134.140
138.140
147.571
163.429
0
50
100
150
ppm (f1)

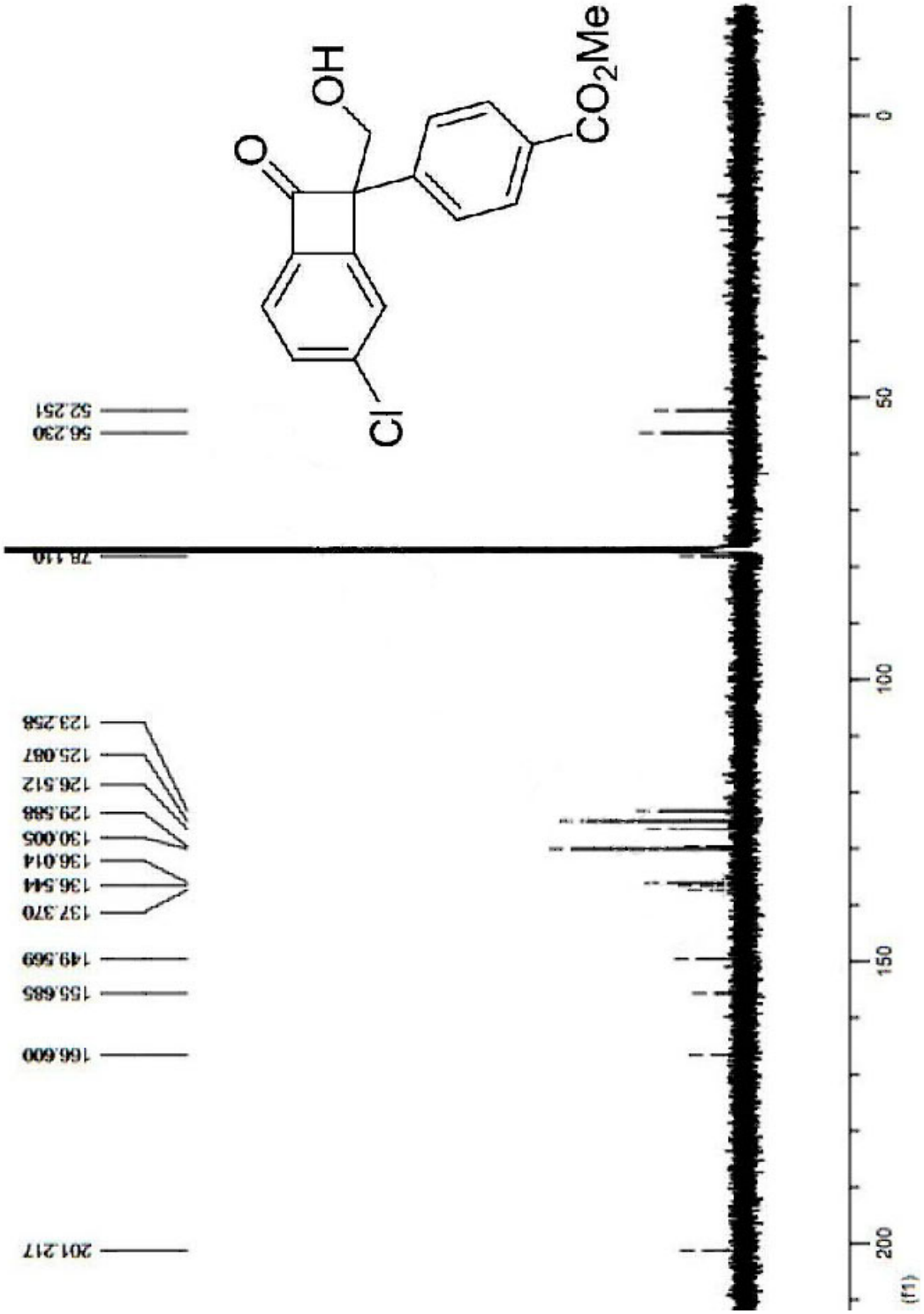

CO2Me
O
Cl
3.955
5.286
5.313
5.695
5.738
6.695
6.723
6.739
6.766
7.312
7.321
7.325
7.653
7.657
7.810
7.831
8.100
8.121
3.11
1.16
1.00
1.03
0.99
2.20
2.02
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

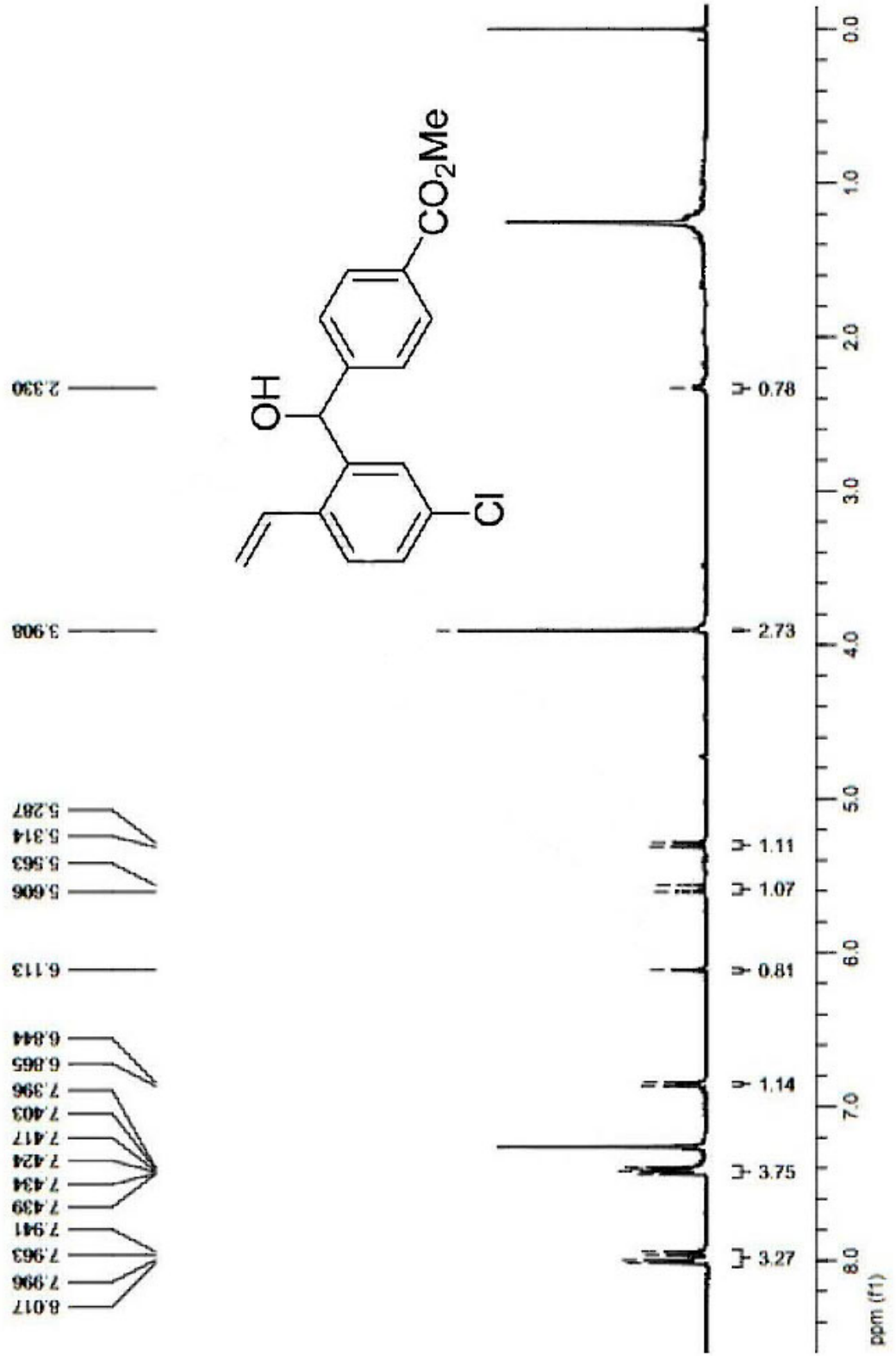

CO2Me
O
Cl
52.554
118.382
126.447
127.369
129.757
130.016
130.392
133.161
134.156
135.360
137.242
139.039
140.741
166.144
196.418
0
50
100
150
200

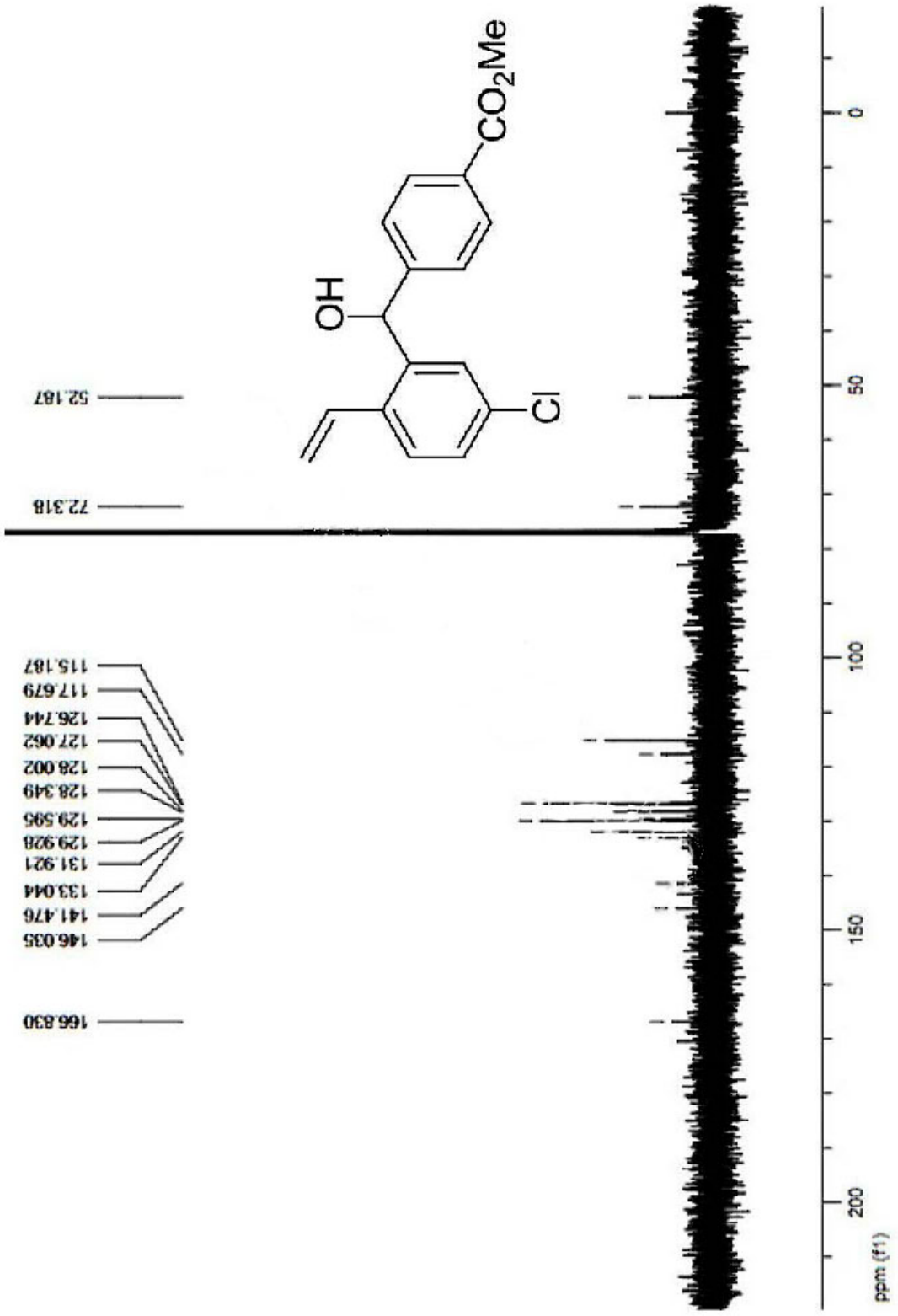

CO2Me
O
O
Cl
2.582
2.588
2.596
2.602
2.909
2.920
2.923
2.934
3.805
3.917
3.923
3.927
3.934
7.308
7.313
7.365
7.369
7.379
7.399
7.767
7.788
8.012
8.033
1.06
1.88
2.98
1.04
1.00
2.01
2.18
2.36
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (f1)

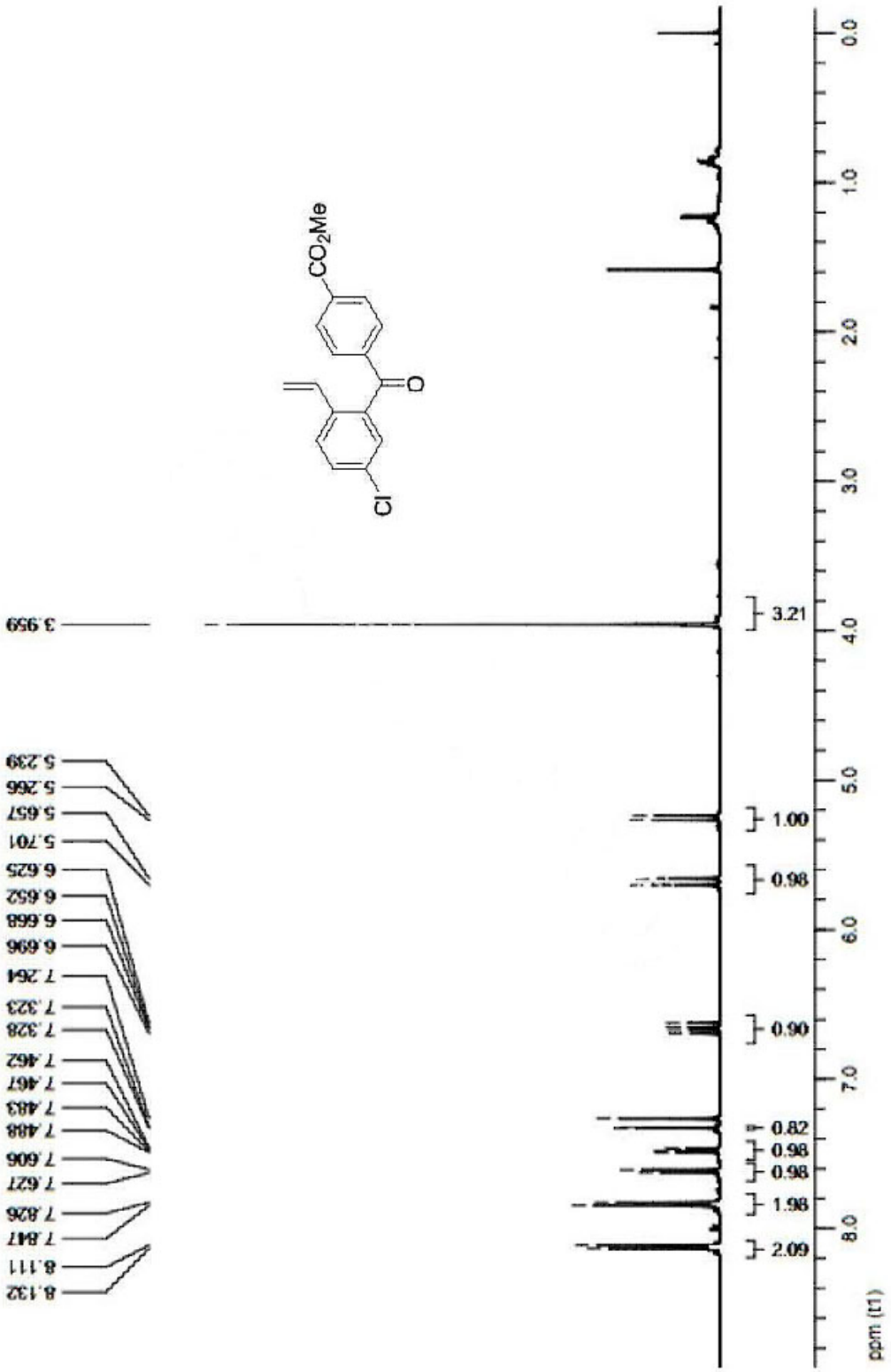

50.760
51.743
52.812
126.018
128.263
130.387
130.836
132.259
134.936
136.710
138.221
141.979
142.054
166.518
195.950
CO2Me
O
O
Cl
0
50
100
150
200
ppm (f1)

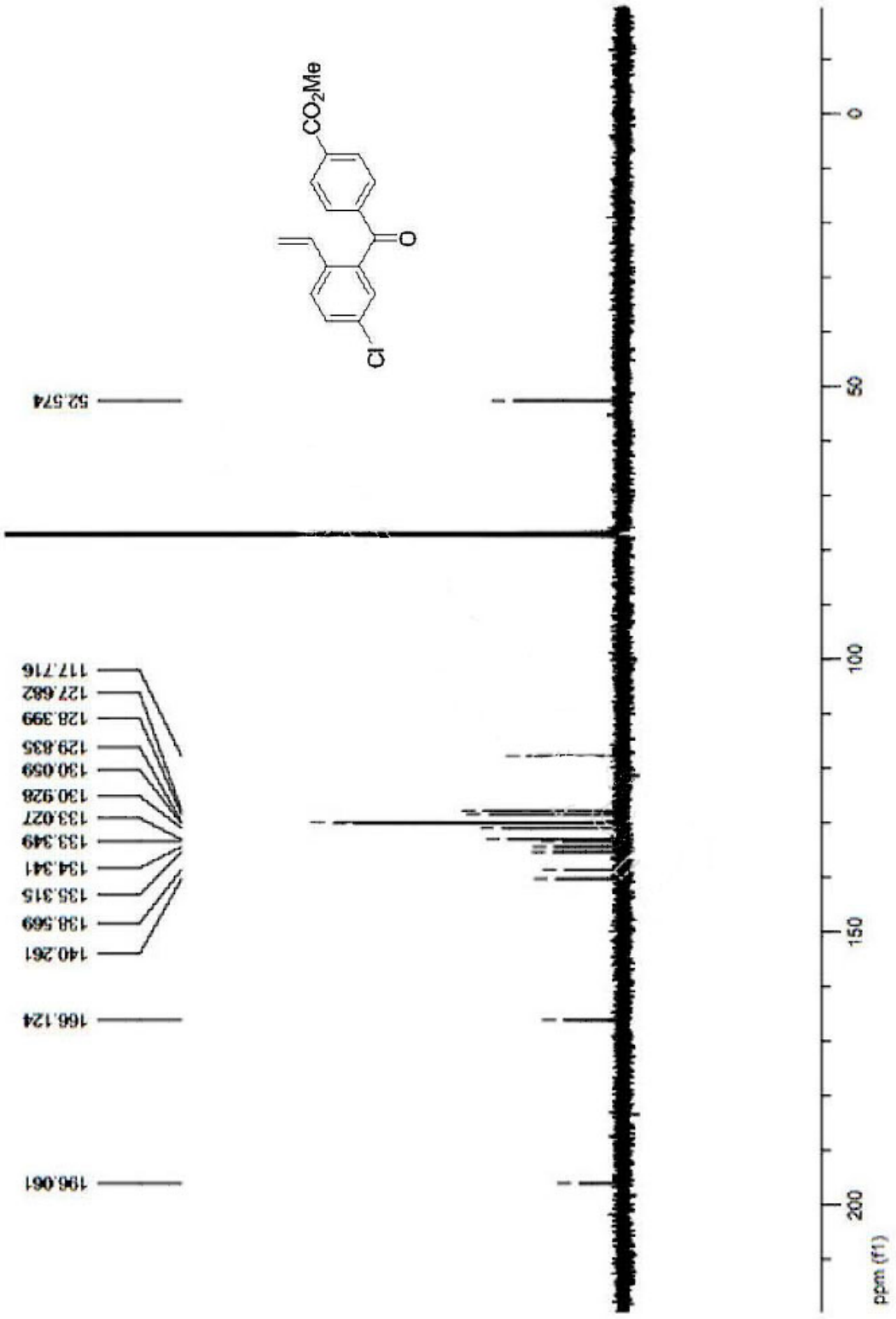

OH
O
CO2Me
Cl
2.039
3.203
3.913
0.83
2.01
2.93
0.99
2.02
1.00
0.92
1.98
7.315
7.336
7.409
7.430
7.600
7.605
7.620
7.625
7.771
7.776
8.000
8.021
ppm (t1)

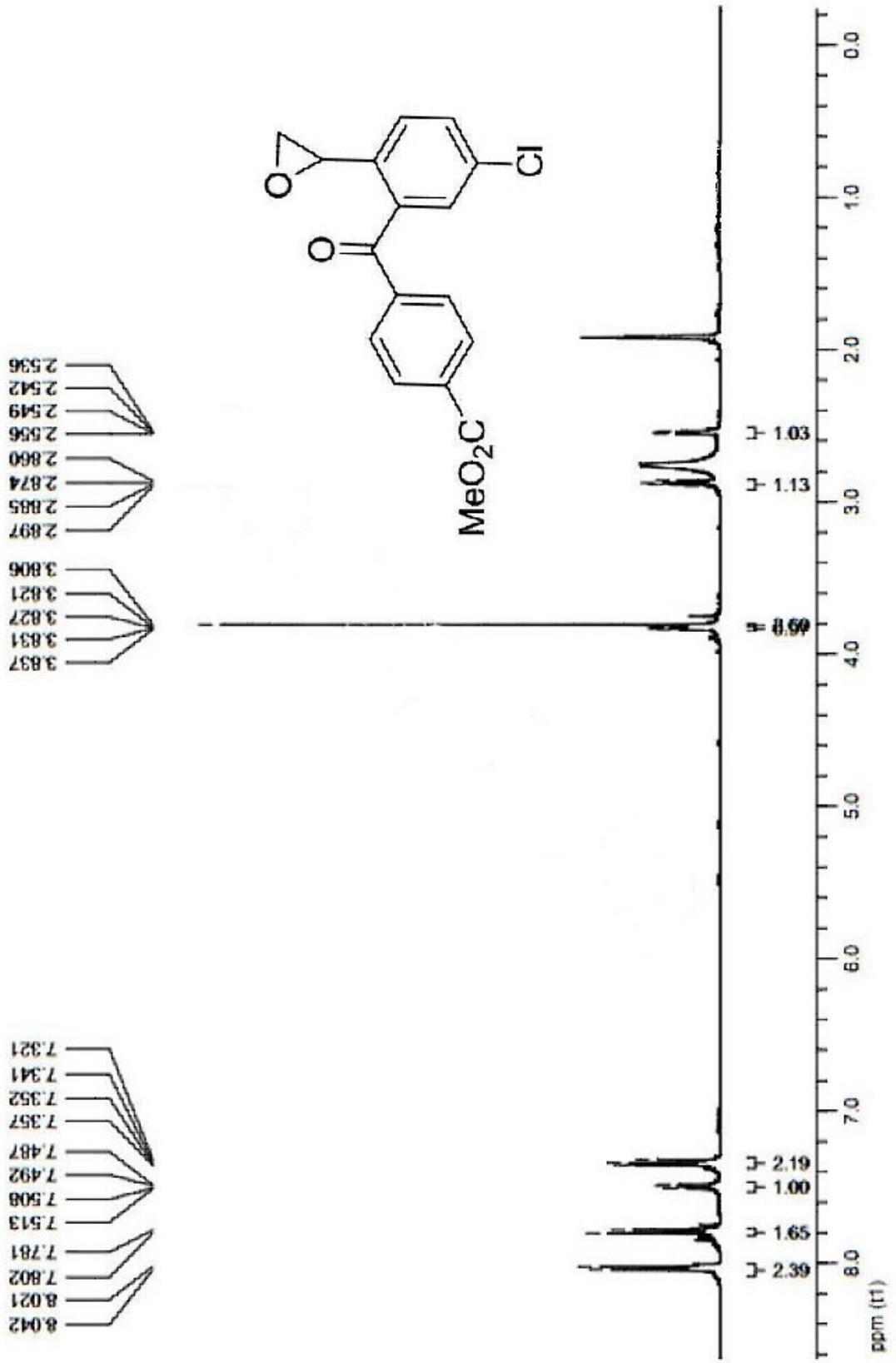

OH
O
CO2Me
Cl
52.251
56.230
78.110
123.258
125.087
126.512
129.588
130.005
136.014
136.544
137.370
149.569
155.685
166.600
201.217
0
50
100
150
200
(f1)

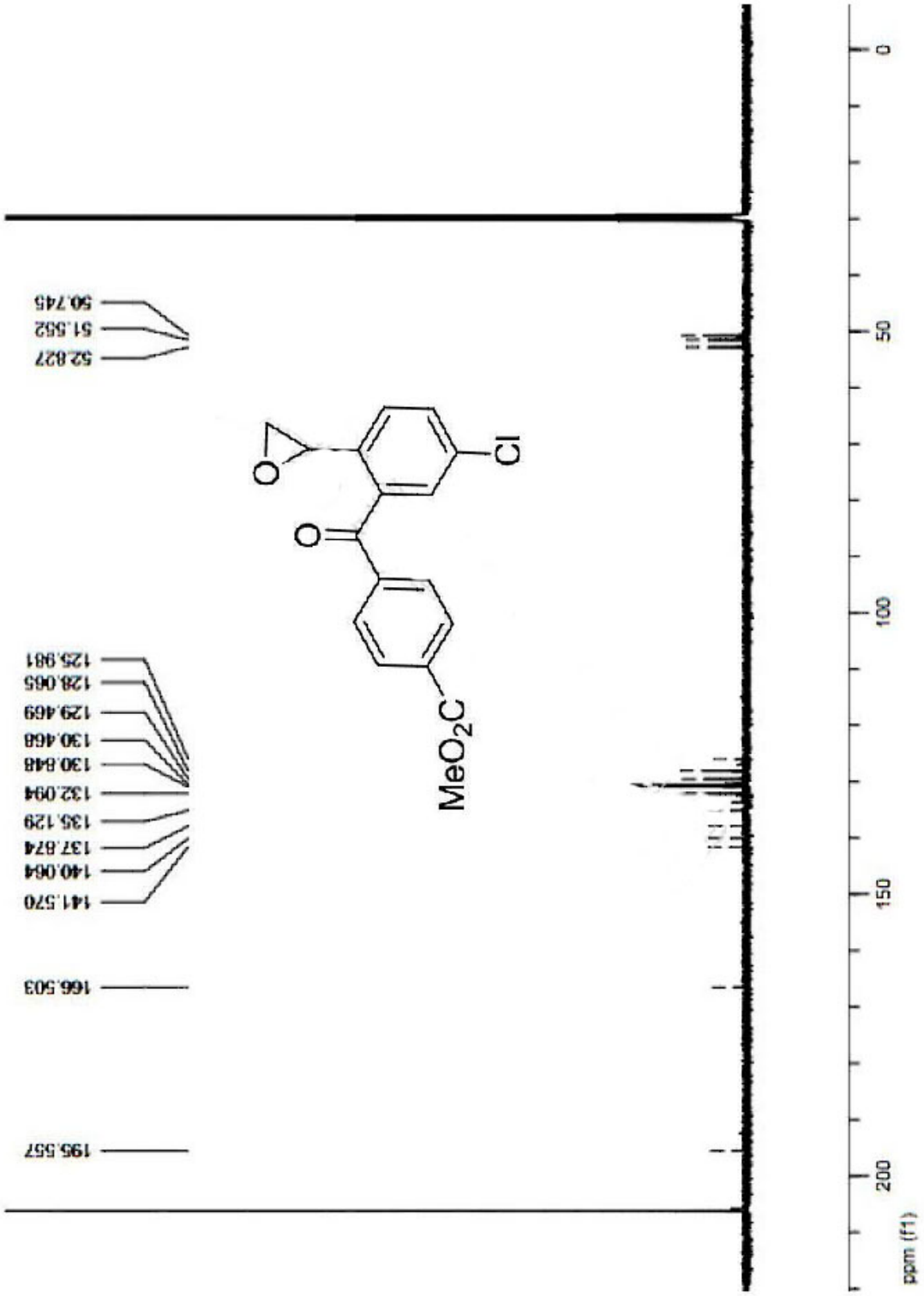

CO2Me
OH
Cl
2.330
3.908
5.287
5.314
5.363
5.606
6.113
6.844
6.865
7.396
7.403
7.417
7.424
7.434
7.439
7.941
7.963
7.996
8.017
0.78
2.73
1.11
1.07
0.81
1.14
3.75
3.27
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (f1)

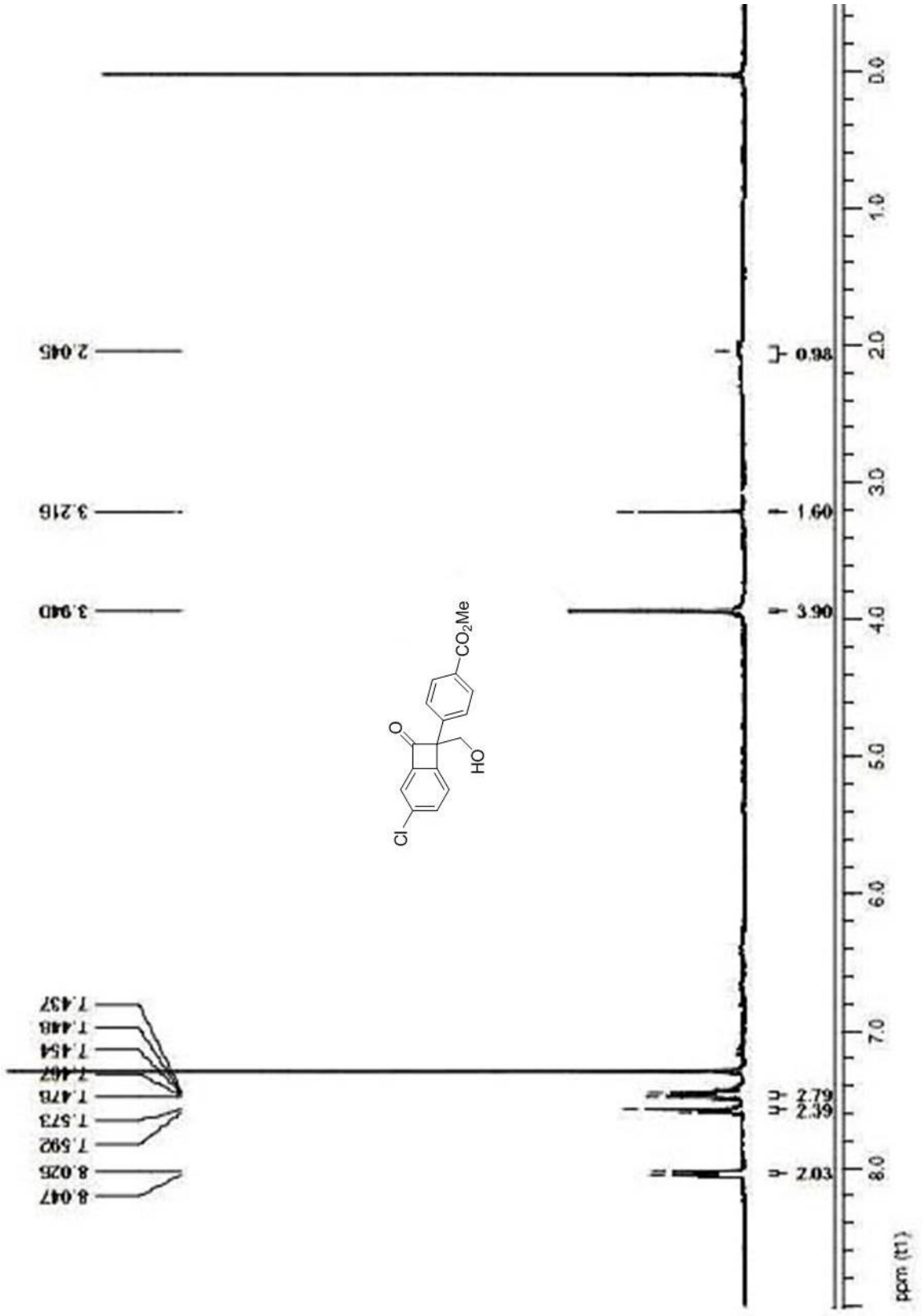

CO2Me
OH
Cl
52.187
72.318
115.187
117.679
126.744
127.062
128.002
128.349
129.595
129.928
131.921
133.044
141.476
146.035
166.830
0
50
100
150
200
ppm (f1)

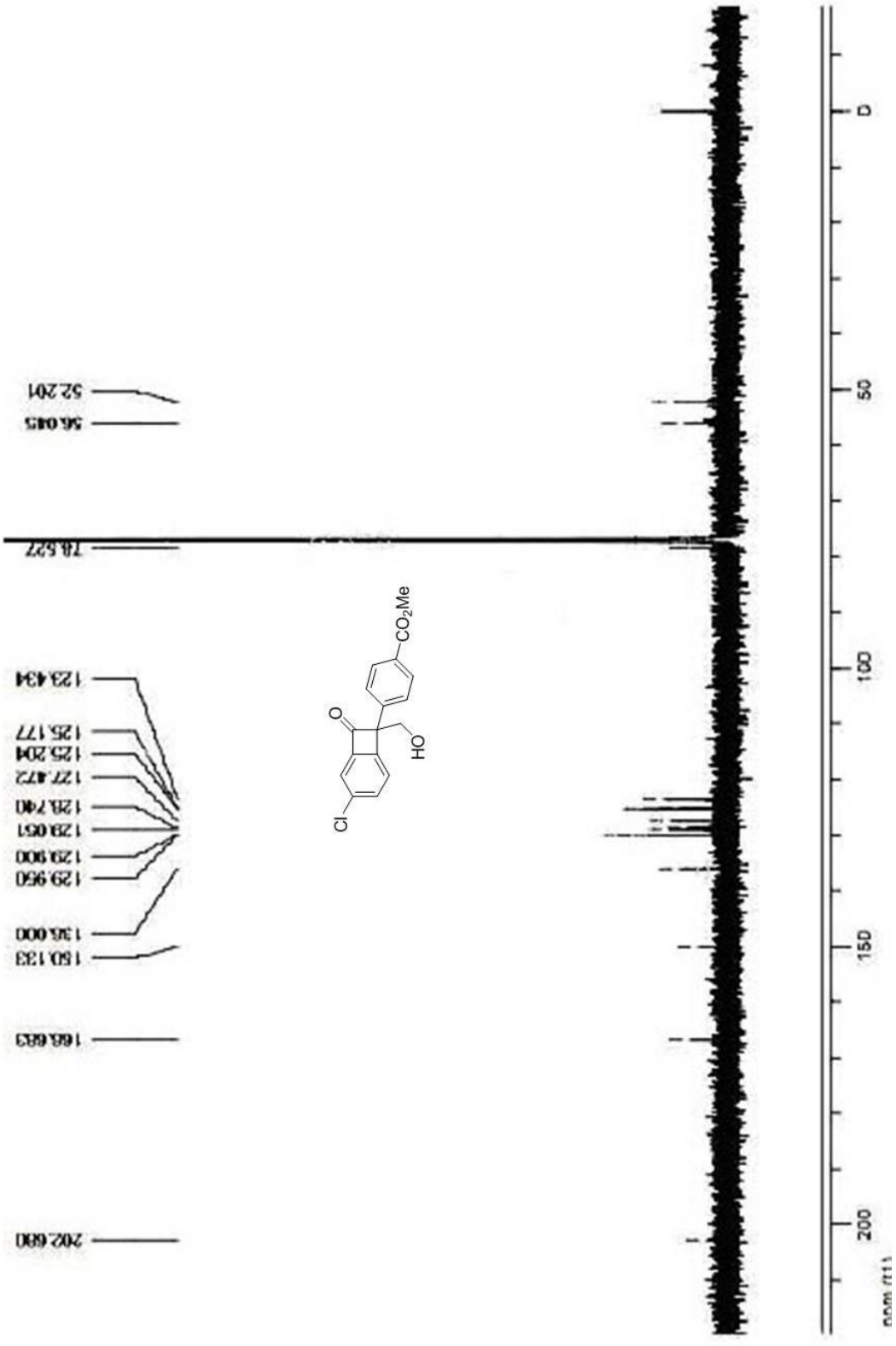

CO2Me
O
Cl
3.959
5.239
5.266
5.657
5.701
6.625
6.652
6.668
6.696
7.264
7.323
7.328
7.462
7.467
7.483
7.488
7.606
7.627
7.826
7.847
8.111
8.132
3.21
1.00
0.98
0.90
0.82
0.98
0.98
1.98
2.09
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

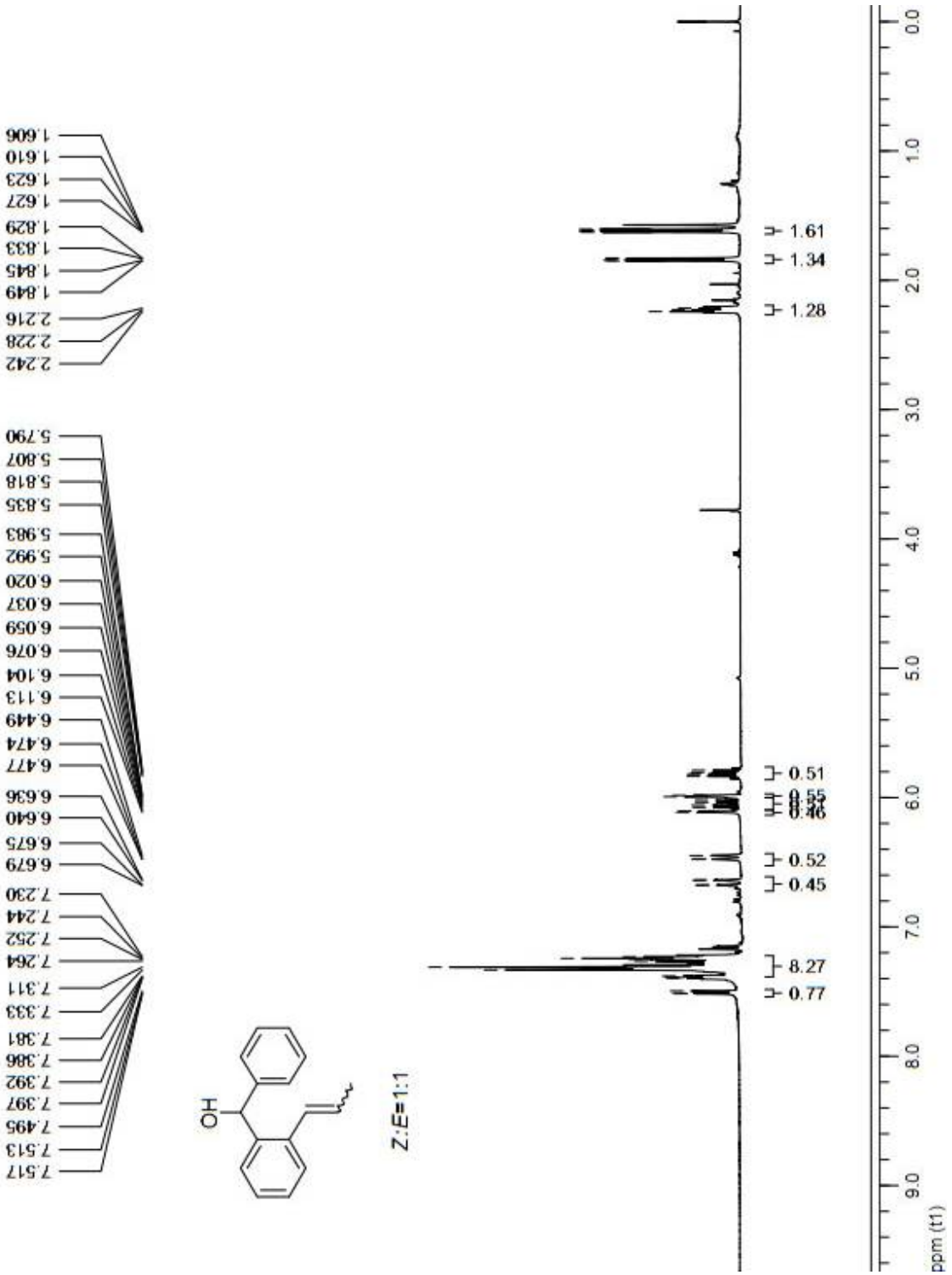

CO2Me
O
Cl
52.574
117.716
127.682
128.399
129.835
130.059
130.928
133.027
133.349
134.341
135.315
138.569
140.261
166.124
196.061
0
50
100
150
200
ppm (f1)

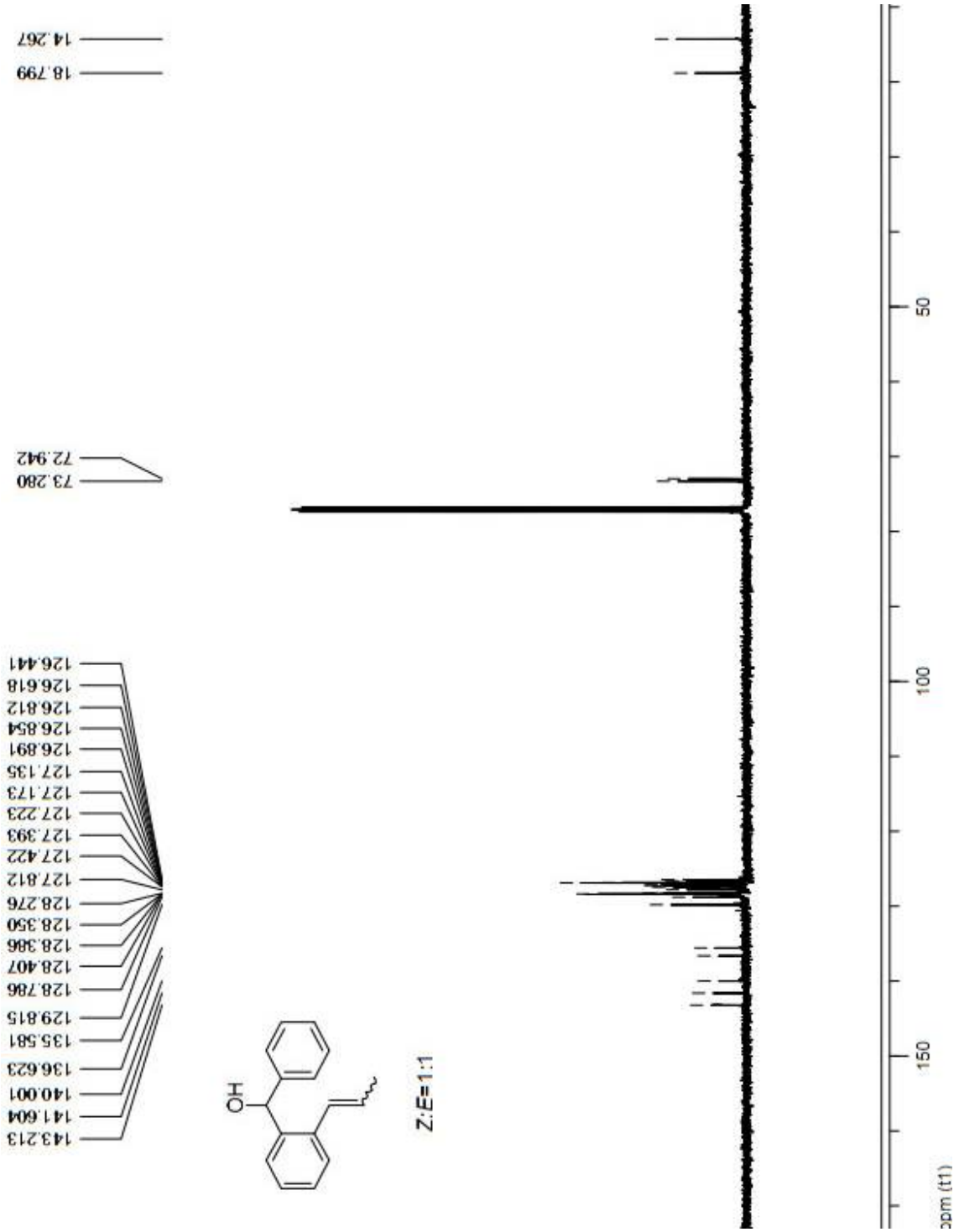

Cl
O
O
MeO2C
2.536
2.542
2.549
2.556
2.860
2.874
2.885
2.897
3.806
3.821
3.827
3.831
3.837
7.321
7.341
7.352
7.357
7.487
7.492
7.508
7.513
7.781
7.802
8.021
8.042
1.03
1.13
3.69
2.19
1.00
1.65
2.39
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

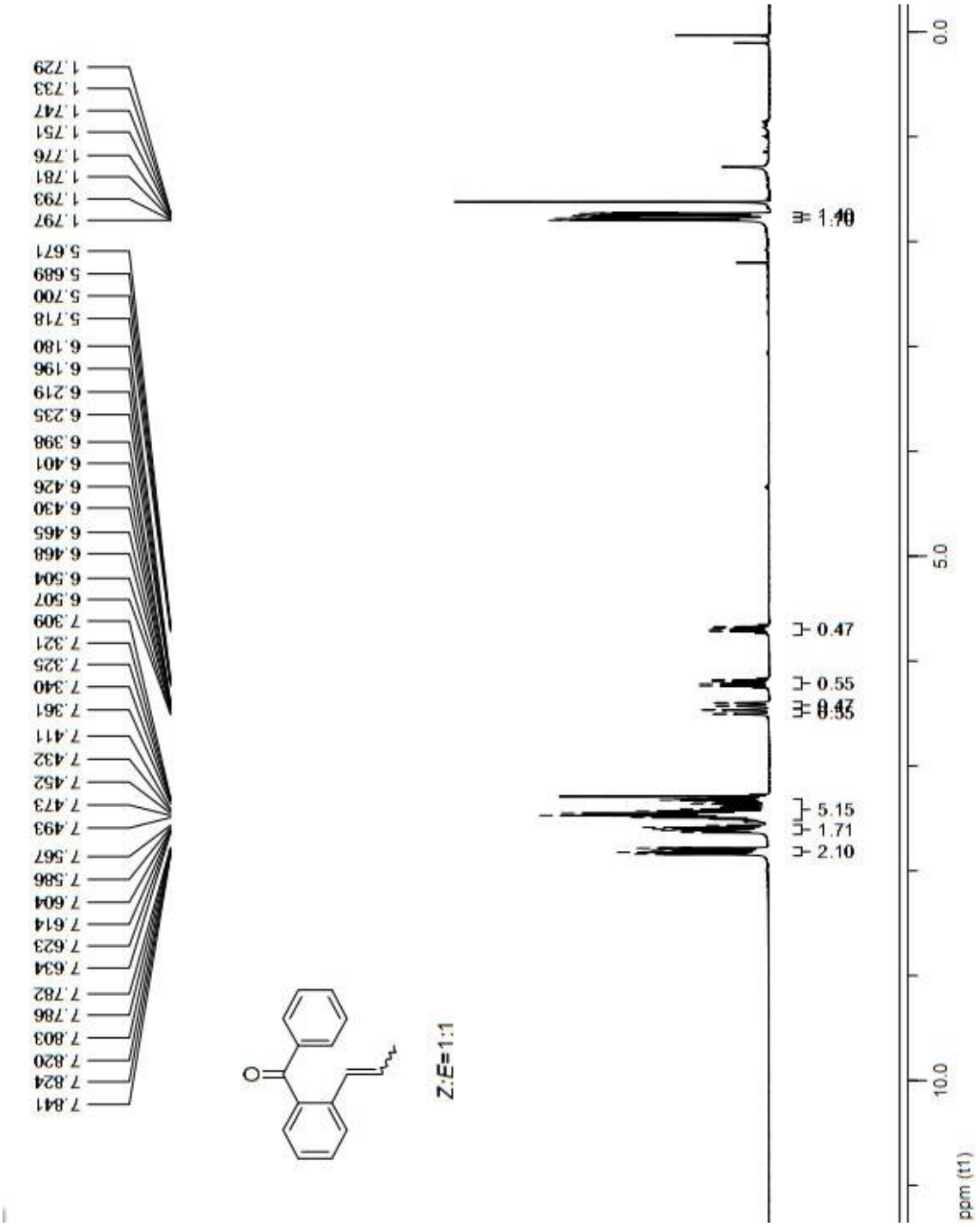

52.827
51.552
50.745
125.981
128.065
129.469
130.468
130.848
132.094
135.129
137.874
140.064
141.570
166.503
195.557
Cl
O
O
MeO2C
0
50
100
150
200
ppm (f1)

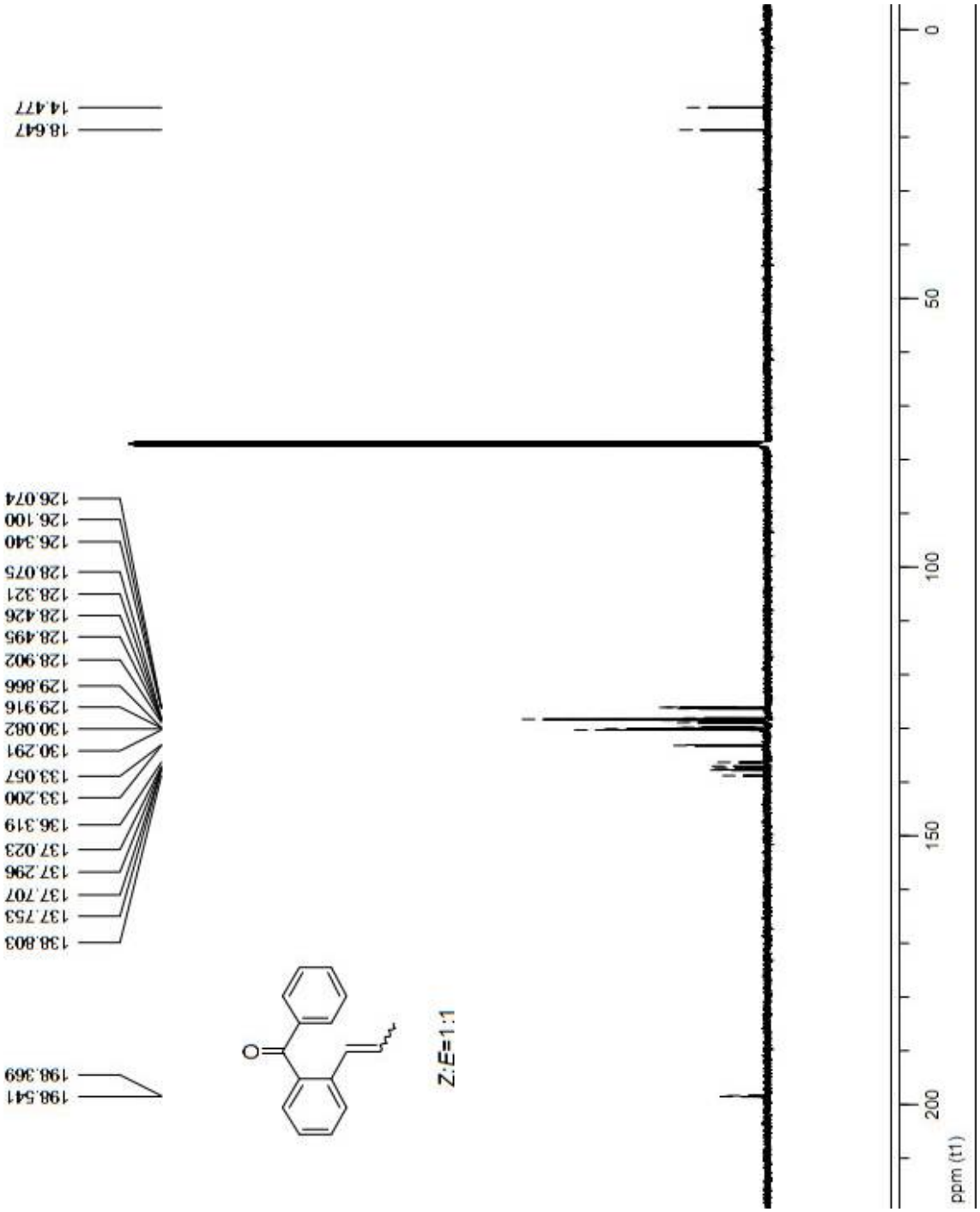

2.045
3.216
3.940
7.437
7.448
7.454
7.467
7.478
7.573
7.592
8.025
8.047
0.98
1.60
3.90
2.79
2.39
2.03
CO2Me
O
HO
Cl
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

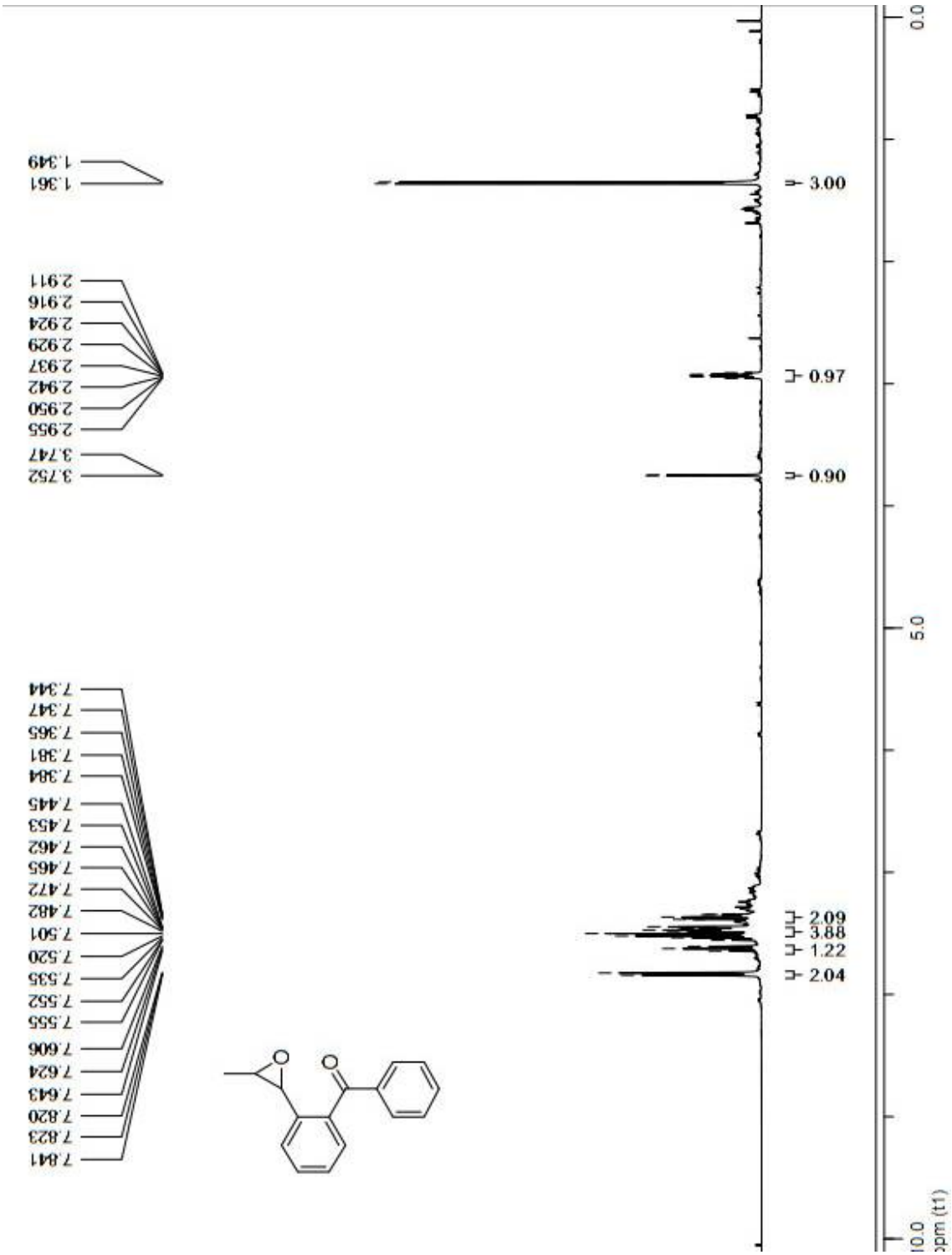

52.201
56.085
78.527
123.434
125.177
125.204
127.472
128.740
129.051
129.900
129.960
135.000
150.133
165.653
202.680
CO2Me
O
HO
Cl
0
50
100
150
200

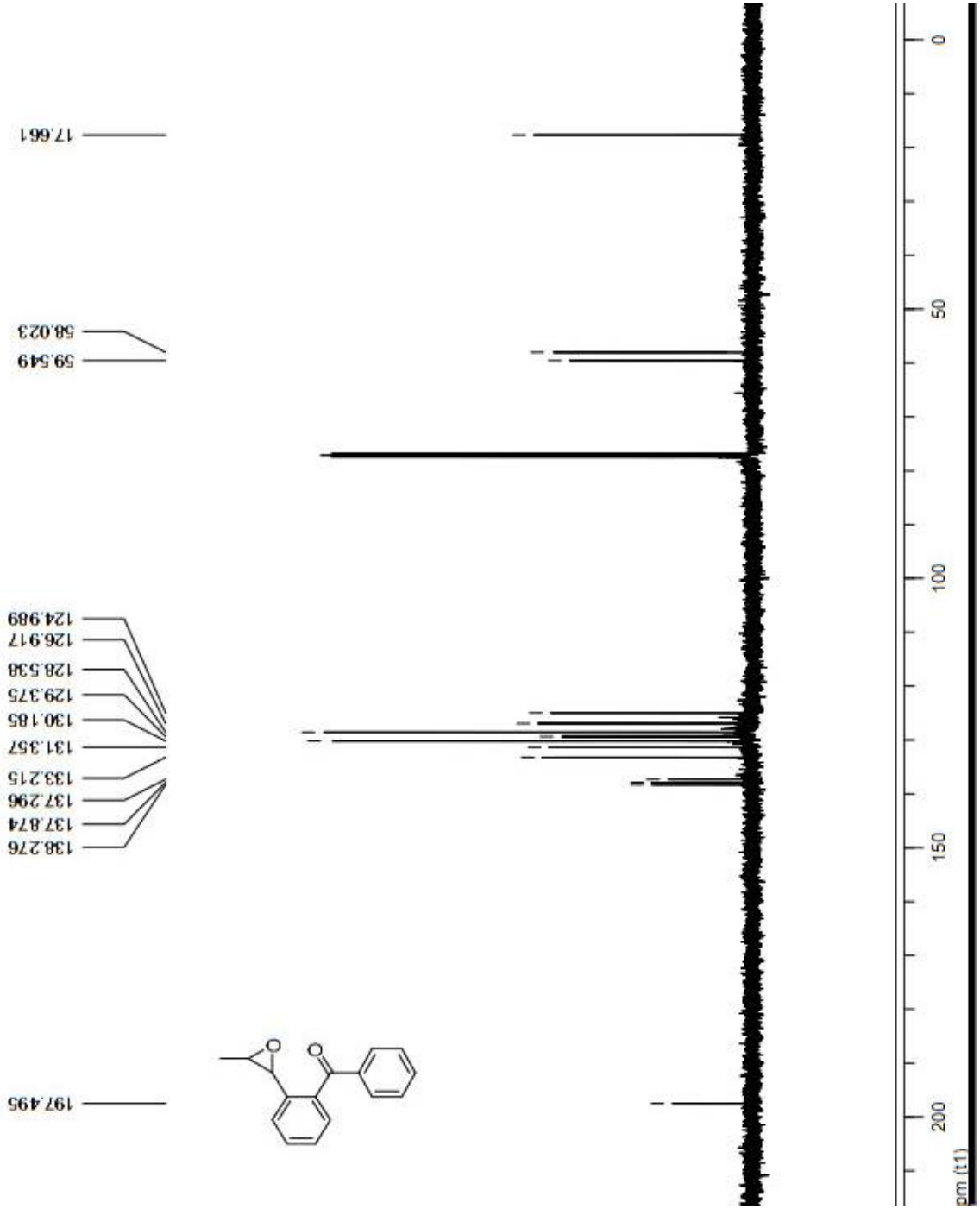

1.606
1.610
1.623
1.627
1.829
1.833
1.845
1.849
2.216
2.228
2.242
5.790
5.807
5.818
5.835
5.983
5.992
6.020
6.037
6.059
6.076
6.104
6.113
6.449
6.474
6.477
6.636
6.640
6.675
6.679
7.230
7.244
7.252
7.264
7.311
7.333
7.381
7.386
7.392
7.397
7.495
7.513
7.517
OH
Z:E=1:1
1.61
1.34
1.28
0.51
0.55
0.46
0.52
0.45
8.27
0.77
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

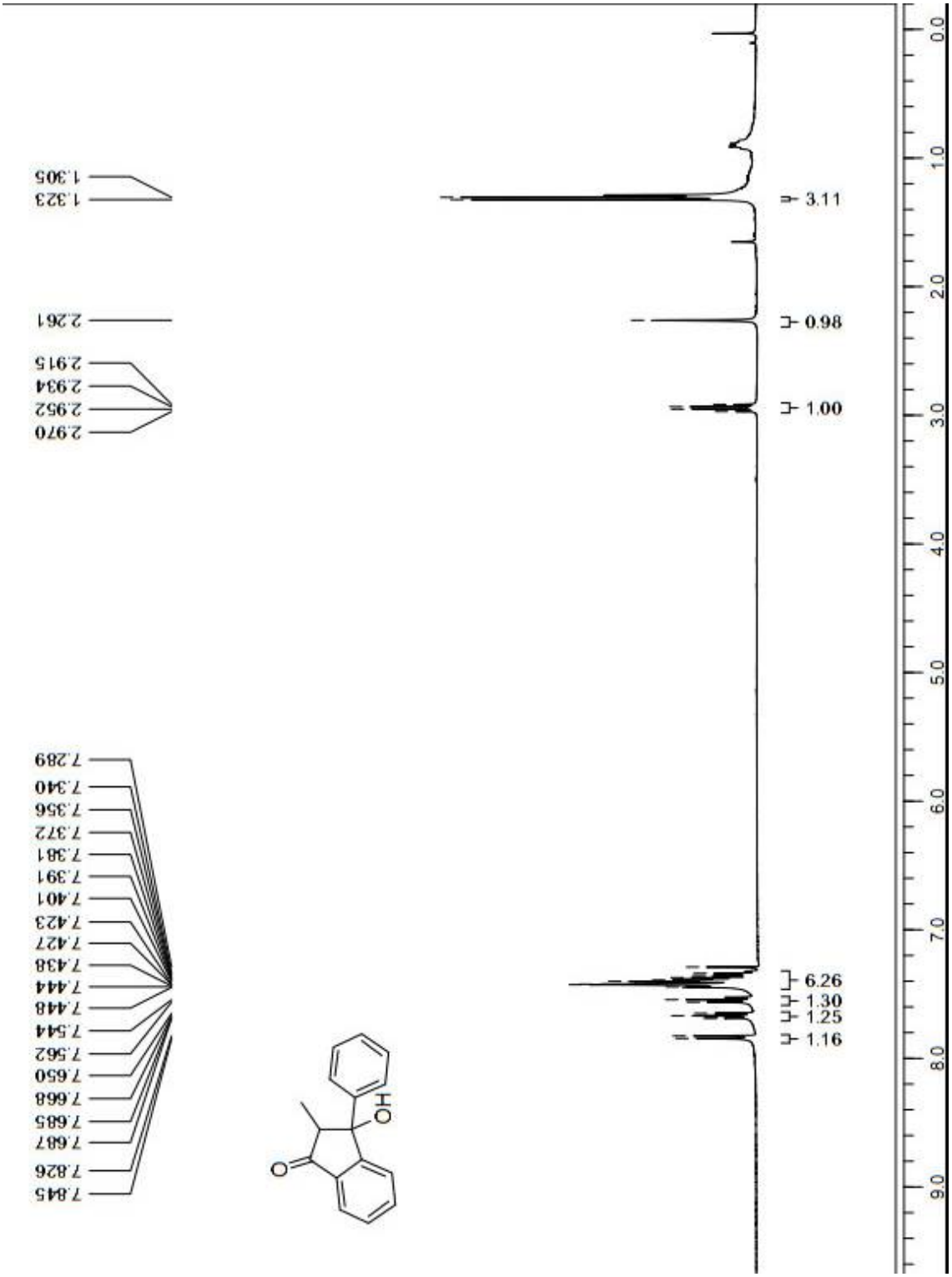

14.267
18.799
72.942
73.280
126.441
126.618
126.812
126.854
126.891
127.135
127.173
127.223
127.393
127.422
127.812
128.276
128.350
128.386
128.407
128.786
129.815
135.581
136.623
140.001
141.604
143.213
OH
Z:E=1:1
50
100
150
ppm (t1)

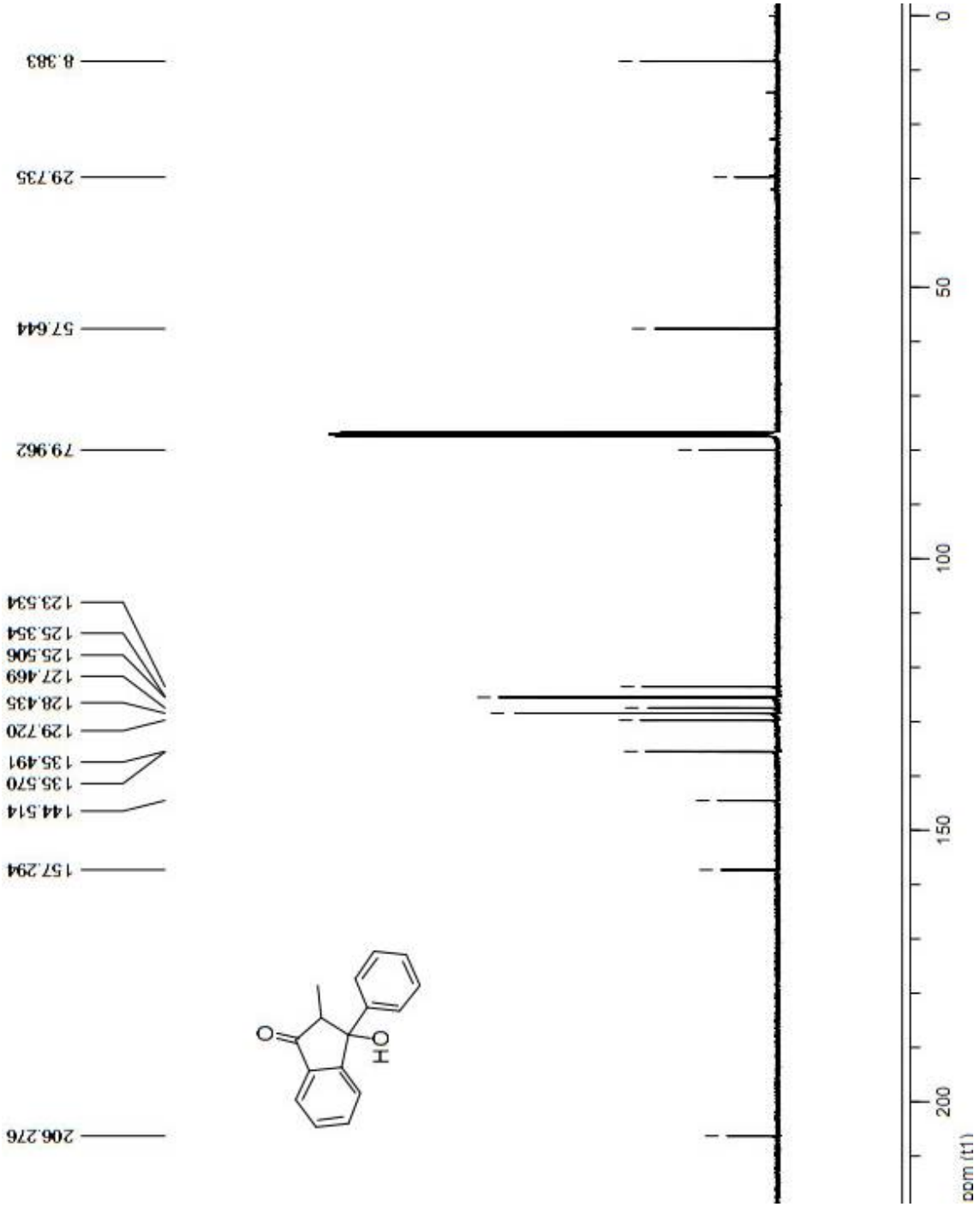

1.729
1.733
1.747
1.751
1.776
1.781
1.793
1.797
5.671
5.689
5.700
5.718
6.180
6.196
6.219
6.235
6.398
6.401
6.426
6.430
6.465
6.468
6.504
6.507
7.309
7.321
7.325
7.340
7.361
7.411
7.432
7.452
7.473
7.493
7.567
7.586
7.604
7.614
7.623
7.634
7.782
7.786
7.803
7.820
7.824
7.841
O
Z:E=1:1
0.47
0.55
5.15
1.71
2.10
0.0
5.0
10.0
ppm (t1)

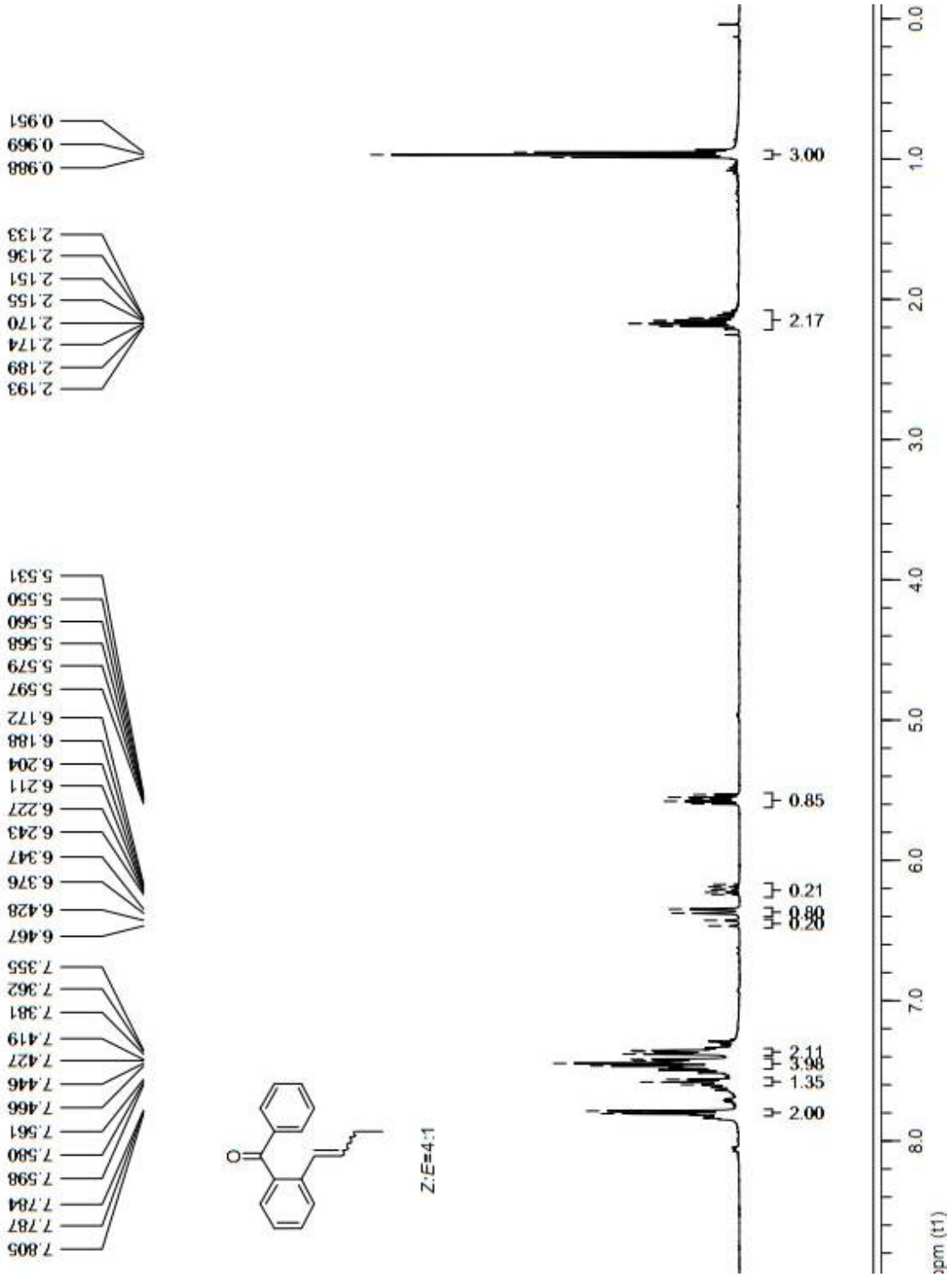

14.477
18.647
126.074
126.100
126.340
128.075
128.321
128.426
128.495
128.902
129.866
129.916
130.082
130.291
133.057
133.200
136.319
137.023
137.296
137.707
137.753
138.803
198.369
198.541
Z:E=1:1
0
50
100
150
200
ppm (t1)

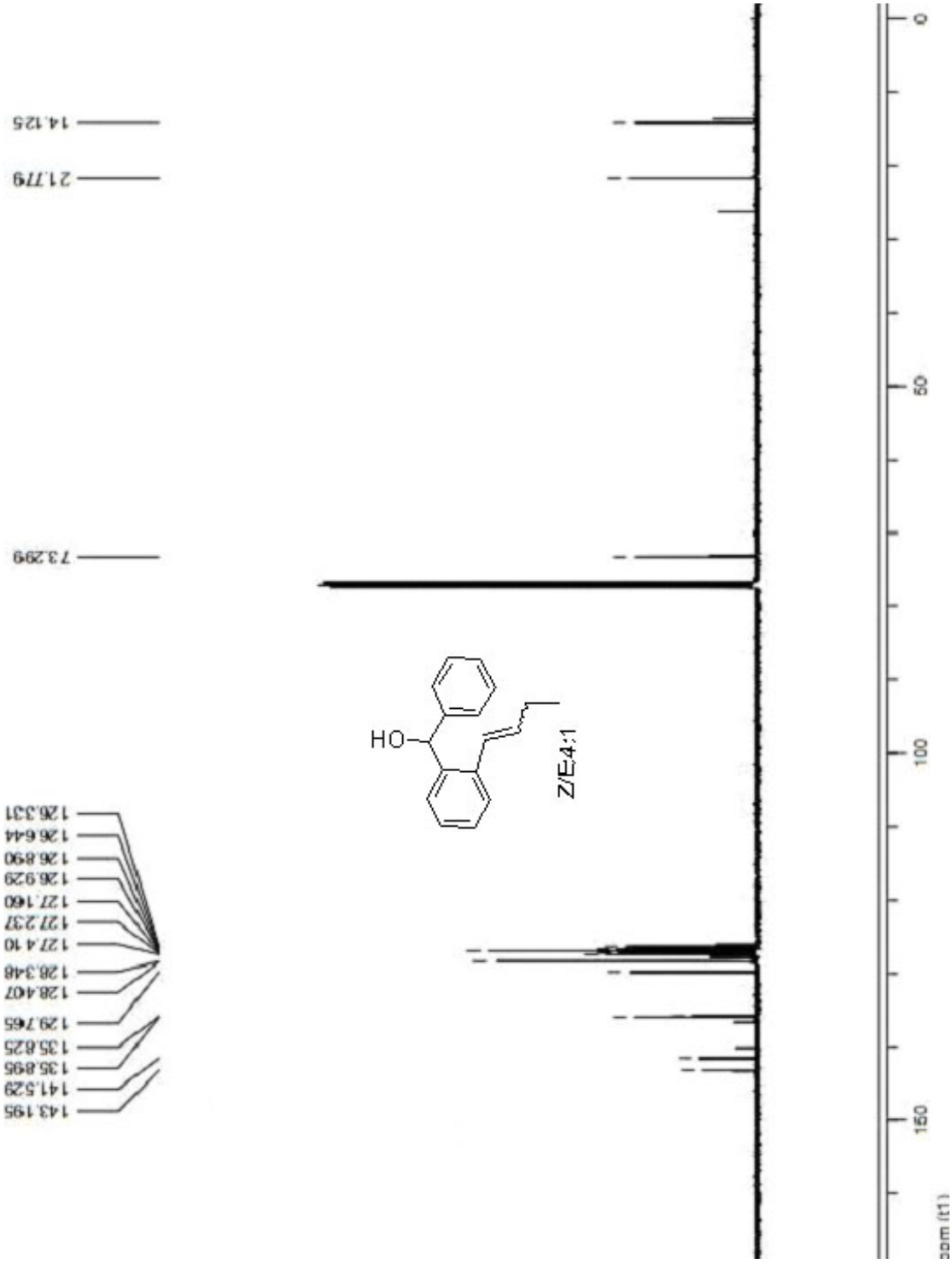


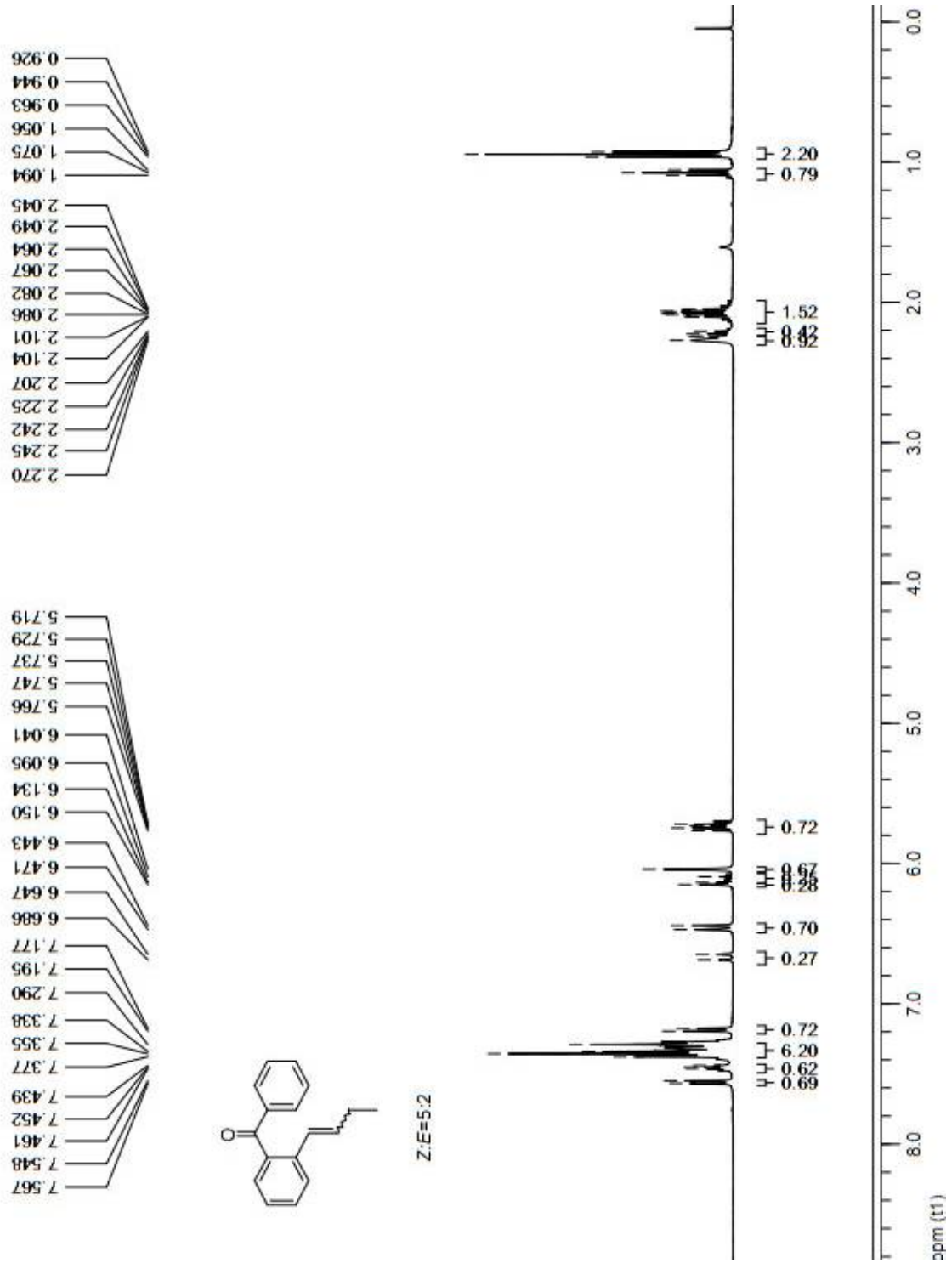

17.661
58.023
59.549
124.989
126.917
128.538
129.375
130.185
131.357
133.215
137.296
137.874
138.276
197.495
0
50
100
150
200
ppm (t1)

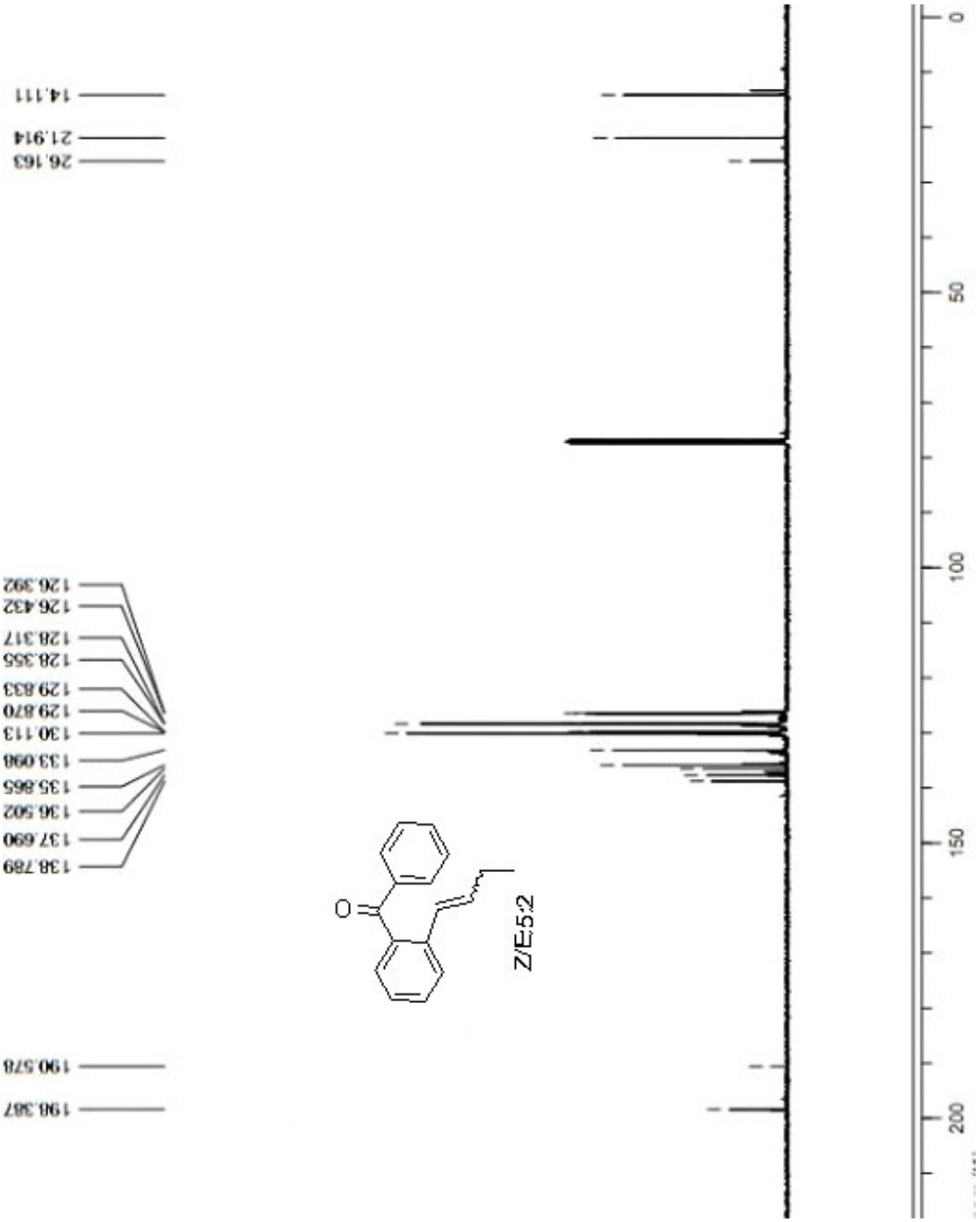

1.305
1.323
2.261
2.915
2.934
2.952
2.970
7.289
7.340
7.356
7.372
7.381
7.391
7.401
7.423
7.427
7.438
7.444
7.448
7.544
7.562
7.650
7.668
7.685
7.687
7.826
7.845
3.11
0.98
1.00
6.26
1.30
1.25
1.16
OH
O
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

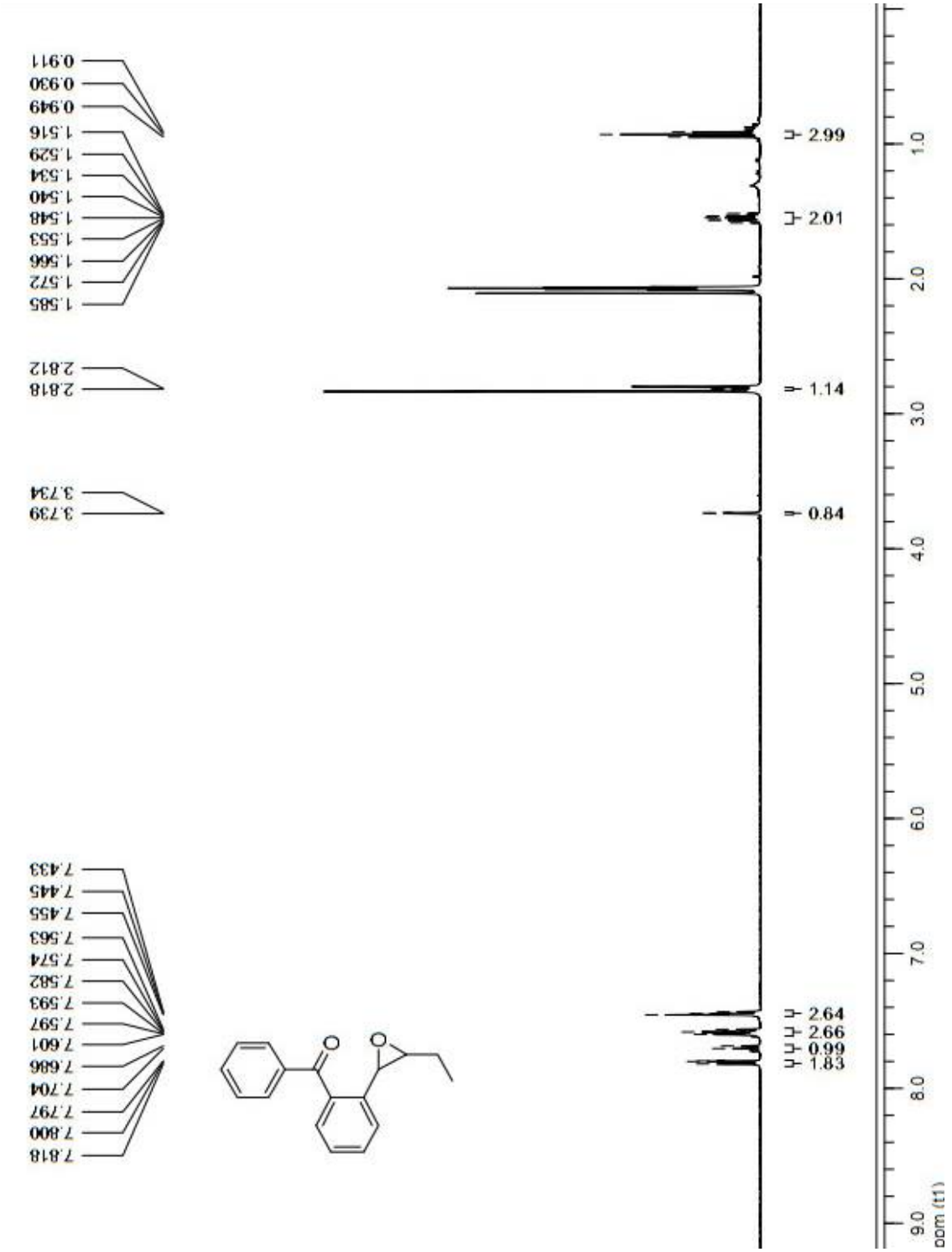


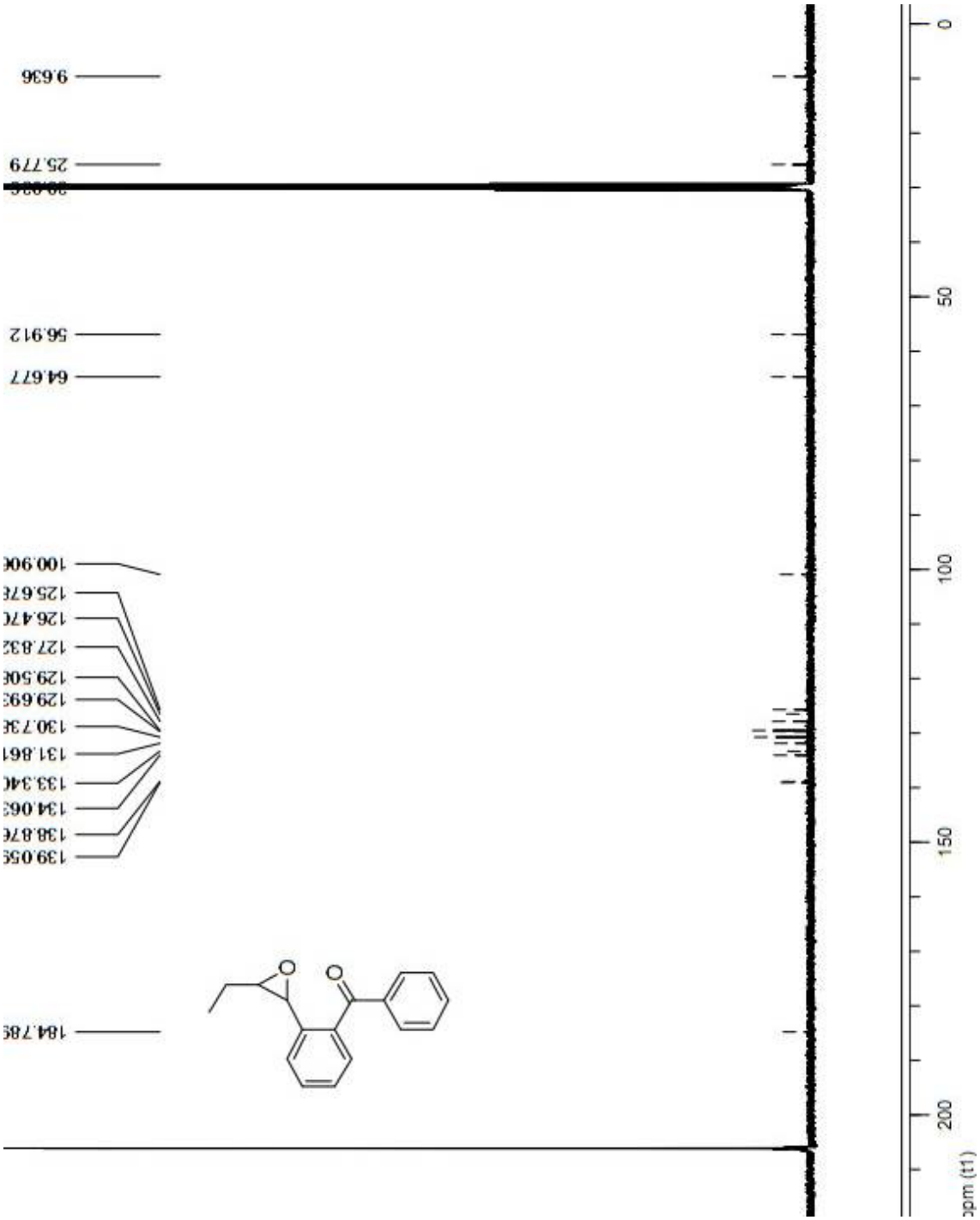

0.951
0.969
0.988
2.133
2.136
2.151
2.155
2.170
2.174
2.189
2.193
5.531
5.550
5.560
5.568
5.579
5.597
6.172
6.188
6.204
6.211
6.227
6.243
6.347
6.376
6.428
6.467
7.355
7.362
7.381
7.419
7.427
7.446
7.466
7.561
7.580
7.598
7.784
7.787
7.805
3.00
2.17
0.85
0.21
0.80
0.20
2.11
3.98
1.35
2.00
Z:E=4:1
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

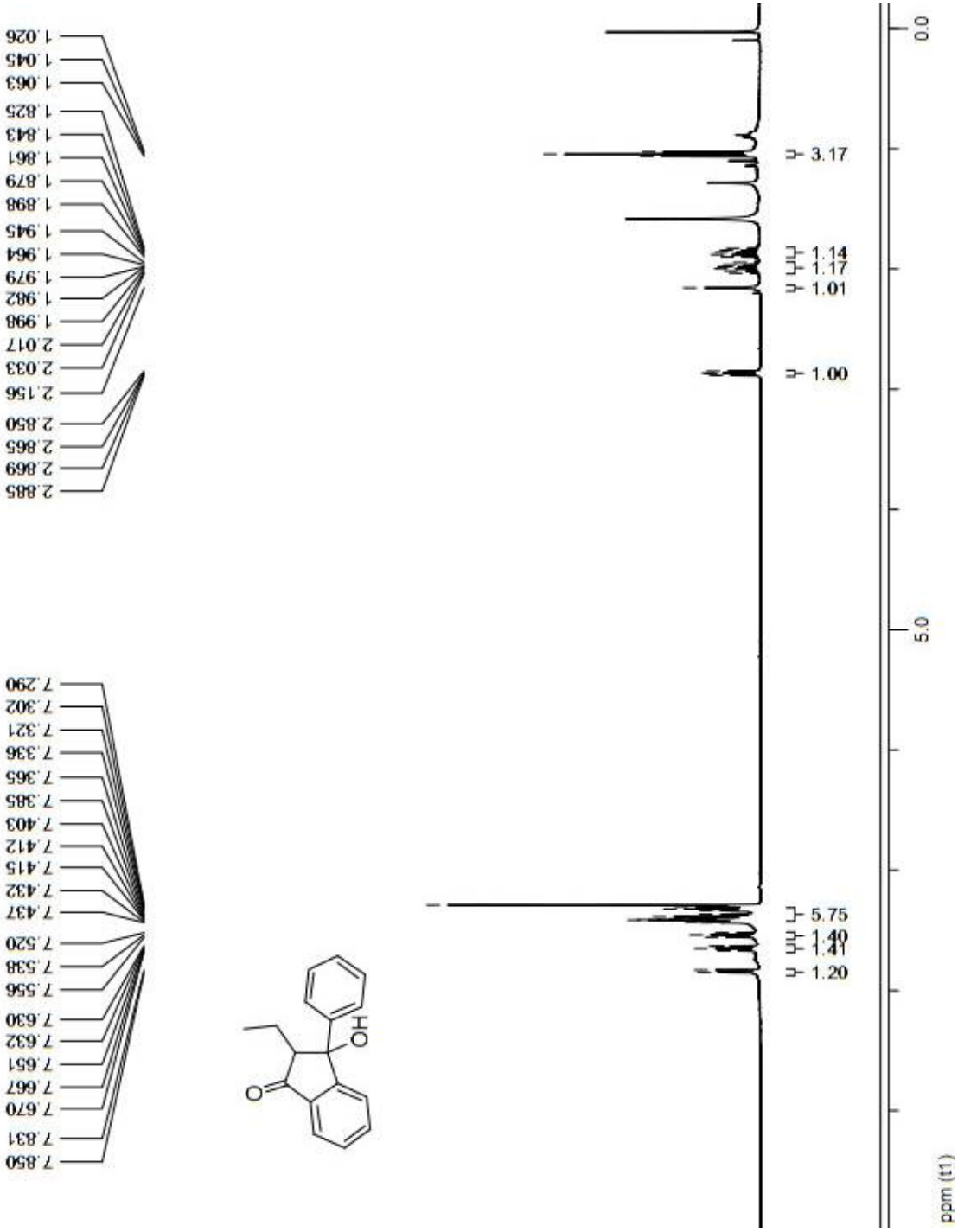

14.125
21.779
73.299
126.331
126.644
126.890
126.929
127.160
127.237
127.410
128.348
128.407
129.765
135.825
135.895
141.529
143.195
HO
Z/E;4:1
0
50
100
150

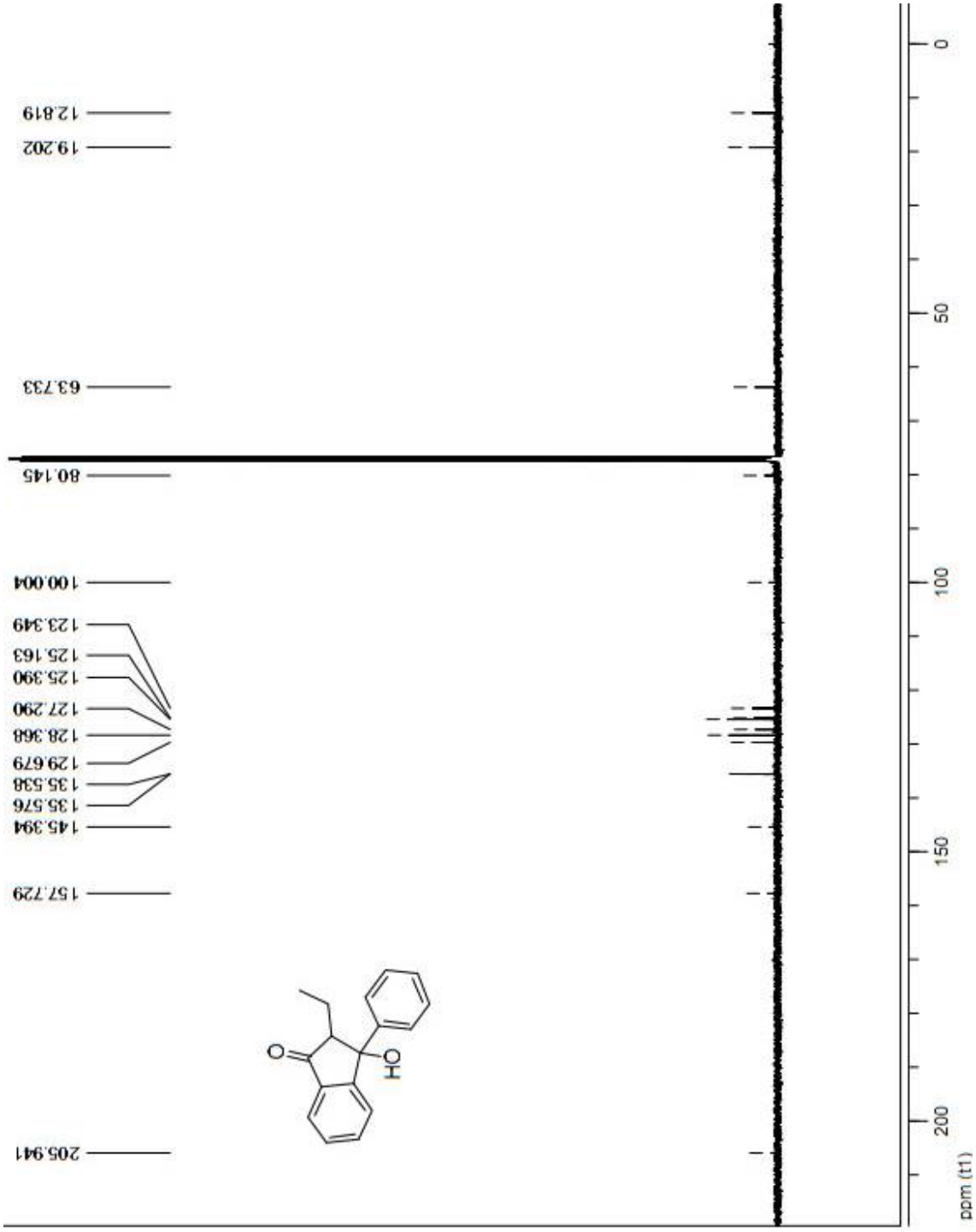

0.926
0.944
0.963
1.056
1.075
1.094
2.045
2.049
2.064
2.067
2.082
2.086
2.101
2.104
2.207
2.225
2.242
2.245
2.270
5.719
5.729
5.737
5.747
5.766
6.041
6.095
6.134
6.150
6.443
6.471
6.647
6.686
7.177
7.195
7.290
7.338
7.355
7.377
7.439
7.452
7.461
7.548
7.567
O
Z:E=5:2
2.20
0.79
1.52
0.72
0.70
0.27
0.72
6.20
0.62
0.69
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

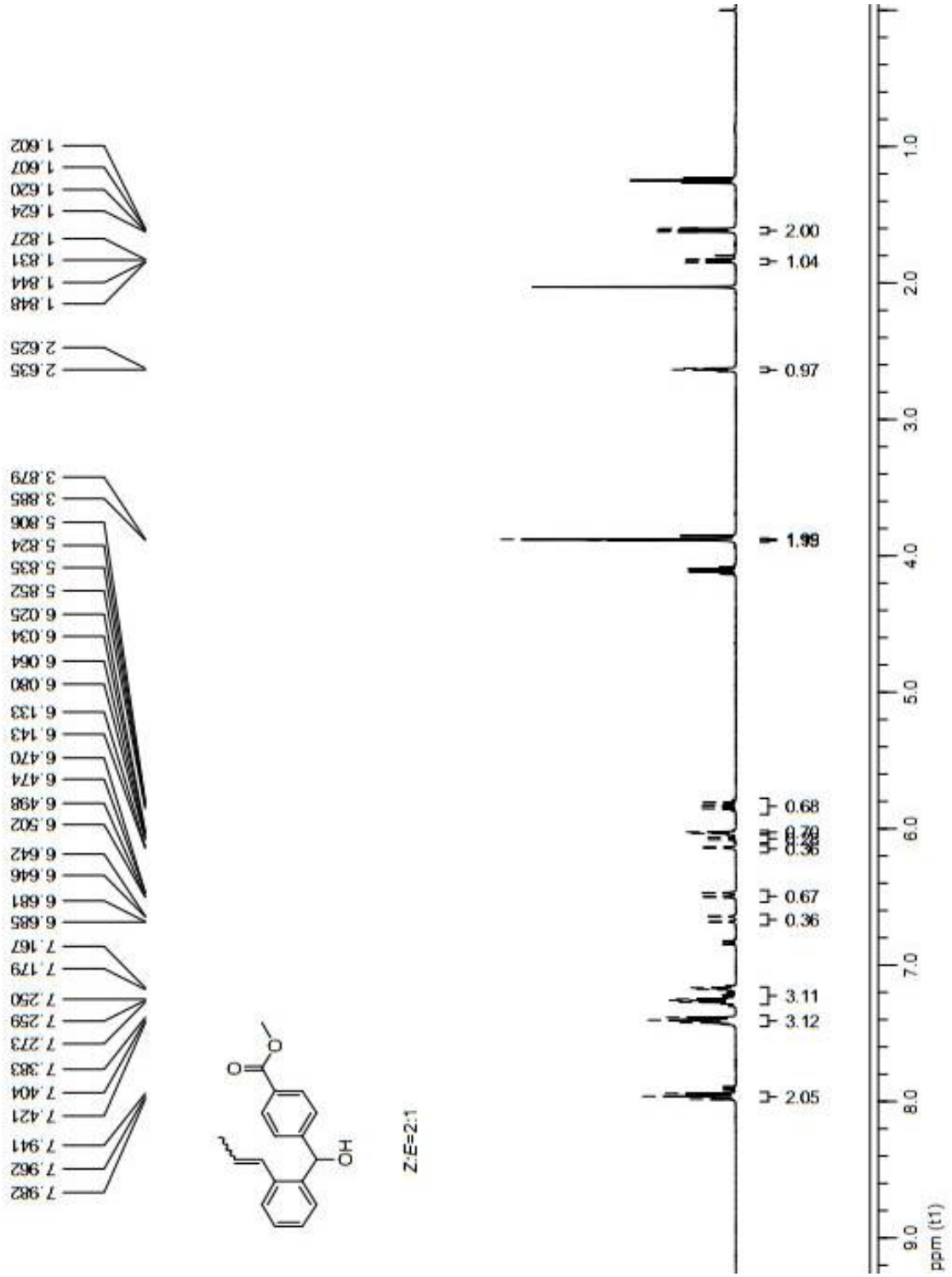

14.111
21.914
26.163
126.392
126.432
128.317
128.355
129.833
129.870
130.113
133.098
135.865
136.502
137.690
138.789
190.578
196.387
O
Z/E:5:2
0
50
100
150
200

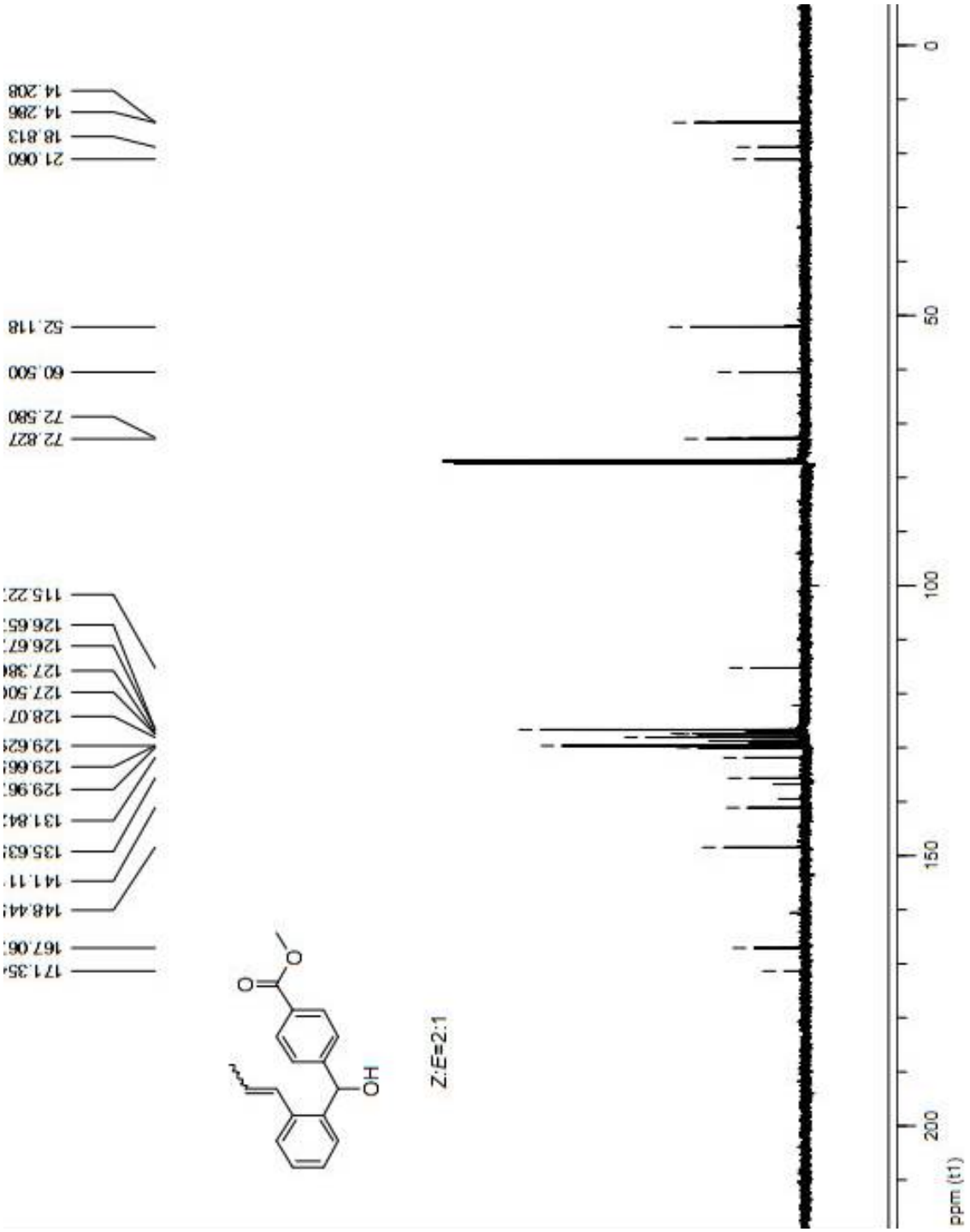

0.911
0.930
0.949
1.516
1.529
1.534
1.540
1.548
1.553
1.566
1.572
1.585
2.812
2.818
3.734
3.739
7.433
7.445
7.455
7.563
7.574
7.582
7.593
7.597
7.601
7.686
7.704
7.797
7.800
7.818
2.99
2.01
1.14
0.84
2.64
2.66
0.99
1.83
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

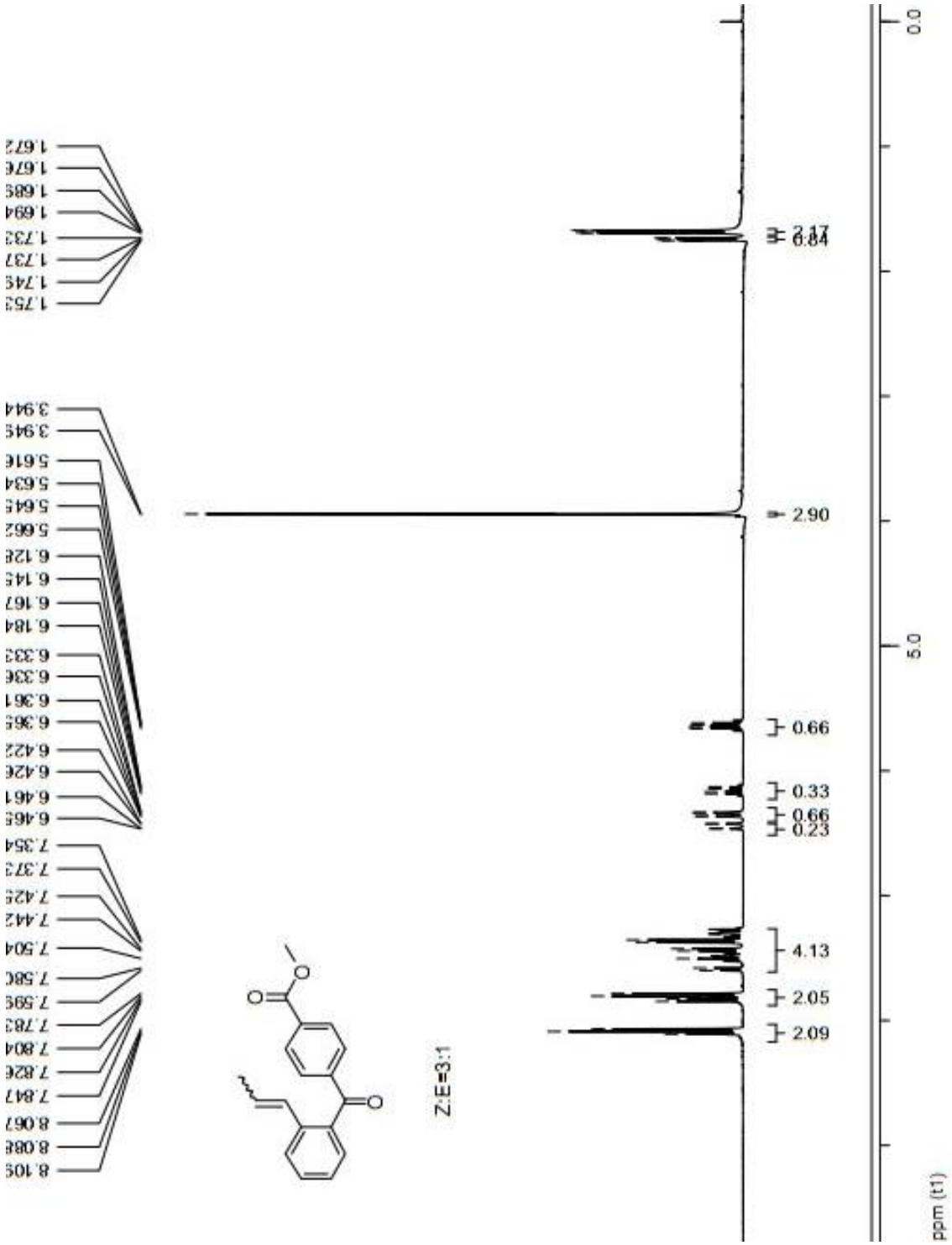

9.636
25.779
56.912
64.677
100.906
125.676
126.470
127.832
129.506
129.693
130.736
131.861
133.340
134.063
138.876
139.059
184.785
0
50
100
150
200
ppm (t1)

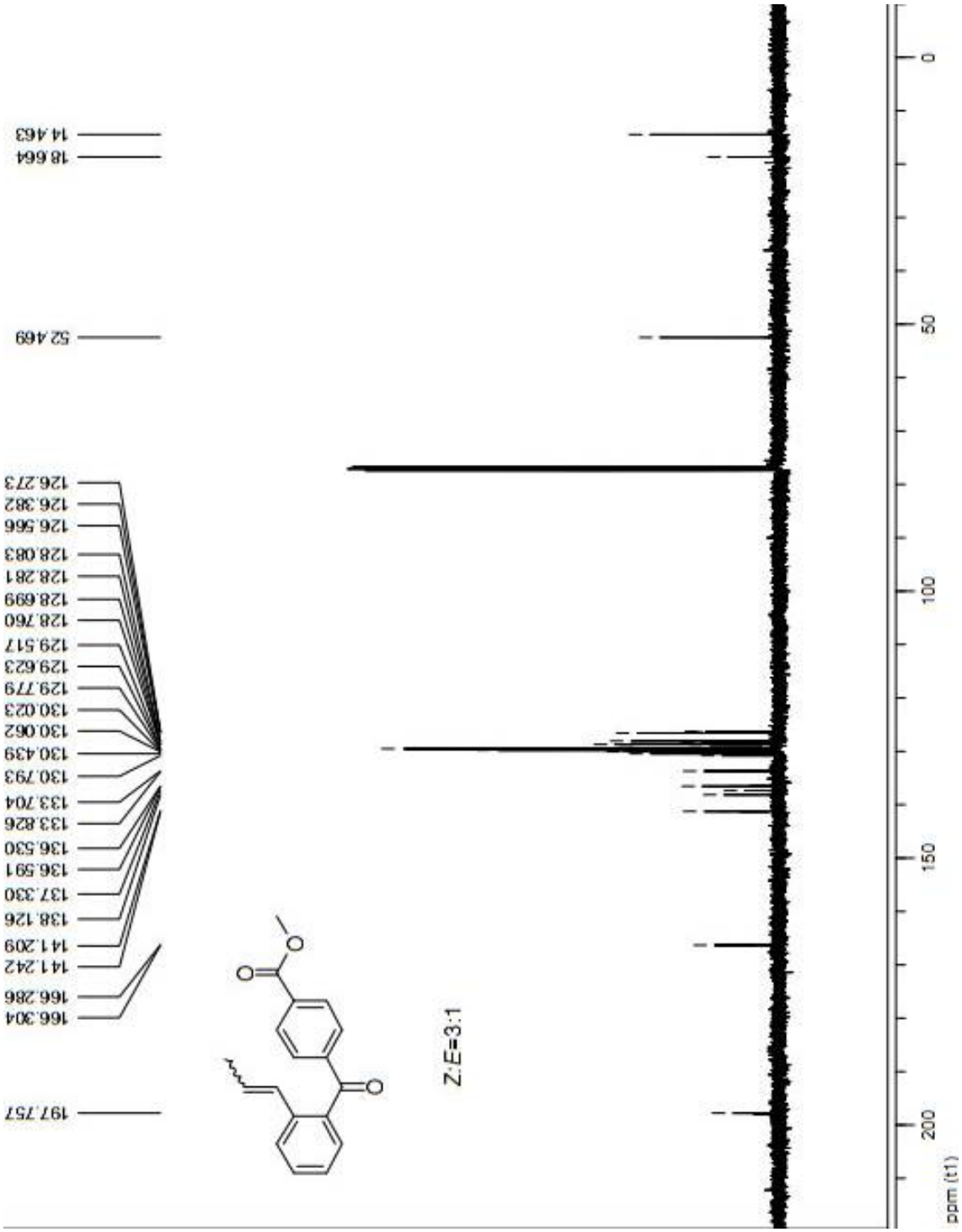

1.026
1.045
1.063
1.825
1.843
1.861
1.879
1.898
1.945
1.964
1.979
1.982
1.998
2.017
2.033
2.156
2.850
2.865
2.869
2.885
7.290
7.302
7.321
7.336
7.365
7.385
7.403
7.412
7.415
7.432
7.437
7.520
7.538
7.556
7.630
7.632
7.651
7.667
7.670
7.831
7.850
3.17
1.14
1.17
1.01
1.00
5.75
1.40
1.41
1.20
OH
O
0.0
5.0
ppm (t1)

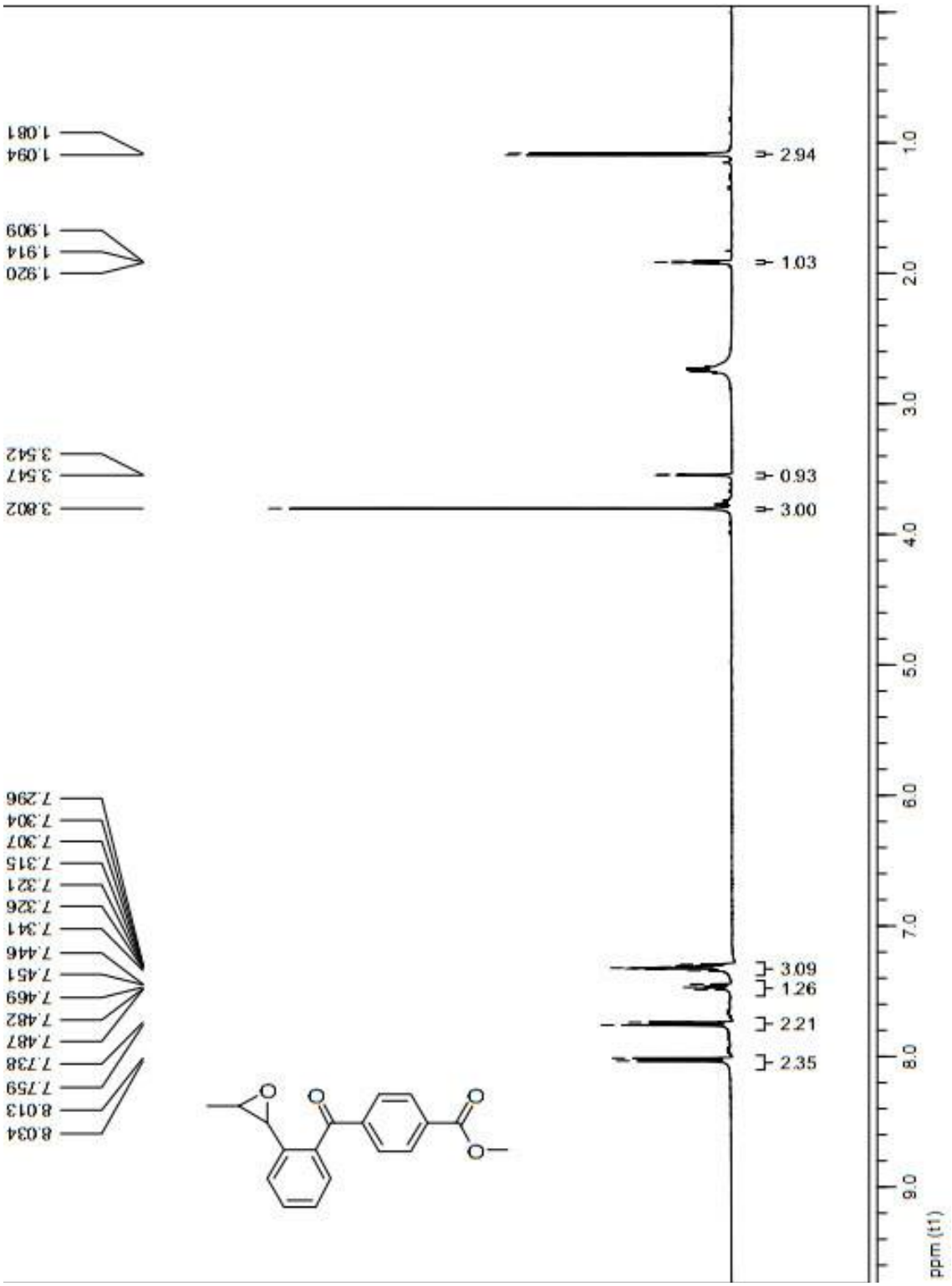

12.819
19.202
63.733
80.145
100.004
123.349
125.163
125.390
127.290
128.368
129.679
135.538
135.576
145.394
157.729
205.941
O
OH
0
50
100
150
200
ppm (t1)

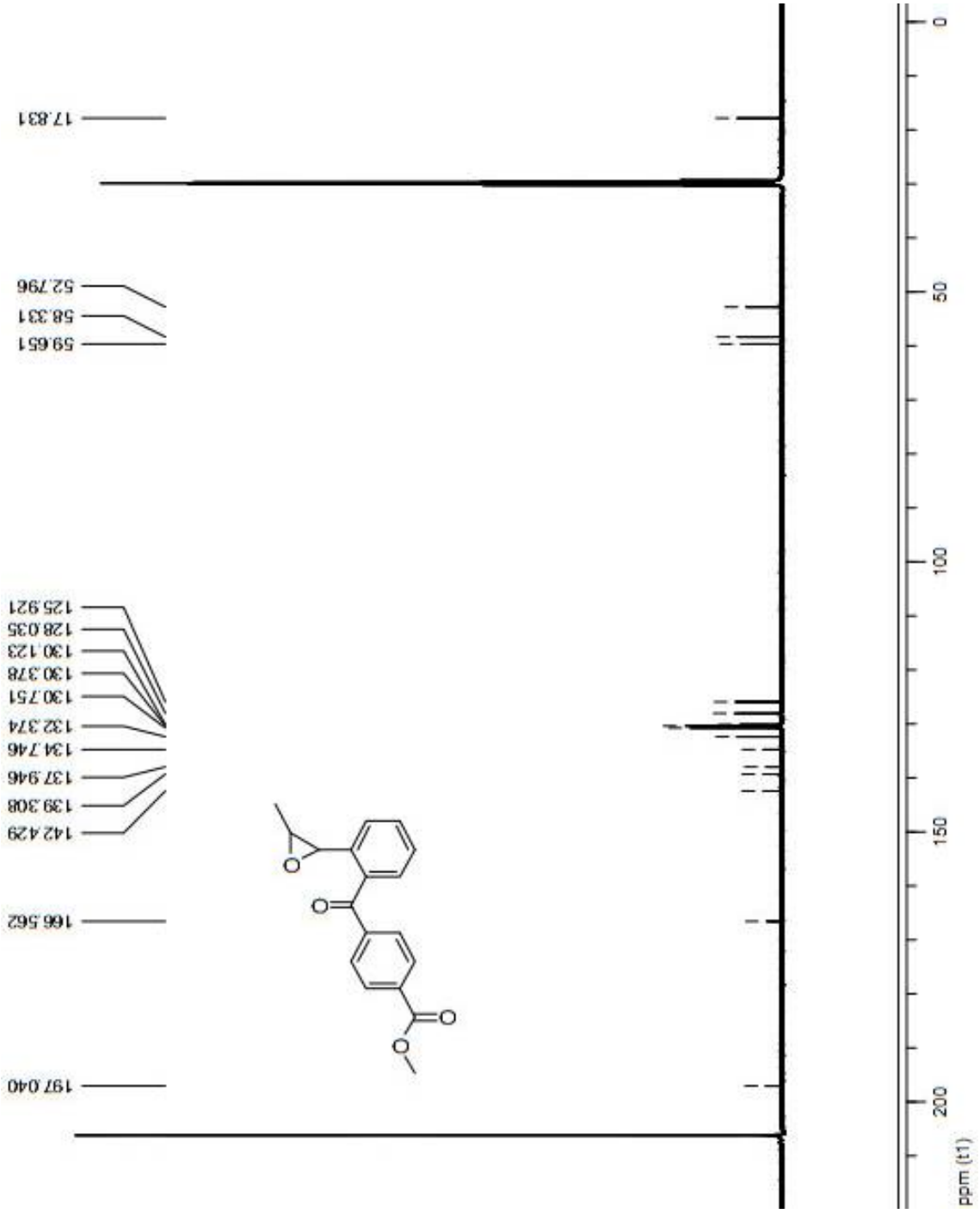

1.602
1.607
1.620
1.624
1.827
1.831
1.844
1.848
2.625
2.635
3.879
3.885
5.806
5.824
5.835
5.852
6.025
6.034
6.064
6.080
6.133
6.143
6.470
6.474
6.498
6.502
6.642
6.646
6.681
6.685
7.167
7.179
7.250
7.259
7.273
7.383
7.404
7.421
7.941
7.962
7.982
O
O
OH
Z:E=2:1
2.00
1.04
0.97
1.99
0.68
0.67
0.36
3.11
3.12
2.05
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

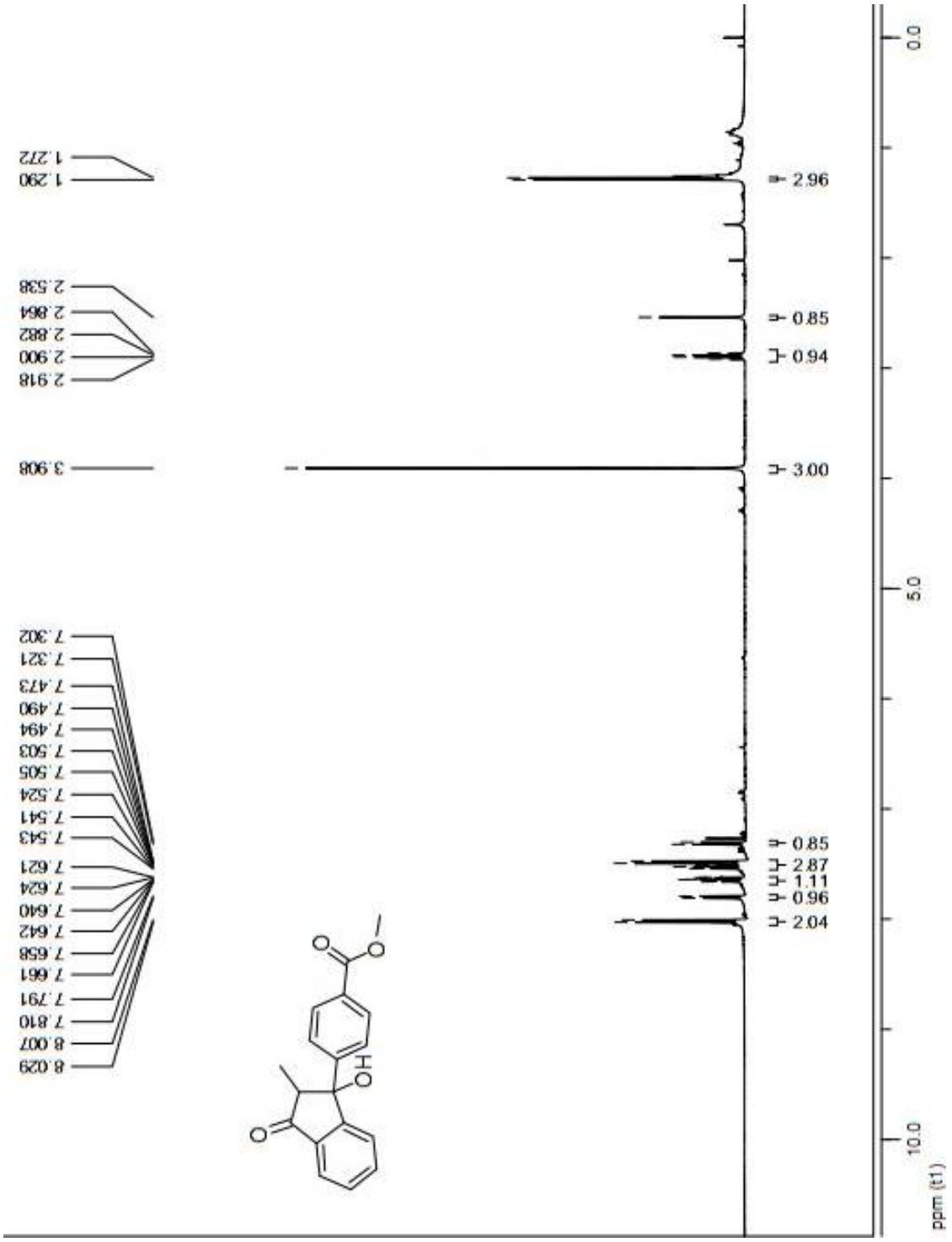

14.208
14.286
18.813
21.060
52.118
60.500
72.580
72.827
115.22
126.65
126.67
127.38
127.50
128.07
129.62
129.66
129.96
131.84
135.63
141.11
148.44
167.06
171.35
O
O
OH
Z:E=2:1
0
50
100
150
200
ppm (t1)

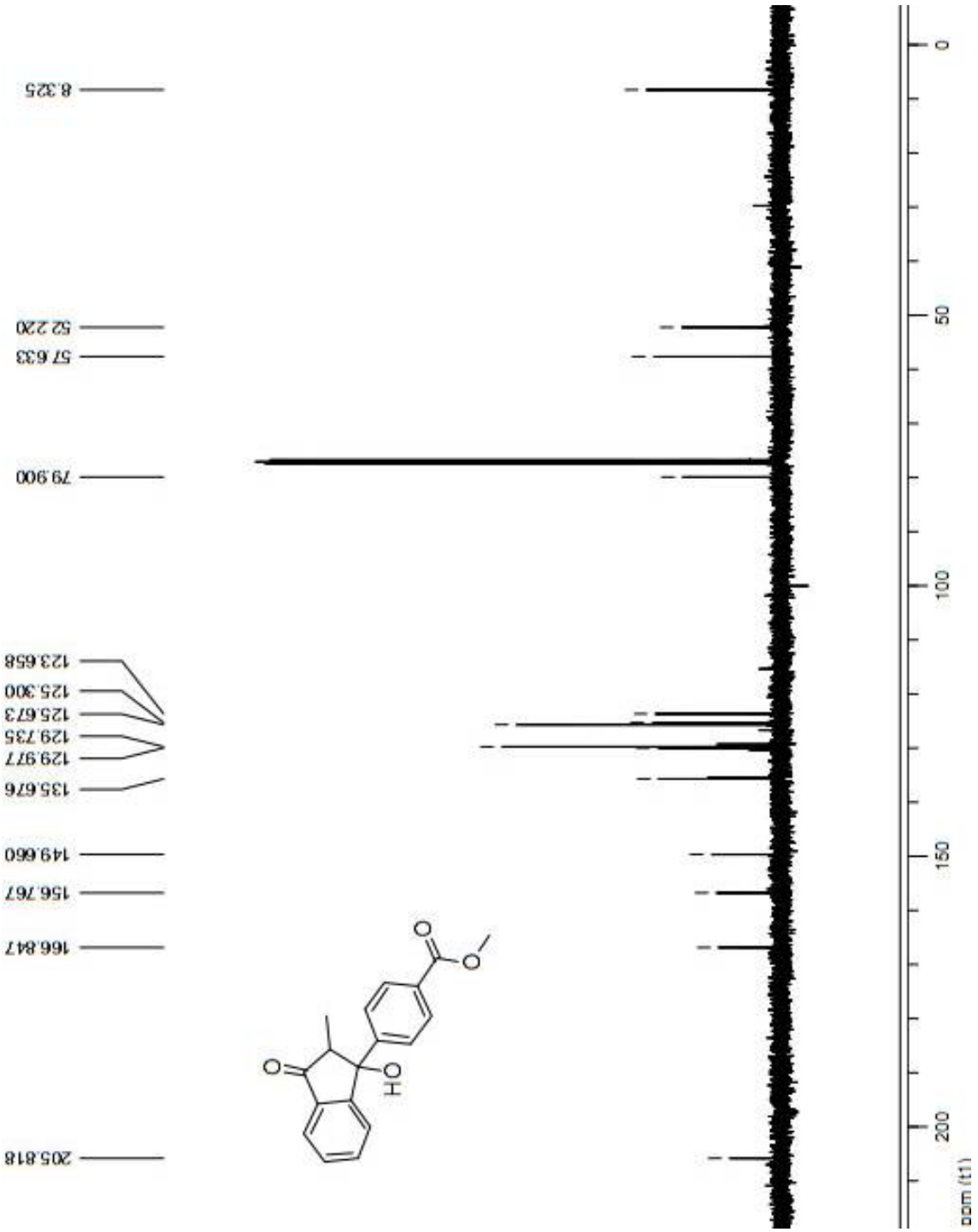

1.672
1.676
1.686
1.694
1.732
1.737
1.748
1.752
3.944
3.945
5.616
5.634
5.645
5.662
6.128
6.145
6.167
6.184
6.332
6.336
6.361
6.365
6.422
6.426
6.461
6.465
7.354
7.372
7.425
7.442
7.504
7.580
7.599
7.783
7.804
7.826
7.847
8.067
8.086
8.105
2.17
6.84
2.90
0.66
0.33
0.66
0.23
4.13
2.05
2.09
Z:E=3:1
0.0
5.0
ppm (t1)

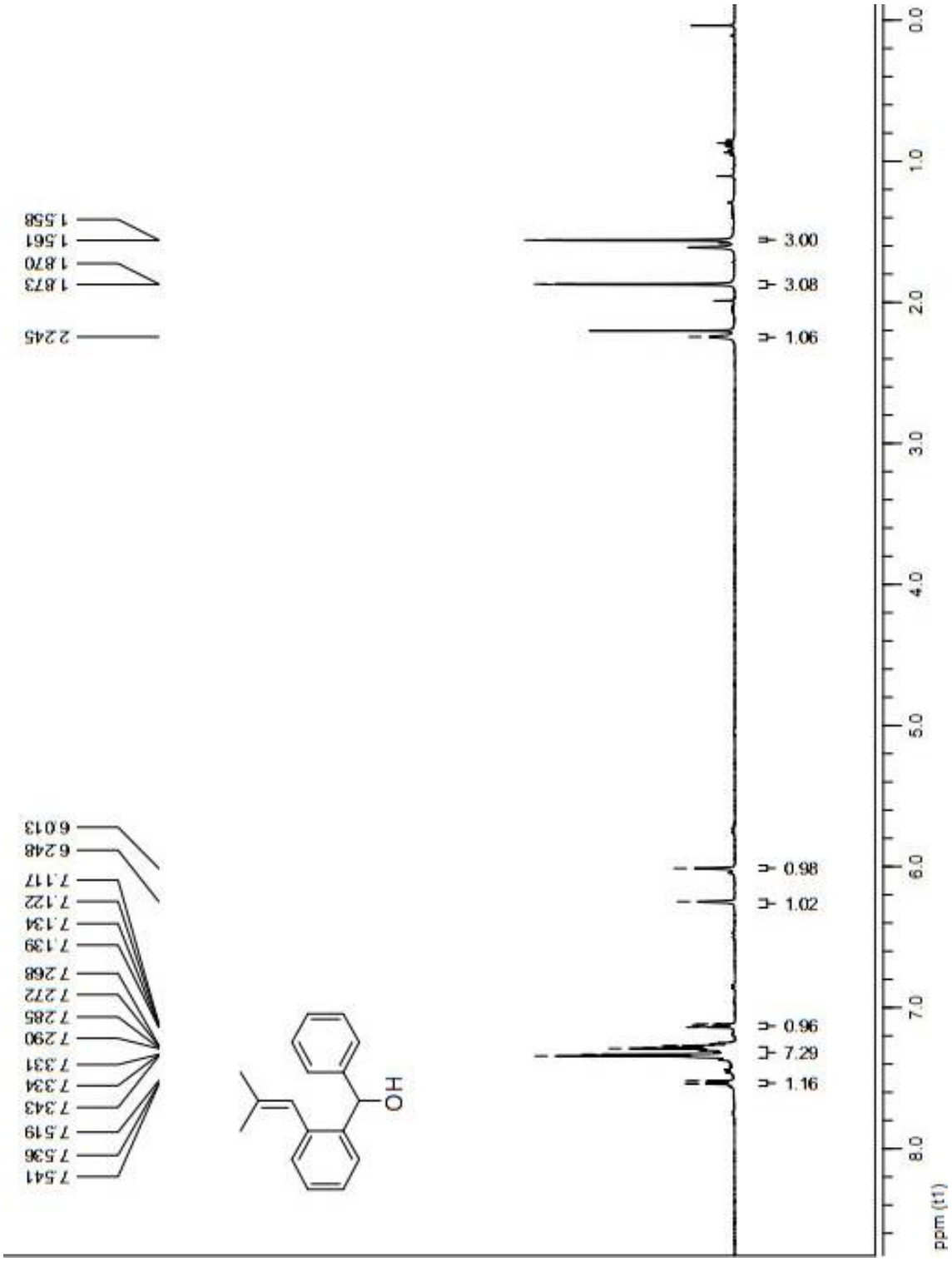

14.463
18.664
52.469
126.273
126.382
126.566
128.083
128.281
128.699
128.760
129.517
129.623
129.779
130.023
130.062
130.439
130.793
133.704
133.826
136.530
136.591
137.330
138.126
141.209
141.242
166.286
166.304
197.757
Z:E=3:1
0
50
100
150
200
ppm (t1)

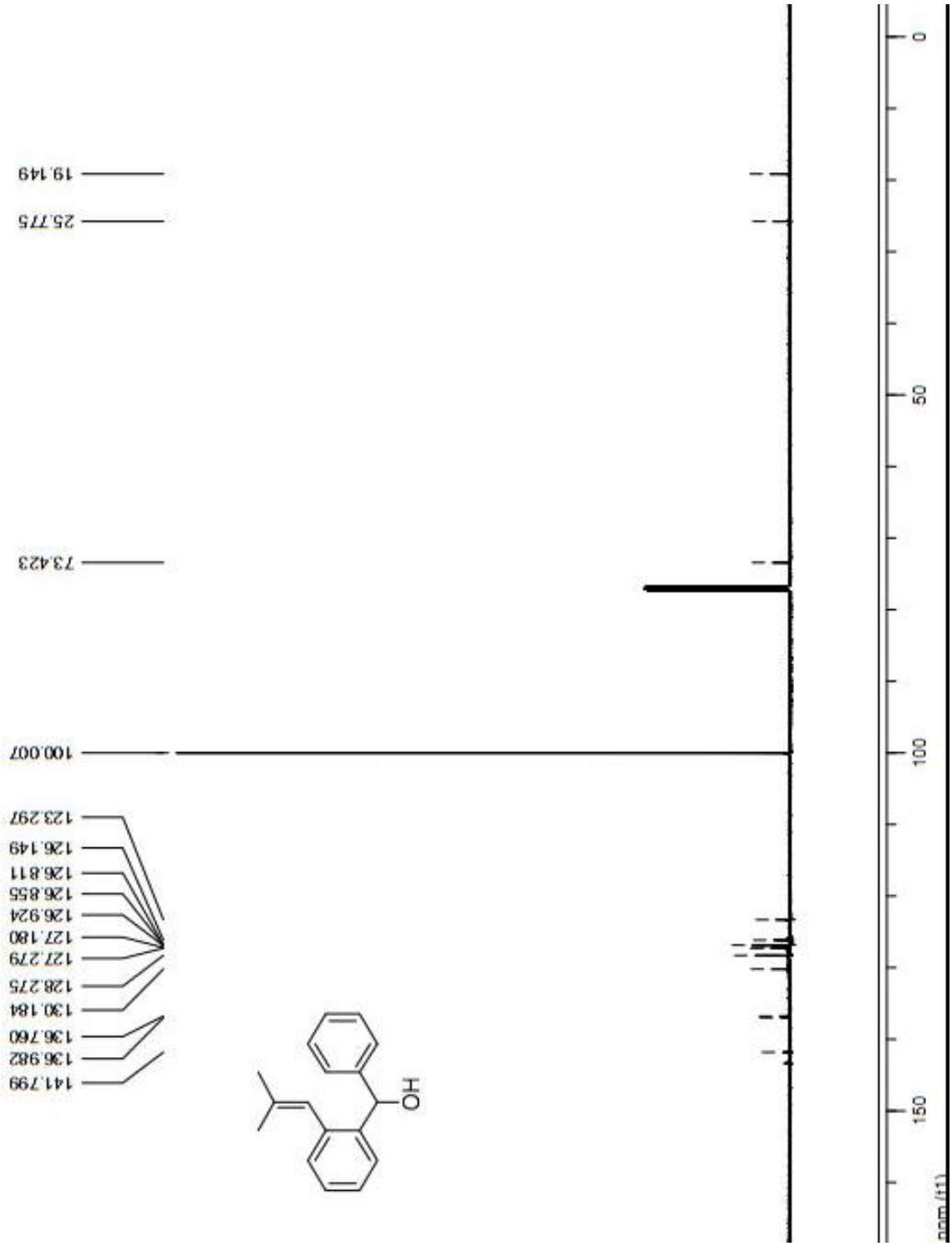

1.081
1.094
1.909
1.914
1.920
3.542
3.547
3.802
7.296
7.304
7.307
7.315
7.321
7.326
7.341
7.446
7.451
7.469
7.482
7.487
7.738
7.759
8.013
8.034
2.94
1.03
0.93
3.00
3.09
1.26
2.21
2.35
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

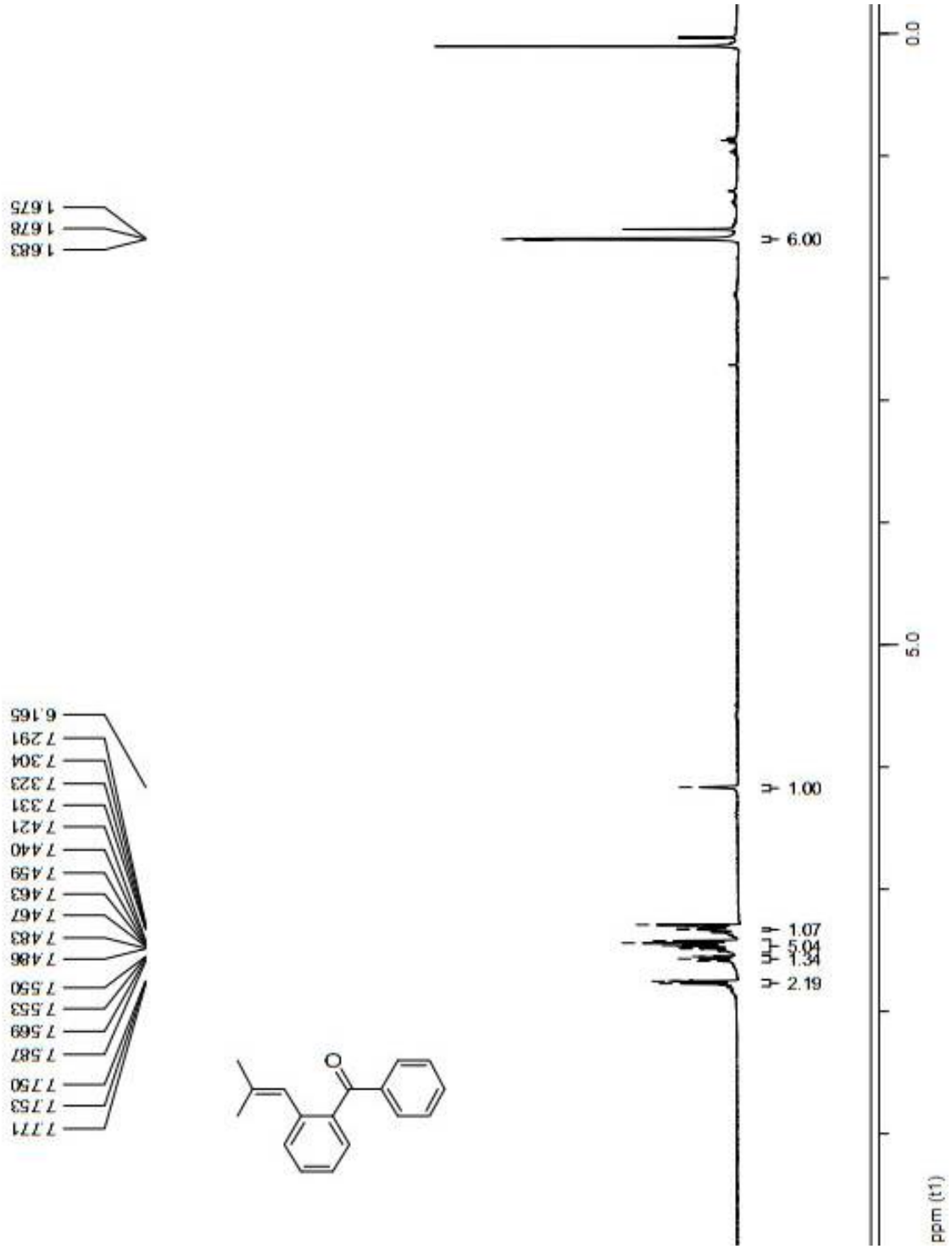


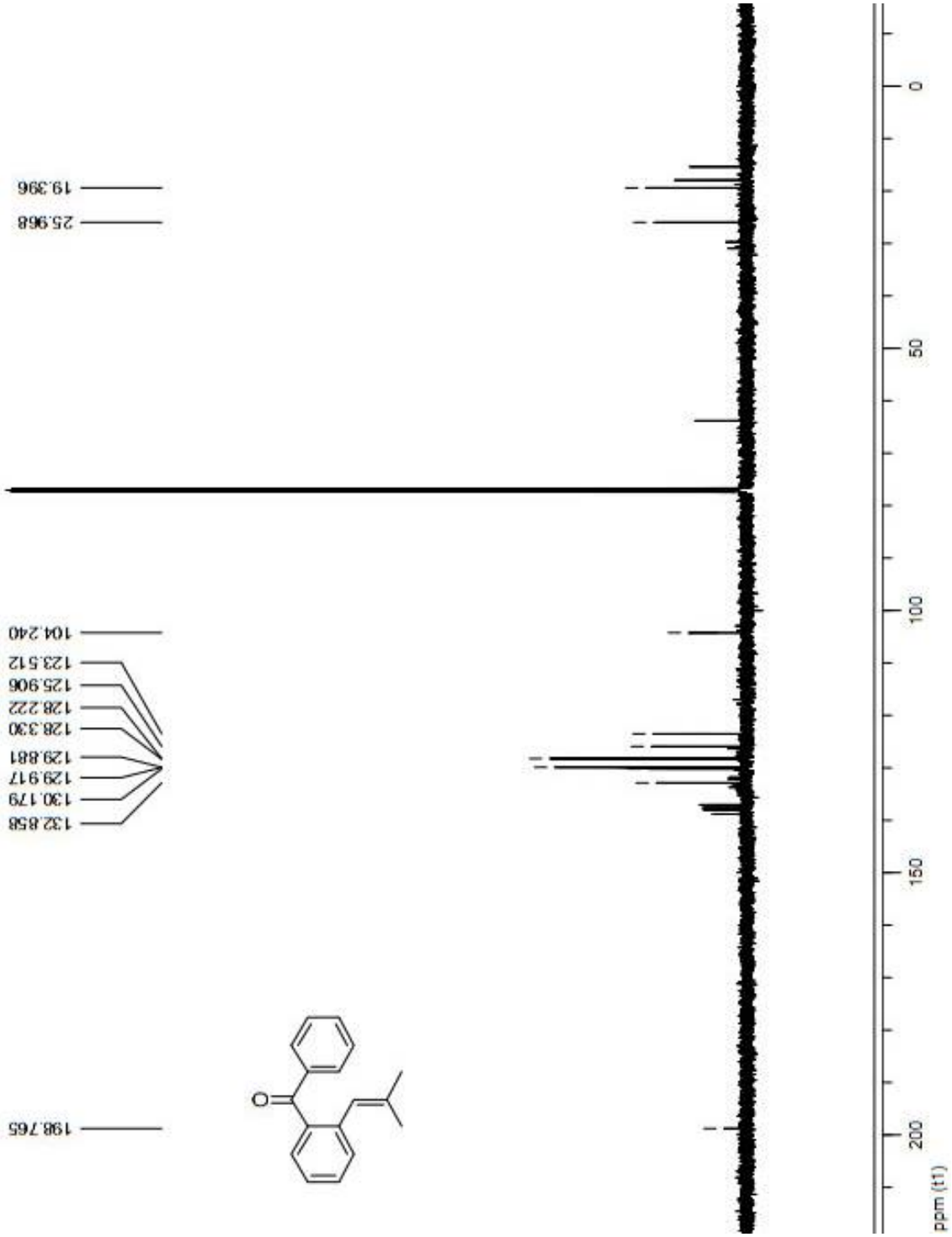

1.272
1.290
2.538
2.864
2.882
2.900
2.918
3.908
7.302
7.321
7.473
7.490
7.494
7.503
7.505
7.524
7.541
7.543
7.621
7.624
7.640
7.642
7.658
7.661
7.791
7.810
8.007
8.029
2.96
0.85
0.94
3.00
0.85
2.87
1.11
0.96
2.04
O
O
OH
O
0.0
5.0
10.0
ppm (t1)

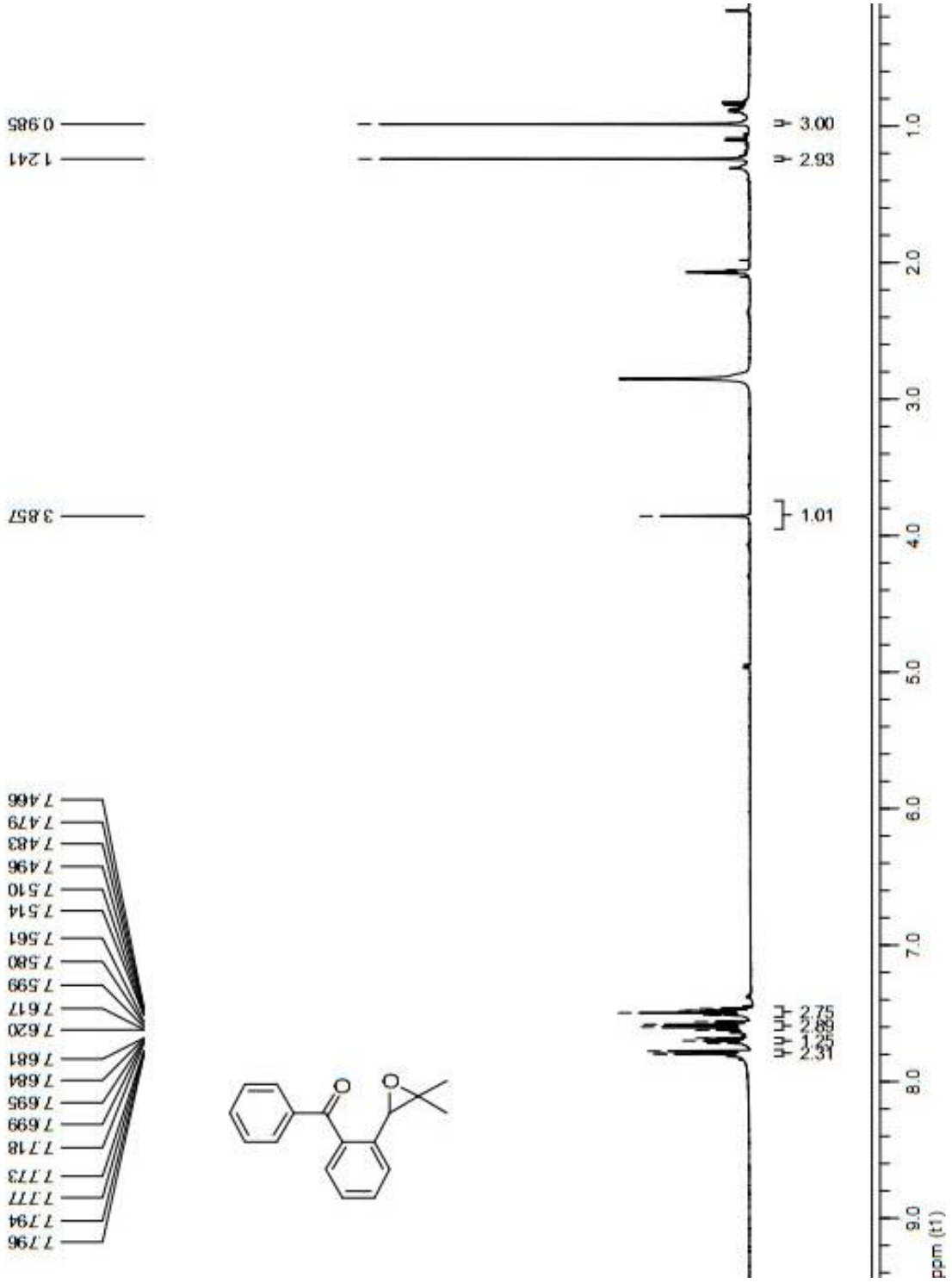


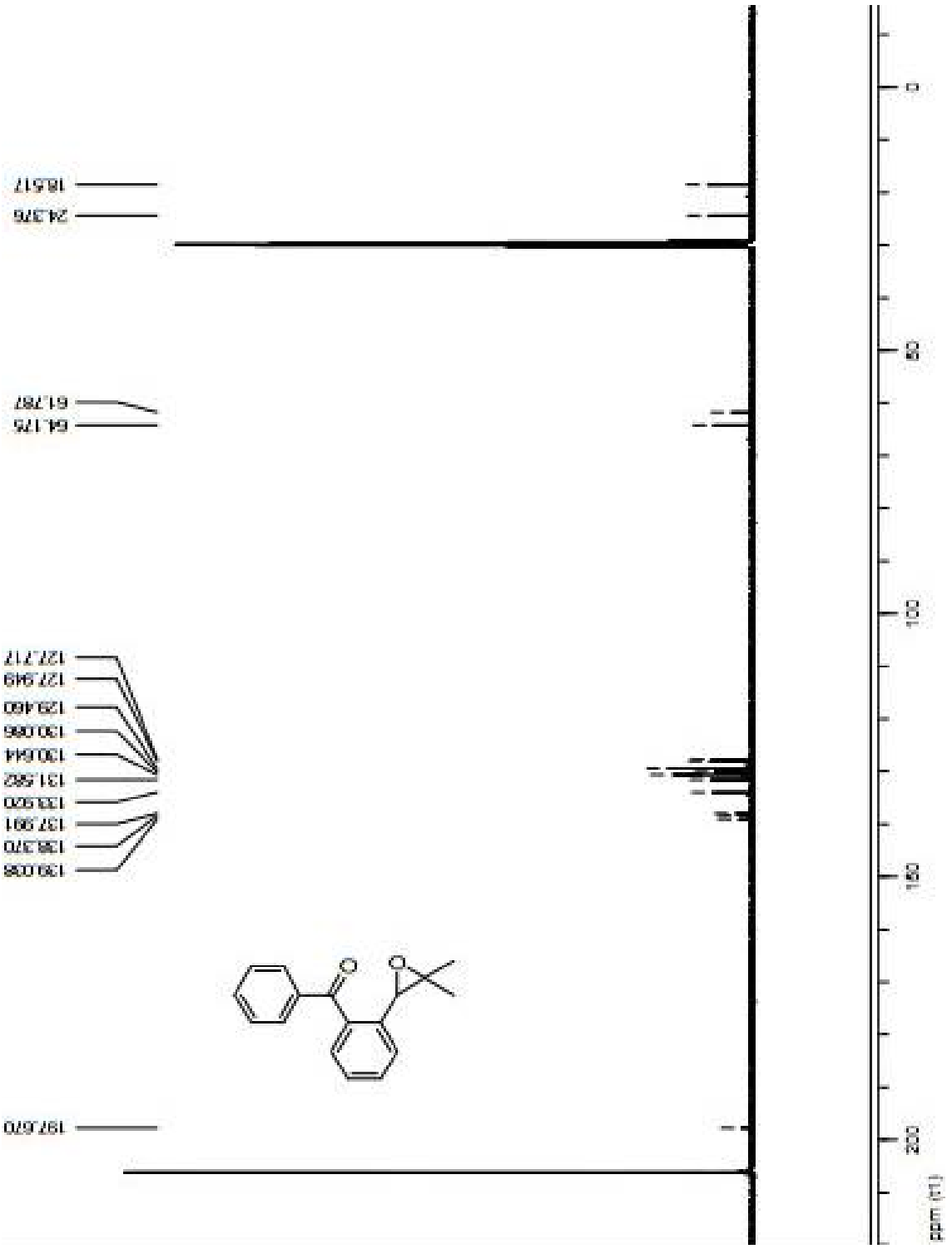

1.558
1.561
1.870
1.873
2.245
6.013
6.248
7.117
7.122
7.134
7.139
7.268
7.272
7.285
7.290
7.331
7.334
7.343
7.519
7.536
7.541
OH
3.00
3.08
1.06
0.98
1.02
0.96
7.29
1.16
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

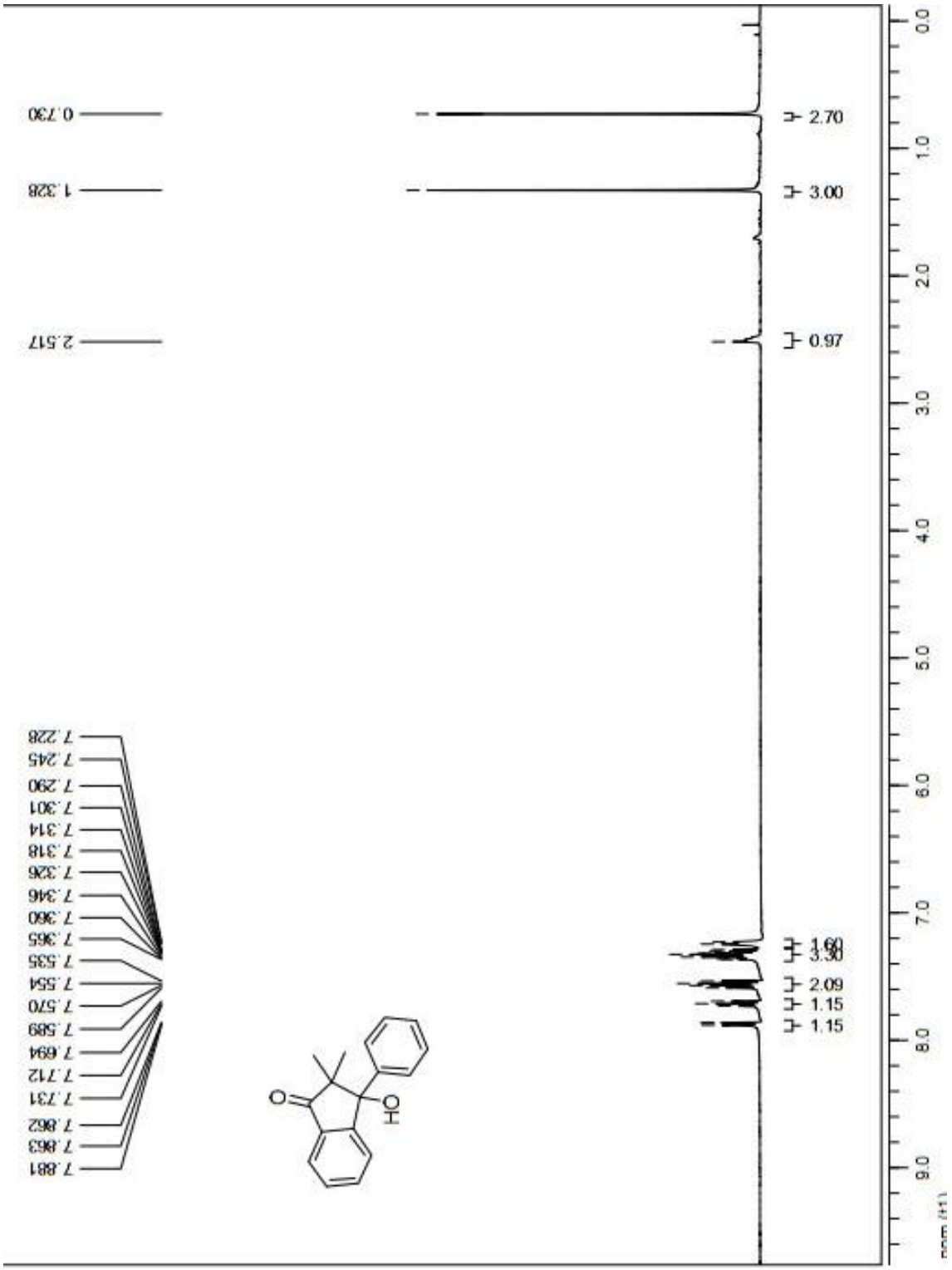

19.149
25.775
73.423
100.007
123.297
126.149
126.811
126.855
126.924
127.180
127.279
128.275
130.184
136.760
136.982
141.799
OH
0
50
100
150
ppm (t1)

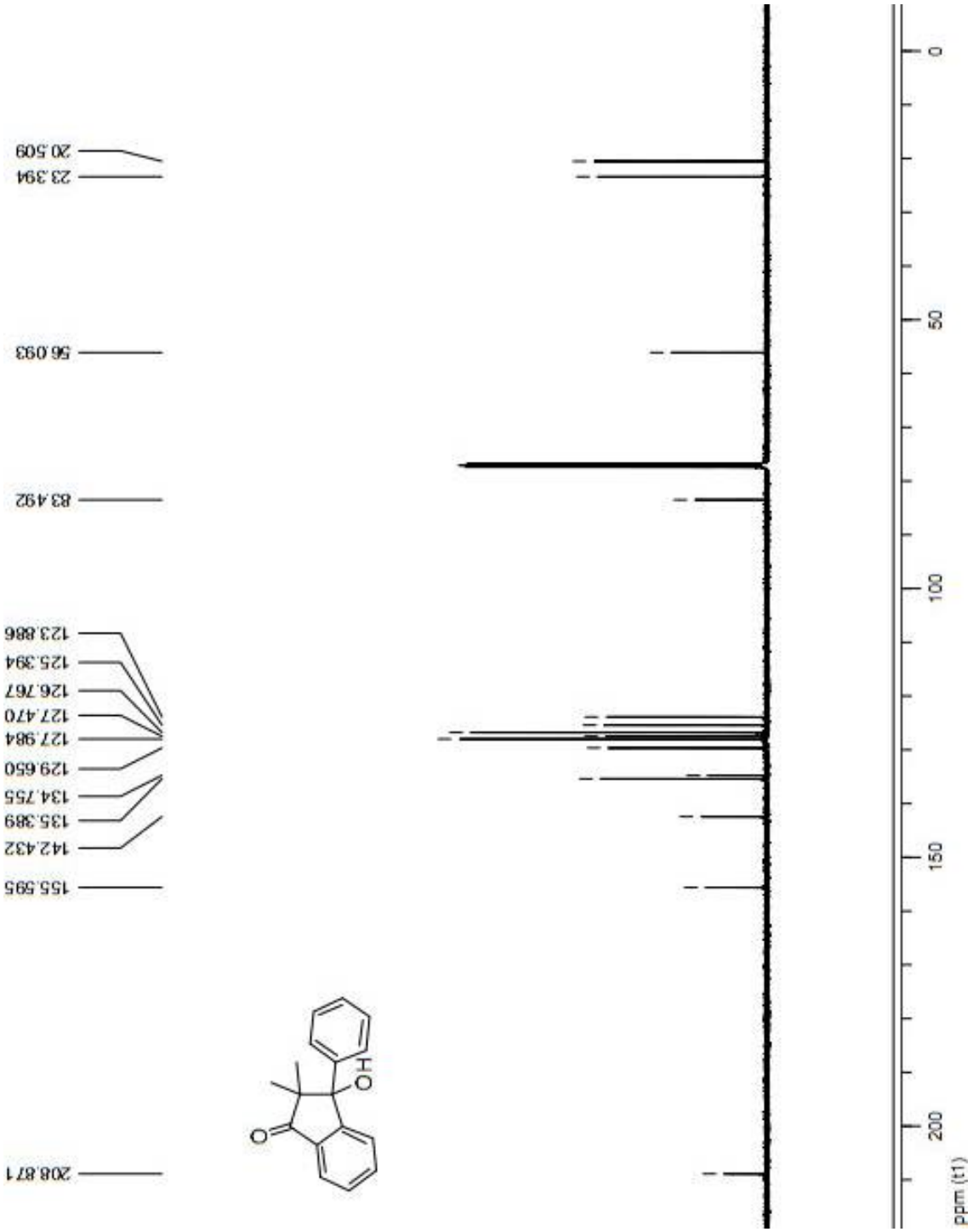


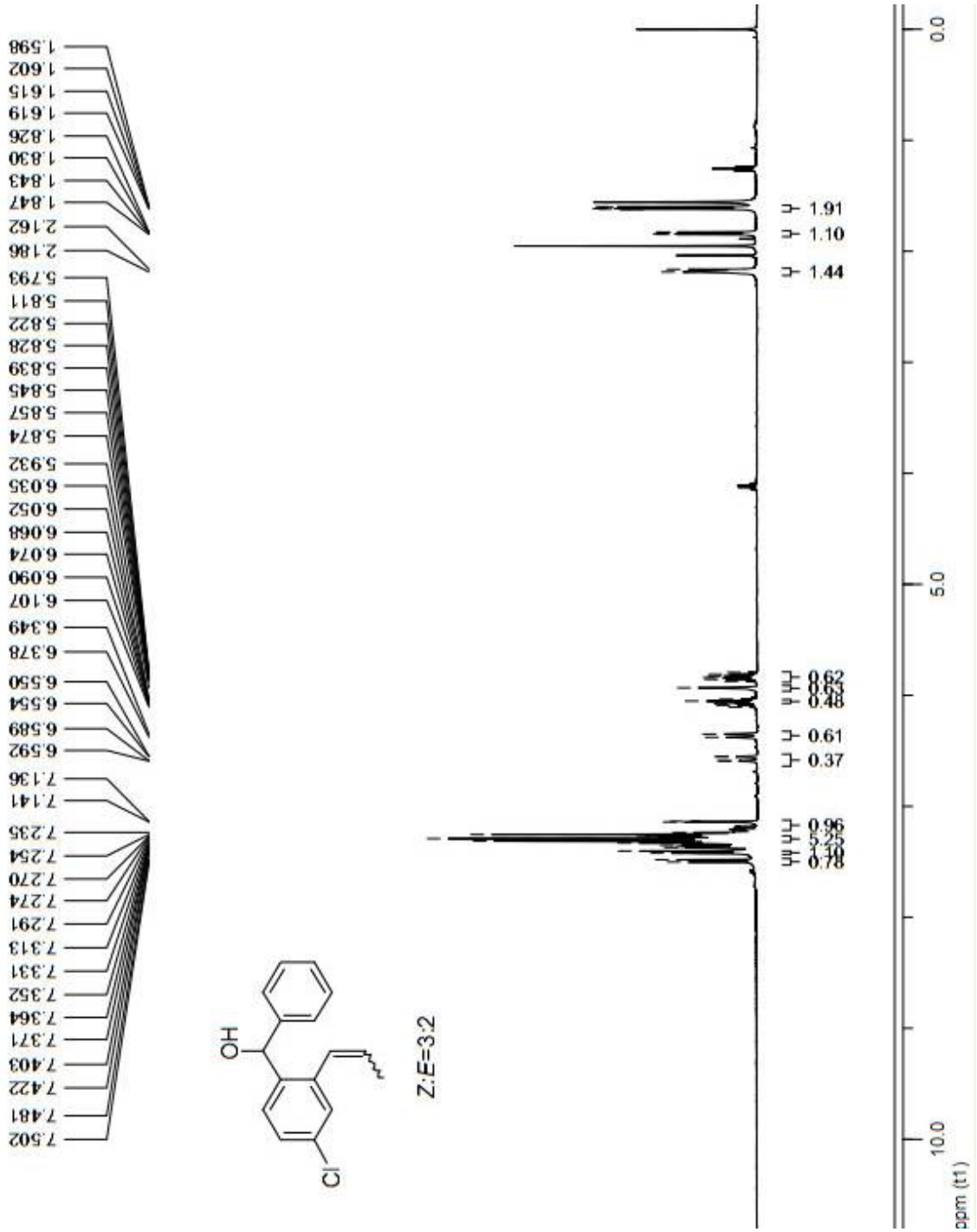


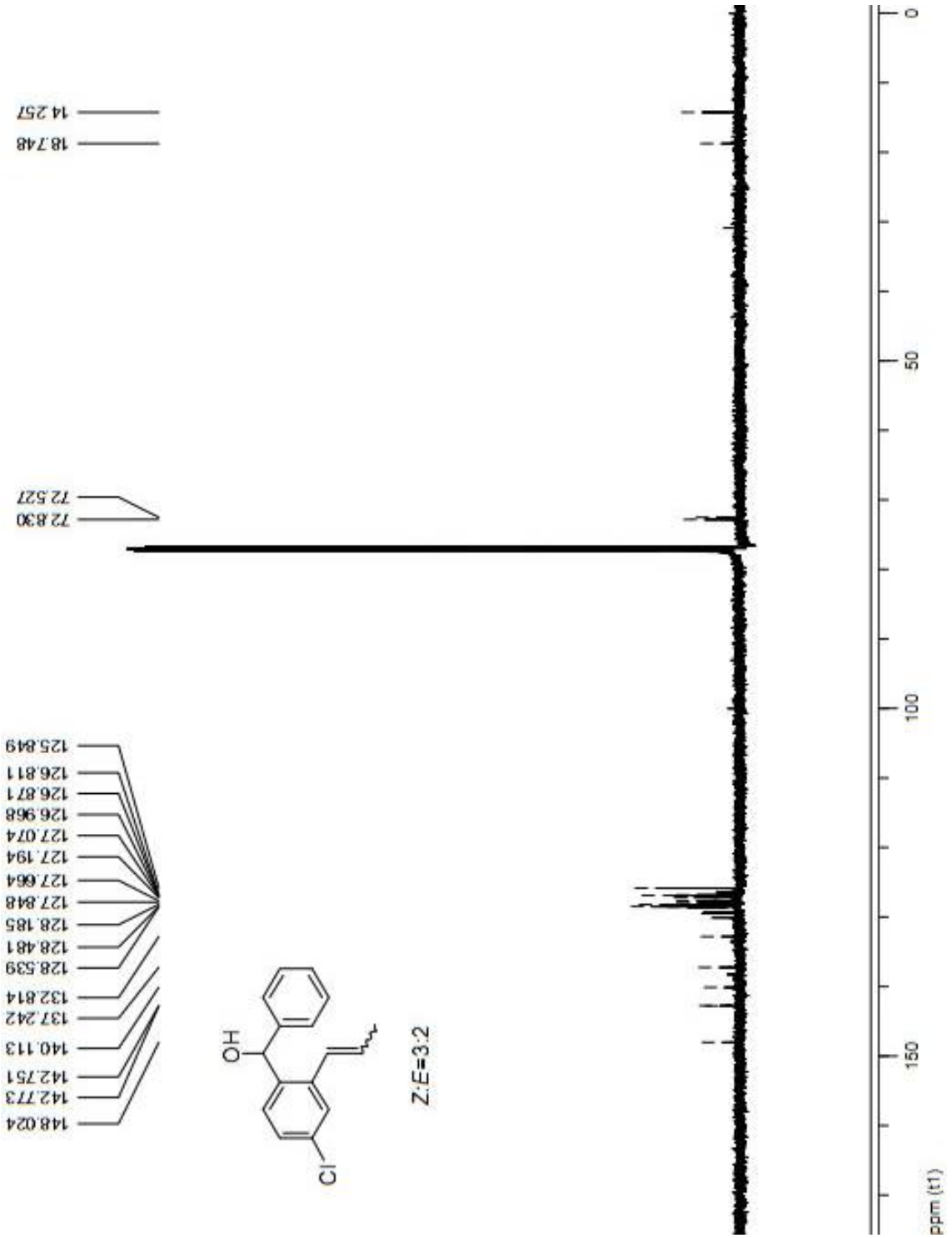


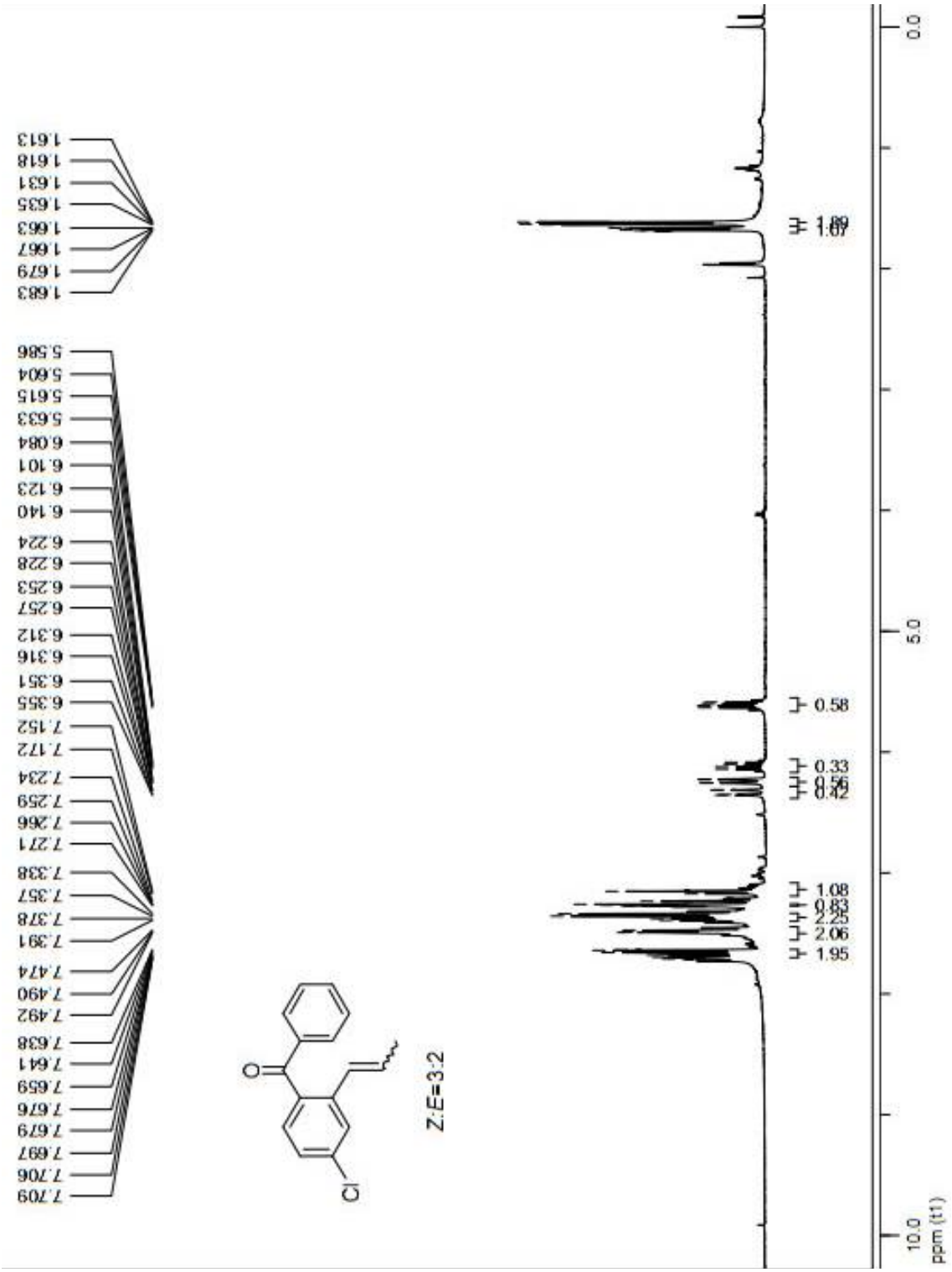

18.617
24.376
61.787
64.175
127.717
127.949
129.460
130.086
130.644
131.582
133.920
137.991
138.370
139.038
197.670
0
50
100
150
200
ppm (t1)

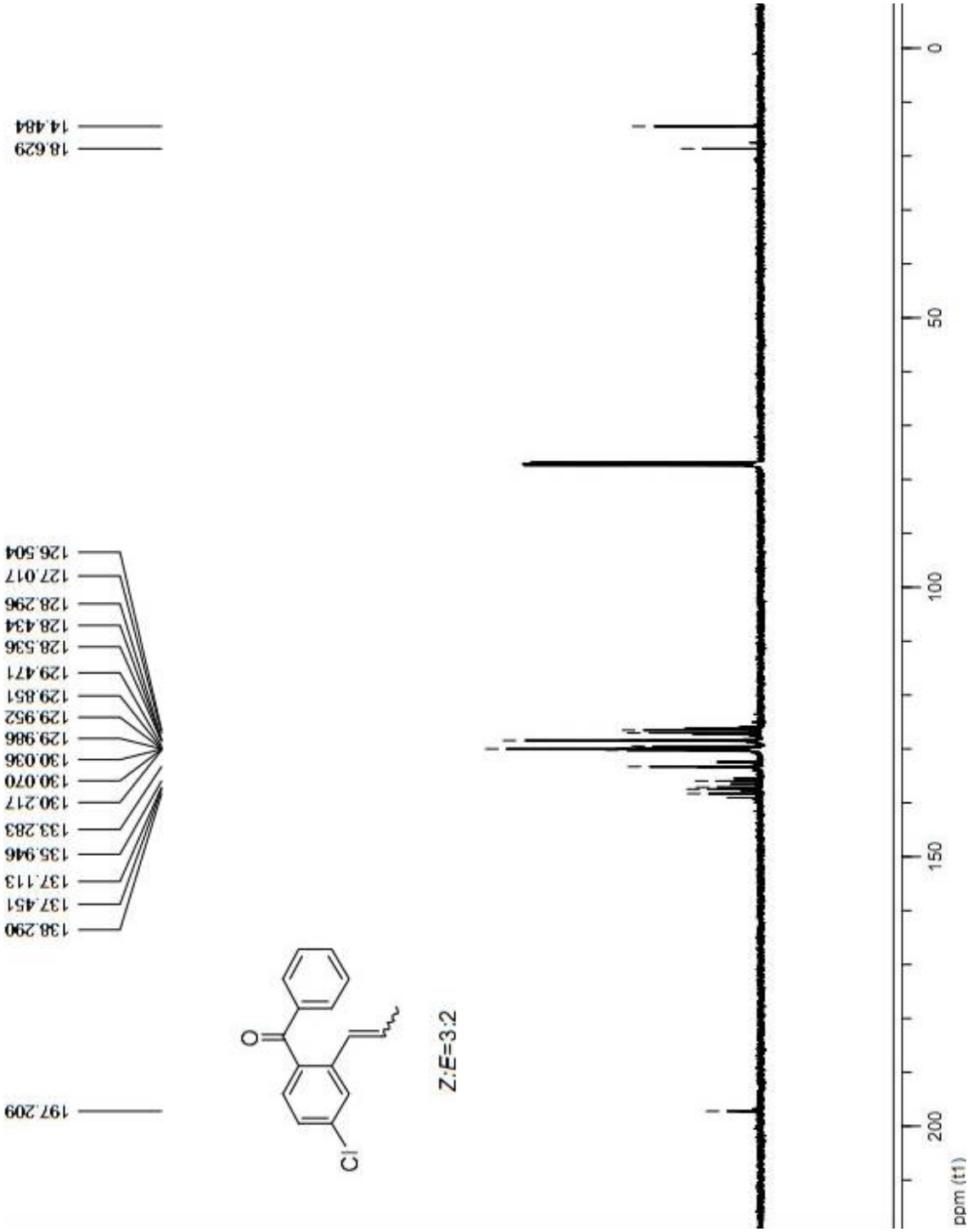

0.730
1.328
2.517
7.228
7.245
7.290
7.301
7.314
7.318
7.326
7.346
7.360
7.365
7.535
7.554
7.570
7.589
7.694
7.712
7.731
7.862
7.863
7.881
2.70
3.00
0.97
1.60
3.30
2.09
1.15
1.15
O
OH
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

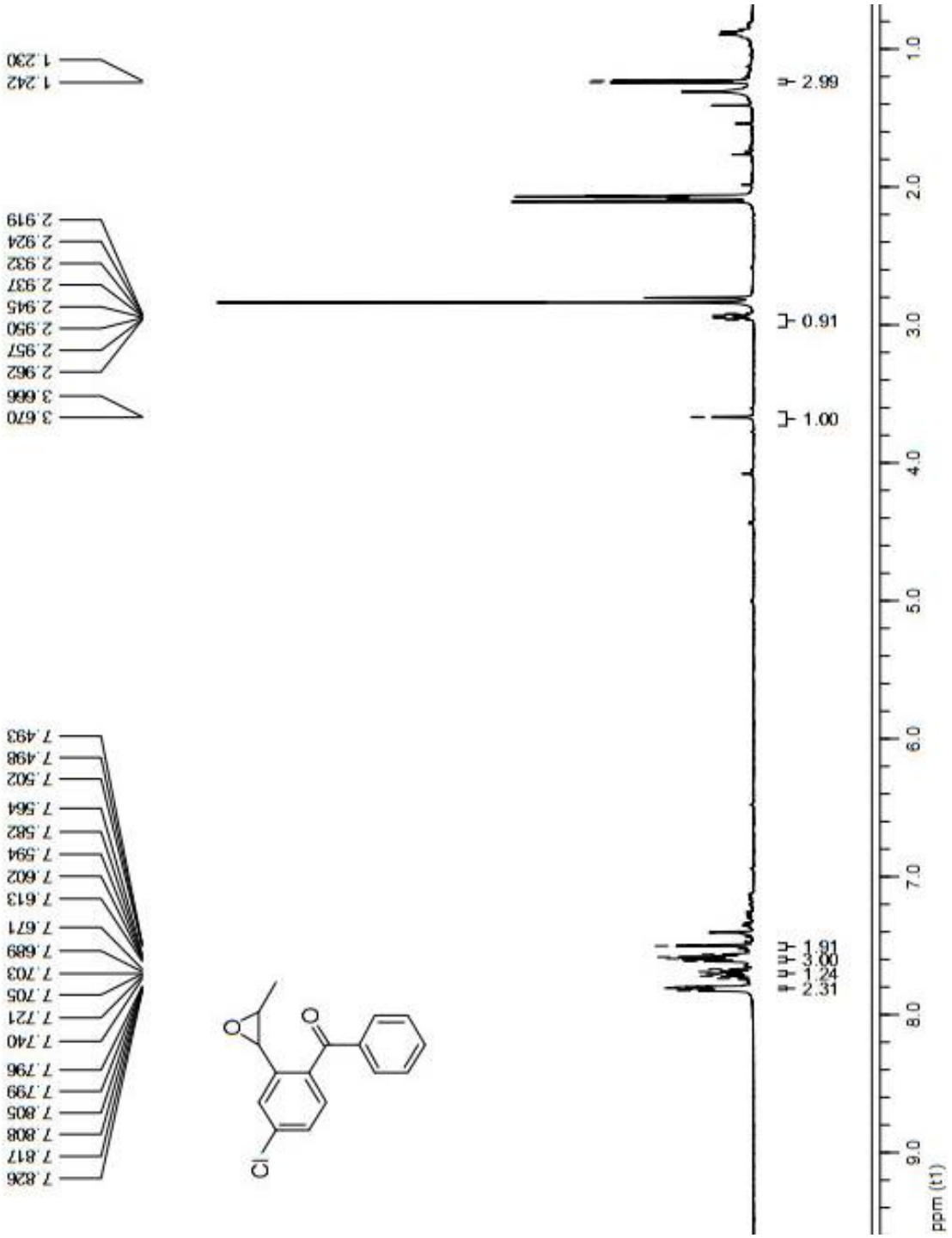

20.509
23.394
56.093
83.492
123.886
125.394
126.767
127.470
127.984
129.650
134.755
135.389
142.432
155.595
208.871
OH
O
0
50
100
150
200
ppm (t1)

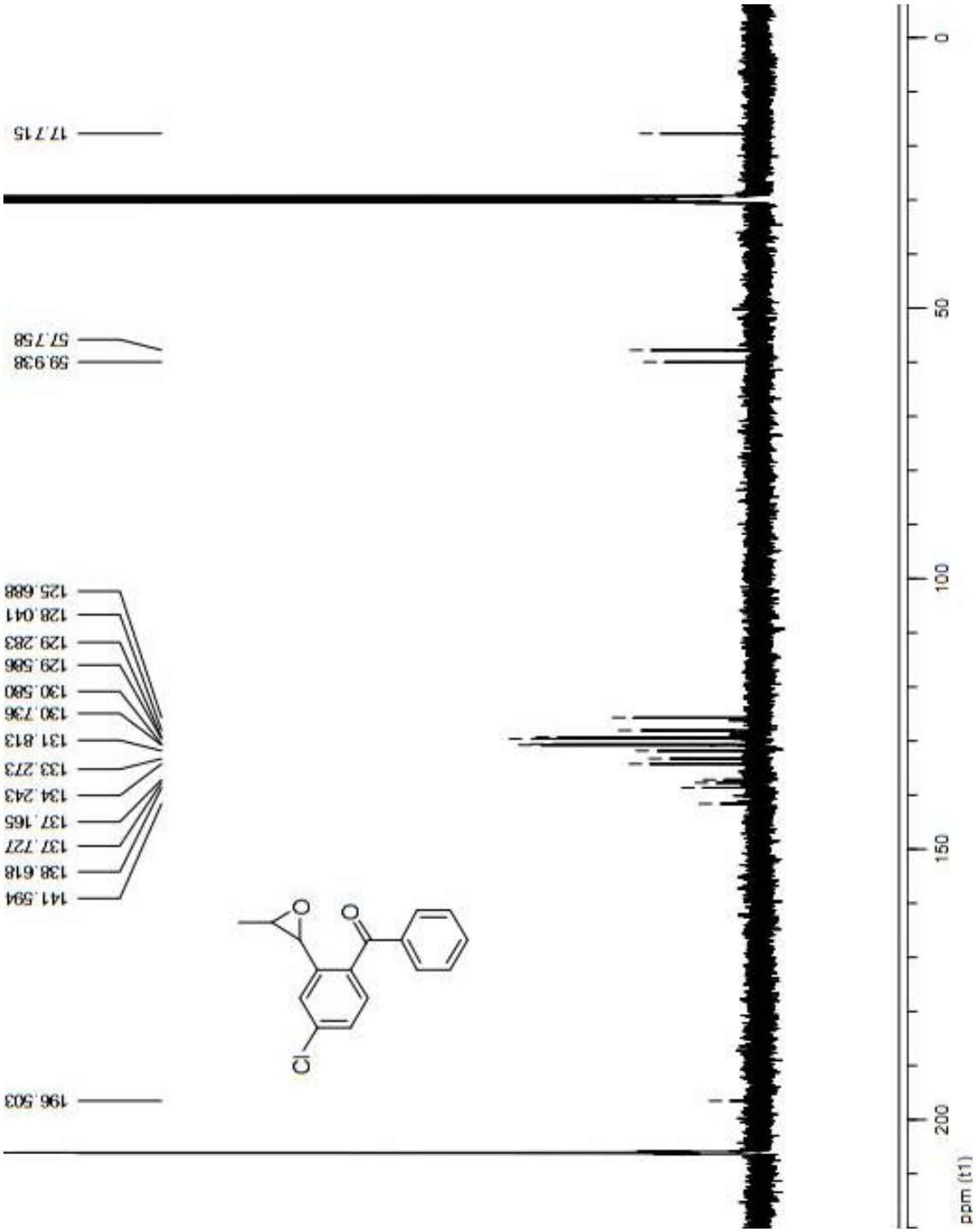

1.598
1.602
1.615
1.619
1.826
1.830
1.843
1.847
2.162
2.186
5.793
5.811
5.822
5.828
5.839
5.845
5.857
5.874
5.932
6.035
6.052
6.068
6.074
6.090
6.107
6.349
6.378
6.550
6.554
6.589
6.592
7.136
7.141
7.235
7.254
7.270
7.274
7.291
7.313
7.331
7.352
7.364
7.371
7.403
7.422
7.481
7.502
OH
Cl
Z:E=3:2
1.91
1.10
1.44
0.62
0.61
0.48
0.61
0.37
0.96
0.78
0.0
5.0
10.0
ppm (t1)

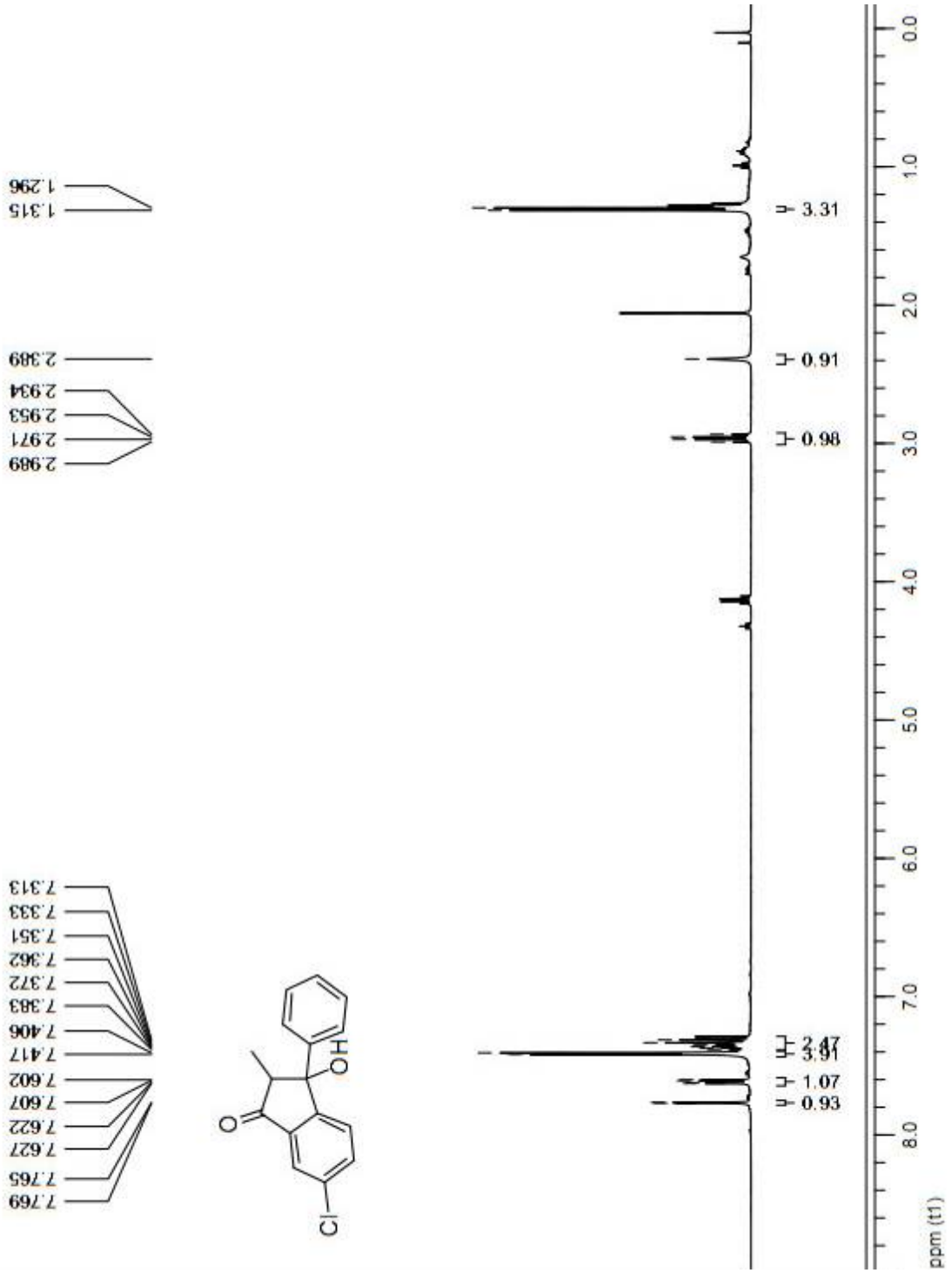

14.257
18.748
72.527
72.830
125.849
126.811
126.871
126.968
127.074
127.194
127.664
127.848
128.185
128.481
128.539
132.814
137.242
140.113
142.751
142.773
148.024
OH
Cl
Z:E=3:2
0
50
100
150
ppm (t1)

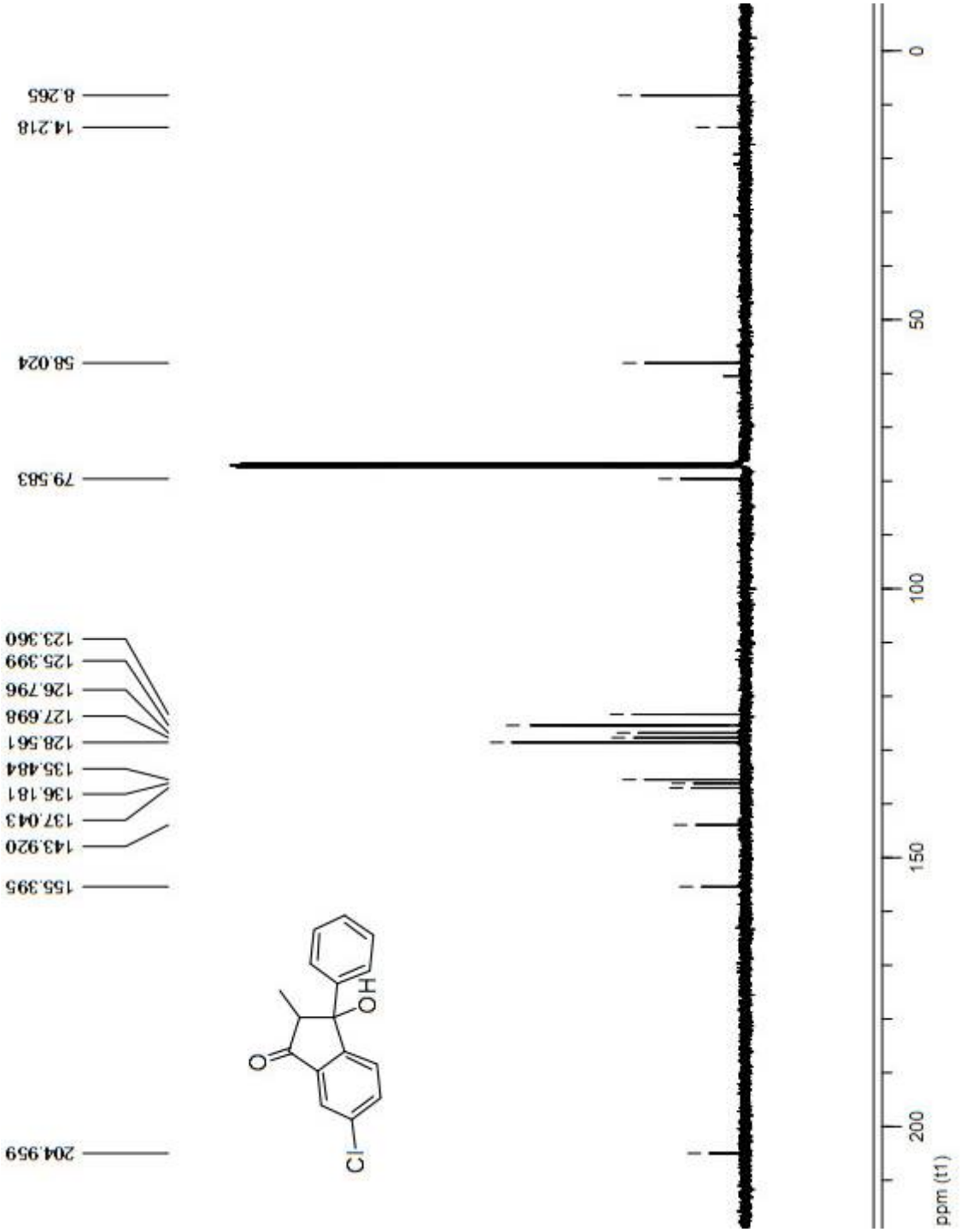

1.613
1.618
1.631
1.635
1.663
1.667
1.679
1.683
5.586
5.604
5.615
5.633
6.084
6.101
6.123
6.140
6.224
6.228
6.253
6.257
6.312
6.316
6.351
6.355
7.152
7.172
7.234
7.259
7.266
7.271
7.338
7.357
7.378
7.391
7.474
7.490
7.492
7.638
7.641
7.659
7.676
7.679
7.697
7.706
7.709
O
Cl
Z:E=3:2
3H 1.89 1.87
1H 0.58
1H 1H 1H 0.33 0.56 0.42
1H 1H 1H 1H 1H 1.08 0.83 2.25 2.06 1.95
0.0
5.0
10.0
ppm (t1)

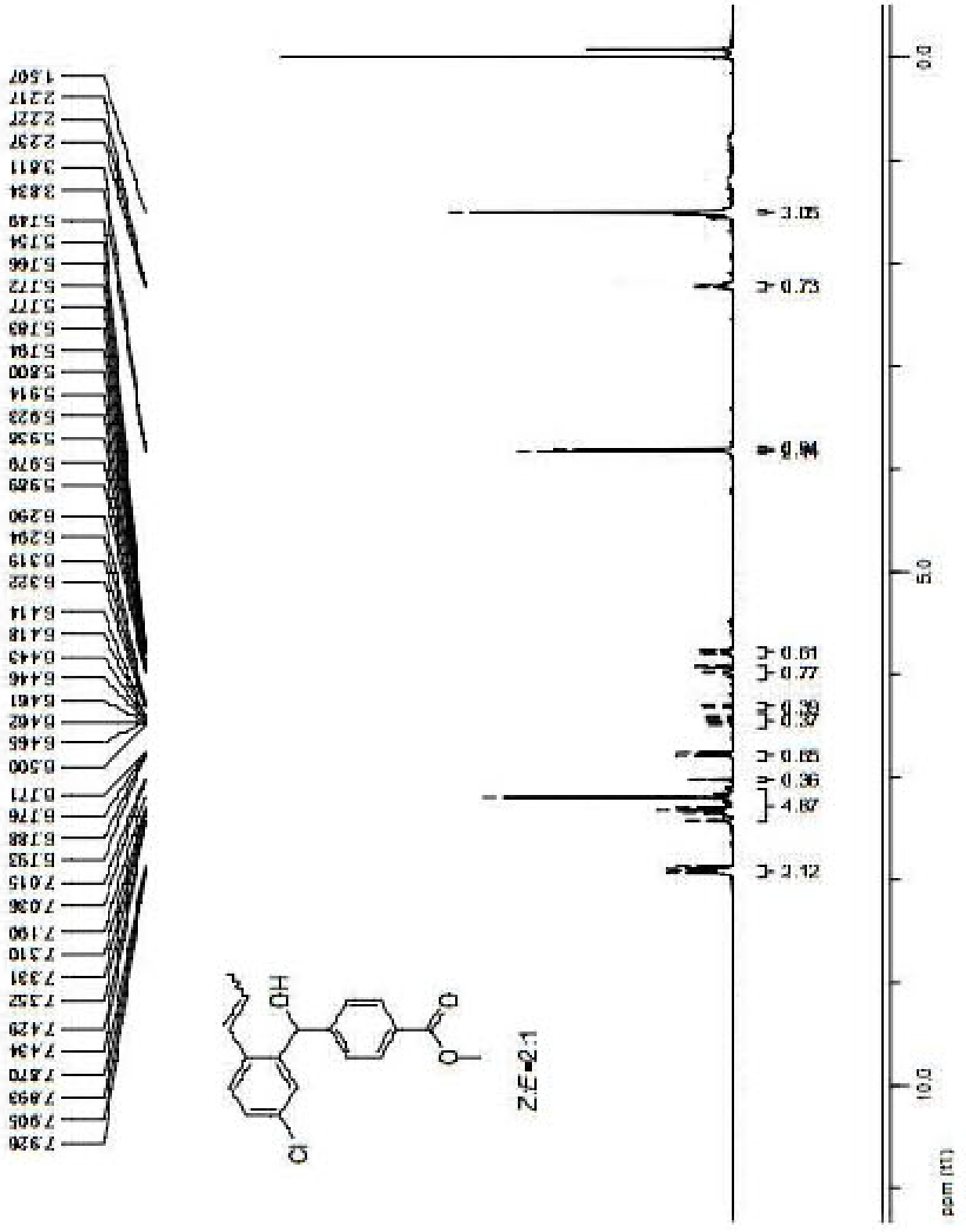

14.484
18.629
126.504
127.017
128.296
128.434
128.536
129.471
129.851
129.952
129.986
130.036
130.070
130.217
133.283
135.946
137.113
137.451
138.290
197.209
O
Cl
Z:E=3:2
0
50
100
150
200
ppm (t1)

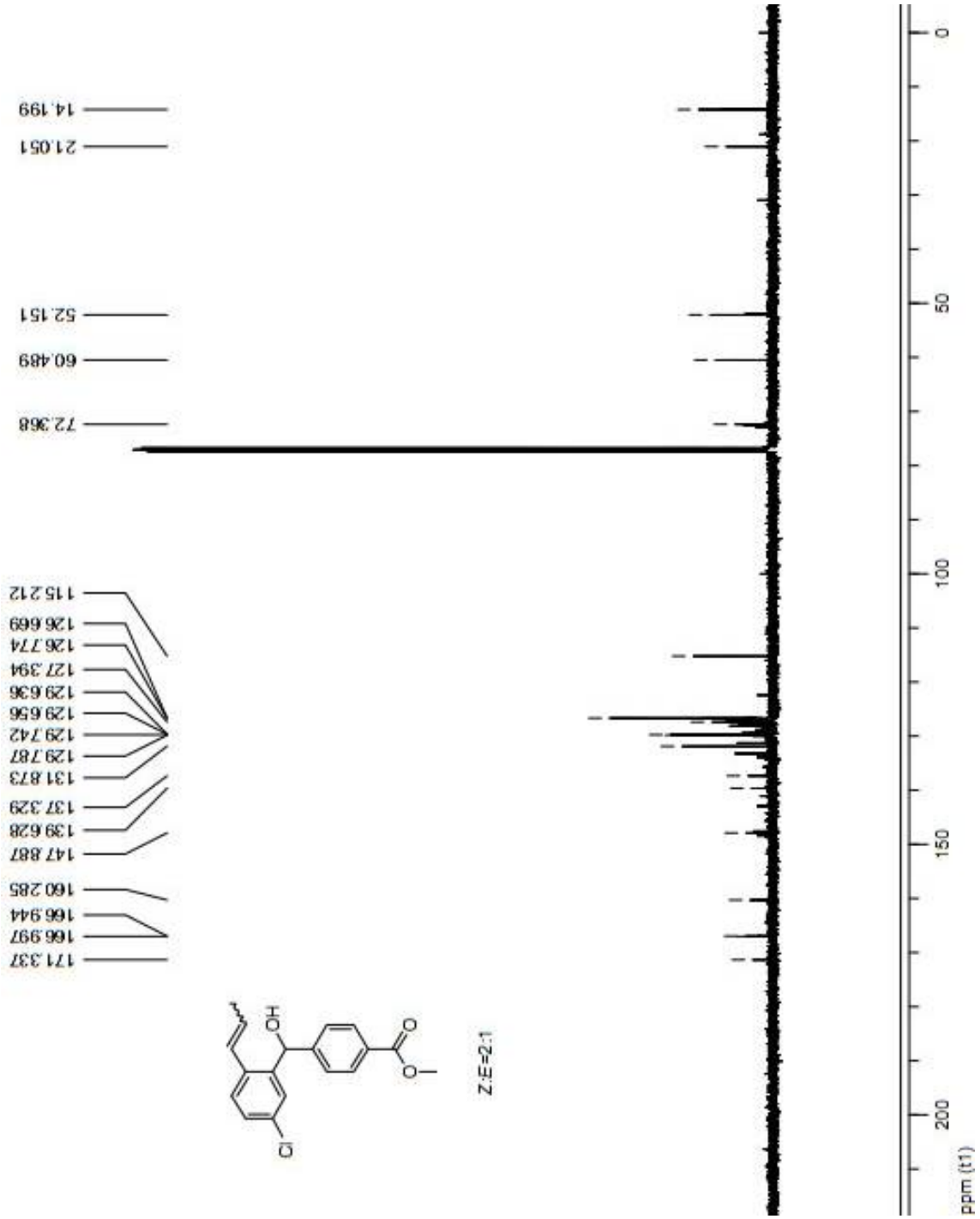

1.230
1.242
2.919
2.924
2.932
2.937
2.945
2.950
2.957
2.962
3.666
3.670
7.493
7.498
7.502
7.564
7.582
7.594
7.602
7.613
7.671
7.689
7.703
7.705
7.721
7.740
7.796
7.799
7.805
7.808
7.817
7.826
2.99
0.91
1.00
1.91
3.00
1.24
2.31
Cl
O
O
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

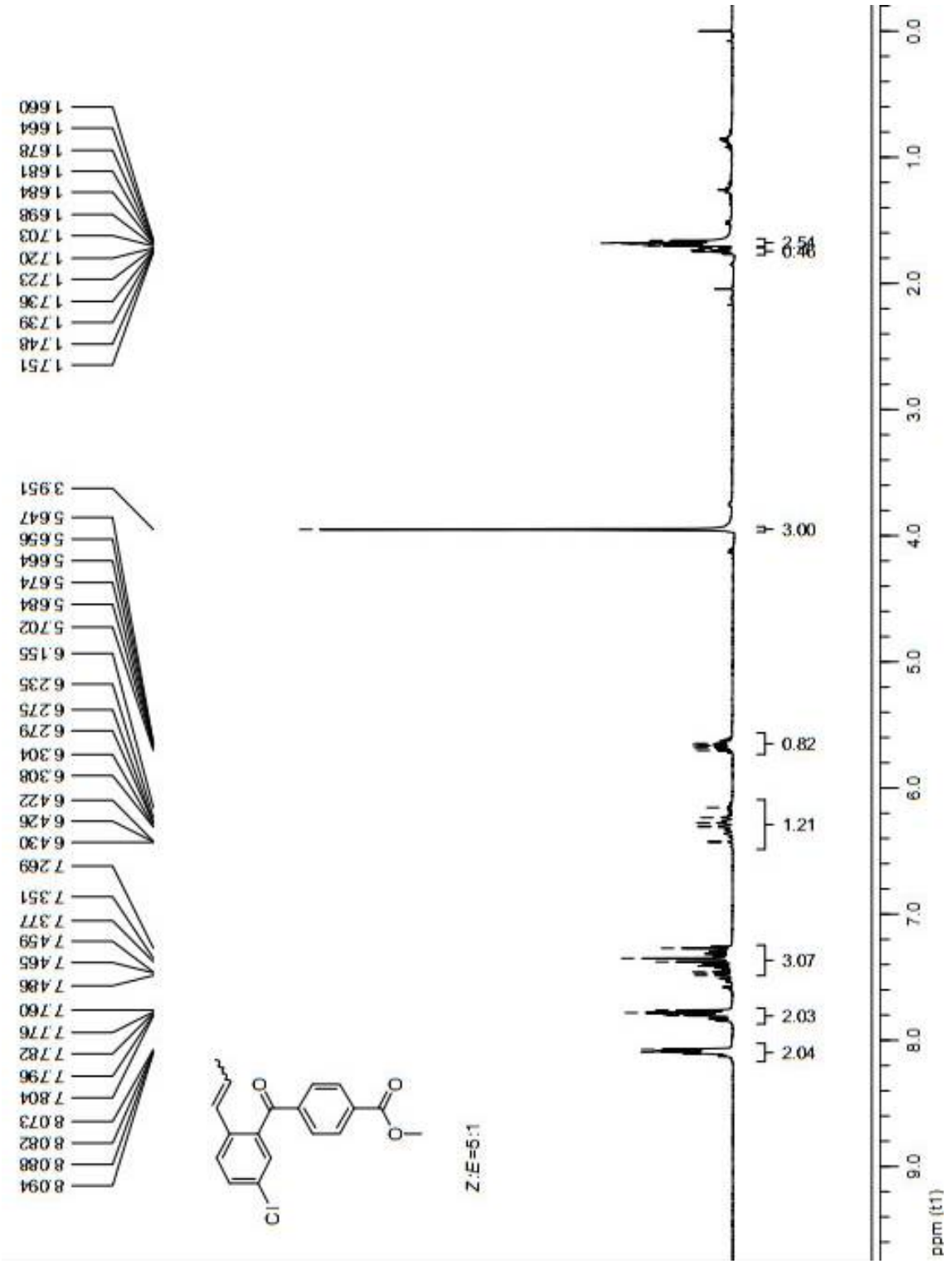


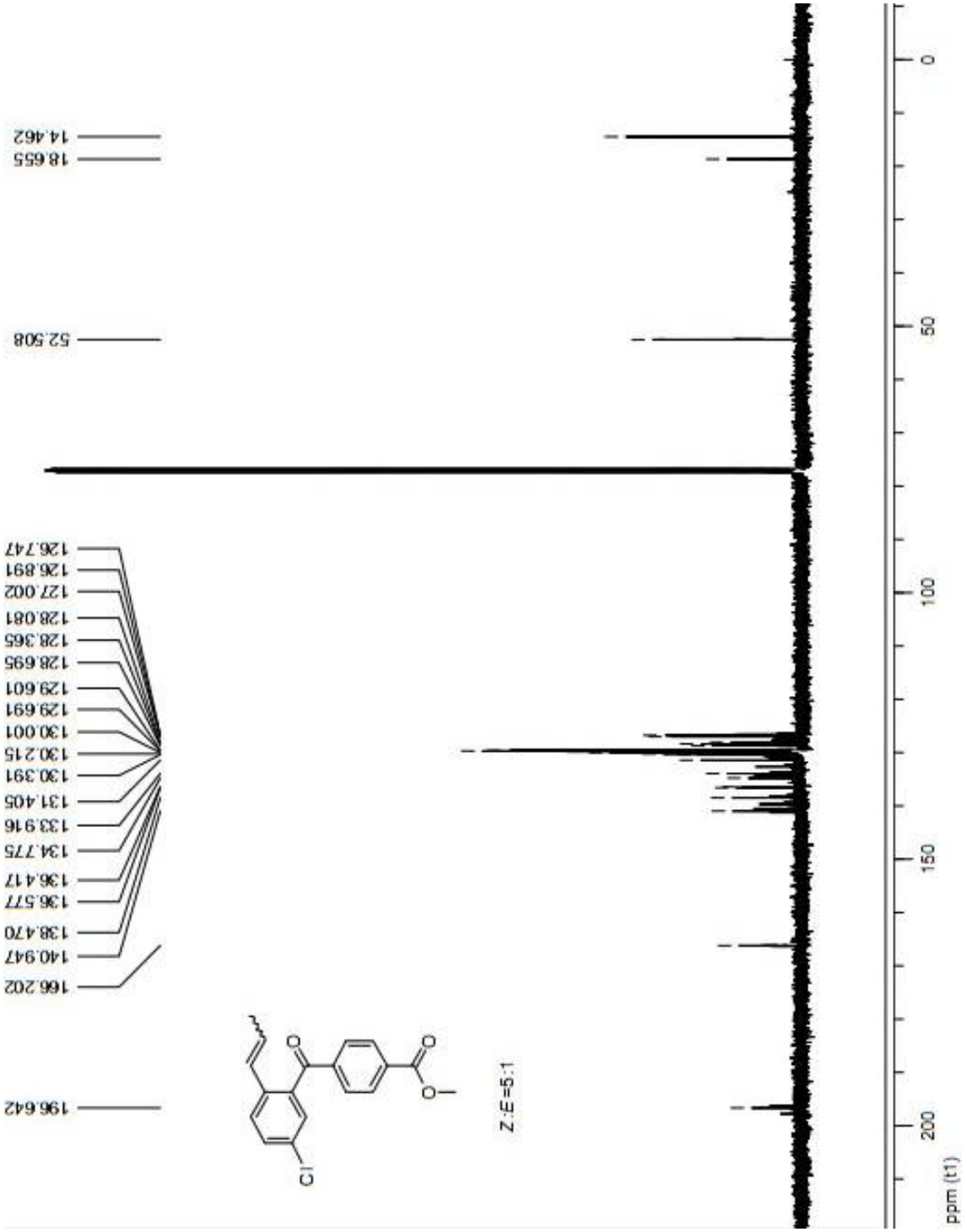

1.296
1.315
2.389
2.934
2.953
2.971
2.989
7.313
7.333
7.351
7.362
7.372
7.383
7.406
7.417
7.602
7.607
7.622
7.627
7.765
7.769
OH
O
Cl
3.31
0.91
0.98
2.47
3.91
1.07
0.93
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

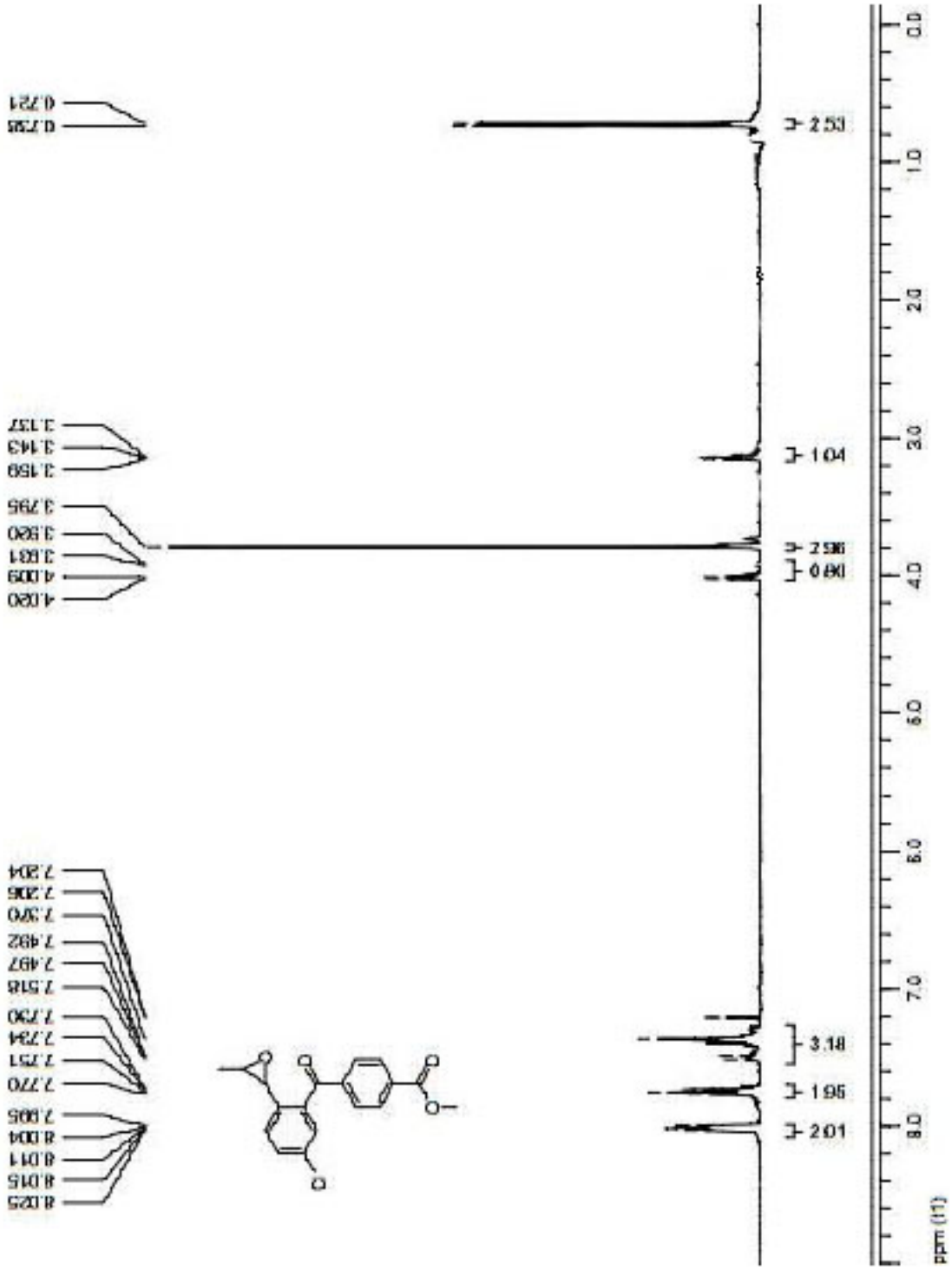

8.265
14.218
58.024
79.583
123.360
125.399
126.796
127.698
128.561
135.484
136.181
137.043
143.920
155.395
204.959
O
OH
Cl
0
50
100
150
200
ppm (t1)

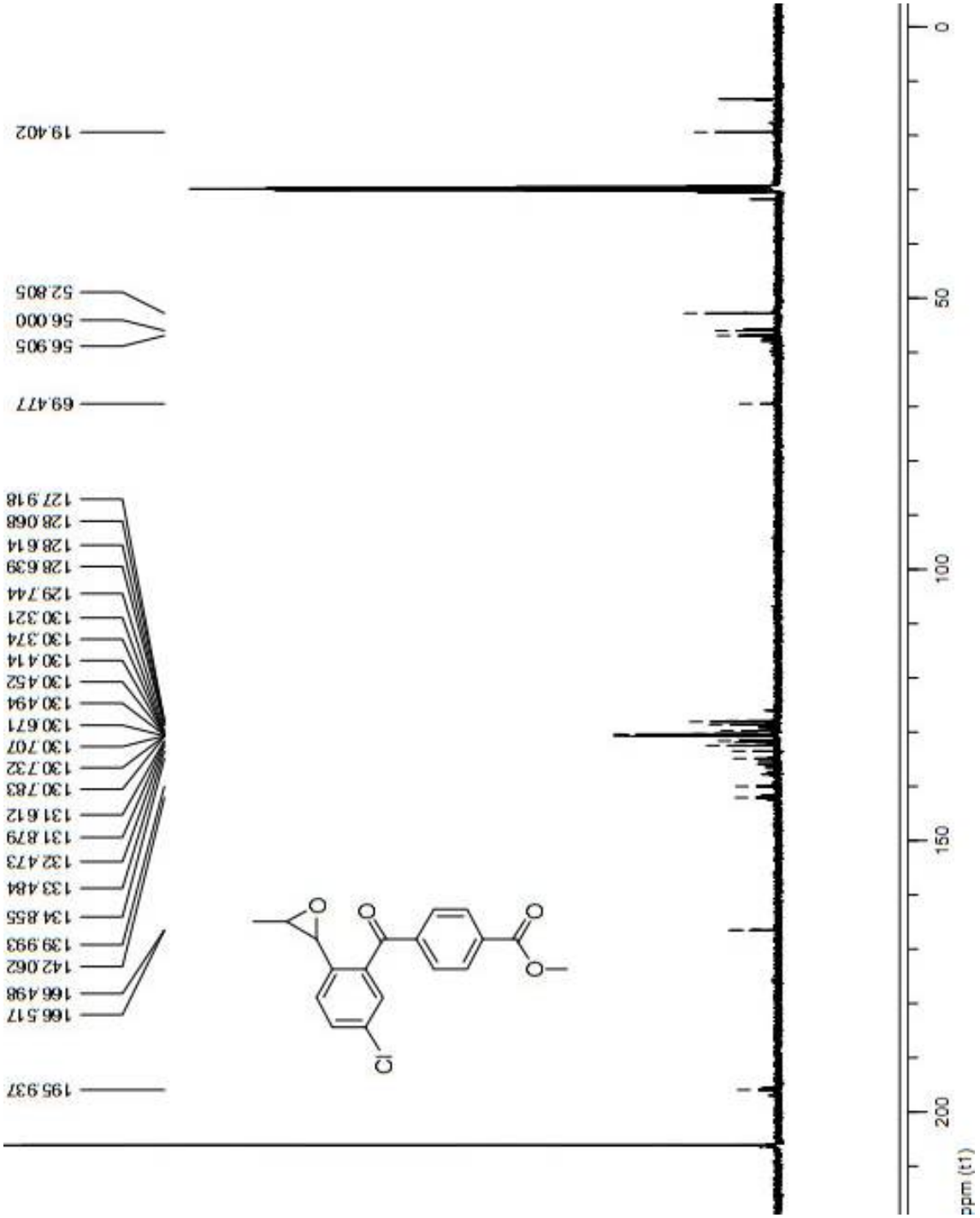

1.507
2.217
2.227
2.257
3.811
3.834
5.749
5.754
5.766
5.772
5.777
5.783
5.794
5.800
5.914
5.923
5.936
5.979
5.989
6.290
6.294
6.319
6.322
6.414
6.418
6.445
6.446
6.461
6.462
6.465
6.500
6.771
6.776
6.788
6.793
7.015
7.036
7.190
7.310
7.331
7.352
7.429
7.434
7.870
7.893
7.905
7.926
3.05
0.73
0.94
0.61
0.77
0.85
0.36
4.87
2.12
OH
O
O
Cl
Z:E=2:1
0.0
5.0
10.0
ppm (t1)

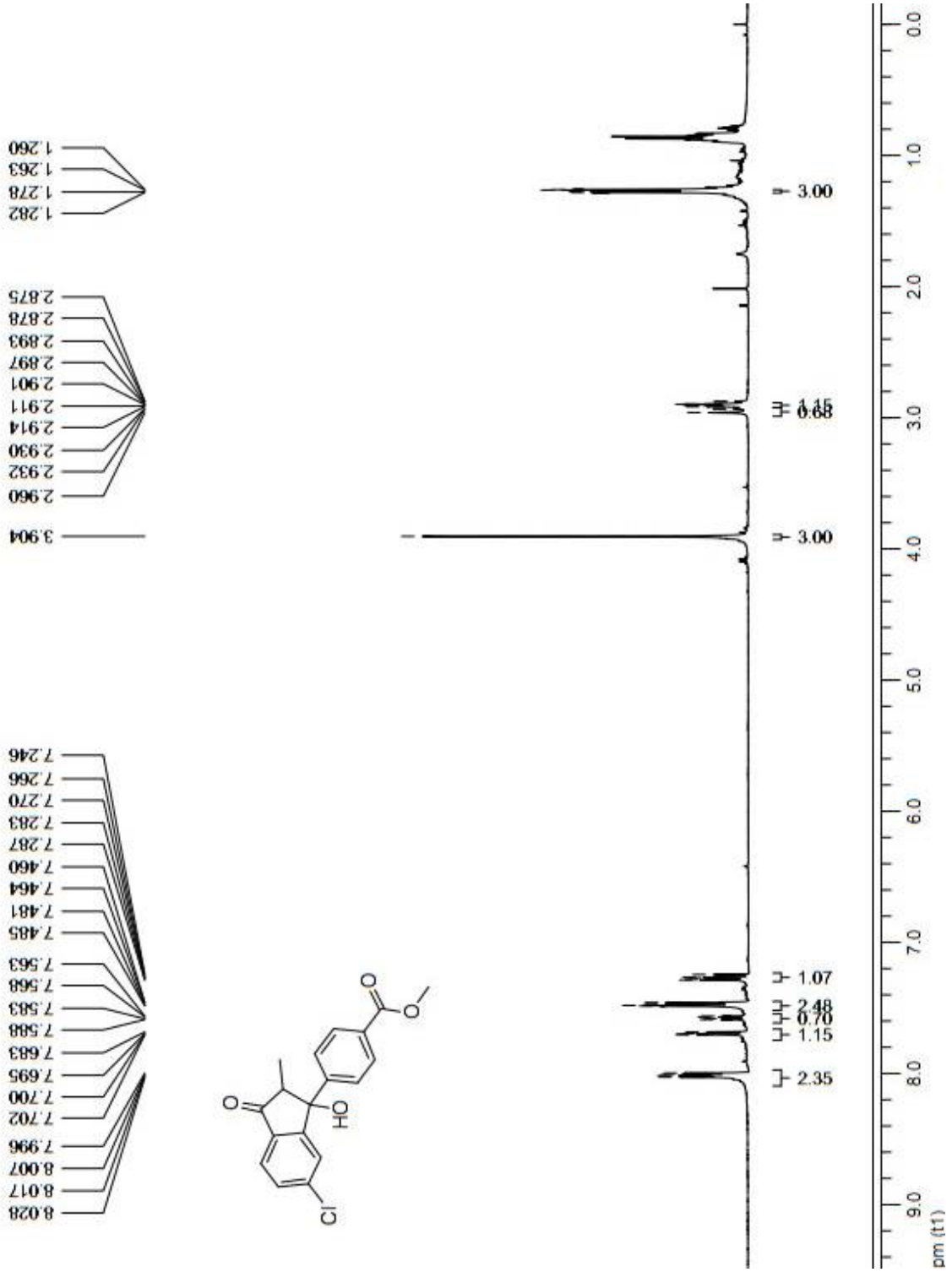

14.199
21.051
52.151
60.489
72.368
115.212
126.669
126.774
127.394
129.636
129.656
129.742
129.787
131.873
137.329
139.628
147.887
160.285
166.944
166.997
171.337
OH
O
O
Cl
Z:E=2:1
0
50
100
150
200
ppm (t1)

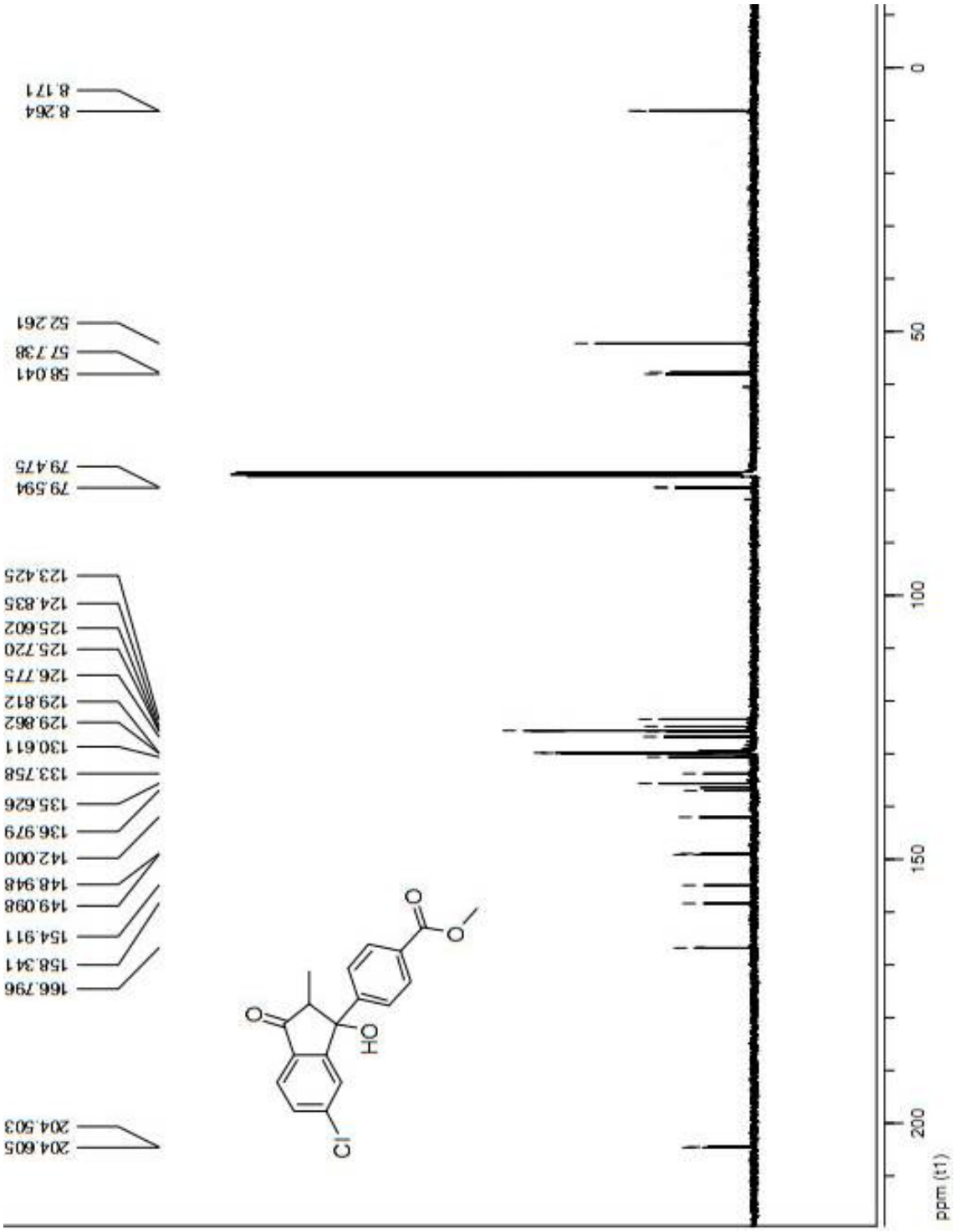

1.660
1.664
1.678
1.681
1.684
1.698
1.703
1.720
1.723
1.736
1.739
1.748
1.751
3.951
5.647
5.656
5.664
5.674
5.684
5.702
6.155
6.235
6.275
6.279
6.304
6.308
6.422
6.426
6.430
7.269
7.351
7.377
7.459
7.465
7.486
7.760
7.776
7.782
7.796
7.804
8.073
8.082
8.088
8.094
2.54
0.46
3.00
0.82
1.21
3.07
2.03
2.04
Z:E=5:1
Cl
O
O
O
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

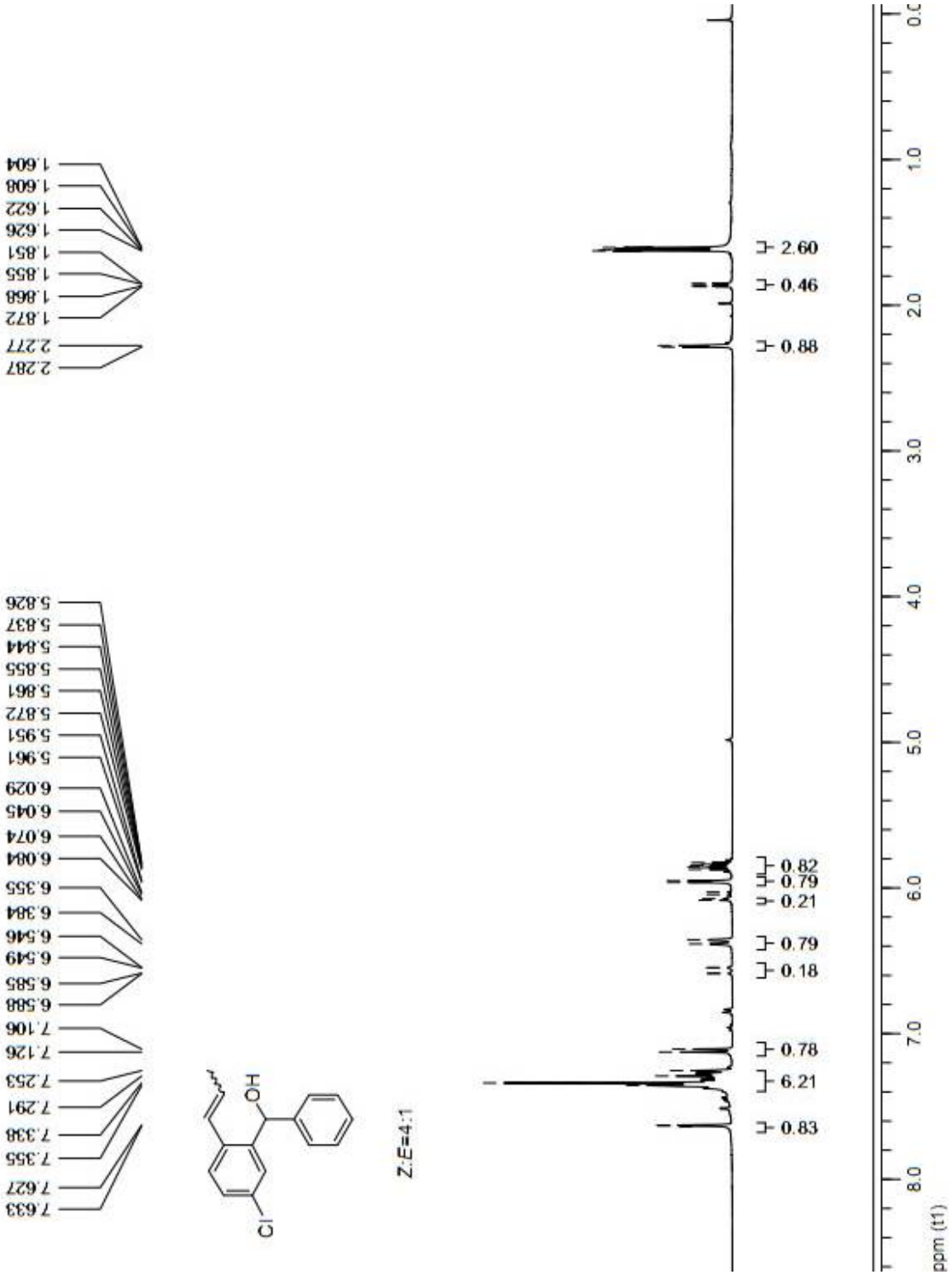

14.462
18.655
52.508
126.747
126.891
127.002
128.081
128.365
128.695
129.601
129.691
130.001
130.215
130.391
131.405
133.916
134.775
136.417
136.577
138.470
140.947
166.202
196.642
Z:E=5:1
Cl
O
O
O
0
50
100
150
200
ppm (t1)

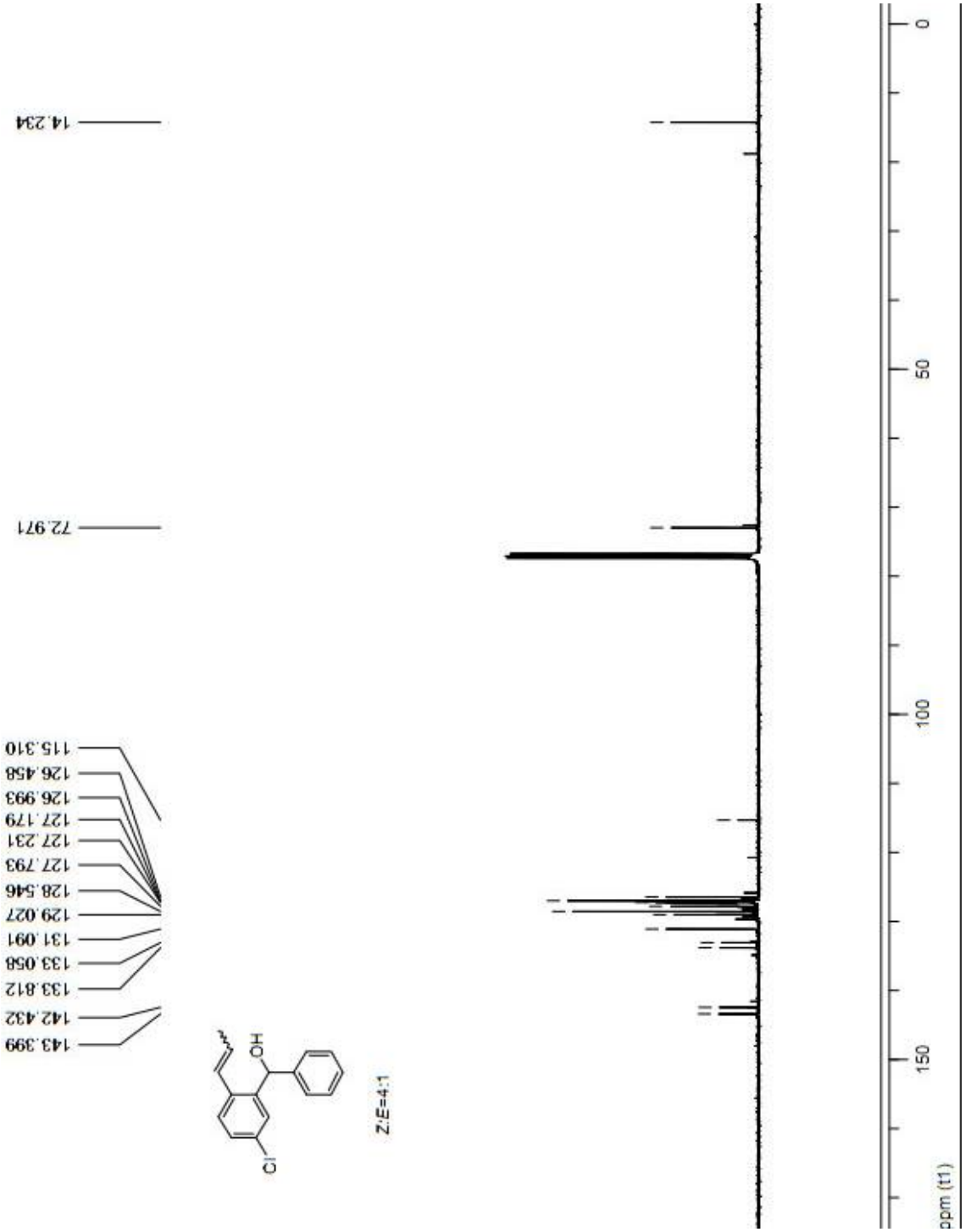

0.721
0.738
3.137
3.143
3.159
3.795
3.820
3.831
4.009
4.020
7.204
7.206
7.370
7.492
7.497
7.518
7.730
7.734
7.751
7.770
8.005
8.004
8.011
8.015
8.025
2.53
1.04
2.56
0.80
3.18
1.95
2.01
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

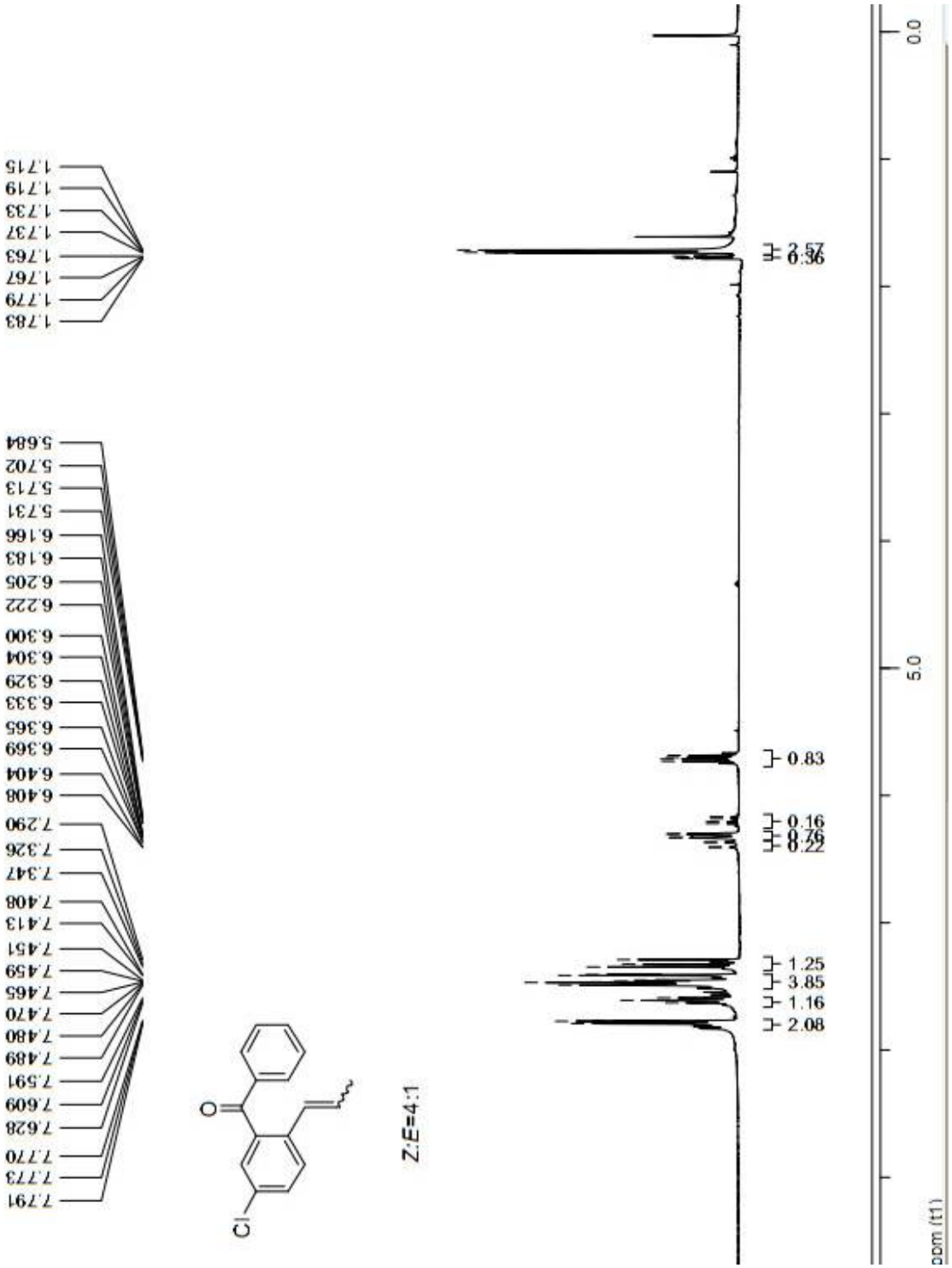

19.402
52.805
56.000
56.905
69.477
127.918
128.068
128.614
128.639
129.744
130.321
130.374
130.414
130.452
130.494
130.671
130.707
130.732
130.783
131.612
131.879
132.473
133.484
134.855
139.993
142.062
166.498
166.517
195.937
Cl
O
O
O
O
0
50
100
150
200
ppm (t1)

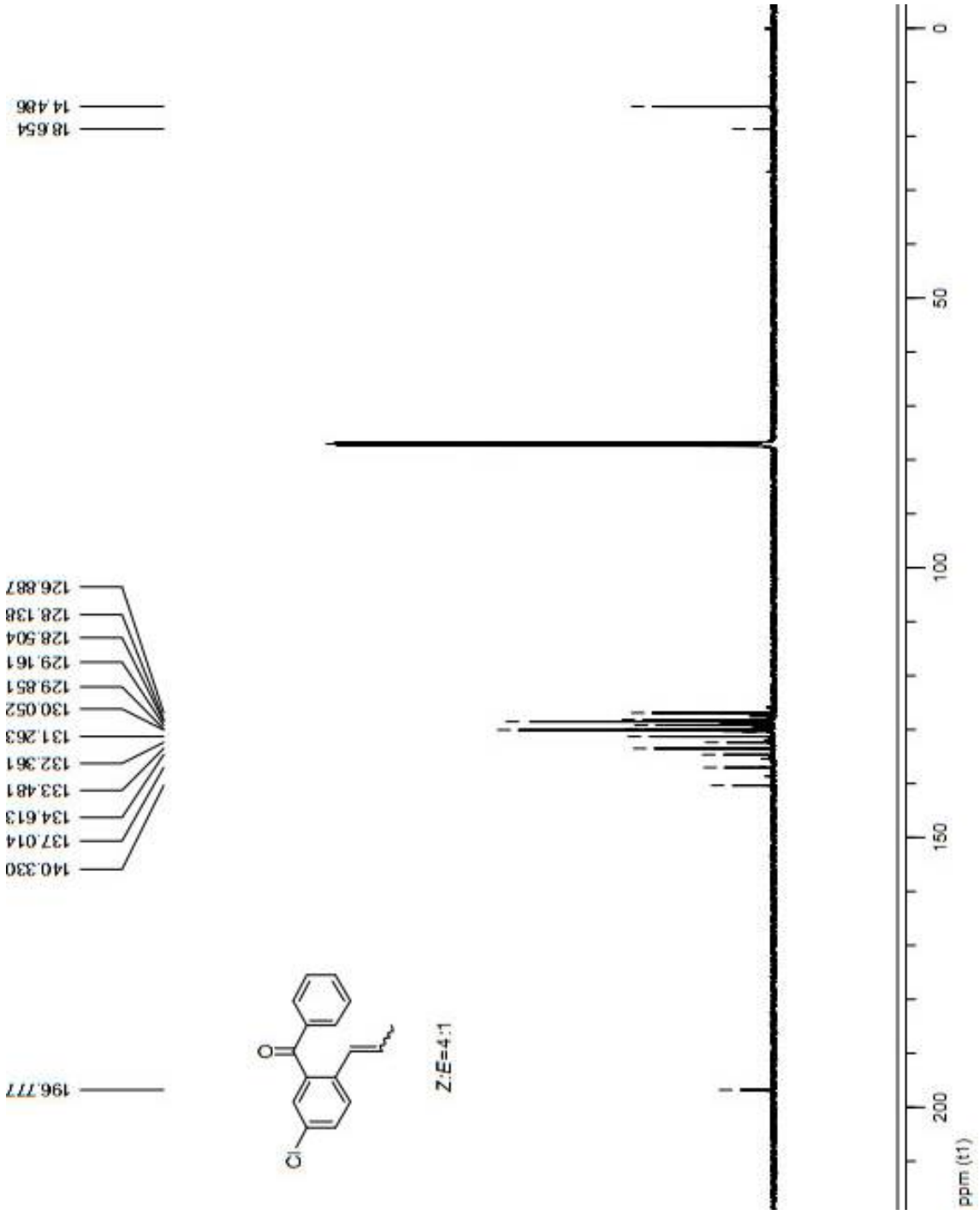

1.260
1.263
1.278
1.282
2.875
2.878
2.893
2.897
2.901
2.911
2.914
2.930
2.932
2.960
3.904
7.246
7.266
7.270
7.283
7.287
7.460
7.464
7.481
7.485
7.563
7.568
7.583
7.588
7.683
7.695
7.700
7.702
7.996
8.007
8.017
8.028
3.00
4.15
0.68
3.00
1.07
2.48
0.70
1.15
2.35
O
O
HO
O
Cl
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (f1)

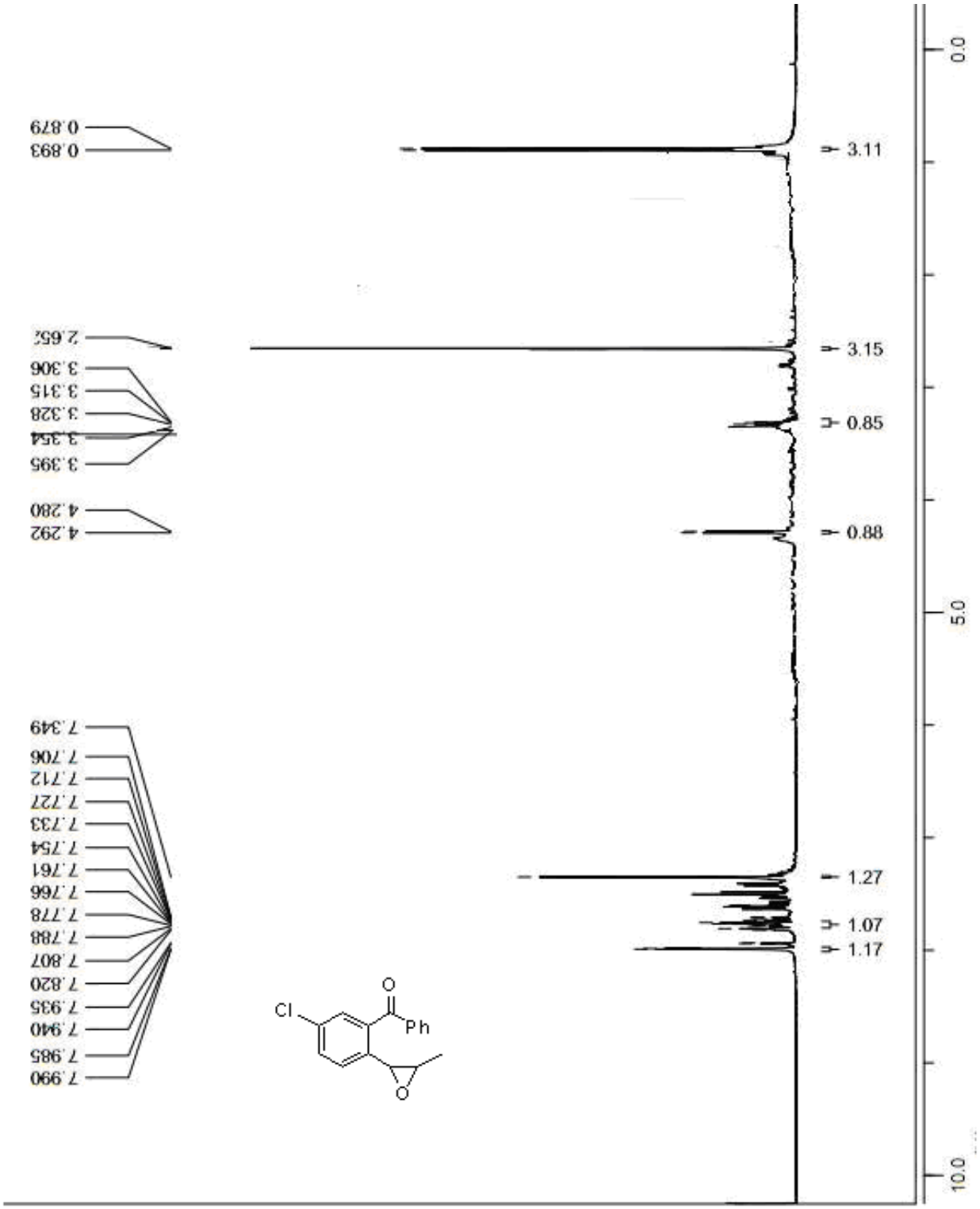


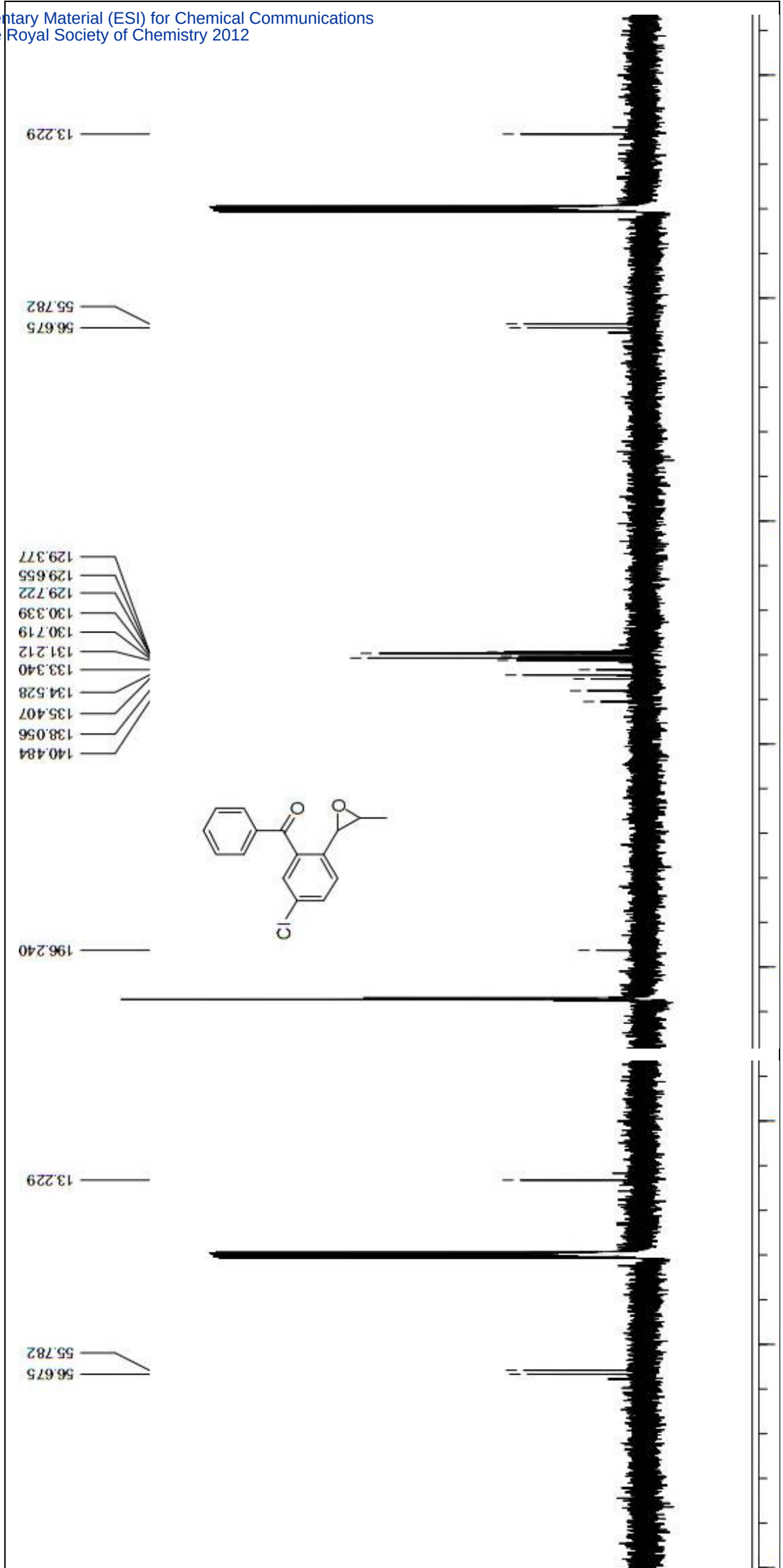

1.604
1.608
1.622
1.626
1.851
1.855
1.868
1.872
2.277
2.287
5.826
5.837
5.844
5.855
5.861
5.872
5.951
5.961
6.029
6.045
6.074
6.084
6.355
6.384
6.546
6.549
6.585
6.588
7.106
7.126
7.253
7.291
7.338
7.355
7.627
7.633
OH
Cl
Z:E=4:1
2.60
0.46
0.88
0.82
0.79
0.21
0.79
0.18
0.78
6.21
0.83
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
ppm (t1)

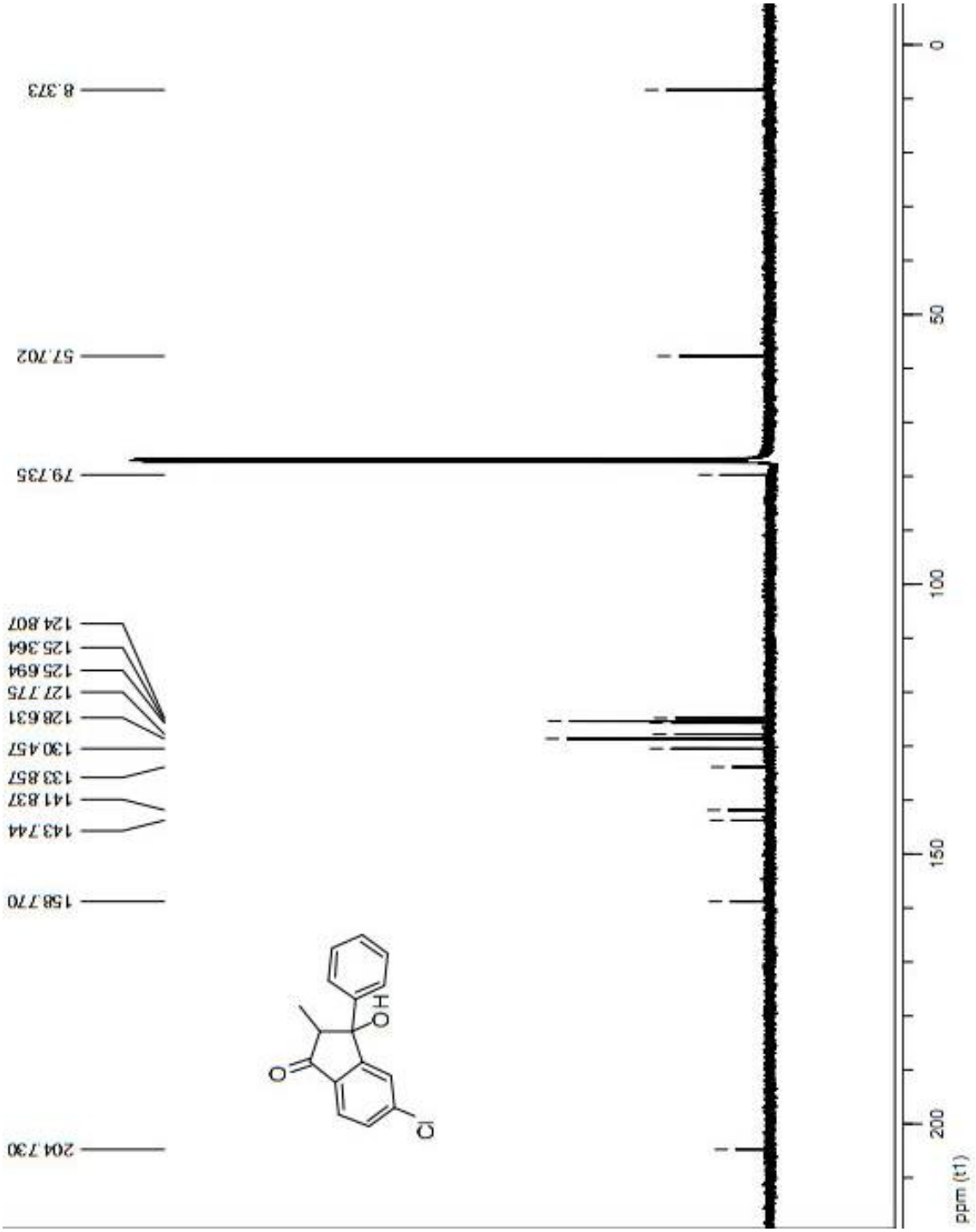

14.234
72.971
115.310
126.458
126.993
127.179
127.231
127.793
128.546
129.027
131.091
133.058
133.812
142.432
143.399
OH
Cl
Z:E=4:1
0
50
100
150
ppm (t1)

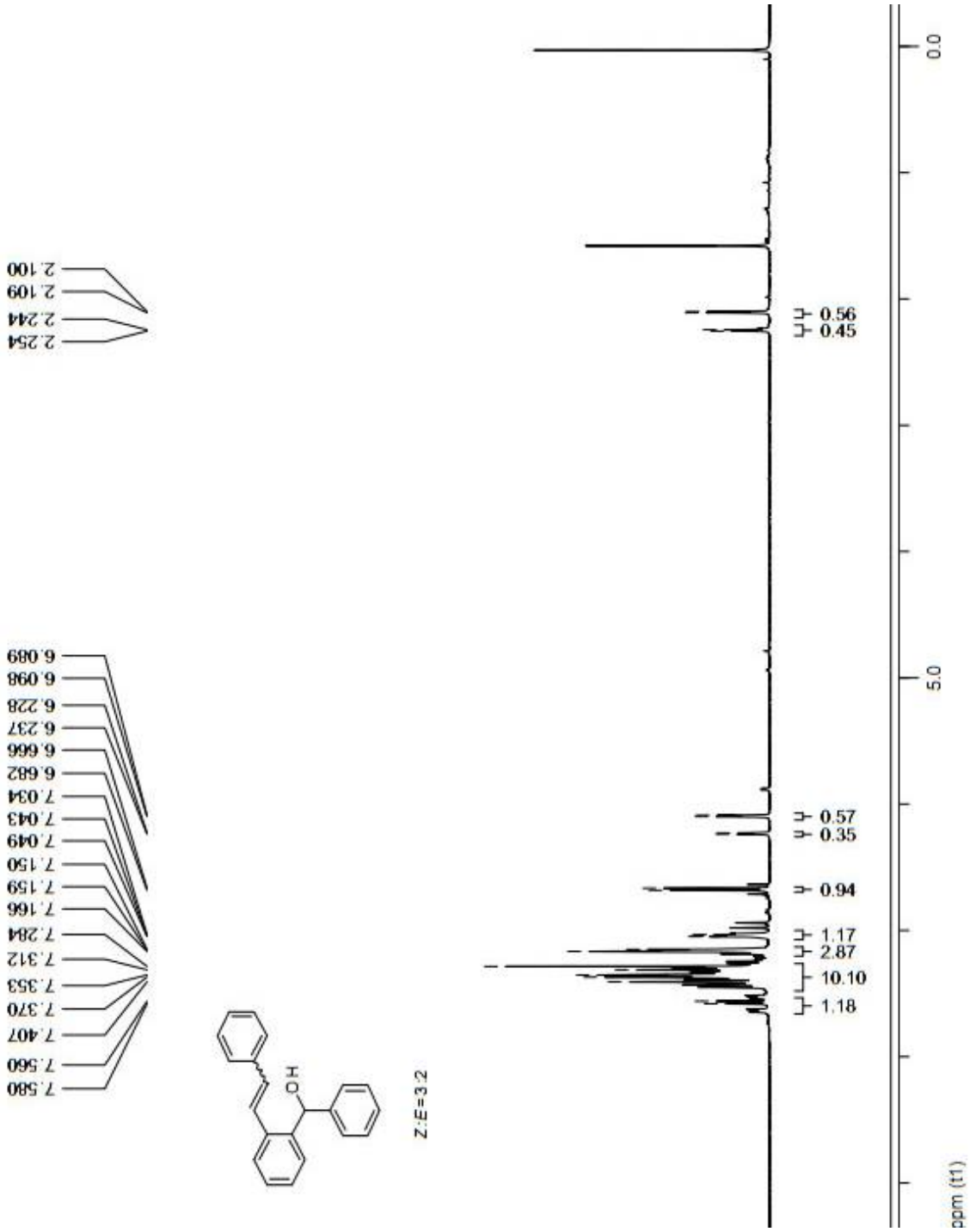


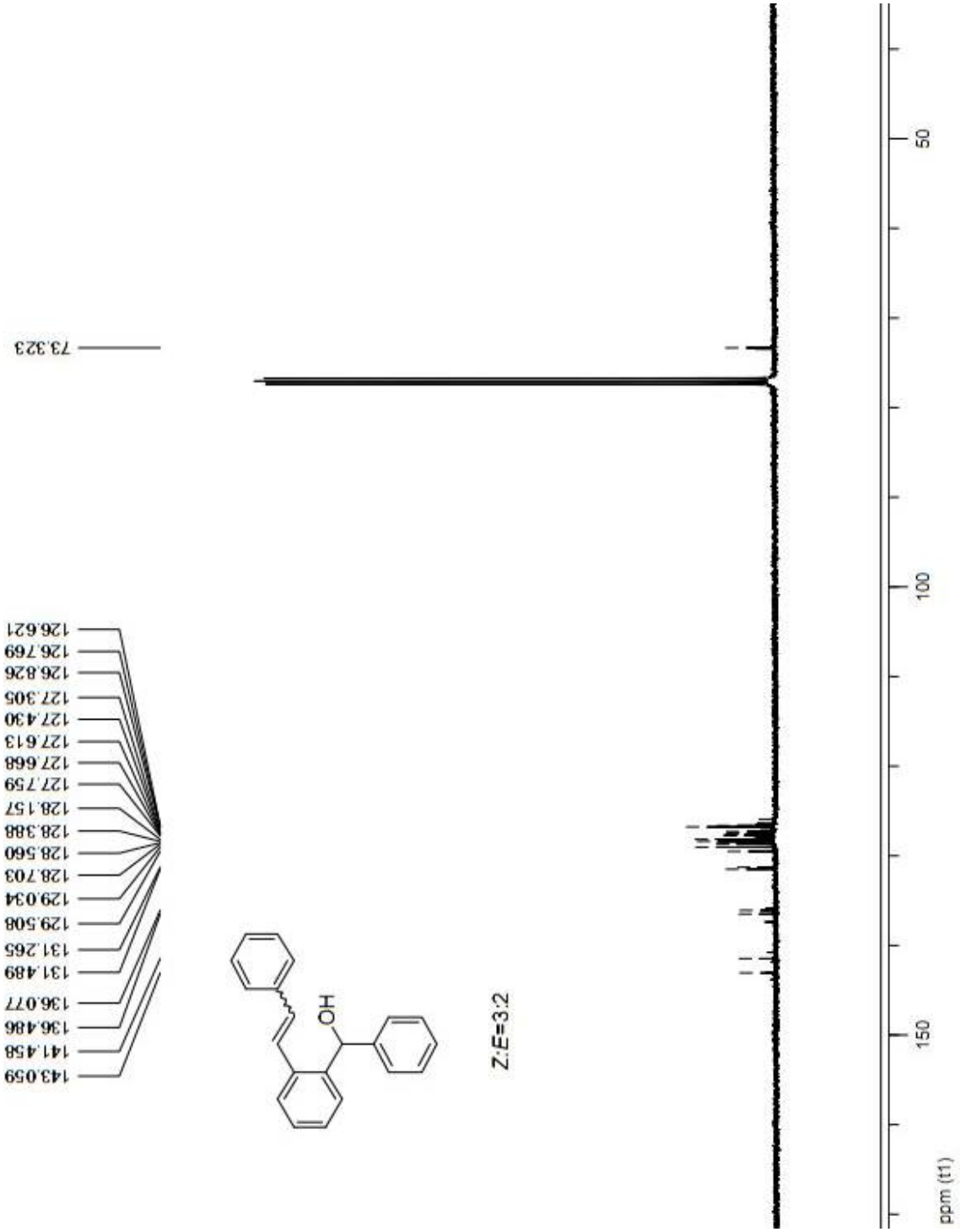

14.486
18.654
126.887
128.138
128.504
129.161
129.851
130.052
131.263
132.361
133.481
134.613
137.014
140.330
196.777
O
Cl
Z:E=4:1
0
50
100
150
200
ppm (t1)

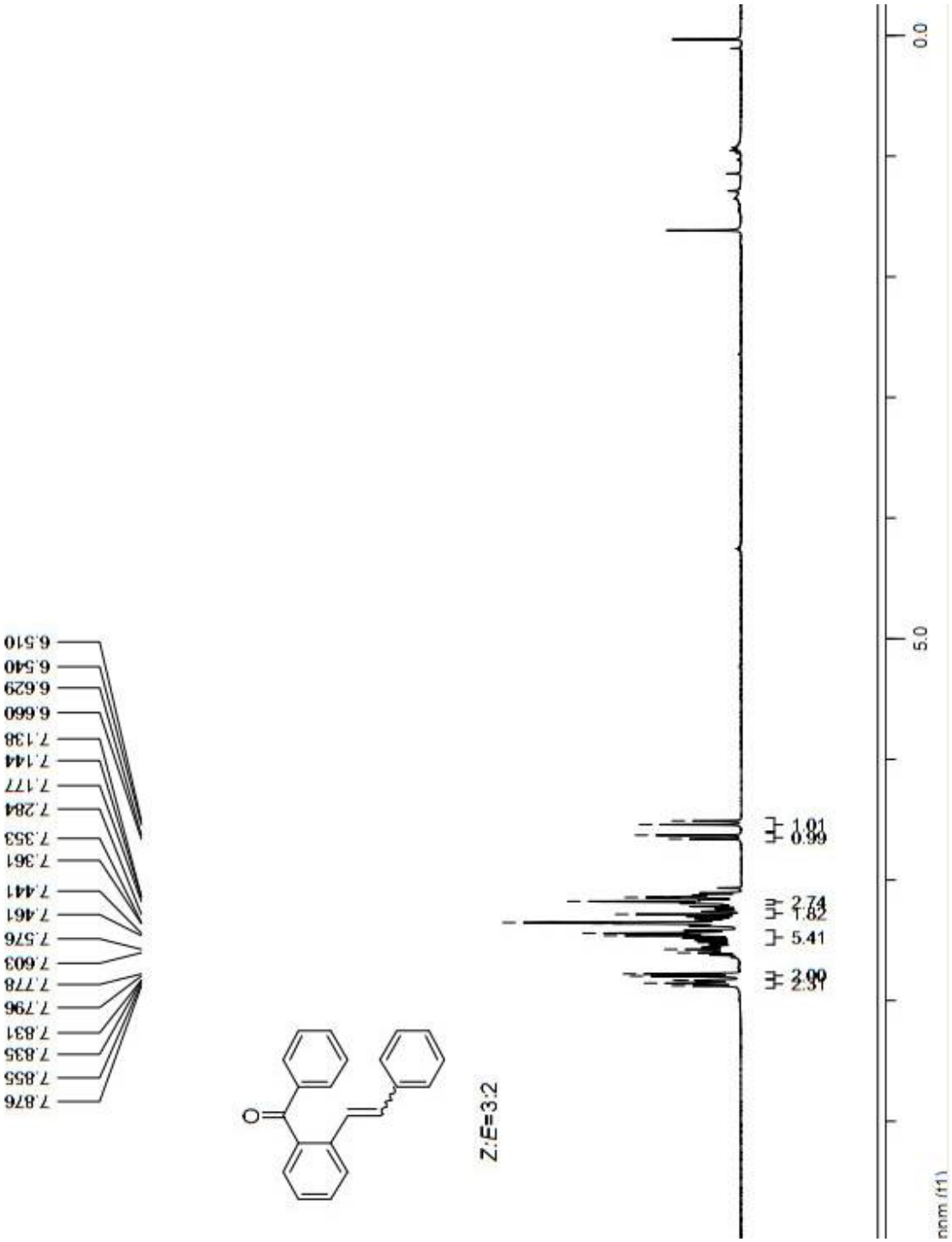


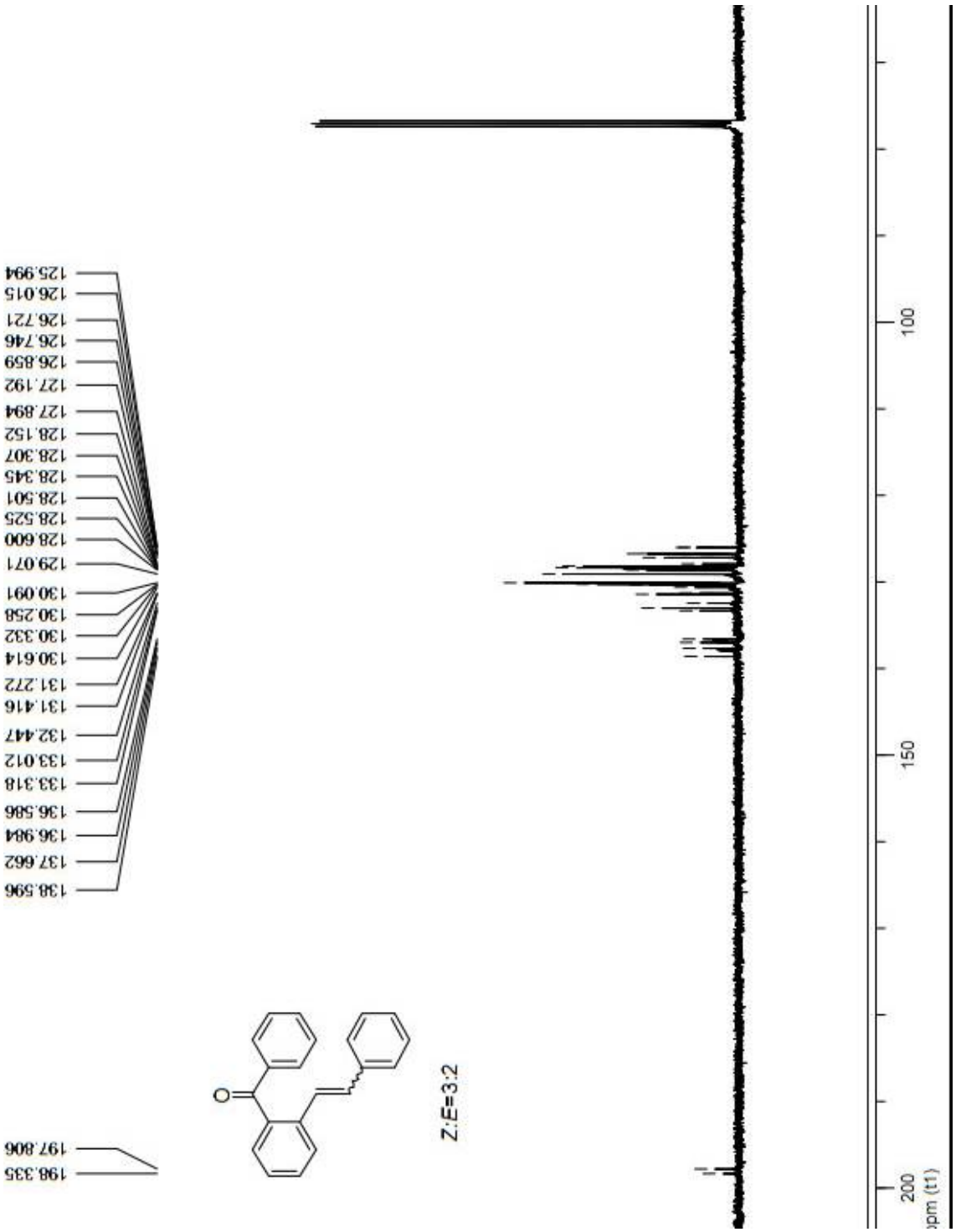


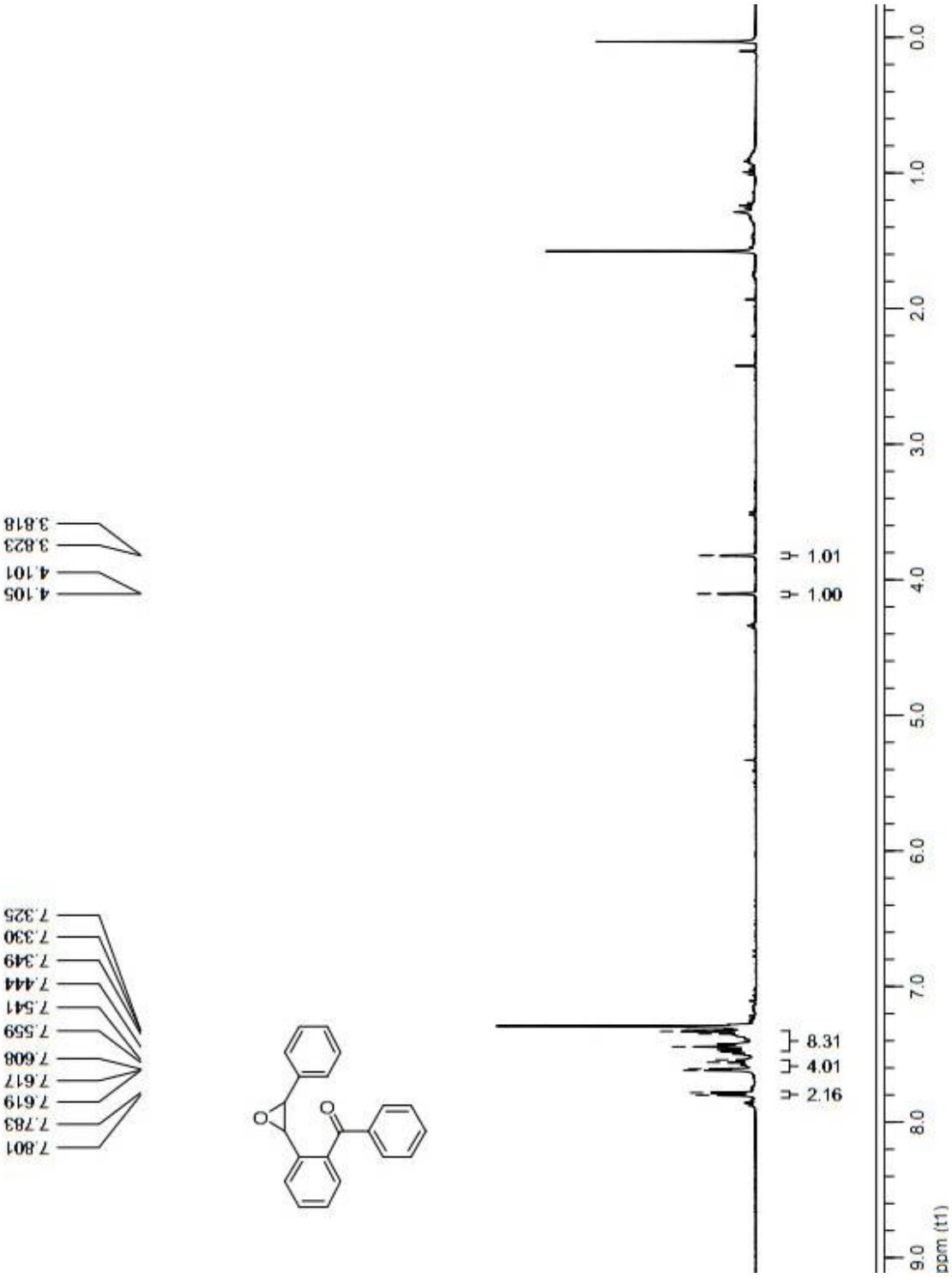

8.373
57.702
79.735
124.807
125.364
125.694
127.775
128.631
130.457
133.857
141.837
143.744
158.770
204.730
O
OH
Cl
0
50
100
150
200
ppm (t1)

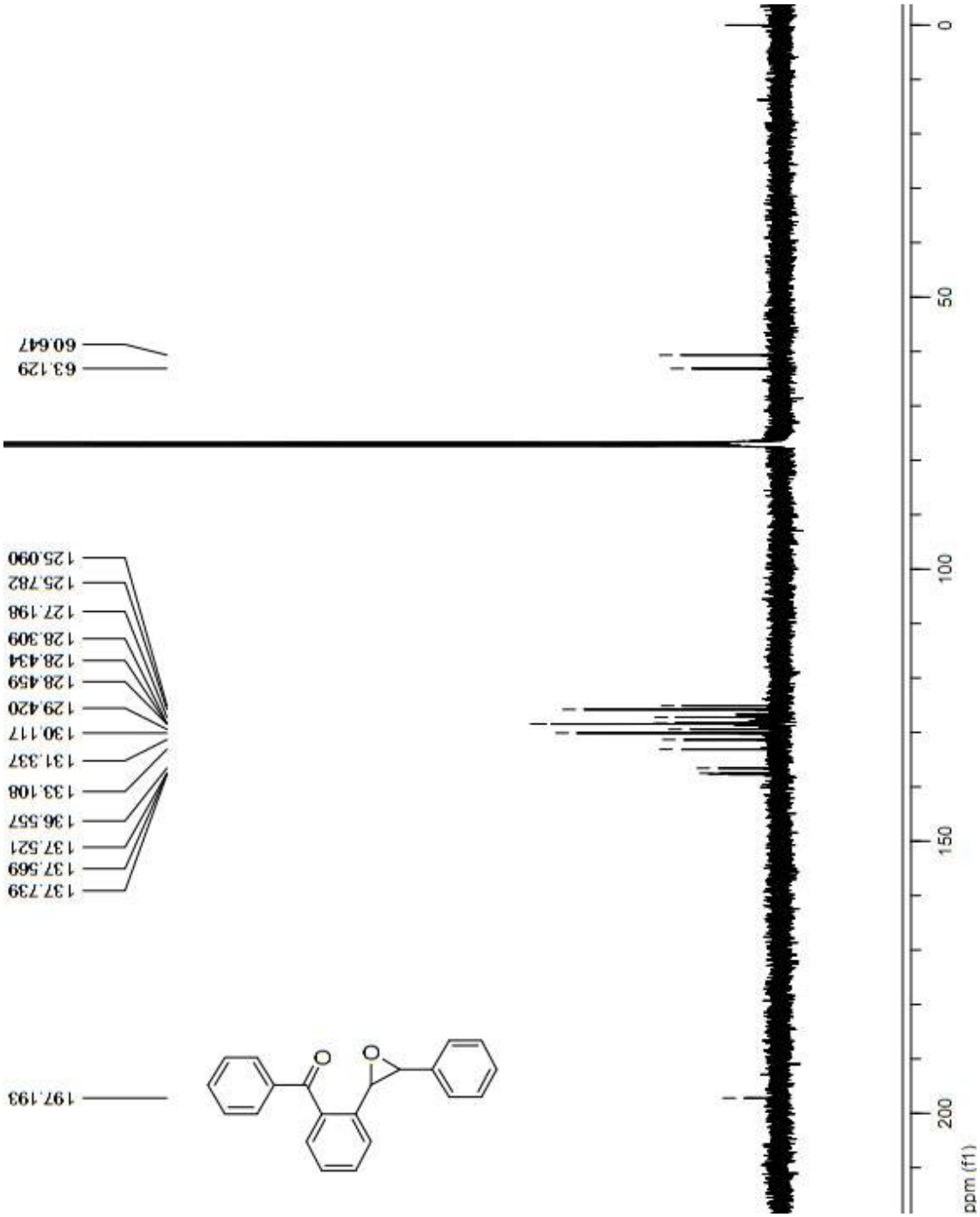

2.100
2.109
2.244
2.254
6.089
6.098
6.228
6.237
6.666
6.682
7.034
7.043
7.049
7.150
7.159
7.166
7.284
7.312
7.353
7.370
7.407
7.560
7.580
OH
Z:E=3:2
0.56
0.45
0.57
0.35
0.94
1.17
2.87
10.10
1.18
0.0
5.0
ppm (t1)

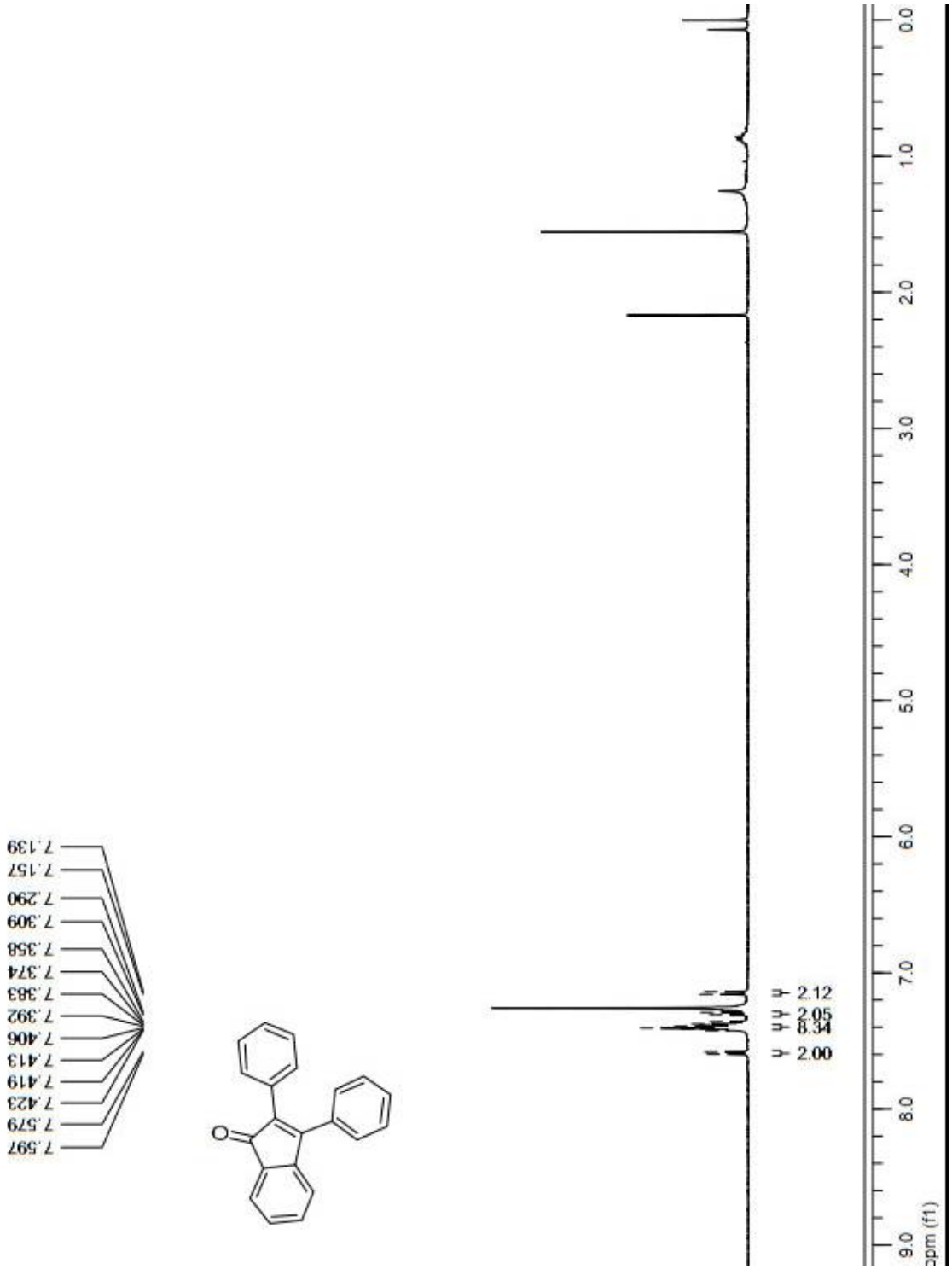


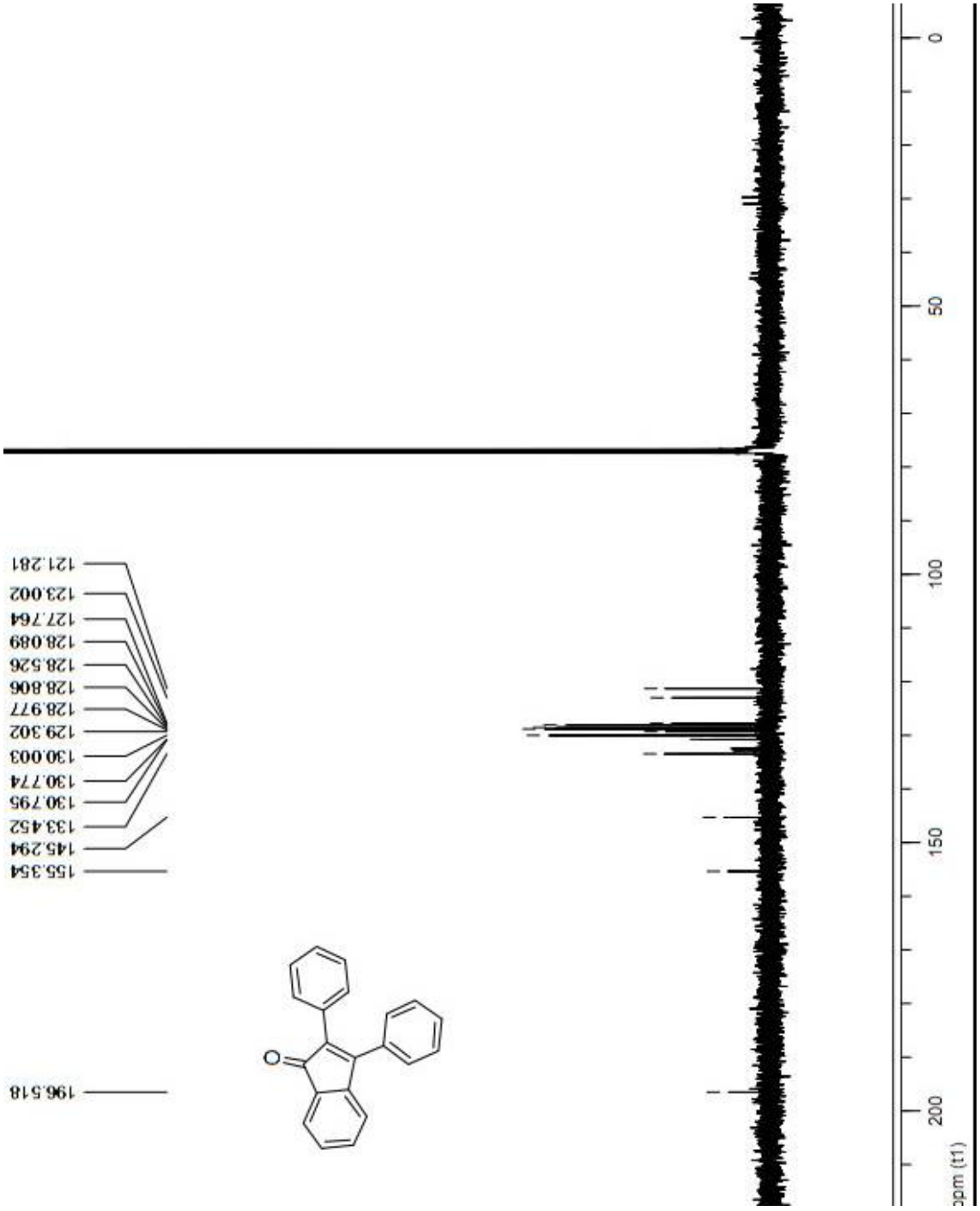

6.510
6.540
6.629
6.660
7.138
7.144
7.177
7.284
7.353
7.361
7.441
7.461
7.576
7.603
7.778
7.796
7.831
7.835
7.855
7.876
O
Z:E=3:2
1.01
0.99
2.74
1.82
5.41
2.00
2.31
0.0
5.0

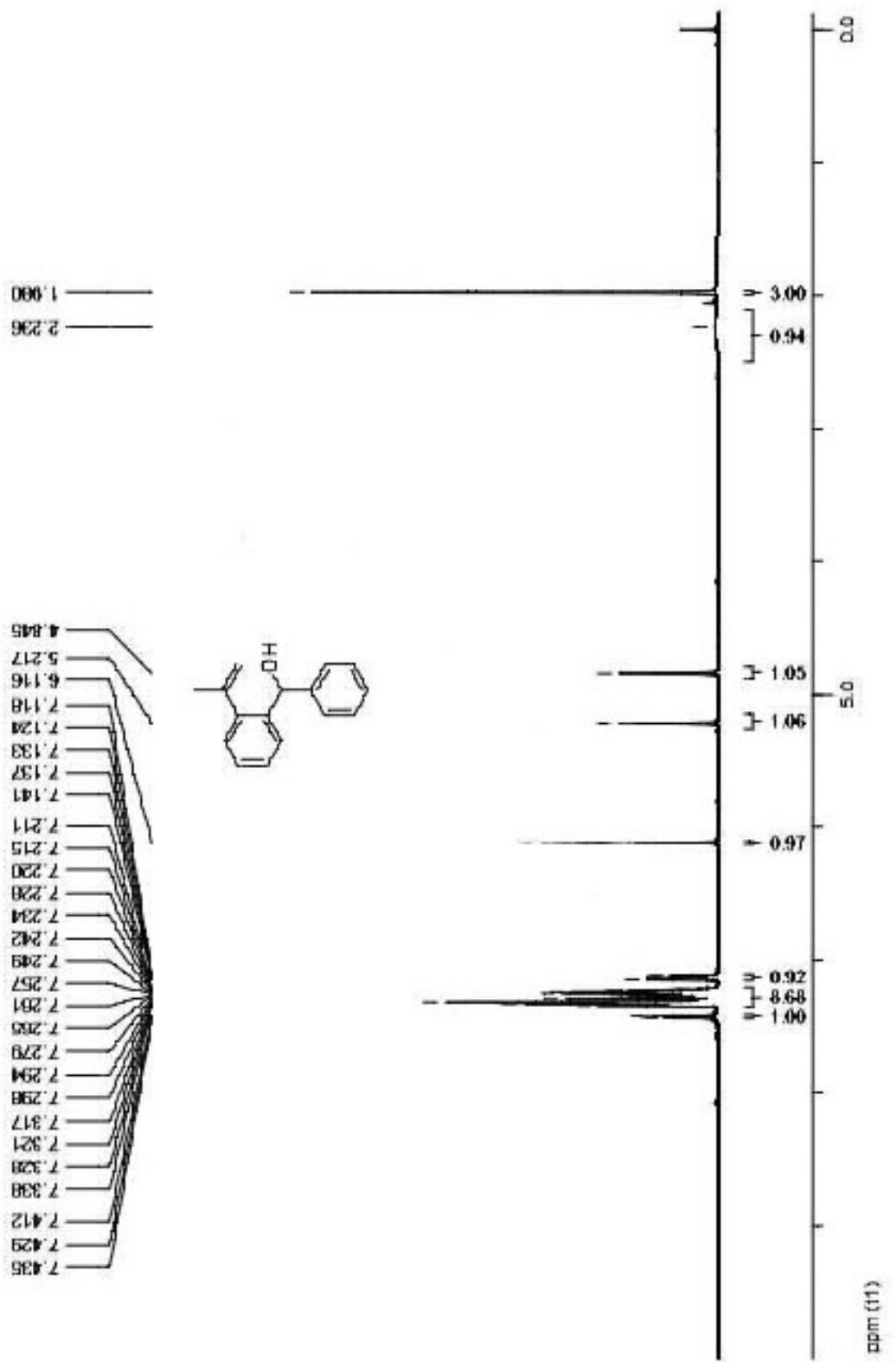

125.994
126.015
126.721
126.746
126.859
127.192
127.894
128.152
128.307
128.345
128.501
128.525
128.600
129.071
130.091
130.258
130.332
130.614
131.272
131.416
132.447
133.012
133.318
136.586
136.984
137.662
138.596
197.806
198.335
O
Z:E=3:2
100
150
200
ppm (t1)

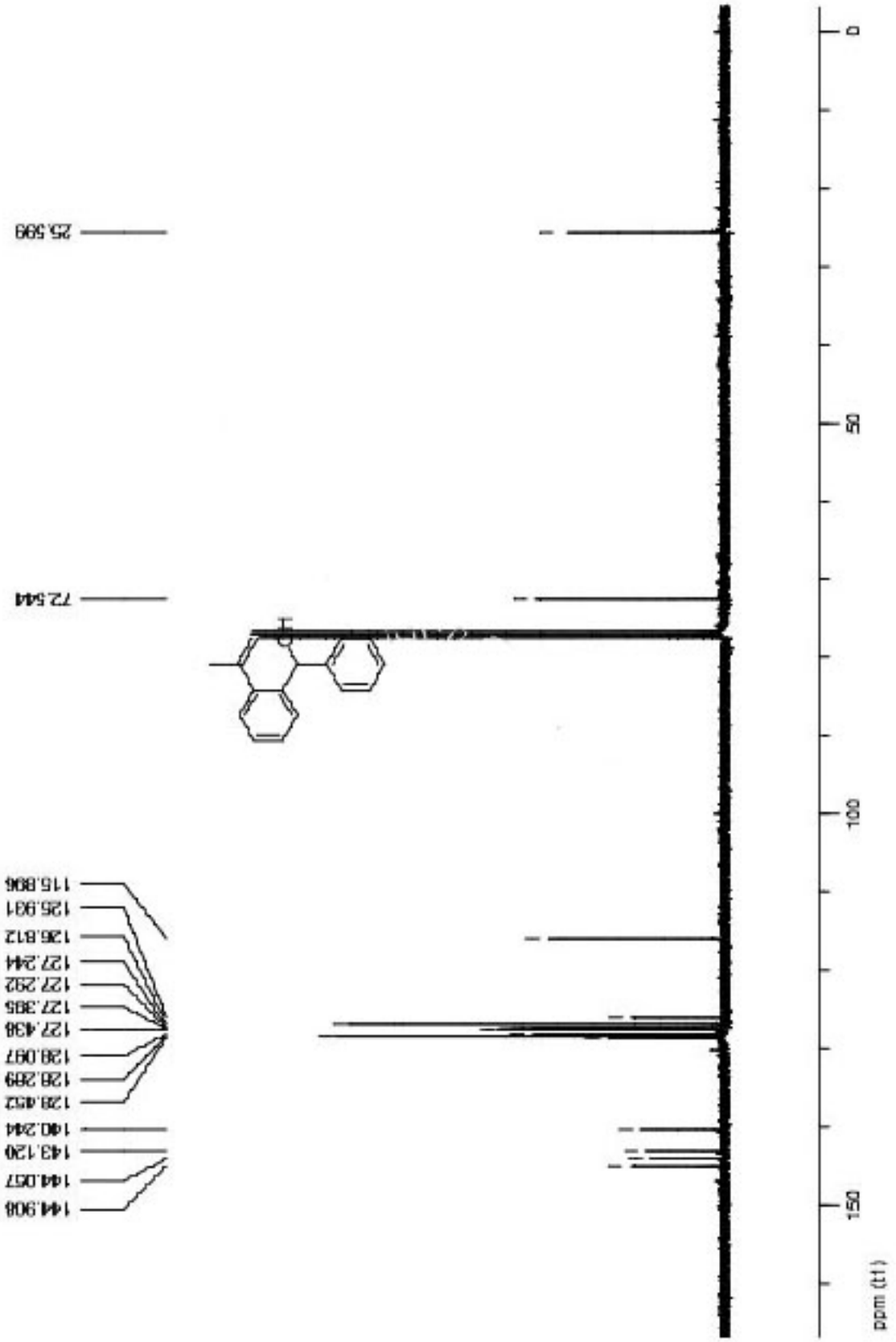

3.818
3.823
4.101
4.105
7.325
7.330
7.349
7.444
7.541
7.559
7.608
7.617
7.619
7.783
7.801
1.01
1.00
8.31
4.01
2.16
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (t1)

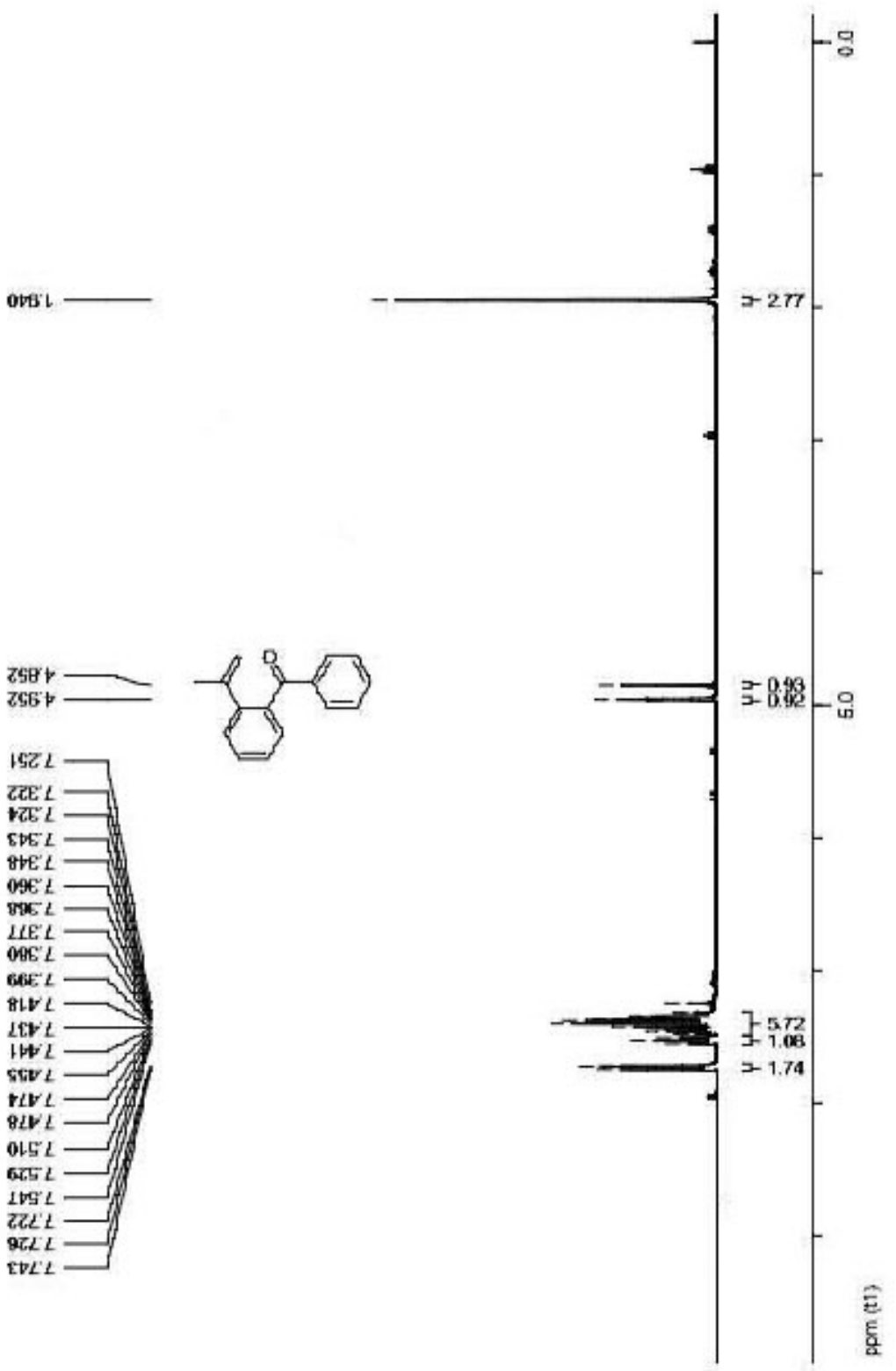

60.647
63.129
125.090
125.782
127.198
128.309
128.434
128.459
129.420
130.117
131.337
133.108
136.557
137.521
137.569
137.739
197.193
0
50
100
150
200
ppm (f1)

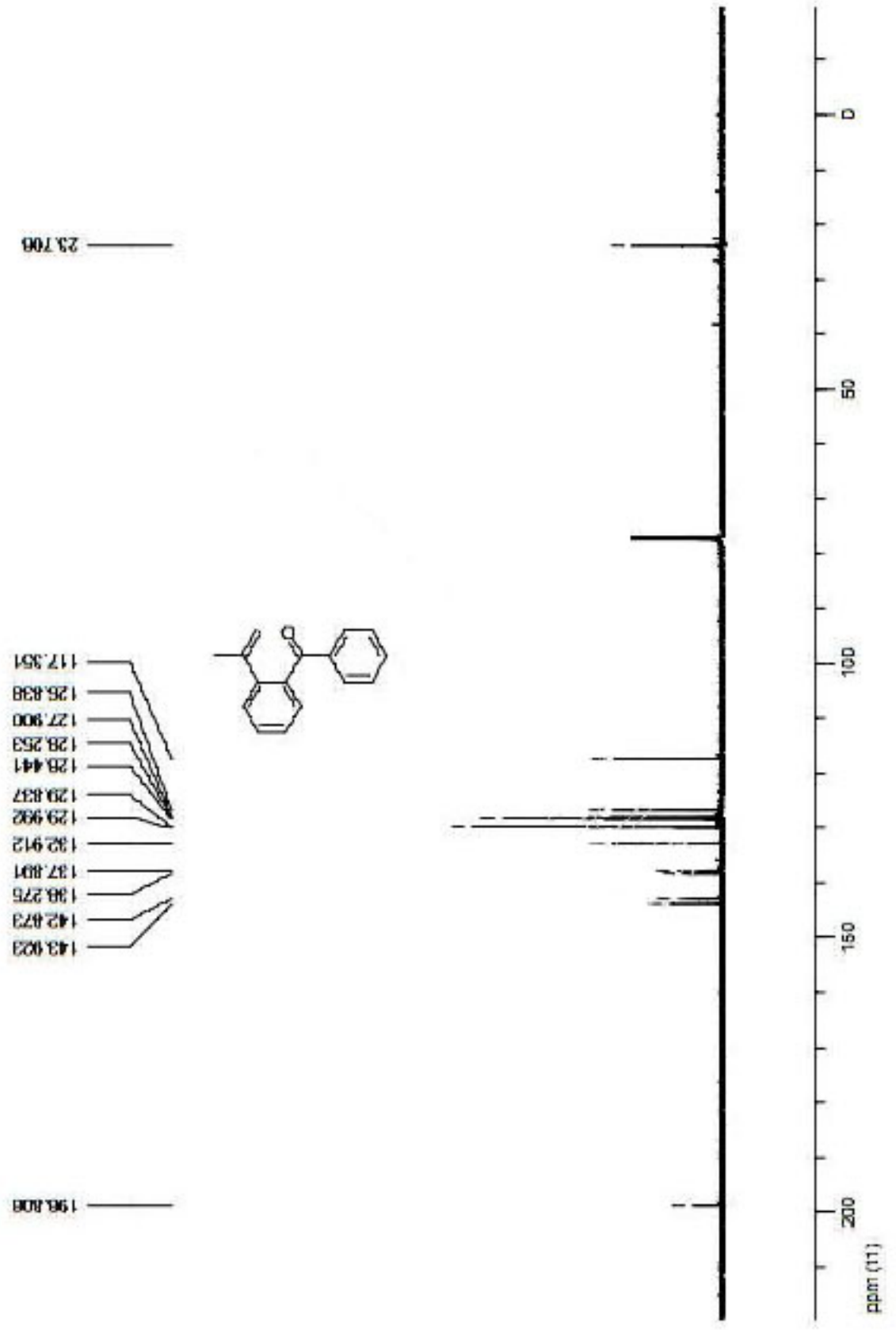

7.139
7.157
7.290
7.309
7.358
7.374
7.383
7.392
7.406
7.413
7.419
7.423
7.579
7.597
2.12
2.05
8.34
2.00
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
ppm (f1)

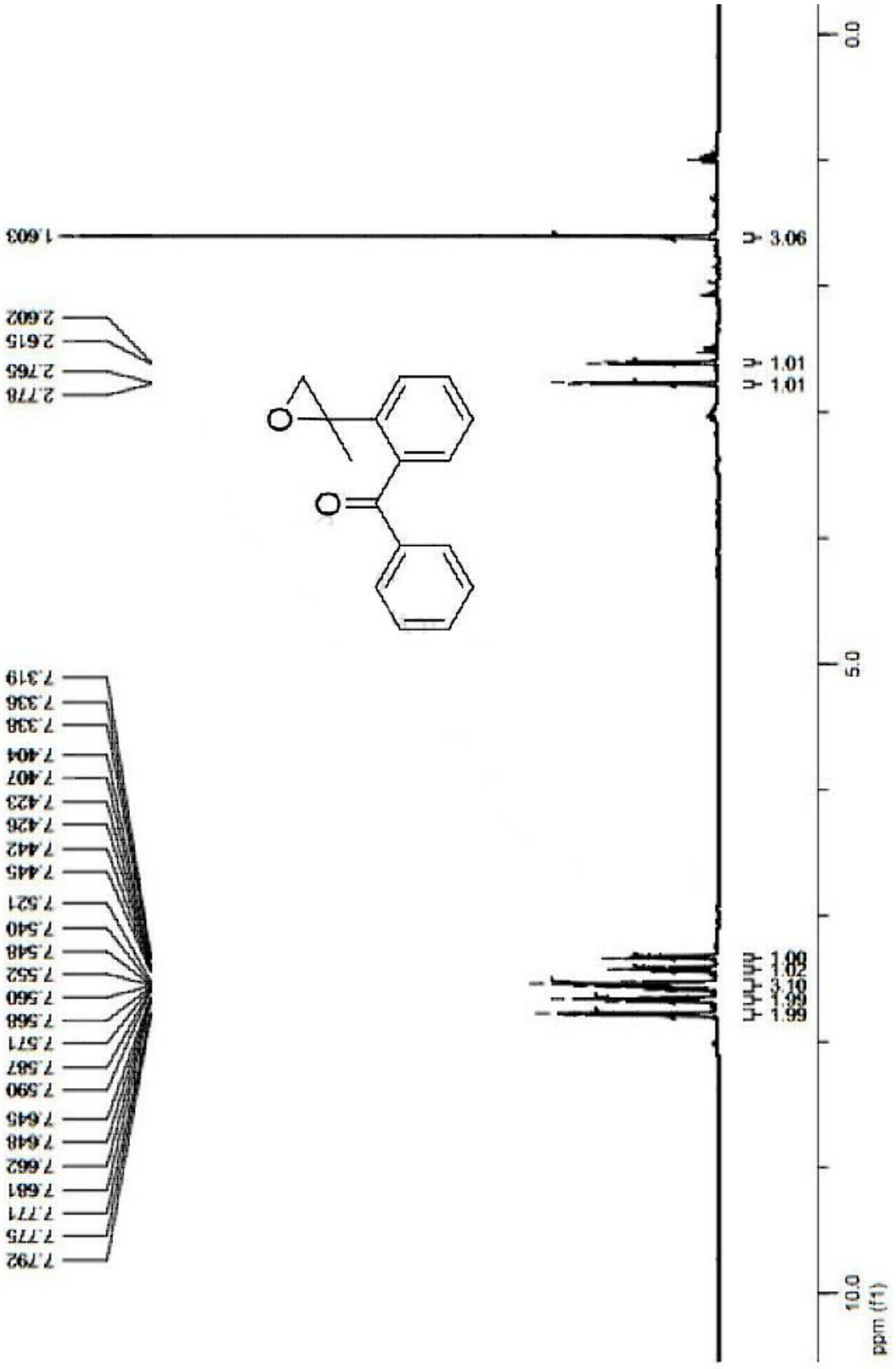

121.281
123.002
127.764
128.089
128.526
128.806
128.977
129.302
130.003
130.774
130.795
133.452
145.294
155.354
196.518
0
50
100
150
200
ppm (t1)

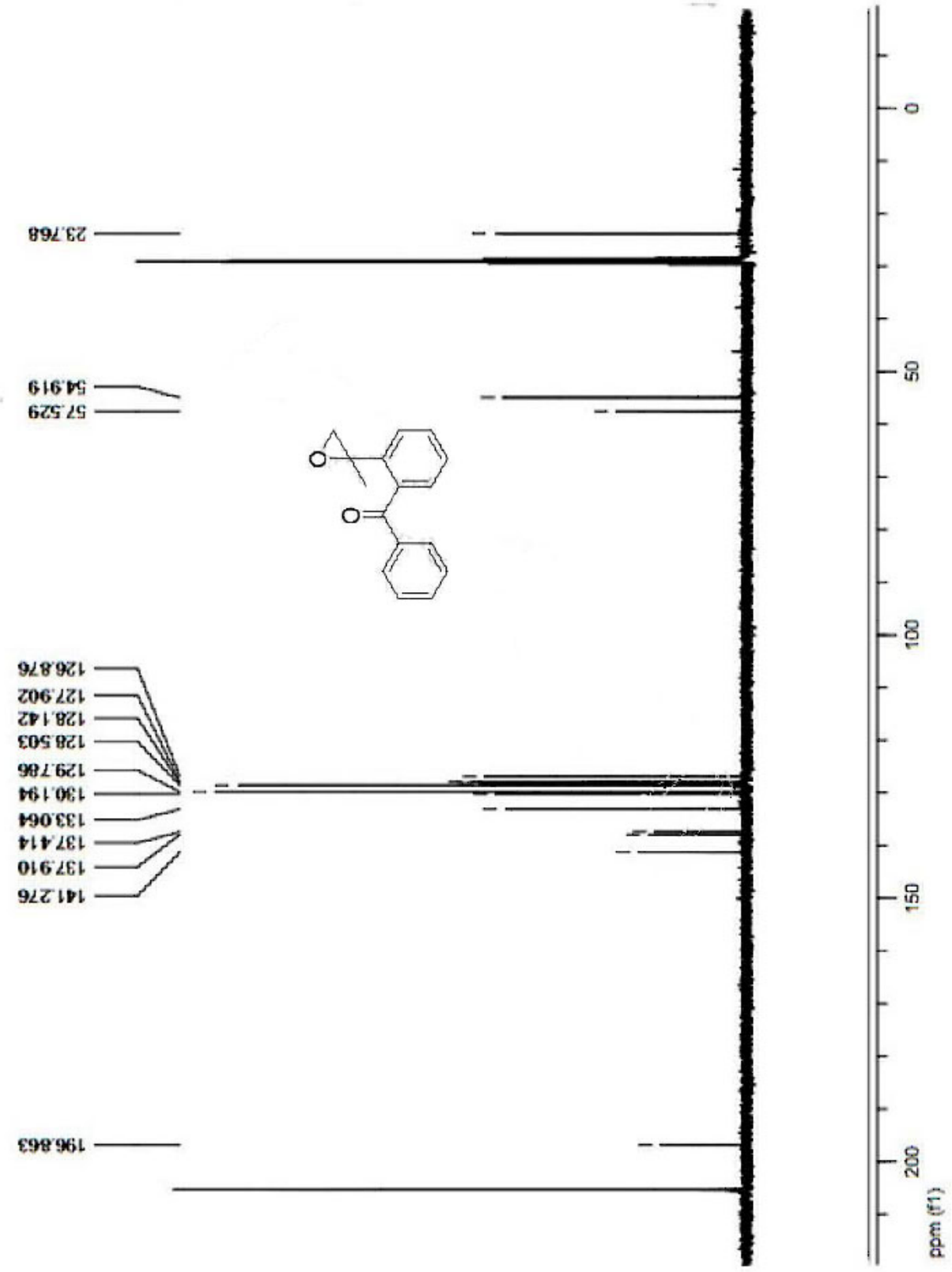

1.000
2.236
4.845
5.217
6.116
7.118
7.124
7.133
7.137
7.141
7.211
7.215
7.220
7.228
7.234
7.242
7.249
7.257
7.261
7.265
7.279
7.294
7.298
7.317
7.321
7.328
7.338
7.412
7.429
7.435
OH
3.00
0.94
1.05
1.06
0.97
0.92
8.68
1.00
0.0
5.0
ppm (t1)

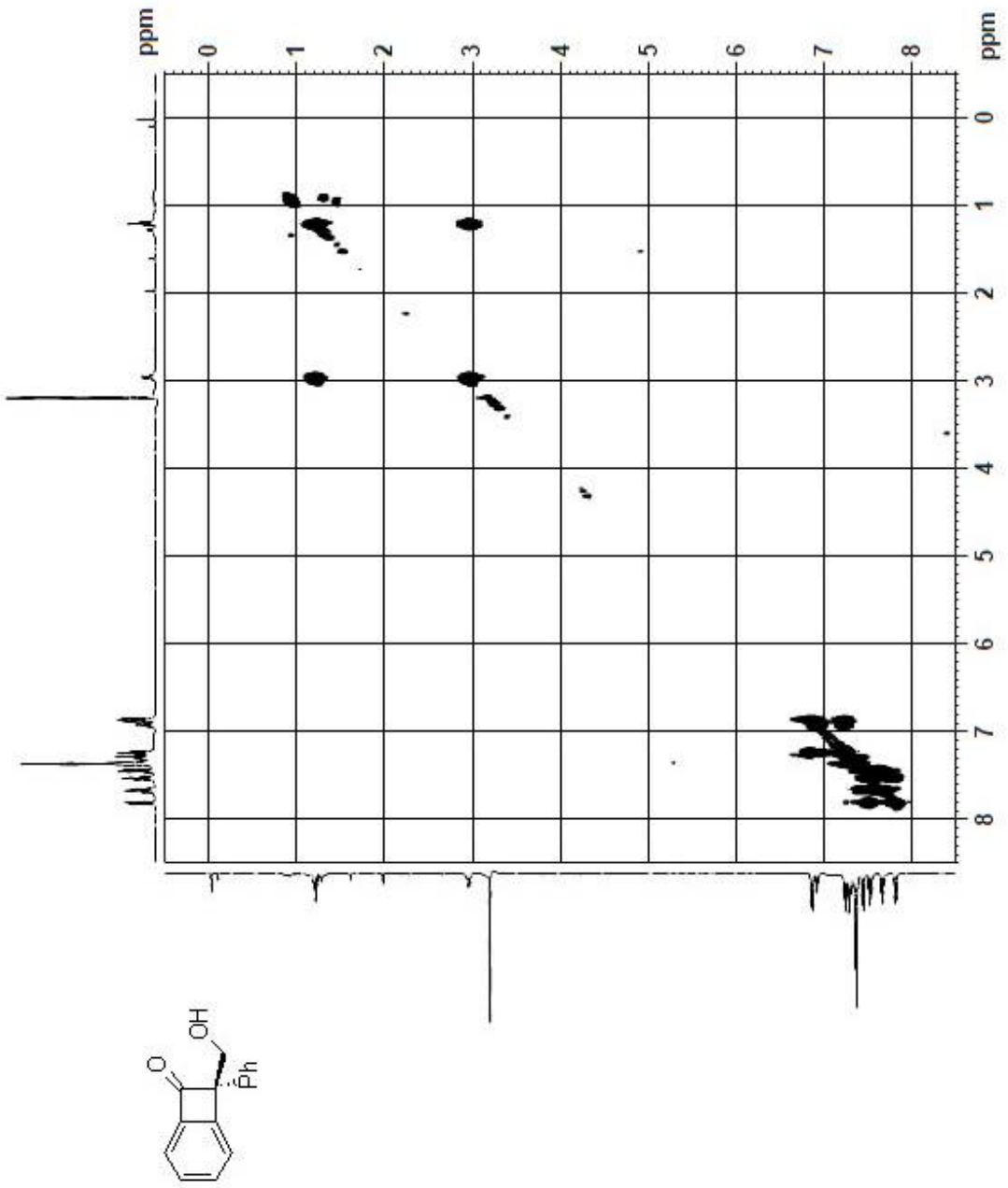

25.589
72.544
115.806
125.931
126.812
127.244
127.292
127.385
127.438
128.087
128.289
128.452
140.244
143.120
144.057
144.908
0
50
100
150
ppm (t1)

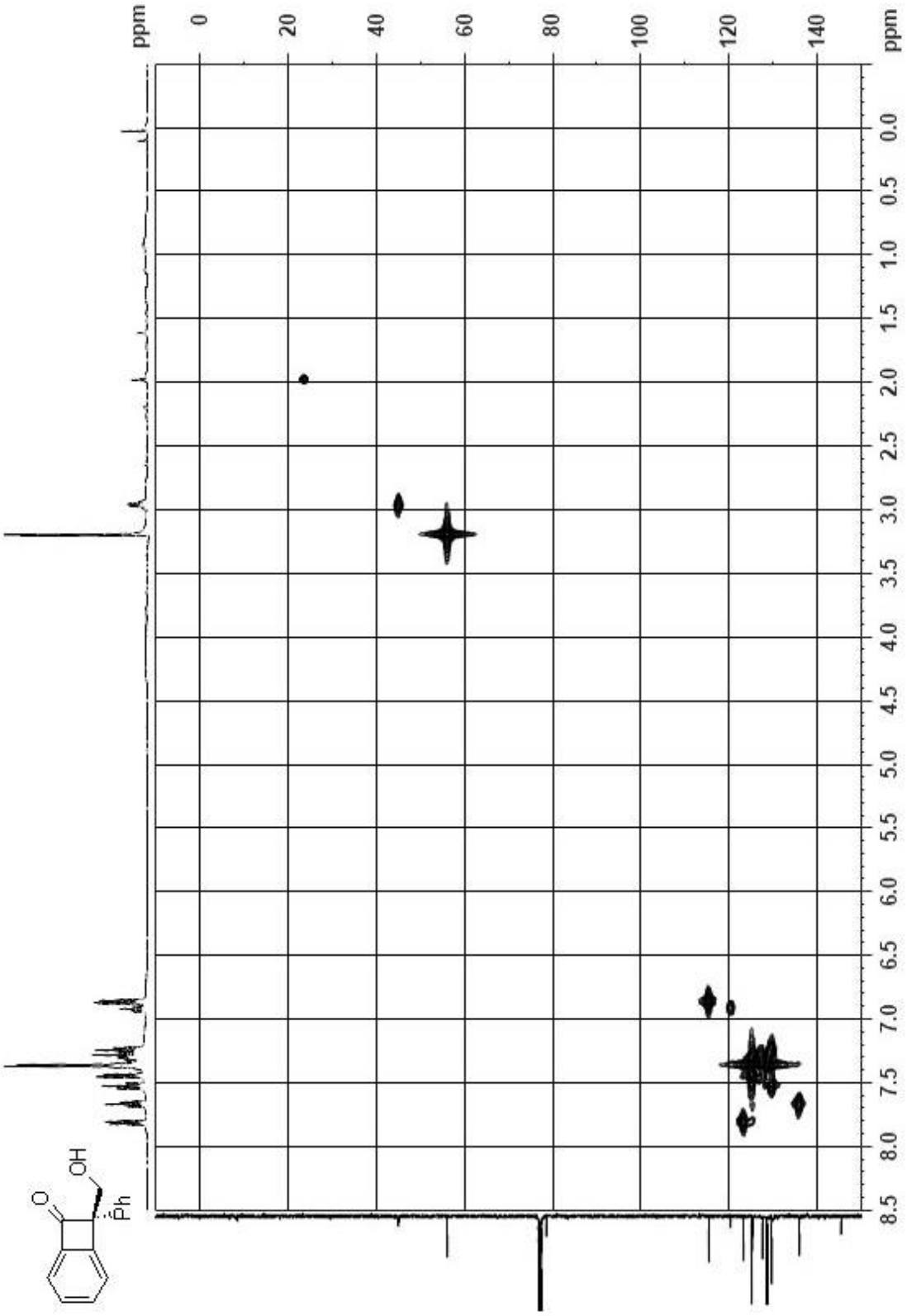

1.840
4.852
4.952
7.251
7.322
7.324
7.343
7.348
7.360
7.368
7.377
7.380
7.399
7.418
7.437
7.441
7.455
7.474
7.478
7.510
7.529
7.547
7.722
7.726
7.743
2.77
0.93
0.92
5.72
1.08
1.74
0.0
5.0
ppm (t1)

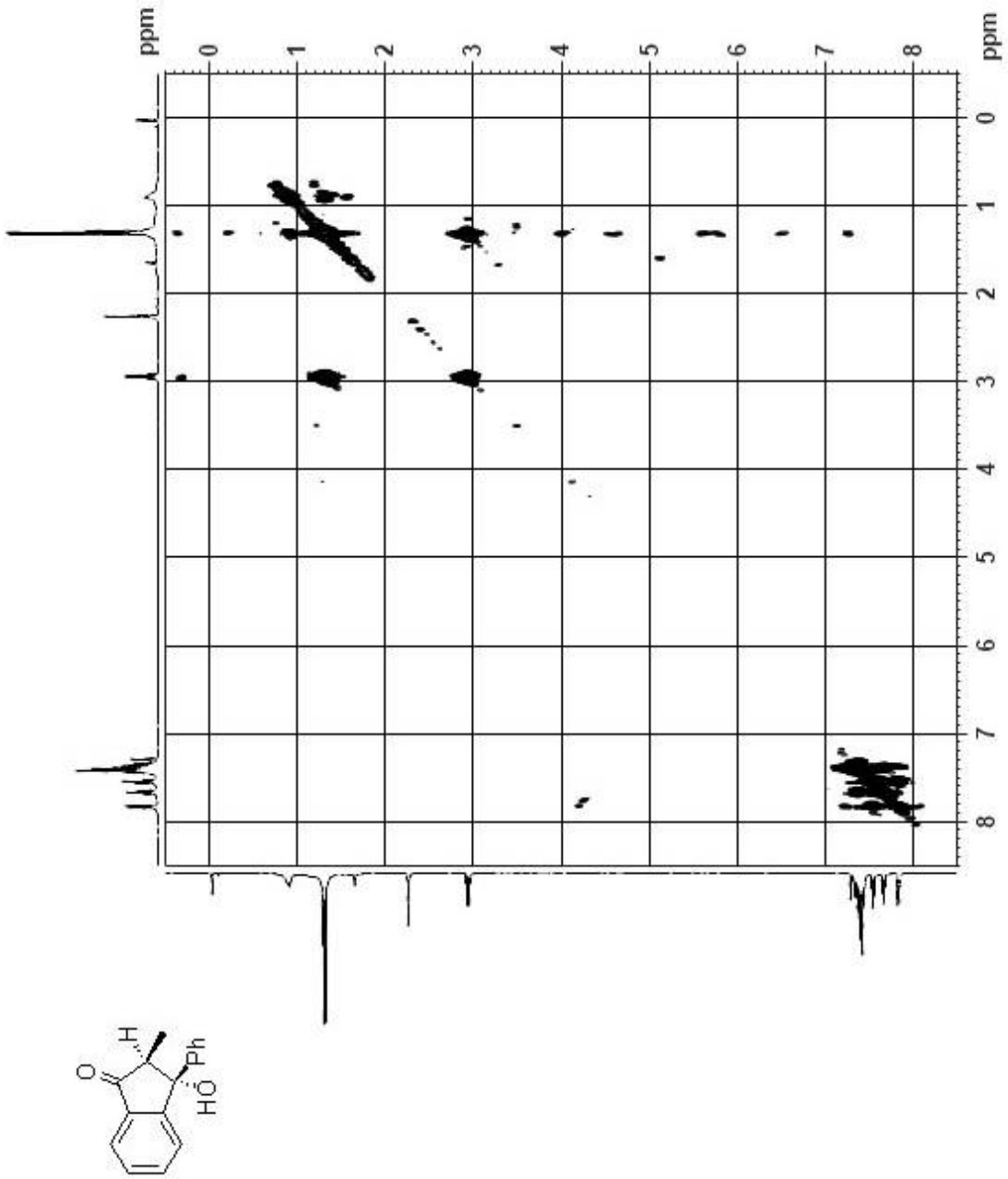

23.706
117.351
125.838
127.900
128.253
128.441
129.837
129.992
132.912
137.891
138.275
142.873
143.023
196.808
0
50
100
150
200
ppm (t1)

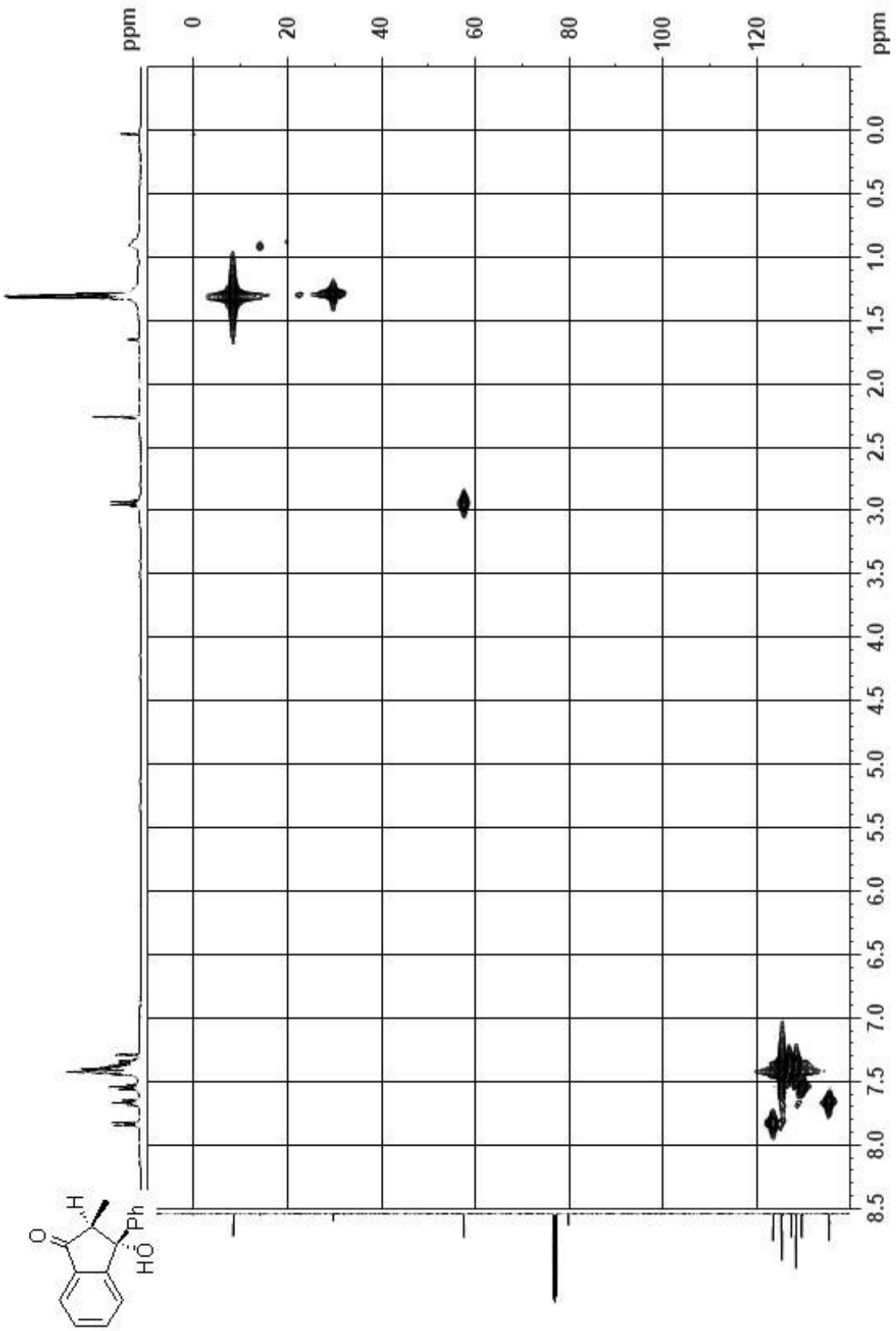

1.603
2.602
2.615
2.765
2.778
7.319
7.336
7.338
7.404
7.407
7.423
7.426
7.442
7.445
7.521
7.540
7.548
7.552
7.560
7.568
7.571
7.587
7.590
7.645
7.648
7.662
7.681
7.771
7.775
7.792
3.06
1.01
1.01
0.0
5.0
10.0
ppm (f1)

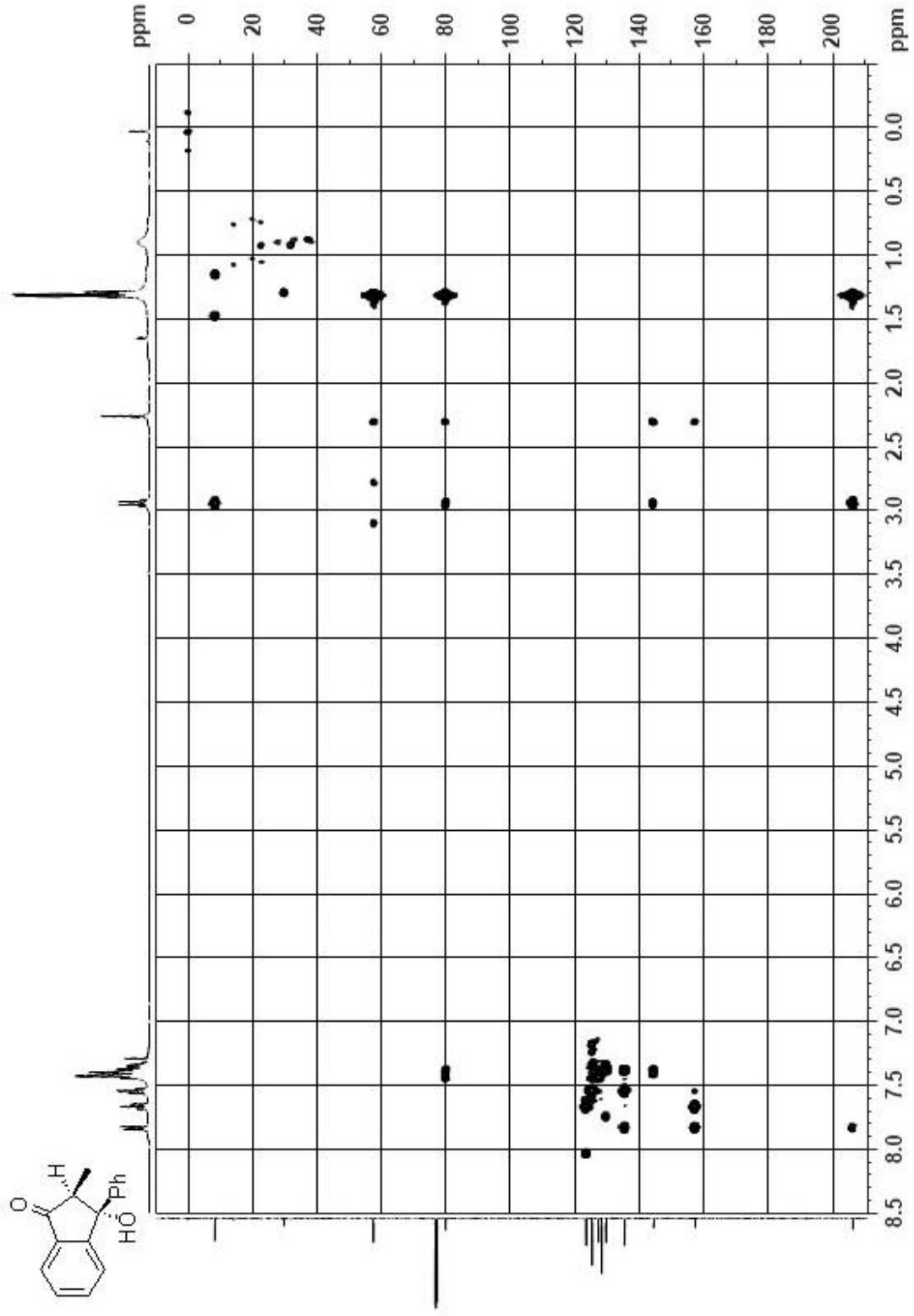


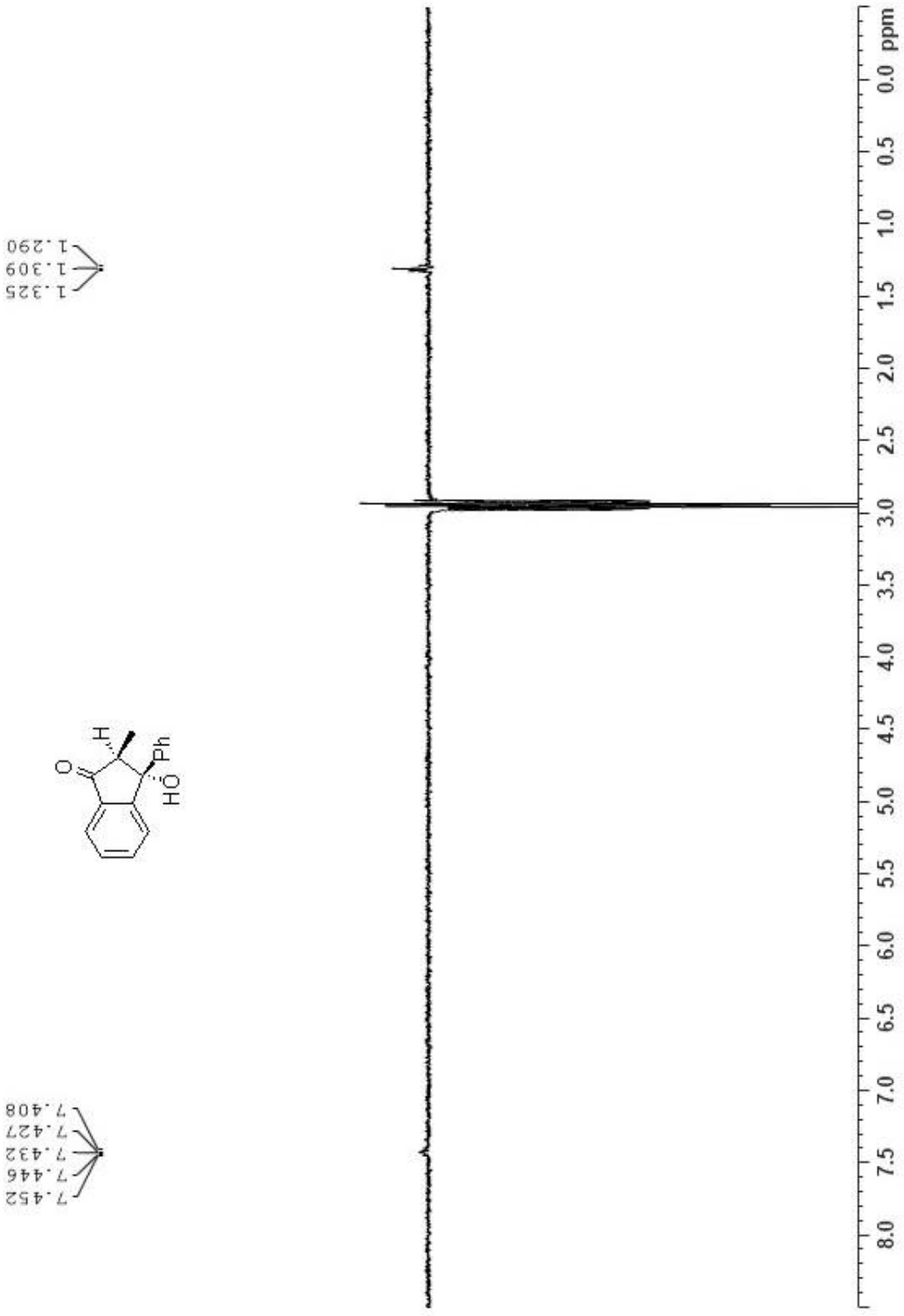

ppm
0
1
2
3
4
5
6
7
8
ppm
OH
O
Ph

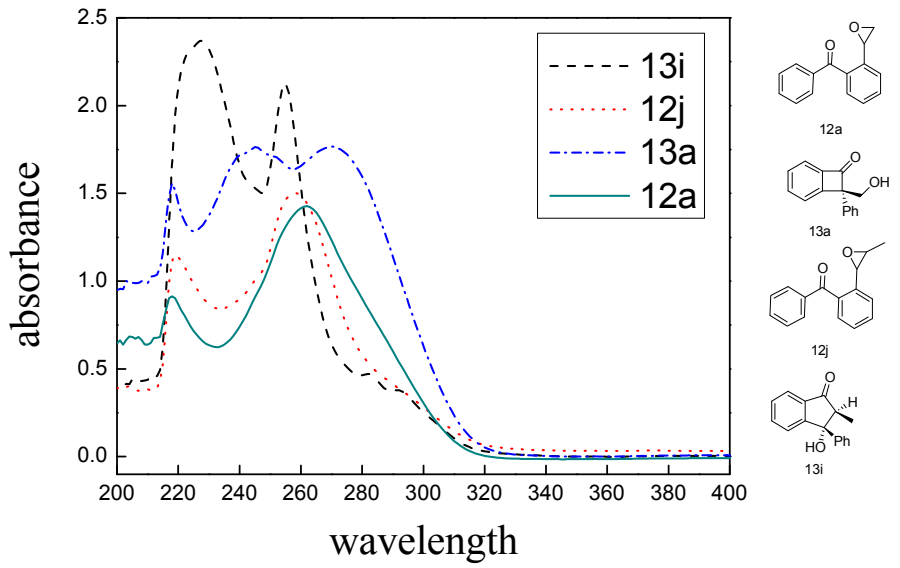

ppm
0
20
40
60
80
100
120
140
ppm
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
OH
O
Ph


ppm
0
1
2
3
4
5
6
7
8
ppm
O
H
Ph
HO


ppm
0
20
40
60
80
100
120
ppm
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
O
H
Ph
HO


ppm
0
20
40
60
80
100
120
140
160
180
200
ppm
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
O
H
Ph
HO


1.290
1.309
1.325
7.408
7.427
7.432
7.446
7.452
O
H
Ph
HO
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
ppm



Absorption spectra of substracts **12a** and **12j** in each 1.0×10^{-5}, photoproducts **13a** and **13i** in each 1.0×10^{-4} mol/L concentration in MeOH.