Supporting Information for the manuscript entitled:

IR Studies of H/D Exchange of Water, Hydroxyl and Carboxylic Groups reveal slowly diffusing Lattice Defects in Hydrated Porous Organic Networks

By

Natalia Pérez-Hernández,*[,†] Martín Febles,[‡] Cirilo Pérez,[‡] Johann Spandl,[§] Julio D. Martín,[#] Hans-Heinrich Limbach,*[†]

[†]*Institut für Chemie und Biochemie - Physikalishe und Theoretische Chemie, Freie Universität Berlin, Takusstr. 3, D-14195 Berlin, Germany,* [‡]*Instituto de Bioorgánica, Universidad de La Laguna-CSIC, Ctra. Vieja de La Esperanza 2, 38206 La Laguna, Tenerife, Spain,* [§]*Institut für Chemie und Biochemie - Anorganische Chemie, Freie Universität Berlin, Fabeckstr. 34/36, D-14195 Berlin, Germany,* [#] *Instituto de Investigaciones Químicas, CSIC, Avda. Américo Vespucio 49, 41092 Seville, Spain*

TABLE OF CONTENTS:

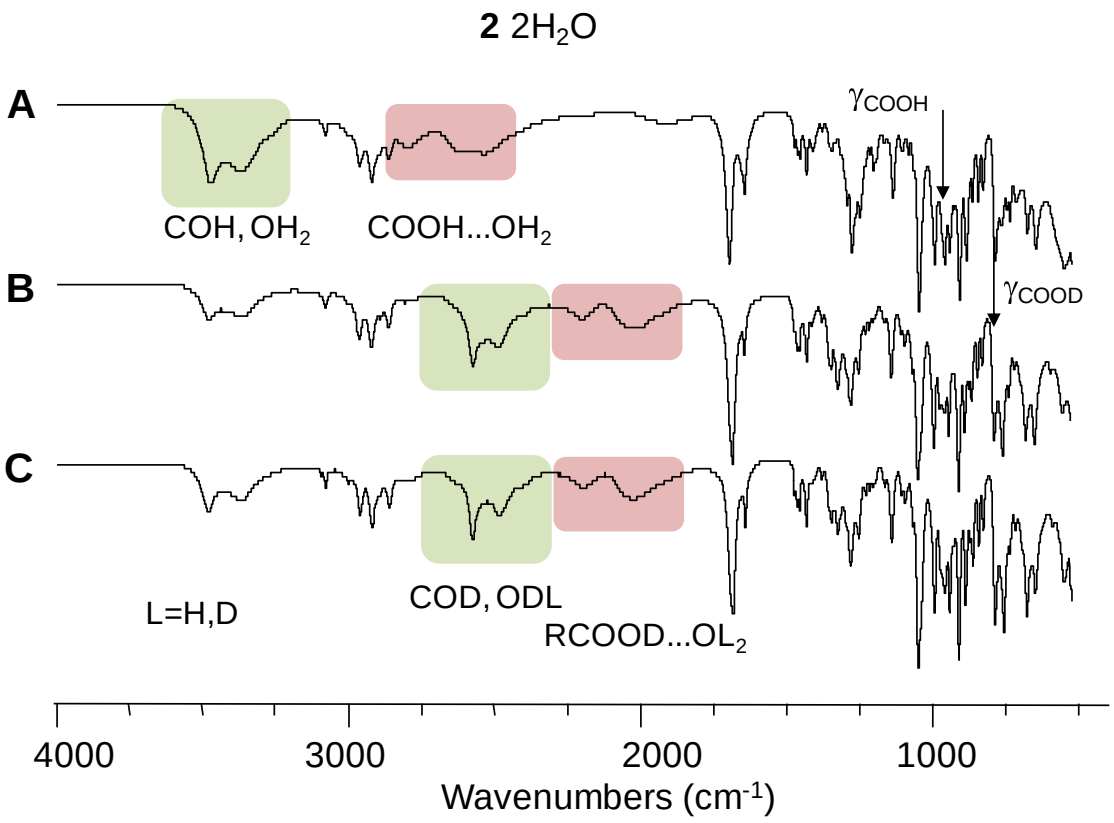


Figure S1: Full ATR-IR spectra of compound **2** $2H_2O$. (A) Protonated sample. (B) Sample pre-deuterated three times using CH_3OD and then crystallized from a non polar solvent (CCl_4) saturated in D_2O. (C) Sample partially deuterated after treatment with D_2O vapor. The COH and OH_2 (COD, ODL, L= H, D) stretching bands are highlighted in green, the COOH (COOD) are highlighted in pink). Indicated with arrows are the sharp band around 960 cm^{-1} which disappears upon deuteration, and the new band that appears upon deuteration at 750 cm^{-1}. We tentatively assign these bands to the out of plane bending vibrations γ_{COOH} and γ_{COOD}.

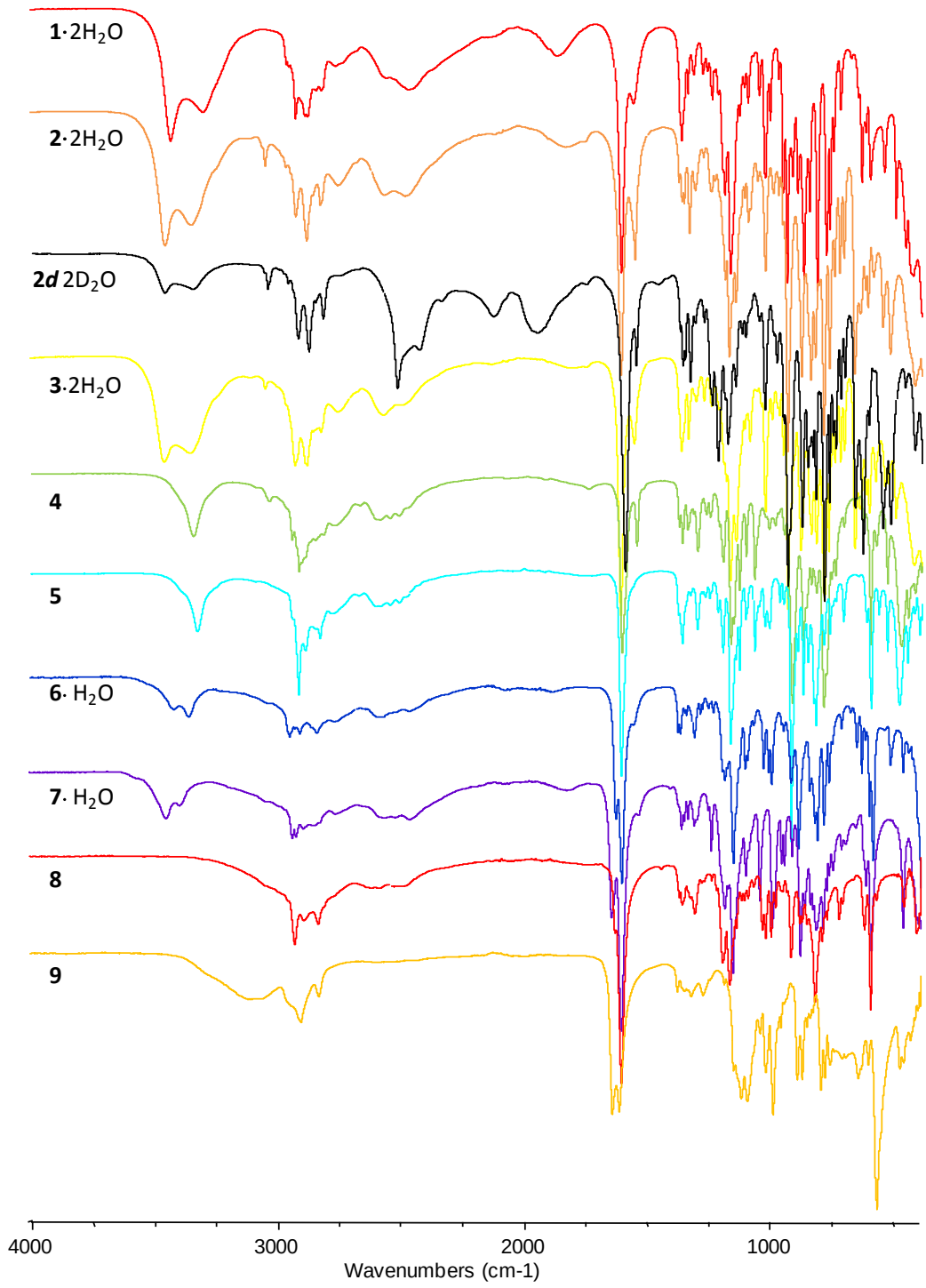


Figure S2: Full ATR-IR spectra of all compounds that appear in Chart 1 (see manuscript).

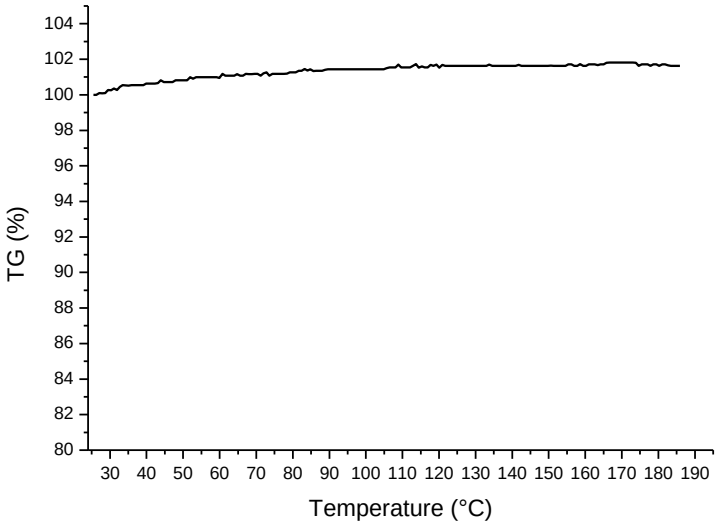
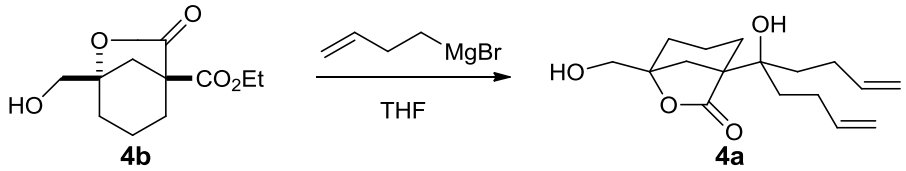


Figure S3: Thermogravimetric experiment of compound **5**, showing the absence of water loss and thus confirming that **5** forms an anhydrous structure. The experiment was performed with a NETZSCH TG 209 equipment using a temperature ramp of 5ºC/min and 1.107 mg of substance.

Synthesis and analytical data for compound **4a** and **4**:

The synthesis and analytical data of compound **4b** is reported in detail in reference 1.[1]

- Preparation of compound **4a** [(1R,5S)1-(1-Butenyl-1-hydroxypent-4-enyl)-5-hydroxymethyl-6-oxabicyclo[3.2.1]octan-7-one]



4b (1.44 g, 6.35 mmol, 1.0 equiv) solved in dry THF (10 mL) was treated with 3-butenylmagnesium bromide (31.8 mL, 15.9 mmol, 2.5 equiv, 0.5 M THF solution) under Ar and at -25ºC. The reaction is kept at this temperature during 1h. After this time, the temperature is allowed to reach 0ºC. After approximately 2h the starting material is no longer as monitored by TLC. The reaction is poured on ice, the product is extracted with AcOEt and the organic phases are washed with brine and dried over $MgSO_4$. After filtration, the solvent is eliminated under reduced pressure and the residue is purified by silica gel column chromatography to afford compound **4a** (1.47 g, 5.0 mmol, 78.7 % yield)

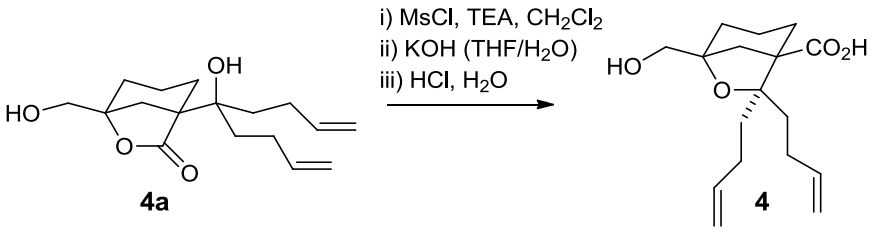
Spectroscopic and physical data:

Amorphous solid; **IR** (film), $CHCl_3$, $\upsilon_{max}(cm^{-1})$: 3443(s, br), 2945(s), 2875(m), 1741(s), 1690(s), 1641(w), 1139(m), 1057(m), 913(s); **^{1}H RMN** ($CDCl_3$, 500 MHz), δ (ppm): 5.80-5.69 (2H, m), 4.98 (2H, ddd, *J* = 17.2, 2.4, 1.6 Hz), 4.92 (1H, brd, *J* = 10.2 Hz), 4.89 (1H, brd, *J* = 10.2 Hz), 4.00 (1H, s), 3.74 (1H, dd, *J* = 12.6, 4.7 Hz), 3.55 (1H, dd, *J* = 12.6, 7.2 Hz), 2.60 (1H, dd, *J* = 7.2, 4.7 Hz), 2.46 (1H, brd, *J* = 11.4 Hz), 2.25-2.21 (1H, m), 2.20-2.16 (1H, m), 2.08-1.88 (4H, m), 1.83 (1H, brdddd, *J* = 13.7, 3.8, 3.0, 3.0 Hz), 1.75-1.61 (2H, m), 1.59-1.51 (3H, m), 1.55 (1H, d, *J* = 11.4 Hz), 1.48-1.37 (2H, m);**^{13}C RMN** ($CDCl_3$, 125 MHZ), δ (ppm): 180.7, 138.6, 138.2, 114.7, 114.6, 85.7, 74.5, 65.5, 56.0, 39.7, 35.3, 34.3, 29.3, 28.4, 28.0, 27.9, 19.4; **MS** (EI) m/z; (rel.int.): 277 ($[M\text{-}OH]^+$,0.8), 263(1.2), 239 (63.2), 221 (19.7), 181 (20.4), 139 (32.8), 121 (46.4),

[1] Pérez-Hernández, N.; Febles, M.; Pérez, C.; Pérez, R.; Rodríguez, M. L.; Foces-Foces, C.; Martín, J. D. *J. Org. Chem.* **2006**, *71*, 1139-1151.

83 (80.6), 67 (12.6), 55 (100).**HRMS** calcd. for $C_{17}H_{25}O_3$ $[M\text{-}OH]^+$: 277.1804; found: 277.1790. Anal. Calcd. for $C_{17}H_{26}O_4$: C, 69.36; H, 8.90. Found C, 69.28, H, 8.92.

- Preparation of compound **4** [(1R,5R)-7,7-di(but-3-en-1-yl)-5-(hydroxymethyl)-6-oxabicyclo[3.2.1]octane-1-carboxylic acid]



Lactone **4a** (540 mg, 1.84 mmol, 1.0 equiv) solved in CH_2Cl_2 (10 mL), was treated under Ar with triethylamine (3.0 mL, 18.4 mmol, 10.0 equiv) at -40ºC. While keeping the temperature between -40ºC and -50ºC, mesyl chloride (0.3 ml, 3.7 mmol, 2.0 equiv) is added. The reaction evolves during 2h. MeOH is added to eliminate the MsCl excess and the system is allowed to reach room temperature. The reaction is poured on ice and the product is extracted with CH_2Cl_2, the organic phases are combined, washed with brine and dried over $MgSO_4$. Once the solvent is eliminated, the obtained residue is further solved in THF (5 mL) and KOH (207 mg, 3.7 mmol, 2.0 equiv) in H_2O (5 ml) is added. After 12 h at room temperature, ice is added to the reaction medium and HCl (5%) is added until acid pH is reached. The product is extracted with AcOEt. The combined organic phases are washed with brine and dried over $MgSO_4$. The solvent is eliminated under reduced pressure. Compound **4** is purified by crystallization in a mixture of CCl_4 and H_2O (512 mg, 1.74 mmol, 94.6% yield).

Spectroscopic and physical data:

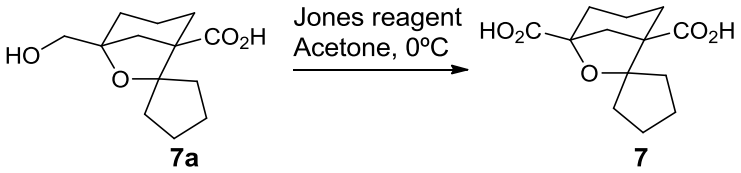
Crystalline solid; **M.P.**: 102.0-102.5ºC; **IR** (ATR), $\upsilon_{max}(cm^{-1})$: 3357(br), 3072(w), 2955(br), 1695(s), 1642(w), 1464(w), 1401(w), 1270(m), 1177(w), 1033(s), 988(w), 909(s), 728(m), 660(w); **^{1}H RMN** ($CDCl_3$, 500 MHz), δ (ppm): 5.87-5.74 (2H, m), 5.03 (1H, brd, *J* = 17.2 Hz), 4.99 (1H, brd, *J* = 17.2 Hz), 4.95 (1H, brd, *J* = 10.2 Hz), 4.93 (1H, brd, *J* = 10.2 Hz), 3.54 (1H, d, *J* = 11.7 Hz), 3.43 (1H, d, *J* = 11.7 Hz), 2.84 (1H, ddd, *J* = 12.0, 2.6, 2.6 Hz), 2.31-2.22 (2H, m), 2.17-1.85 (6H, m), 1.79-1.57 (5H, m), 1.45 (1H, d, *J* = 12.0 Hz), 1.28 (1H, brddd, *J* = 12.0, 12.0, 7.0 Hz);**^{13}C RMN** ($CDCl_3$, 125 MHz), δ (ppm): 178.7, 138.7, 138.5, 114.7, 114.3, 86.9, 82.5, 66.7, 55.8, 40.6, 36.2,

32.0, 31.2, 31.1, 28.9, 28.5, 19.1; **MS** (EI) m/z; (rel.int.): 294 ($[M]^+$,0.6), 239 (100), 221 (30.0), 193 (10.5), 175 (7.5), 157 (3.0), 139 (11.6), 121 (44.7), 93 (9.7), 83 (58.6), 55 (45.7).**HRMS** calcd. for $C_{17}H_{26}O_4$: 294.1831; found: 294.1847. Anal. Calcd. for $C_{17}H_{26}O_4$: C, 69.36; H, 8.90. Found C, 69.40, H, 8.89.

Synthesis and analytical data of compound **7**

The synthesis and analytical data of compound **7a** is detailed in reference 2.[2]

- Preparation of compound **7** [(1R,5R)-7-oxaspiro[bicyclo[3.2.1]octane-6,1'-cyclopentane]-1,5-dicarboxylic acid]



Hydroxyl-acid **7a** (250 mg, 1.04 mmol) is solved in acetone. Under stirring and at 0ºC, the Jones reagent (preparation: 1.0g CrO_3, 1.0 mL H_2SO_4 and 5.0 mL H_2O) is added dropwise. In contact with the solution, the reagent changes its color from orange to green. The Jones reagent is added until the orange color remains in the solution at room temperature. Methanol is added to eliminate the excess of Jones reagent. Afterwards, the reaction is filtered (and washed with diethylether) and the filtrate is concentrated under vacuum. Water and ether are added to the residue and the product is extracted with diethylether. The organic phases are combined, washed with brine and dried over $MgSO_4$. After filtering, the solvent is eliminated under reduced pressure. The residue is purified by silica gel column chromatography and 253 mg of **7** (0.99 mmol, 96% yield) are obtained.

Spectroscopic and physical data:

Crystalline solid; **M.P.**: 168.0-169.5 ºC; **IR** (film), $CHCl_3$, $\upsilon_{max}(cm^{-1})$: 3080(br), 2960(s, br), 2877(m, br), 1710(s, br), 1453(w), 1244(w), 1150(w), 1098(w), 993(w), 937(w), 755(w), 685(w); **^{1}H RMN** (MeOD, 300 MHz), δ (ppm): 2.65 (1H, d, *J* = 11.7 Hz), 2.20 (2H, dd, *J* = 13.7, 7.1 Hz), 2.00 (1H, dd, *J* = 13.2, 6.0 Hz), 1.92 (1H, d, *J* = 11.7 Hz),

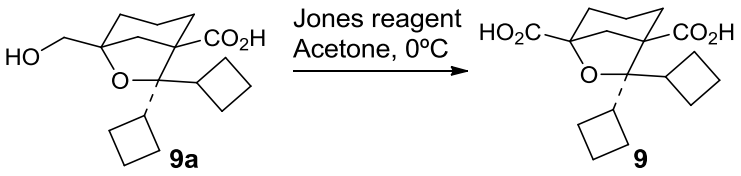
[2] Foces-Foces, C.; Rodríguez, M. L.; Febles, M.; Pérez, C.; Martín, J. D. *Acta Cryst.* **2005**, *C61*, o339-o342.

1.90 (1H, brd, *J* = 12.2 Hz), 1.86-1.73 (7H, m), 1.69 (1H, dd, *J* = 13.2, 5.9 Hz), 1.60 (1H, dd, *J* = 12.2, 6.9 Hz), 1.55 (1H, m);**^{13}C RMN** (MeOD, 75 MHz), δ (ppm): 175.4, 174.9, 99.2, 81.0, 55.2, 42.9, 38.5, 32.4, 31.6, 30.6, 24.2, 23.9, 19.1.; **MS** (EI) m/z; (rel.int.): 254 ([M]$^+$, 16.2), 236 (1.2), 225 (100), 179 (6.6), 170 (6.0), 161 (18.3), 152 (13.3), 135 (16.9), 107 (16.0), 85 (14.5), 67 (15.3).**HRMS** calcd. for $C_{13}H_{18}O_5$: 254.1154; found: 254.1145. Anal. Calcd. for $C_{13}H_{18}O_5$: C, 61.40; H, 7.14. Found C, 61.34, H, 7.48.

Synthesis and analytical data of compound **9**

The synthesis and analytical data of compound **7a** is detailed in reference 2.[2]

- Preparation of compound **9a** [(1R,5R)-7,7-dicyclobutyl-6-oxabicyclo[3.2.1]octane-1,5-dicarboxylic acid]



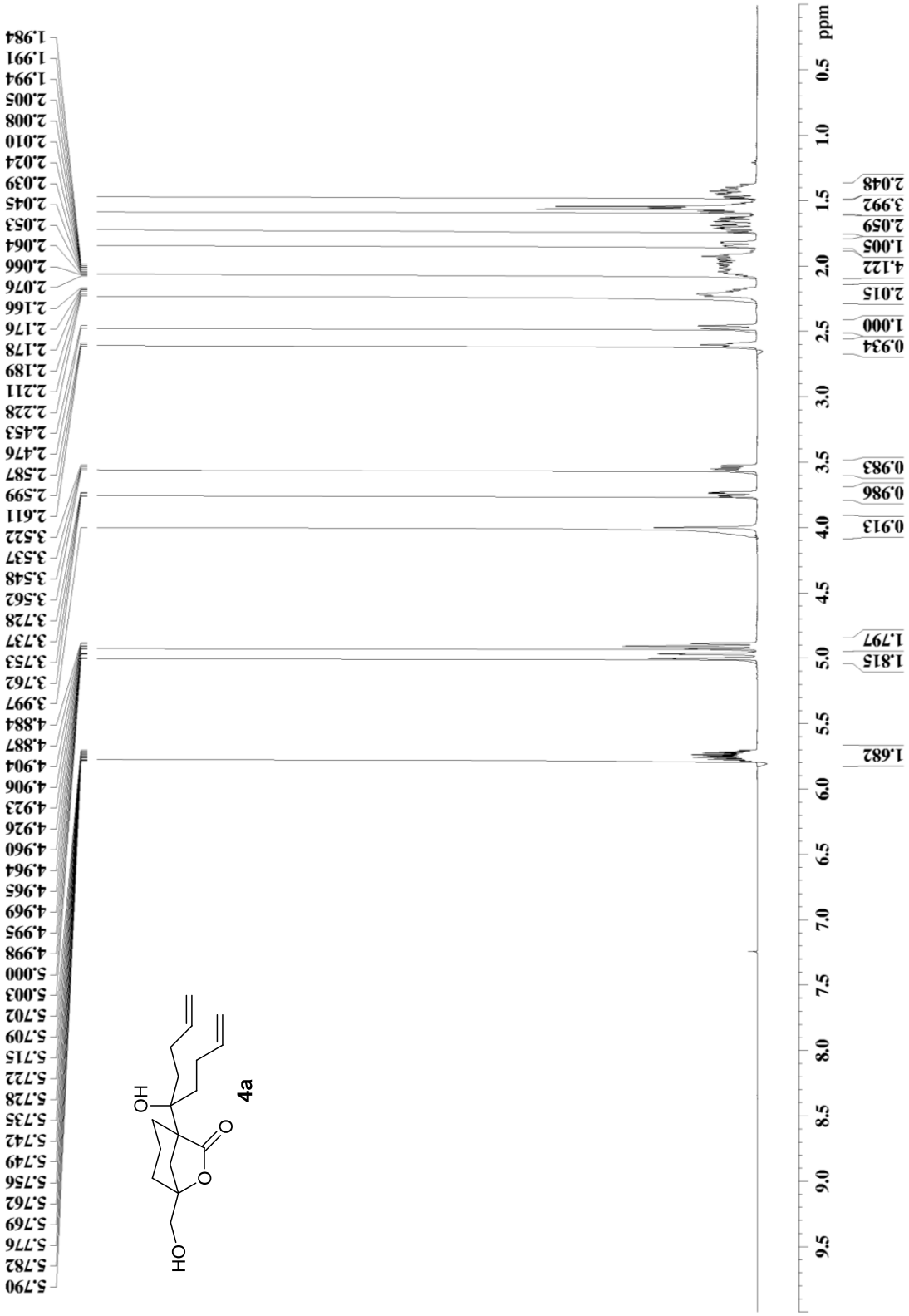
Hydroxyl-acid **9a** (200 mg, 0.68 mmol) is solved in acetone. Under stirring and at 0ºC, the Jones reagent (preparation: 1.0g CrO_3, 1.0 mL H_2SO_4 and 5.0 mL H_2O) is added dropwise. In contact with the solution, the reagent changes its color from orange to green. The Jones reagent is added until the orange color remains in the solution at room temperature. Methanol is added to eliminate the excess of Jones reagent. Afterwards, the reaction is filtered (and washed with diethylether) and the filtrate is concentrated under vacuum. Water and ether are added to the residue and the product is extracted with diethylether. The organic phases are combined, washed with brine and dried over $MgSO_4$. After filtering, the solvent is eliminated under reduced pressure. The residue is purified by silica gel column chromatography and 205 mg of **7** (0.66 mmol, 98% yield) are obtained.

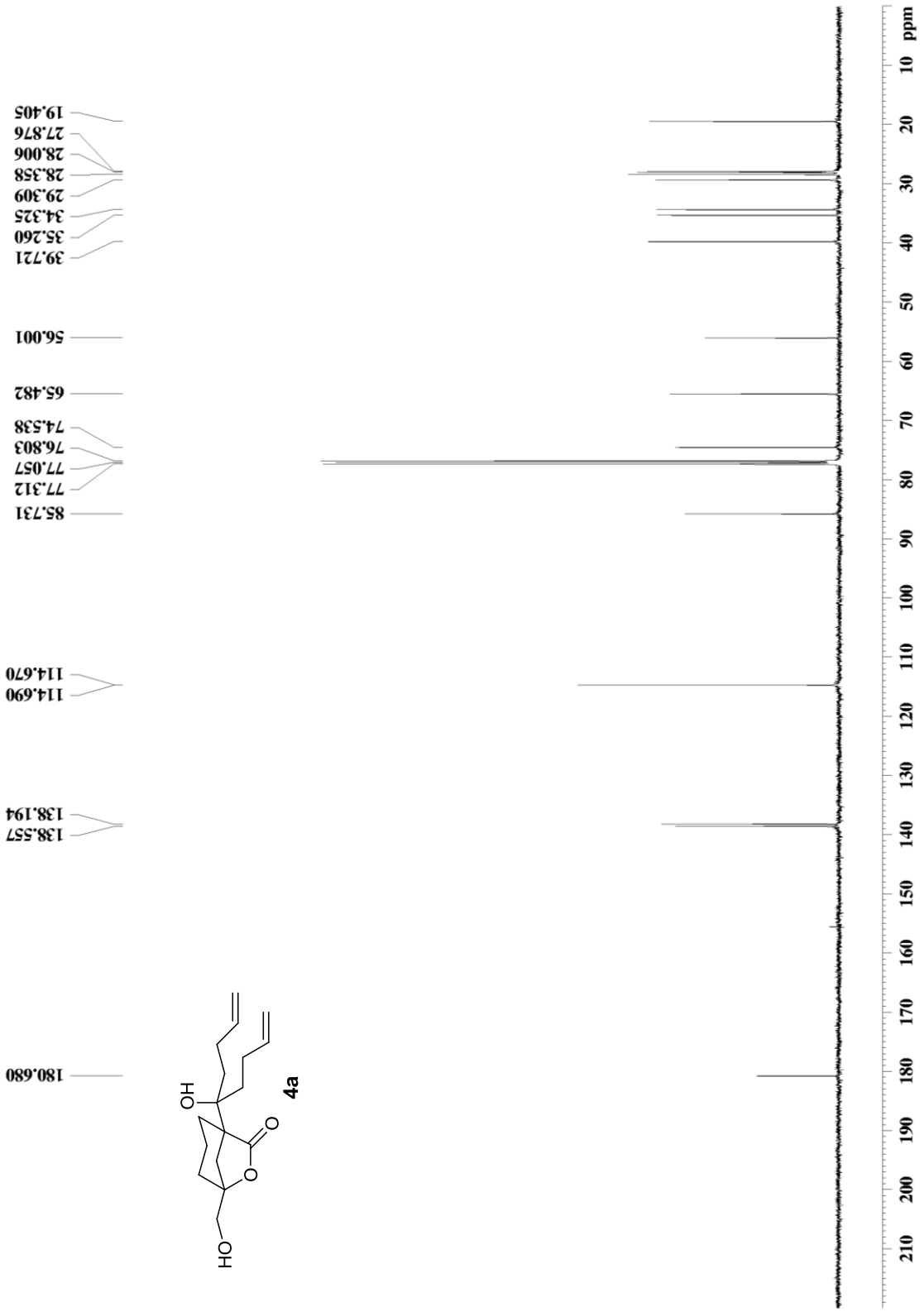
Spectroscopic and physical data:

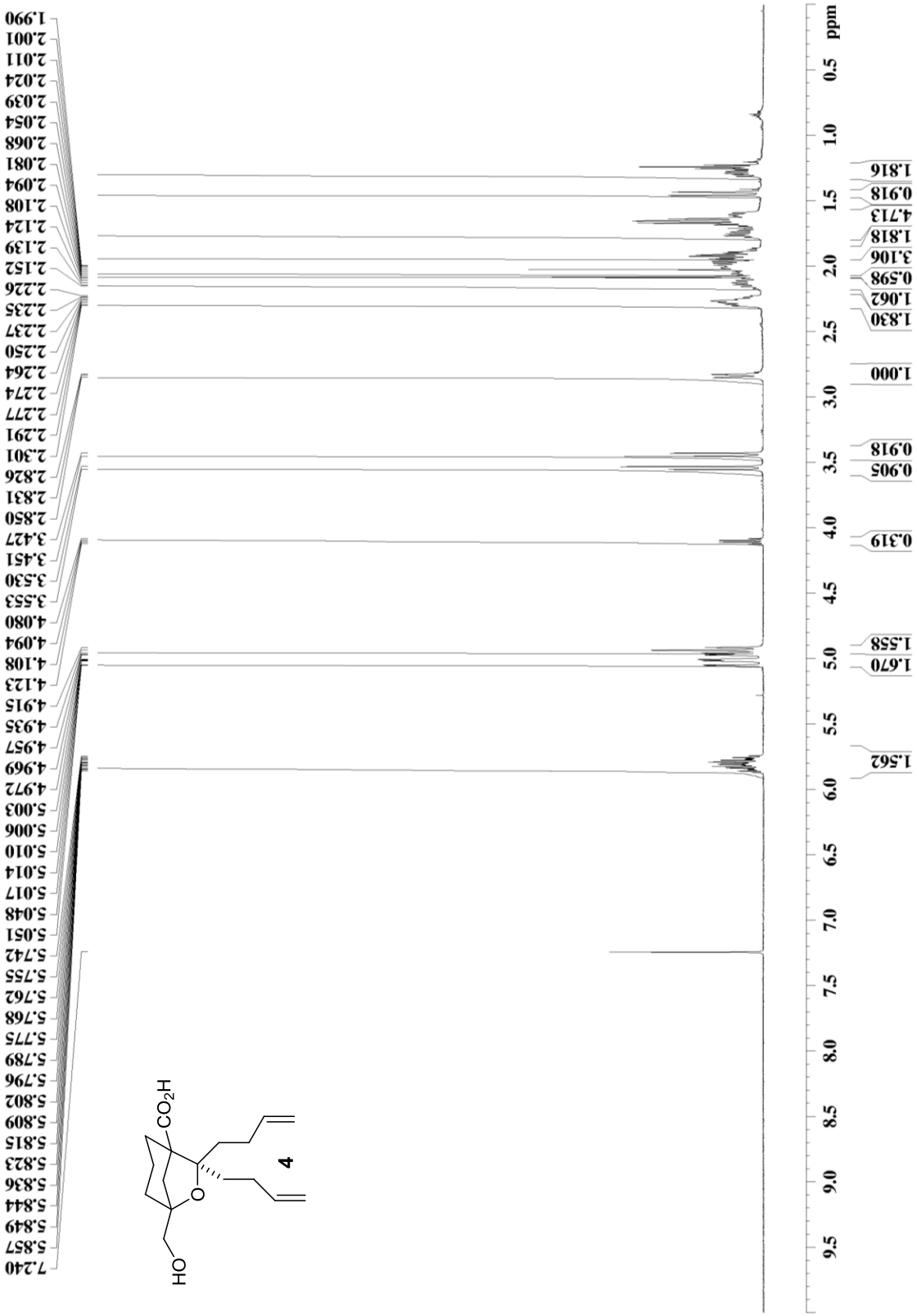
Crystalline solid; **M.P.**: 208.8-209.0 ºC; **IR** (film), $CHCl_3$, υ_{max}(cm^{-1}): 3080(br), 2950(br), 2871(m), 1708(s, br), 1412(w), 1304(w), 1251(m, br), 1130(w), 1006(m), 918(w), 756(s); **^{1}H RMN** (MeOD, 300 MHz), δ (ppm): 3.19 (1H, qui, *J* = 8.7 Hz), 2.77

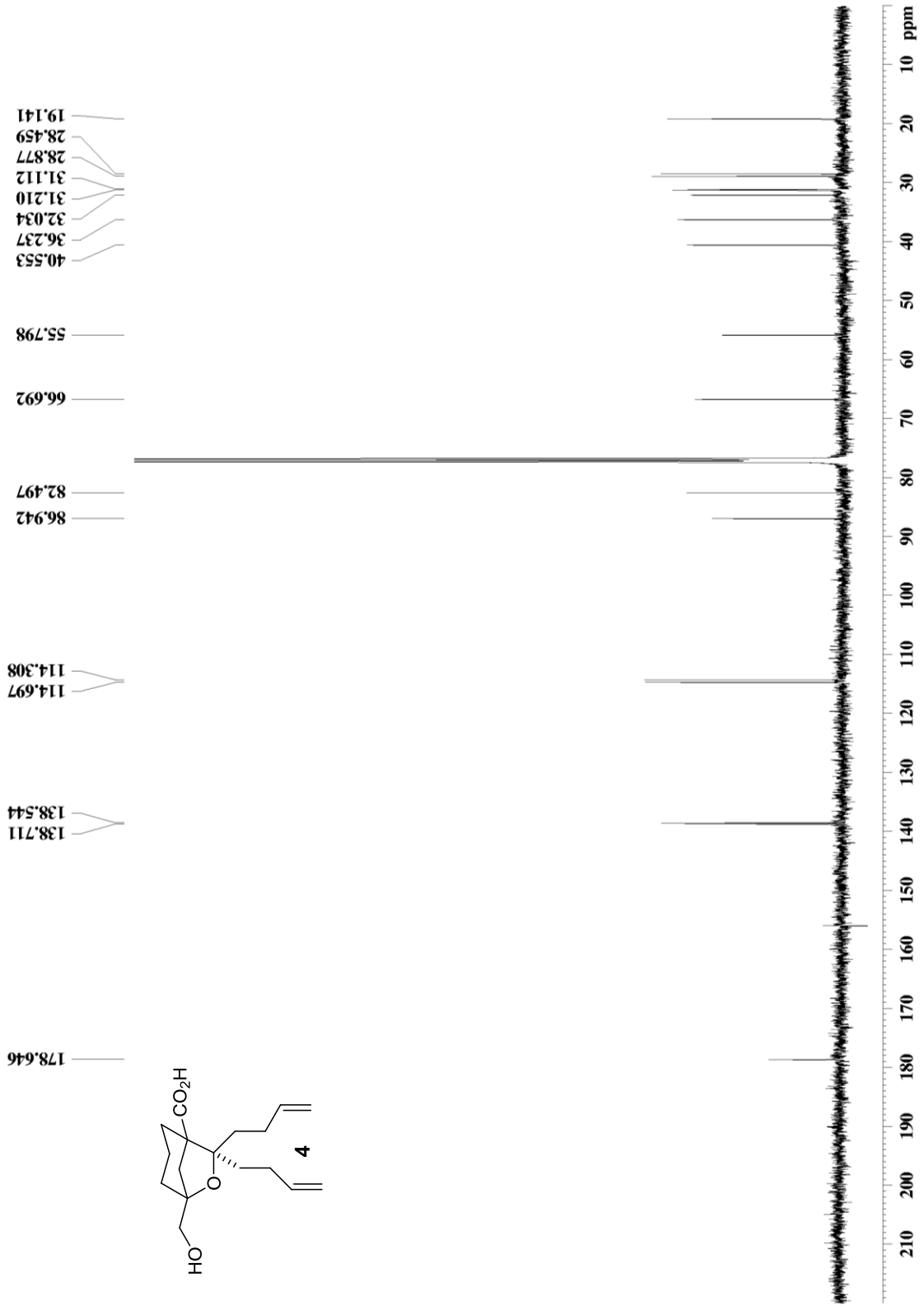
(1H, d, *J* = 12.2 Hz), 2.56 (1H, m), 2.44 (1H, qui, *J* = 9.2 Hz), 2.30 (1H, brt, *J* = 7.2 Hz), 2.28 (1H, d, *J* = 9.6 Hz), 2.18 (1H, d, *J* = 9.6 Hz), 2.10 (1H, dd, *J* = 17.7, 7.9 Hz), 2.07-1.91 (3H, m), 1.86-1.72 (6H, m), 1.70-1.54 (5H, m);**^{13}C RMN** (MeOD, 75 MHz), δ (ppm): 175.4, 175.3, 87.8, 82.3, 56.6, 44.6, 42.4, 39.6, 33.7, 32.4, 27.8, 26.7, 26.4, 26.0, 19.8, 18.2, 17.6.; **MS** (EI) m/z; (rel.int.): 253 ([M- C_4H_7]$^+$, 100), 207 (4.0), 189 (9.2), 161(9.3), 153 (23.7), 145 (4.6), 135 (14.6), 83 (27.1), 55 (47.0).**HRMS** calcd. for $C_{13}H_{17}O_5$ [M- C_4H_7]$^+$: 253.1076; found: 253.1088. Anal. Calcd. for $C_{17}H_{24}O_5$: C, 66.21; H, 7.84. Found C, 66.20, H, 8.28.

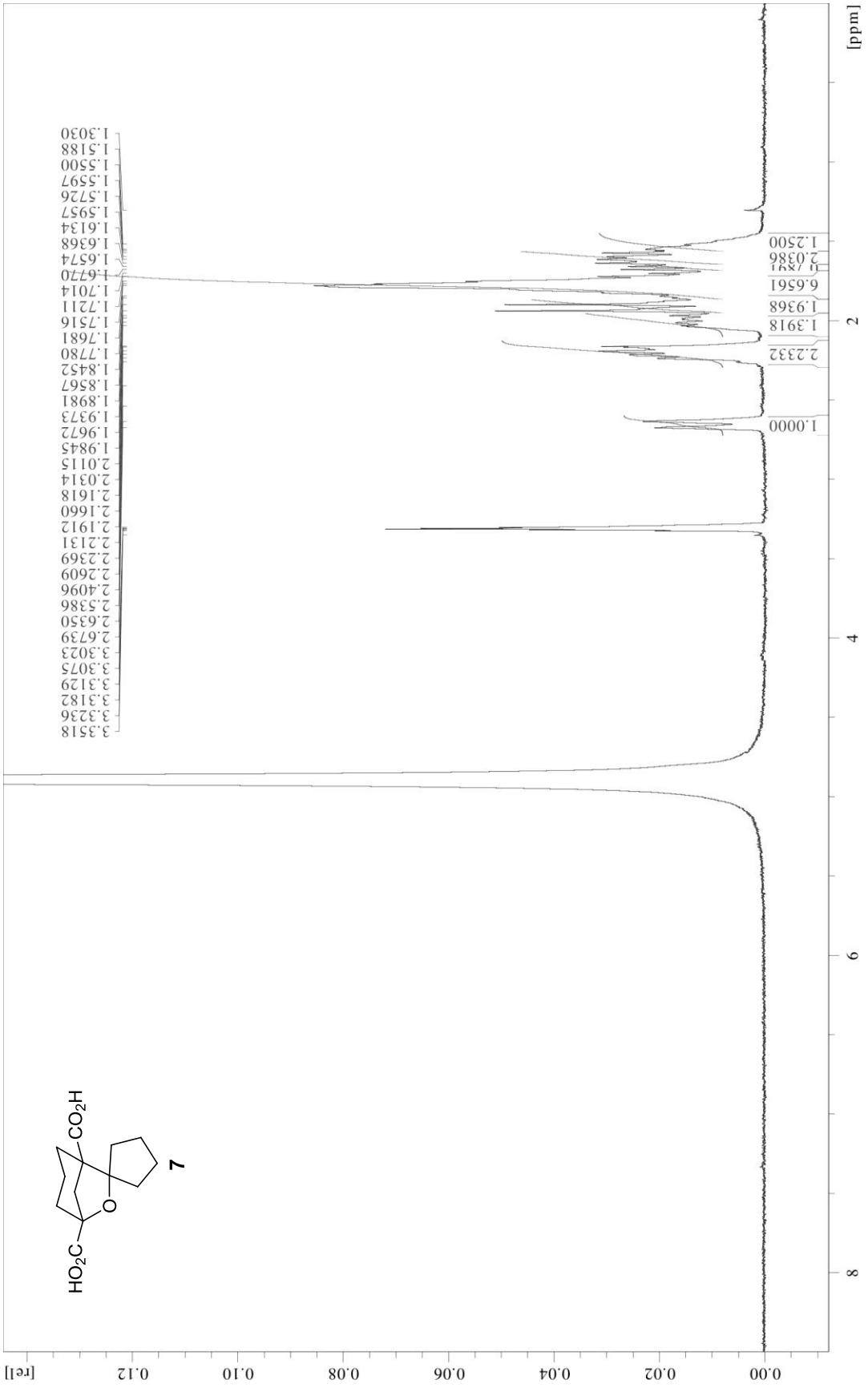
^{1}H and ^{13}C spectra of compounds **4a**, **4**, **7** and **9**

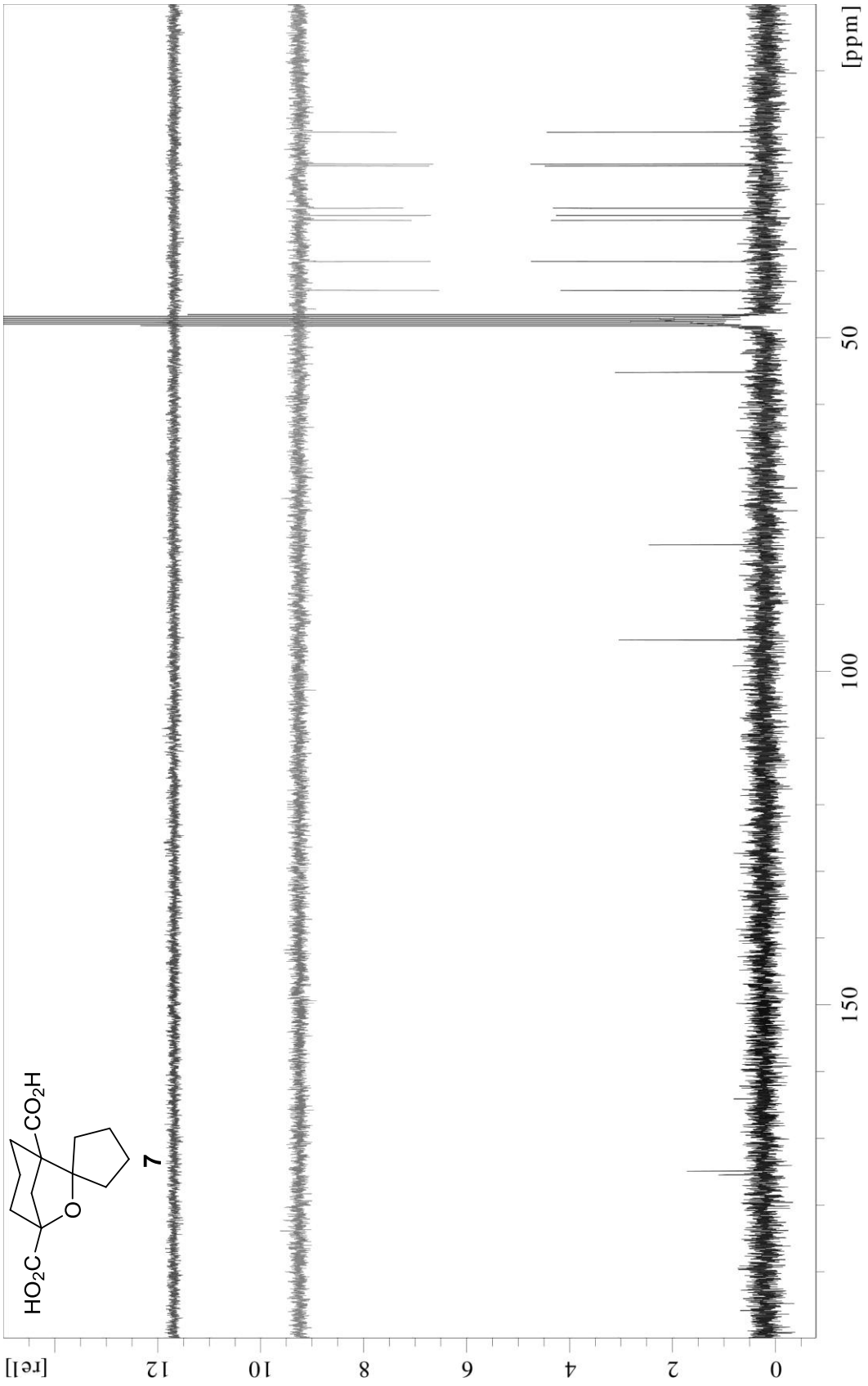


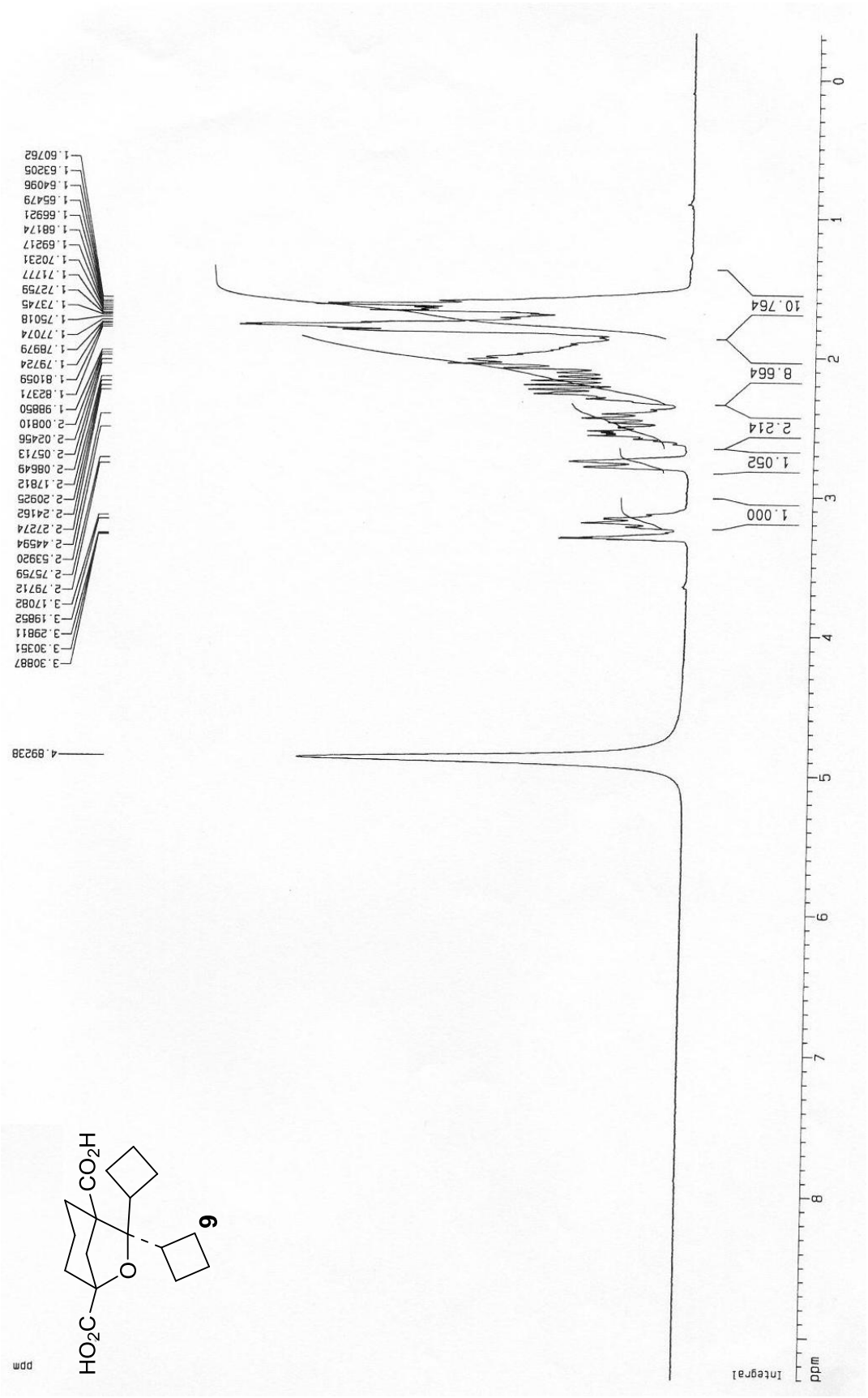

19.405
27.876
28.006
28.358
29.309
34.325
35.260
39.721
56.001
65.482
74.538
76.803
77.057
77.312
85.731
114.670
114.690
138.557
138.194
180.680
OH
O
O
HO
4a
ppm

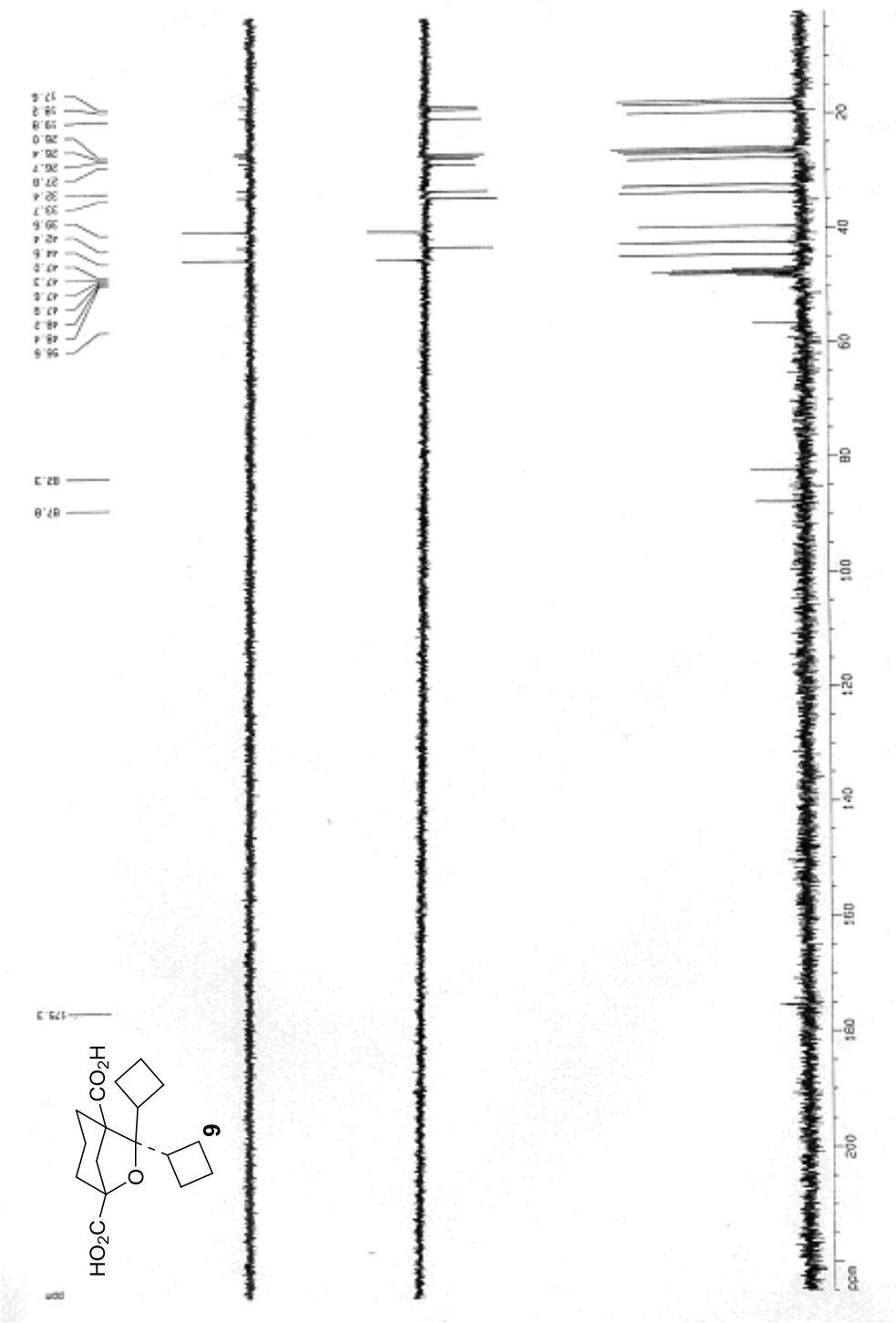

1.990
2.001
2.011
2.024
2.039
2.054
2.068
2.081
2.094
2.108
2.124
2.139
2.152
2.226
2.235
2.237
2.250
2.264
2.274
2.277
2.291
2.301
2.826
2.831
2.850
3.427
3.451
3.530
3.553
4.080
4.094
4.108
4.123
4.915
4.935
4.957
4.969
4.972
5.003
5.006
5.010
5.014
5.017
5.048
5.051
5.742
5.755
5.762
5.768
5.775
5.789
5.796
5.802
5.809
5.815
5.823
5.836
5.844
5.849
5.857
7.240
ppm
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
9.0
9.5
1.816
0.918
4.713
1.818
3.106
0.598
1.062
1.830
1.000
0.918
0.905
0.319
1.558
1.670
1.562
CO2H
HO
O
4


178.646
138.711
138.544
114.697
114.308
86.942
82.497
66.692
55.798
40.553
36.237
32.034
31.210
31.112
28.877
28.459
19.141
ppm
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
CO2H
HO
O
4


[rel]
0.00
0.02
0.04
0.06
0.08
0.10
0.12
[ppm]
8
6
4
2
1.0000
2.2332
1.3918
1.9368
6.6561
2.0386
1.2500
HO2C
CO2H
O
7


[rel]
12
10
8
6
4
2
0
[ppm]
50
100
150
CO_2H
HO_2C
O
7


ppm
Integral
10.764
8.664
2.214
1.052
1.000
4.89238
HO2C
CO2H
O
6


CO2H
HO2C
O
6
ppm