SUPPLEMENTARY MATERIAL

Experimental Procedure

All reactions were carried out under a nitrogen atmosphere. Common solvents were purified before use. Tetrahydrofuran (THF) and diethyl ether (Et_2O) were purified by distillation from potassium-benzophenone ketyl. Dichloromethane (CH_2Cl_2), benzene, and toluene were distilled from calcium hydride. All reagents were reagent grade and purified when necessary. NaHMDS was used from newly opened 100 mL bottles, purchased from Aldrich, Inc. Reactions were monitored by thin layer chromatography (TLC) using 250 mm Whatman precoated silica gel plates. Flash column chromatography was performed over Fisher or EM Science Laboratories silica gel (230-400 mesh). Melting points were measured on a Thomas Hoover capillary melting point apparatus and are uncorrected. Carbon and proton NMR spectra were recorded on Brüker DRX-500 or DRX-400 spectrometer. ^1H NMR chemical shifts are reported as δ values (ppm) relative to internal tetramethylsilane and splitting patterns are designated as: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. Coupling constants are given in hertz (Hz). Infrared spectra (IR) were recorded with Nicolet 20 SXB FTIR spectrometer and are reported in reciprocal centimeter (cm^{-1}). Mass spectra were obtained on either a Kratos MS-30 or a Kratos VG 70-250S mass spectrometer at The Ohio State University Campus Chemical Instrumentation Center.

Materials

Dienes were made using our reported procedure[1] and redistilled prior to use. Aldehydes **2a-i** and methyl pyruvate were purchased from Aldrich and distilled prior to use. Imines **11a** and **11b** were made by known procedures.[2]

General procedure for the hetero-Diels-Alder reaction of diene with aldehydes

To a 25 mL flame-dried flask under a nitrogen atmosphere were added freshly distilled diene **1** (227 mg, 1 mmol, 1.0 equiv.) and 2 mL $CHCl_3$. Aldehyde **2** (1.5 mmol, 1.5 equiv.) was added dropwise via a gas-tight syringe. The reaction mixture was stirred at room temperature for indicated time or until the diene was fully consumed, as monitored by either TLC or NMR. The reaction was then diluted with 15 mL CH_2Cl_2, the yellow solution cooled to -78 °C, and treated dropwise with 142 μL acetyl chloride (2 mmol, 2.0 equiv.). After stirring for ca. 30 min saturated sodium bicarbonate was added. The organic layer was separated, and the water phase was diluted with 15 mL water and extracted twice with CH_2Cl_2. The combined organic phase was dried with magnesium sulfate, filtered, and concentrated to give yellow oil, which was subjected to flash chromatography to afford the desired dihydropyrone **7**.

2-phenyl-2,3-dihydro-pyran-4-one (7a).

^{1}H NMR (500 MHz, $CDCl_3$, ppm) d 7.59 (d, J=6 Hz, 1H), 7.43 (m, 5H), 5.54 (dd, J_1=1 Hz J_2=6 Hz, 1H), 5.43 (dd, J_1=4 Hz J_2=14 Hz, 1H), 2.92 (dd, J_1=14 Hz J_2=17 Hz, 1H), 2.67 (ddd, J_1=1 Hz J_2=4 Hz, J_3=17 Hz 1H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d

192.2, 163.2, 137.8, 128.9, 128.8, 126.1, 107.4, 81.1, 43.4. IR (Neat, cm^{-1}) 1676, 1595, 1403, 1269, 1228.

2-*o*-nitrophenyl-2,3-dihydro-pyran-4-one (7b).

^1H NMR (500 MHz, $CDCl_3$, ppm) d 8.06 (dd, J_1=1 Hz J_2=8 Hz, 1H), 7.85 (dd, J_1=1 Hz J_2=8 Hz, 1H), 7.75 (dt, J_1=1 Hz J_2=8 Hz, 1H), 7.57 (dt, J_1=1 Hz J_2=8 Hz, 1H), 7.49 (d, J=6 Hz, 1H), 6.04 (dd, J_1=3 Hz J_2=14 Hz, 1H), 5.59 (dd, J_1=1 Hz J_2=6 Hz, 1H), 2.97 (ddd, J_1=1 Hz J_2=3 Hz J_3=17 Hz, 1H), 2.78 (dd, J_1=14 Hz J_2=17 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 190.8, 162.5, 134.0, 133.8, 129.5, 128.0, 124.9, 107.9, 77.1, 43.1. IR (Neat, cm^{-1}) 1684, 1523, 1344, 1269. HRMS *m/z* [M^+] calcd for $C_{11}H_9NO_4$ 219.0532, found 219.0533.

2-*p*-methoxyphenyl-2,3-dihydro-pyran-4-one (7c).

^1H NMR (500 MHz, $CDCl_3$, ppm) d 7.46 (d, J=6 Hz, 1H), 7.33 (d, J=9 Hz, 2H), 6.94 (d, J=11 Hz, 2H), 5.51 (d, J=6 Hz, 1H), 5.37 (dd, J_1=3 Hz J_2=14 Hz, 1H), 3.83 (s, 3H), 2.93 (dd, J_1=15 Hz J_2=17 Hz, 1H), 2.62 (dd, J_1=3 Hz J_2=17 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 192.4, 163.3, 160.1, 129.8, 127.7, 114.2, 107.2, 80.9, 55.3, 43.1. IR (Neat, cm^{-1}) 1676, 1594, 1518, 1253. mp. 48-50 °C.

2-furfuryl-2,3-dihydro-pyran-4-one (7d).

^1H NMR (500 MHz, $CDCl_3$, ppm) d 7.48 (dd, J_1=1 Hz J_2=2 Hz, 1H), 7.38 (d, J=6 Hz, 1H), 6.46 (d, J=4 Hz, 1H), 6.41 (dd, J_1=2 Hz J_2=3 Hz, 1H), 5.51 (dd, J_1=1 Hz J_2=6 Hz, 1H), 5.48 (dd, J_1=4 Hz J_2=13 Hz, 1H), 3.10 (dd, J_1=13 Hz J_2=17 Hz, 1H), 2.74 (ddd, J_1=1 Hz J_2=4 Hz J_3=17 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 191.3, 162.4,

150.0, 143.6, 110.6, 109.7, 107.4, 73.5, 39.5. IR (Neat, cm^{-1}) 1677, 1596, 1403, 1272, 1209.

2-*n*-pentyl-2,3-dihydro-pyran-4-one (7e).

^1H NMR (400 MHz, $CDCl_3$, ppm) d 7.36 (d, J=6 Hz, 1H), 5.40 (dd, J_1=1 Hz J_2=6 Hz, 1H), 4.39 (m, 1H), 2.51 (dd, J_1=13 Hz J_2=17 Hz, 1H), 2.45 (ddd, J_1=1 Hz J_2=4 Hz J_3=17 Hz, 1H), 1.80 (m, 1H), 1.66 (m, 1H), 1.40 (m, 6H), 0.90 (t, J=7 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, ppm) d 192.9, 163.4, 106.9, 79.6, 41.8, 34.3, 31.4, 24.4, 22.5, 14.0. IR (Neat, cm^{-1}) 2932, 1680, 1596, 1272.

2-benzyl-2,3-dihydro-pyran-4-one (7f).

^1H NMR (500 MHz, $CDCl_3$, ppm) d 7.33 (m, 3H), 7.28 (m, 1H), 7.22 (m, 2H), 5.40 (dd, J_1=1 Hz J_2=6 Hz, 1H), 4.64 (m, 1H), 3.12 (dd, J_1=7 Hz J_2=14 Hz, 1H), 3.00 (dd, J_1=6 Hz J_2=14 Hz, 1H), 2.54 (dd, J_1=14 Hz J_2=17 Hz, 1H), 2.46 (ddd, J_1=1 Hz J_2=3 Hz J_3=17 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 192.4, 163.1, 135.8, 129.5, 128.6, 127.0, 107.1, 79.8, 41.2, 40.7. IR (Neat, cm^{-1}) 1675, 1595, 1405, 1276. HRMS *m/z* [M^+] calcd for 188.0838, found 188.0838.

2-(1'-methyl)-butyl-2,3-dihydro-pyran-4-one (7g).

The product was identified as a mixture of diastereomers (cis and trans) with 1.3/1 ratio. ^1H NMR (500 MHz, $CDCl_3$, ppm) d 7.38 (d, J=6 Hz, 1H, trans and cis overlap); 5.40 (d, J=6 Hz, 1H, trans and cis overlap); 4.30-4.24 (m, 2H total, cis + trans); 2.63-2.52 (m, 2H total, cis + trans); 2.36 (m, 2H total, cis + trans); 1.87 (m, 1H total); 1.53-1.17 (m; 7H total; cis + trans); 0.98 (d, J=7 Hz, 2H); 0.96 (d, J=7 Hz); 0.92 (t, J=7 Hz,

3H, cis and trans overlap). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 193.3; 193.2; 163.61; 163.58; 106.74; 106.72; 83.2; 82.9; 39.0; 38.1; 36.3; 36.1; 34.2; 33.9; 20.0; 19.9; 14.5; 14.3; 14.1 (some peaks overlap). IR (Neat, cm^{-1}) 2960; 2933; 2874; 1686; 1678; 1405; 1277; 1224; 1039 (some peaks overlap).

2-3'-cyclohexenyl-2,3-dihydro-pyran-4-one (7h).

The product was identified as a mixture of diastereomers with 1.2/1 ratio. ^{1}H NMR (400 MHz, $CDCl_3$, ppm) d 7.39 (d, J=6 Hz, 1H, cis and trans overlap); 5.68 (m, 4H total, cis + trans); 5.42 (dd, J_1=1 Hz J_2=6 Hz, 1H, cis and trans overlap); 4.32-4.21 (m, 2H total, cis + trans); 2.61 (dd, J_1=14 Hz J_2=16 Hz, 1H); 2.57 (dd, J_1=14 Hz J_2=16 Hz, 1H); 2.47 (ddd, J_1=1 Hz J_2=3 Hz J_3=16 Hz, 1H); 2.44 (ddd, J_1=1 Hz J_2=3 Hz J_3=16 Hz, 1H); 2.25-1.72 (m, 12H total, cis + trans); 1.49-1.25 (m, 2H total, cis + trans). ^{13}C NMR (100 MHz, $CDCl_3$, ppm) d 192.5; 163.3; 163.1; 127.0; 126.6; 125.1; 124.8; 106.6; 82.5; 82.3; 38.95; 38.92; 37.2; 37.1; 26.5; 26.3; 24.4; 24.0; 23.6 (some peaks overlap). IR (Neat, cm^{-1}) 3024; 2917; 2840; 1679; 1675; 1406; 1274; 1229; 1037 (some peaks overlap).

2-*t*-butyl-2,3-dihydro-pyran-4-one (7i).

^{1}H NMR (500 MHz, $CDCl_3$, ppm) d 7.41 (dd, $J_1 \sim 0$ Hz J_2=4 Hz, 1H), 5.40 (dd, J_1=1 Hz J_2=5 Hz, 1H), 4.03 (dd, J_1=3 Hz J_2=15 Hz, 1H), 2.53 (dd, J_1=15 Hz J_2=16 Hz, 1H), 2.39 (ddd, J_1=1 Hz J_2=3 Hz, J_3=16 Hz, 1H), 1.00 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 193.6, 163.8, 106.6, 86.9, 37.2, 33.8, 25.4. IR (Neat, cm^{-1}) 2963, 1679, 1596, 1405, 1284, 1272. HRMS *m/z* [M^+] calcd for 154.0994, found 154.0992.

HDA reaction of diene with methyl pyruvate

To a 25 mL flame-dried flask maintained under a nitrogen atmosphere was added 227 mg (1 mmol, 1.0 equiv.) freshly distilled diene **1a** and 2 mL CH_2Cl_2. The reaction solution was cooled to –78 °C and methyl pyruvate (1.5 mmol, 1.5 equiv.) was added dropwise via a gas-tight syringe. The reaction mixture was then brought to –40 °C and stirred at that temperature until the diene was consumed, as monitored by TLC and NMR. After addition of 15 mL of CH_2Cl_2, the resulting yellow solution was cooled to –78 °C and treated via syringe with 142 μL acetyl chloride (2 mmol, 2.0 equiv.). After stirring for additional. 30 min, the reaction was quenched with saturated sodium bicarbonate. The organic layer was separated, and the water phase diluted with 15 mL water and extracted twice with CH_2Cl_2. The combined organic phase was dried with magnesium sulfate, filtered, and concentrated. The resulting yellow oil was purified by flash chromatography to give the desired dihydropyrone **10**.

2-methyl-4-oxo-3,4-dihydro-2*H*-pyran-2-carboxlic acid methyl ester (10).

^{1}H NMR (500 MHz, $CDCl_3$, ppm) d 7.36 (d, J=6 Hz, 1H), 5.44 (dd, J_1=1 Hz J_2=6 Hz, 1H), 3.78 (s, 3H), 3.02 (dd, J_1=1 Hz J_2=17 Hz, 1H), 2.70 (d, J=17 Hz, 1H), 1.67 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 189.9, 171.4, 161.7, 107.3, 82.8, 53.1, 44.6, 24.1. IR (Neat, cm^{-1}) 1745, 1680, 1599, 1276, 1236.

HDA Reactions with Imines

4-oxo-2-phenyl-3,4-dihydro-2*H*-pyridine-1-carboxylic acid methyl ester (12)

To a 25 ml flame-dried flask was added freshly distilled diene **1a** (227 mg, 1.0 mmol, 1.0 equiv.) and 1.0 mL CH_2Cl_2. The resulting solution was cooled to –78 °C and treated dropwise with 196 mg (1.2 mmol, 1.2 equiv.) of dienophile **11** in 1.0 mL CH_2Cl_2. The reaction was stirred at –78 °C for 3 hours and quenched with 15 mL of a 4:1 THF/1N HCl solution. The mixture was allowed to warm up to room temperature and stirred for 2 hours, then quenched with 10 mL of saturated sodium bicarbonate solution. The organic layer was separated and the aqueous layer extracted three times with CH_2Cl_2. The combined organic phase was dried over magnesium sulfate, filtered, and concentrated to give yellow oil, which was purified by flash chromatography over silica gel (50% ethyl acetate/hexane) to afford **12** as a colorless oil (178 mg, 77%). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) d 7.96 (br d, J=7 Hz, 1H); 7.27 (m, 3H); 7.22 (m, 2H); 5.73 (d, J=7 Hz, 1H); 5.40 (d, J=7 Hz, 1H); 3.85 (s, 3H); 3.15 (dd, J_1=7 Hz, J_2=17 Hz, 1H); 2.82 (d, J=17 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 191.8; 142.3; 138.3; 128.9; 128.0; 125.9; 108.0; 55.9; 54.3; 41.8 (1 CH overlaps with others). IR (Neat, cm^{-1}) 1792; 1672; 1605; 1401; 1340; 1320; 1302; 1208.

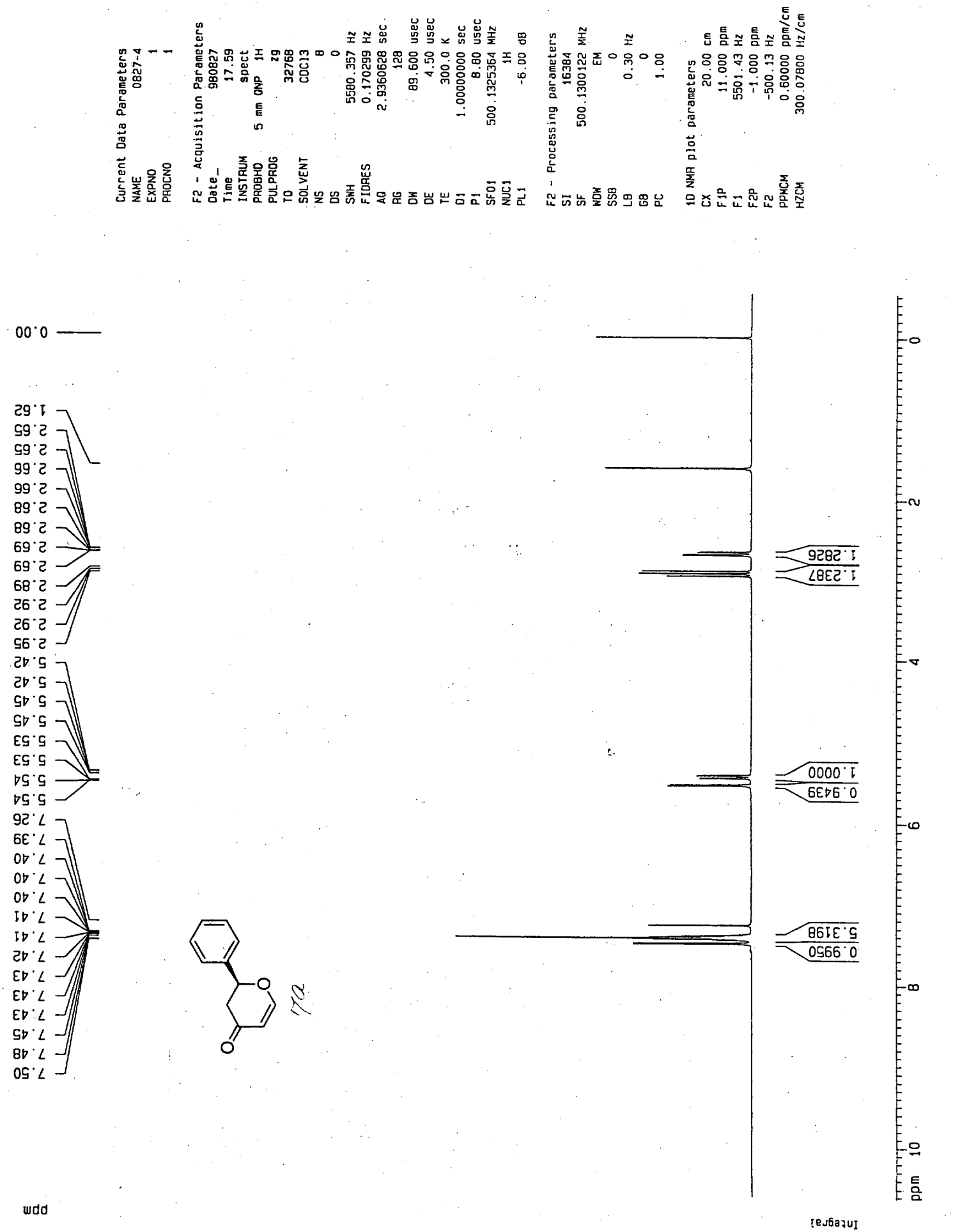
.4-oxo-1-phenyl-3,4-dihydro-2*H*-pyridine-2-carboxylic acid methyl ester (14)

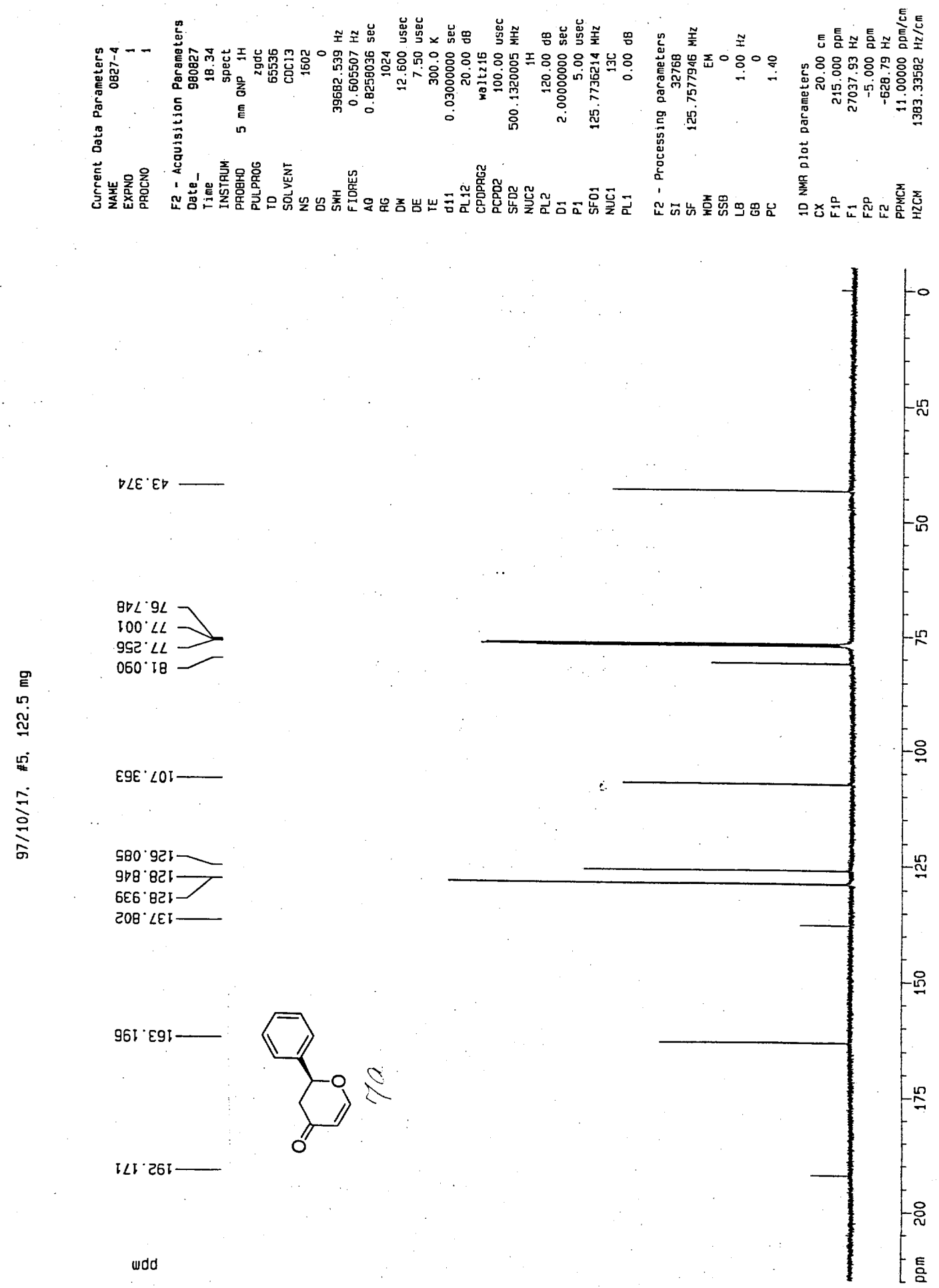
^{1}H NMR (400 MHz, $CDCl_3$, ppm) d 7.47 (d, J=8 Hz, 1H); 7.39 (t, J=9 Hz, 2H); 6.83 (d, J=9 Hz, 2H); 5.68 (d, J=6 Hz, 1H); 5.39 (d, J=8 Hz, 1H); 3.85 (s, 3H); 3.77 (s, 3H); 3.12 (dd, J_1=8 Hz, J_2=17 Hz, 1H); 2.78 (d, J=17 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) d 192.2; 159.3; 153.3; 142.2; 130.4; 127.3; 114.1; 107.8; 55.3; 55.2; 54.2; 41.8. IR (Neat, cm^{-1}) 1732; 1670; 1607; 1514; 1338; 1321; 1208.

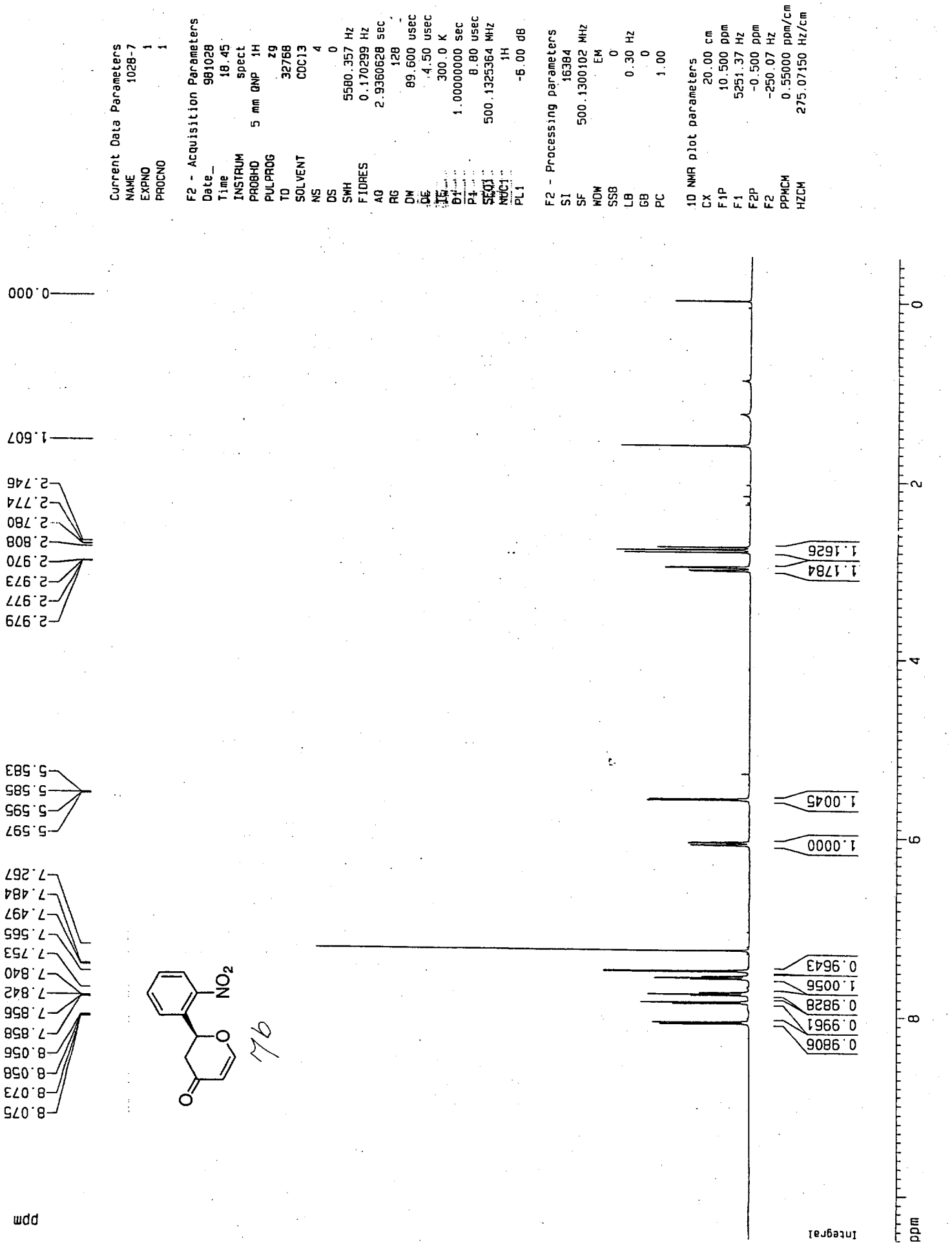
References

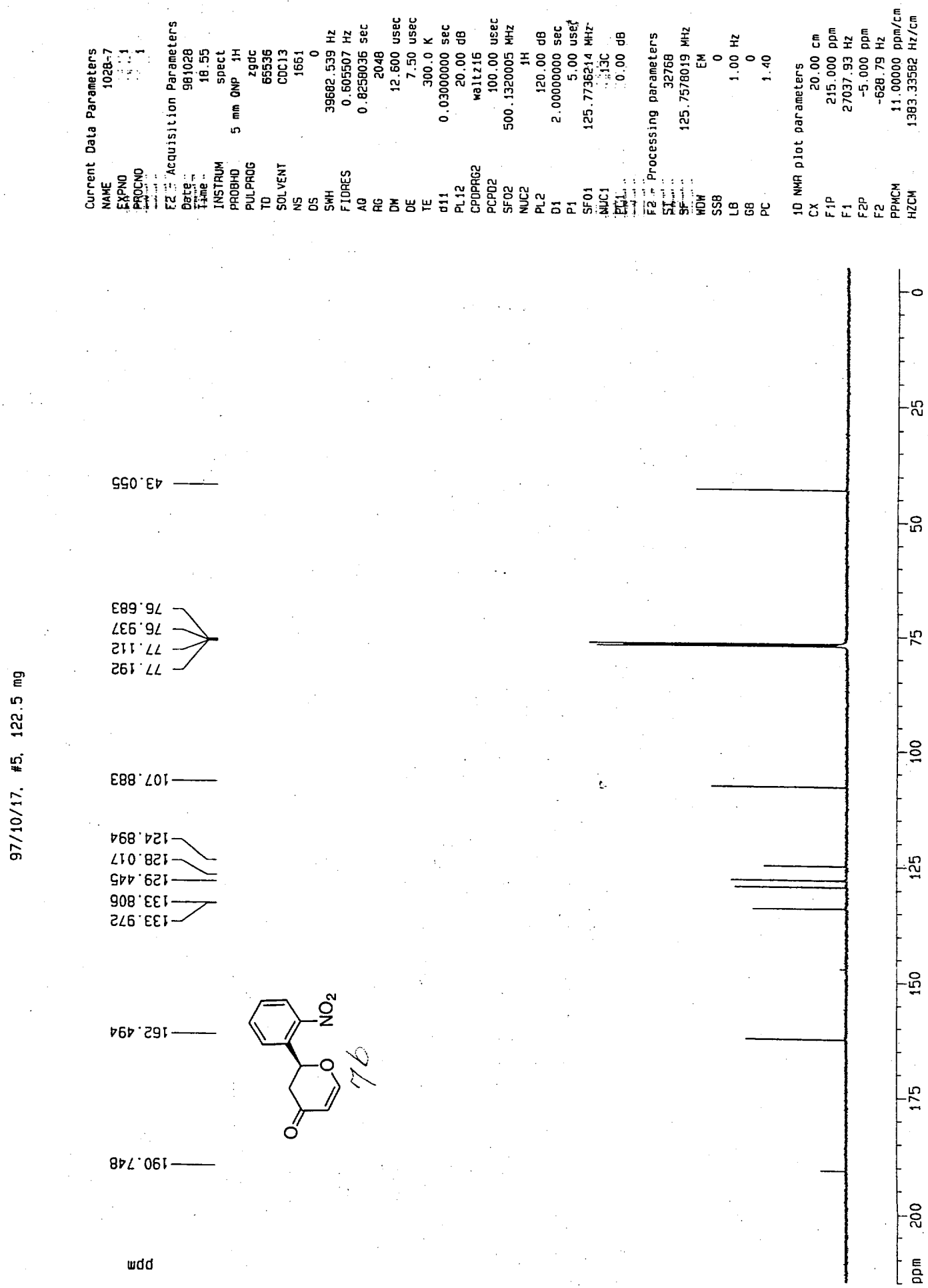
1. Kozmin, S. A.; Janey, J. M.; Rawal, V. H. *J. Org. Chem.* **1999**, *64*, 3039-3052.

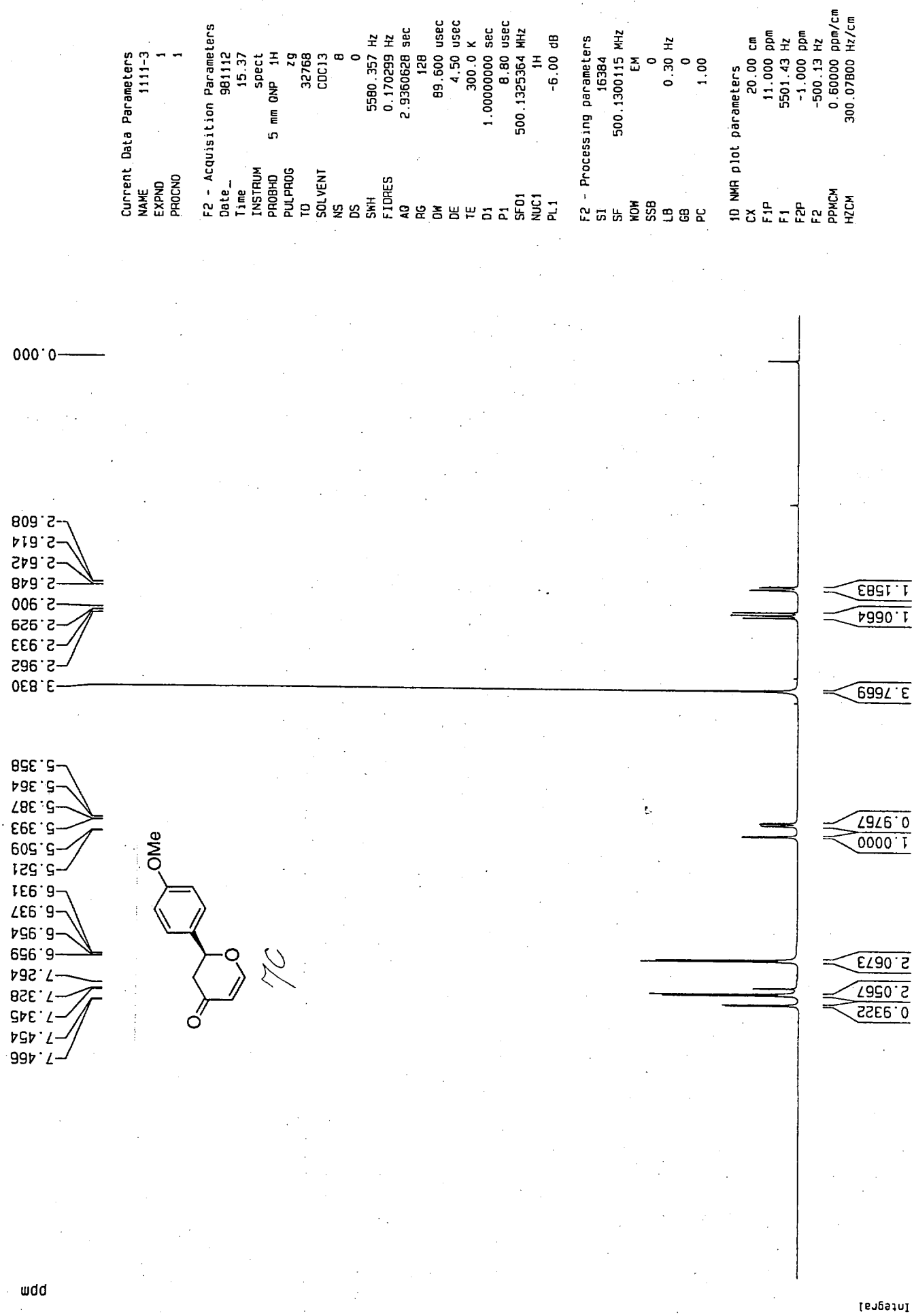
2. (a) Georg, G. I.; Harriman, G. C. B.; Peterson, S. A. *J. Org. Chem.* **1995**, *60*, 7366. (b) Vidal, J.; Damestoy, S.; Guy, L.; Hannachi, J-C.; Aubry, A.; Collet, A. *Chem. Eur. J.* **1997**, *3*, 1691.

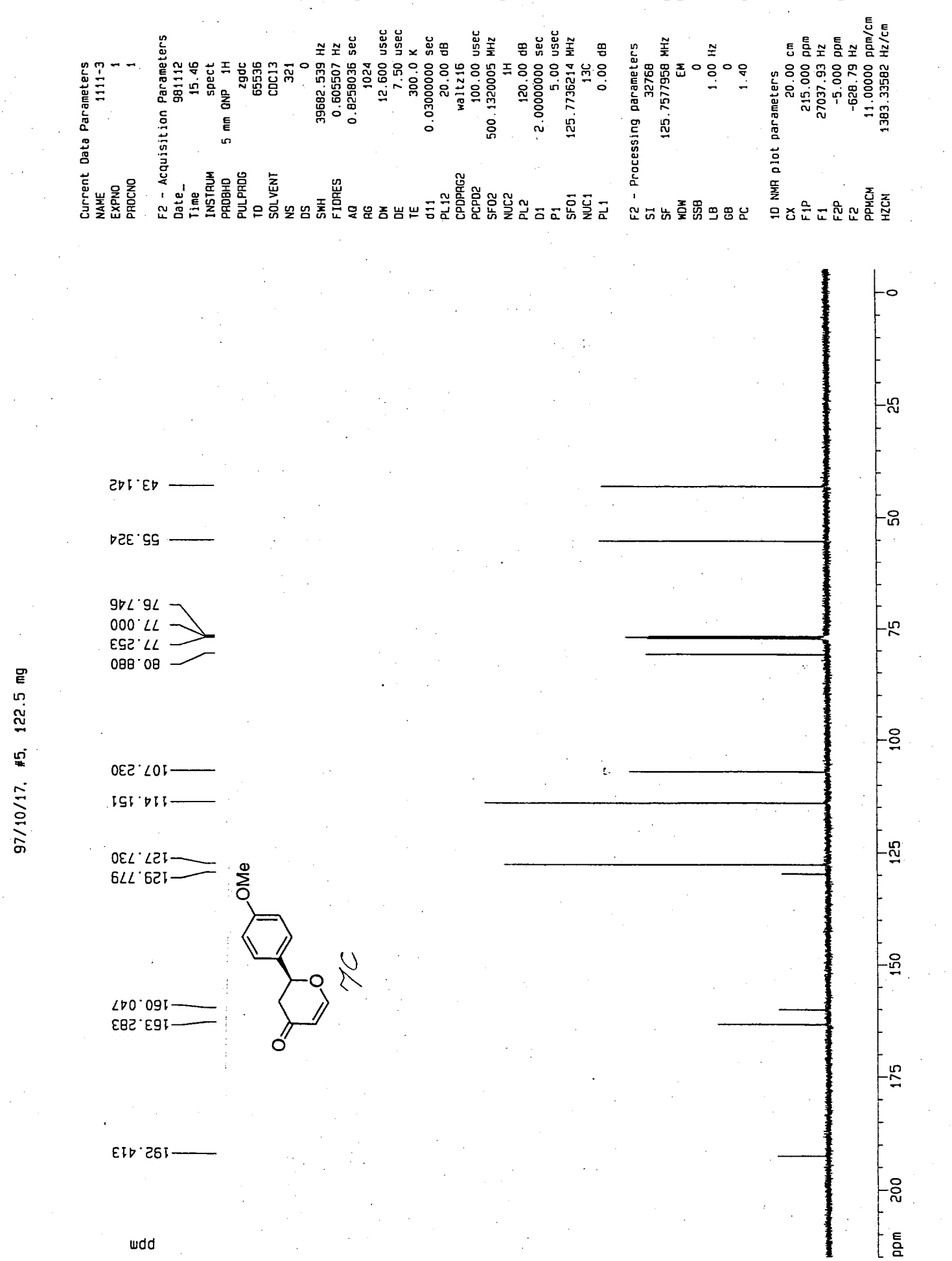


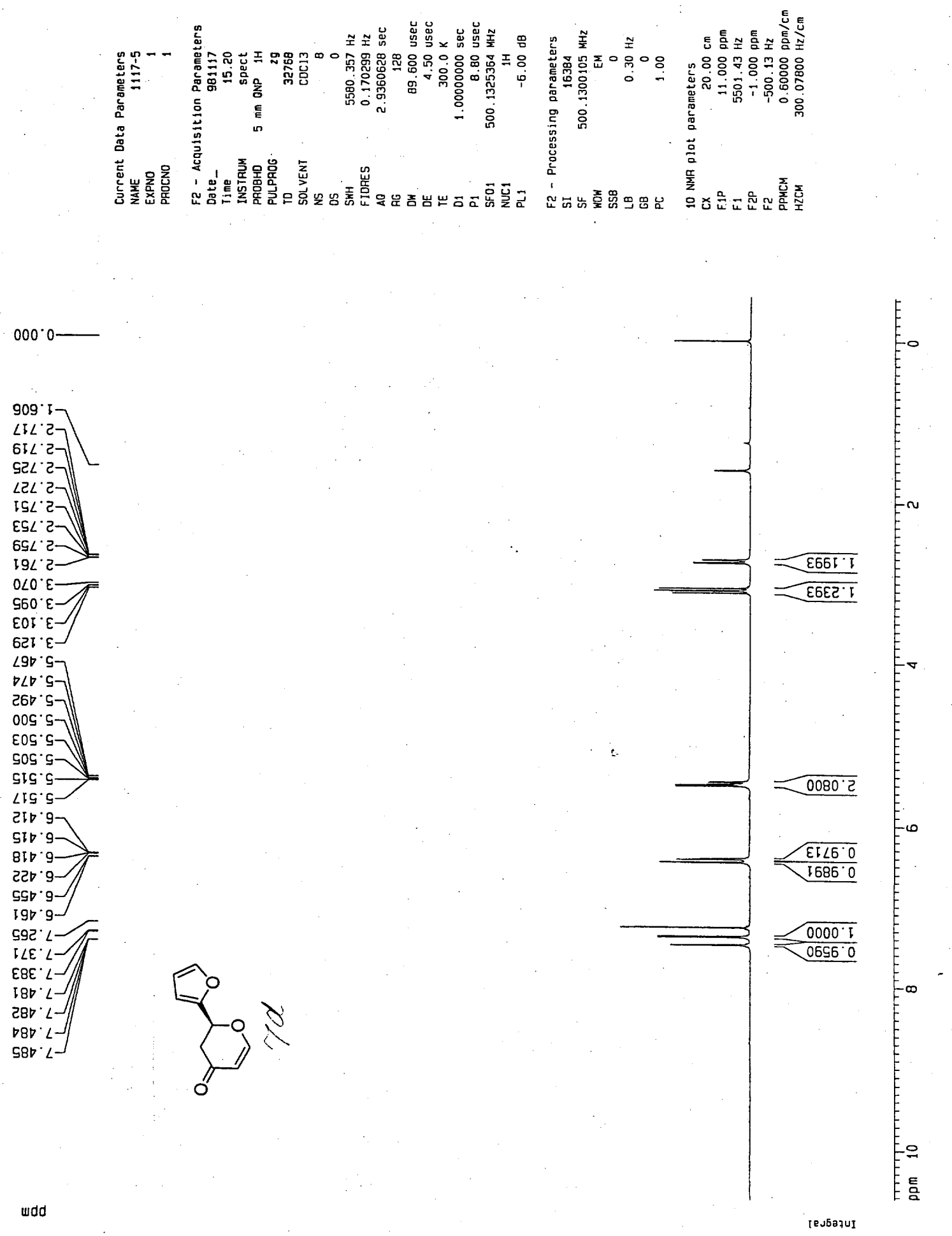


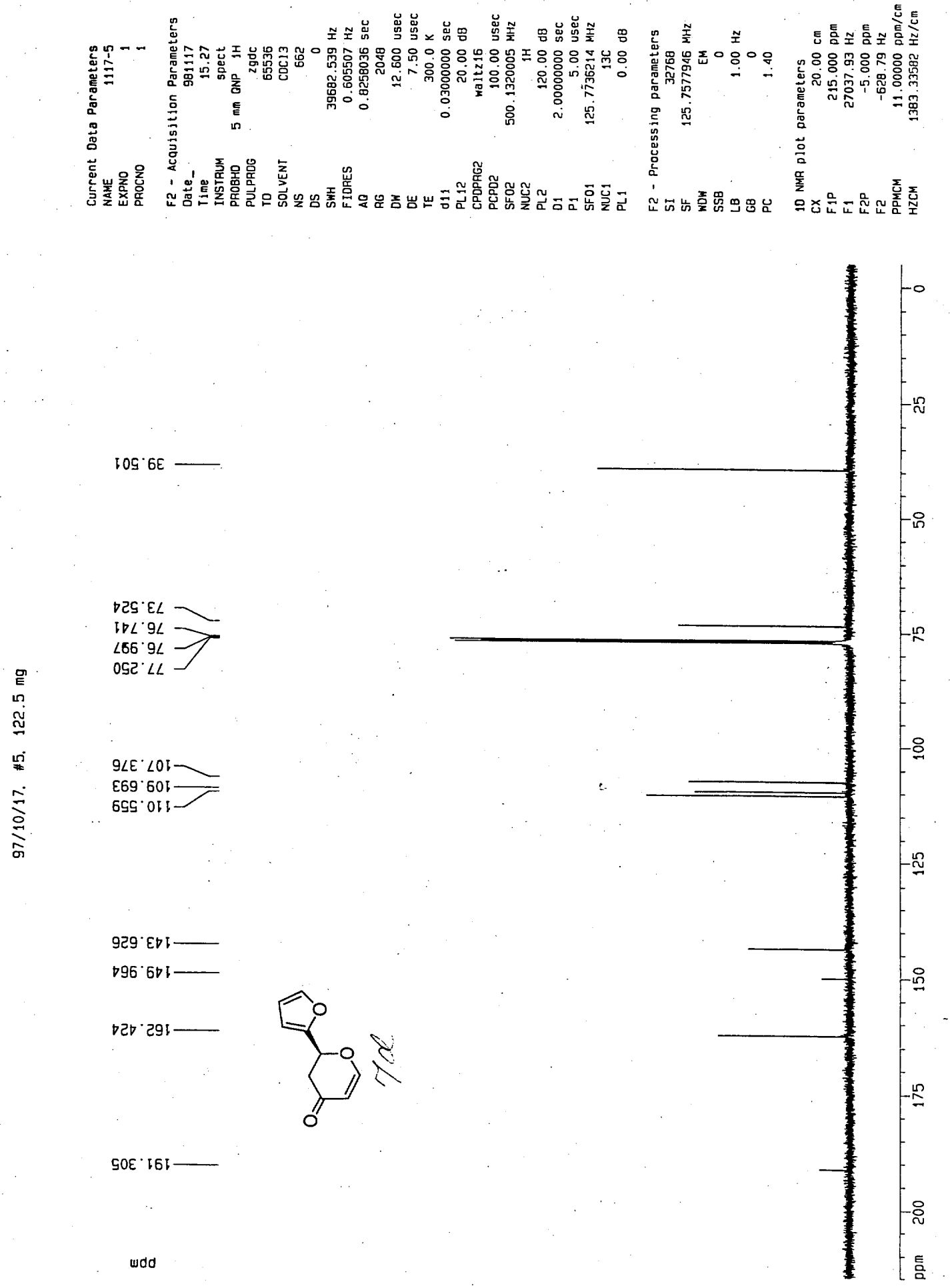


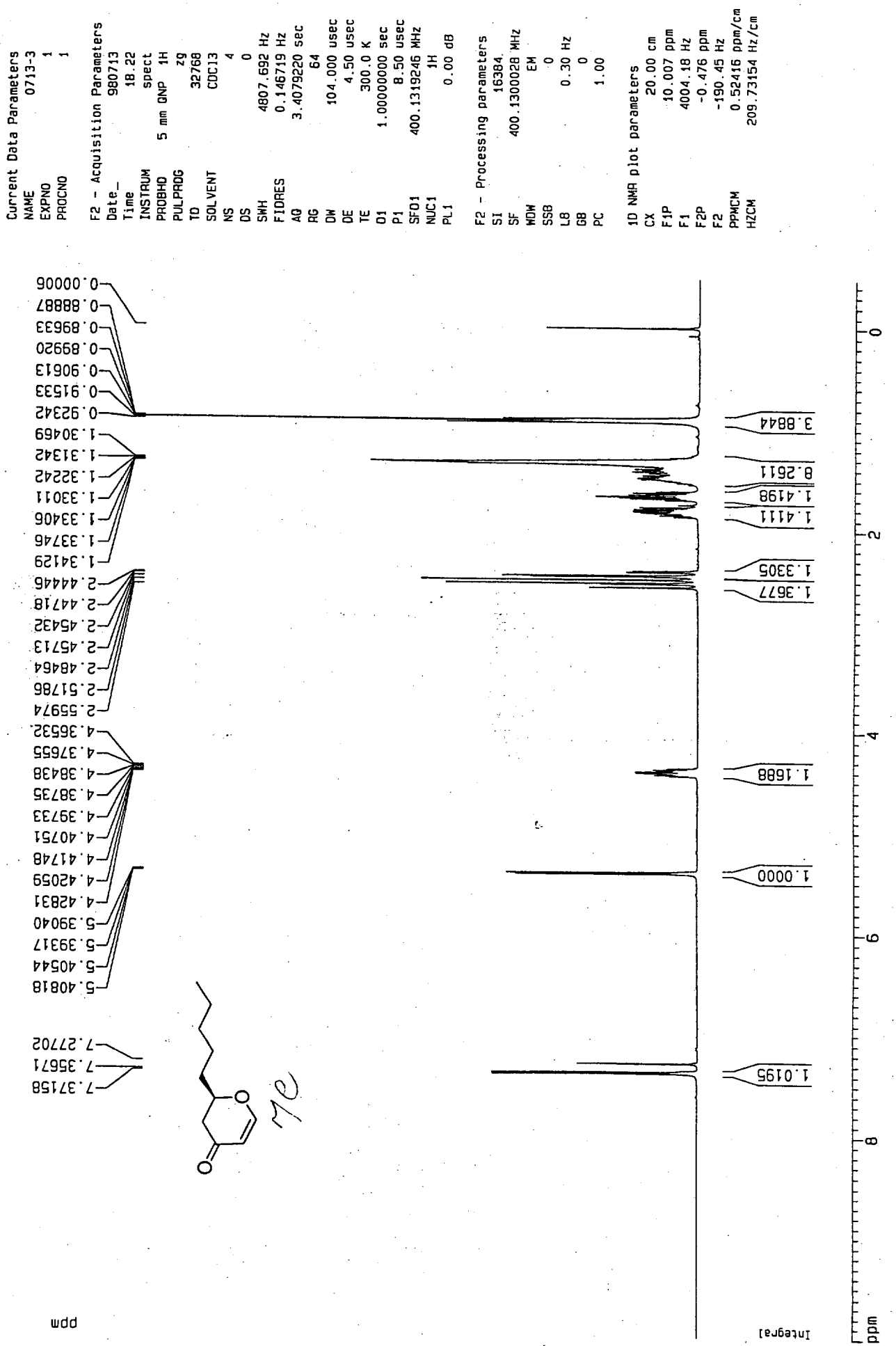


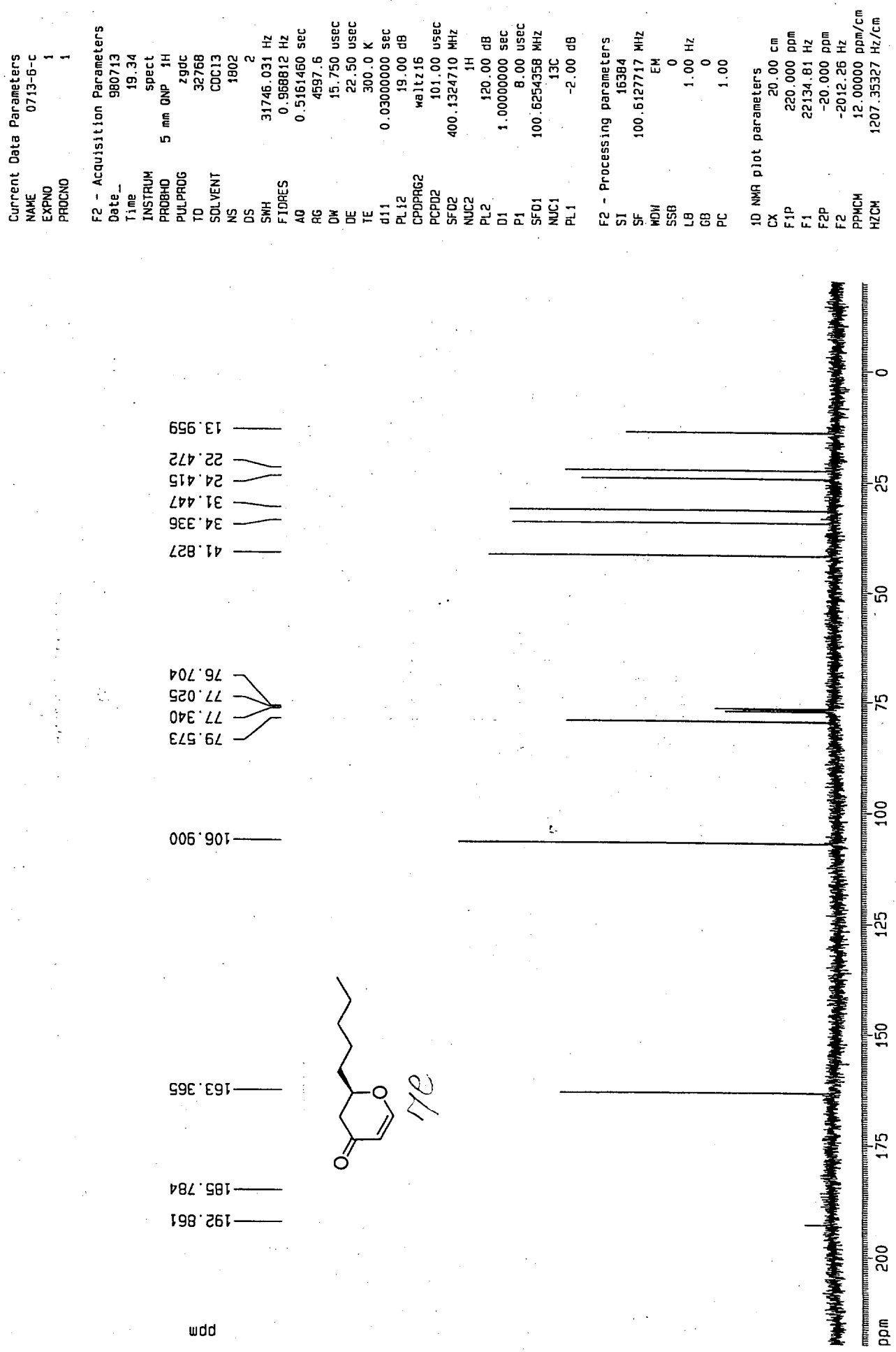


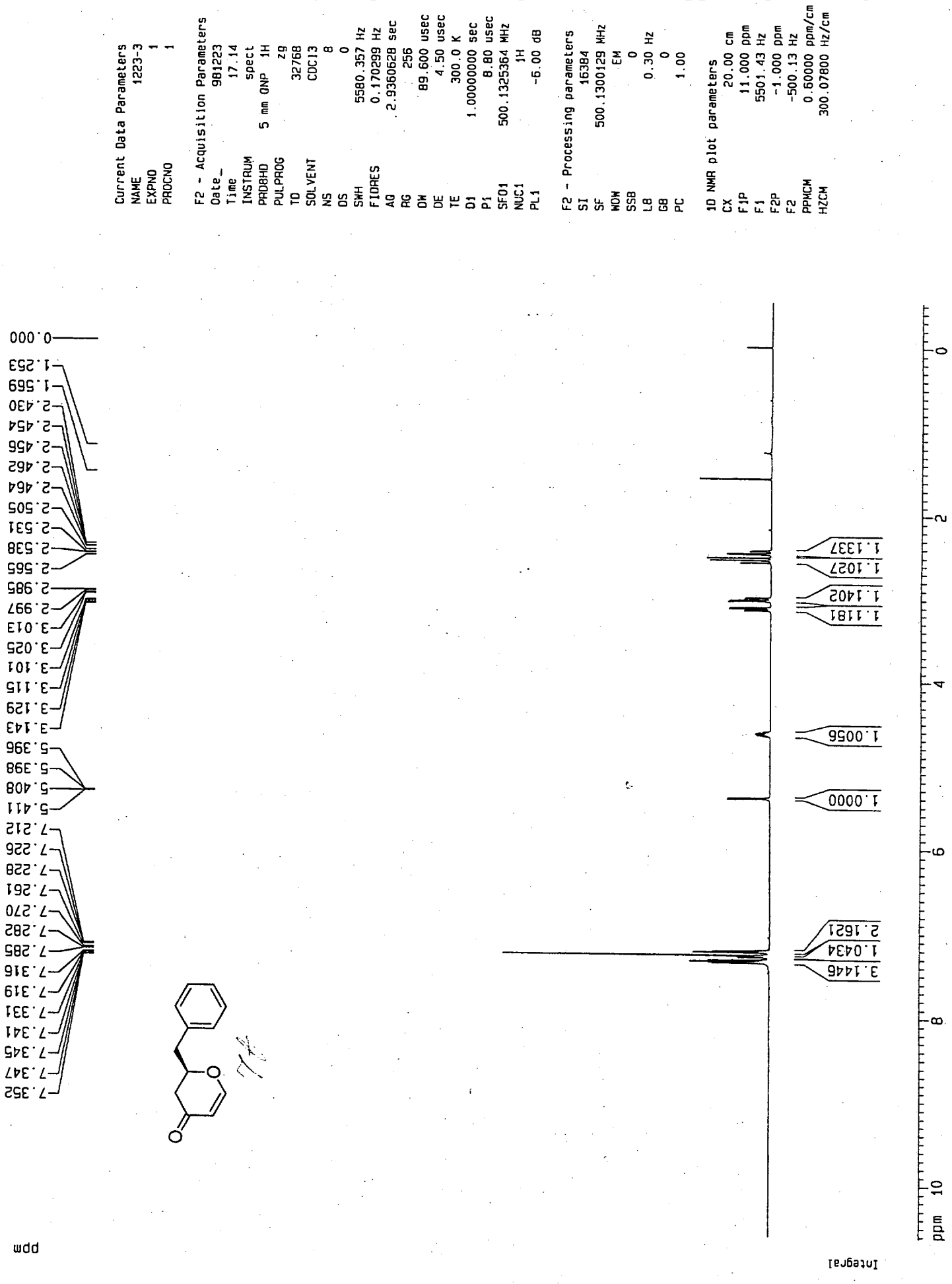


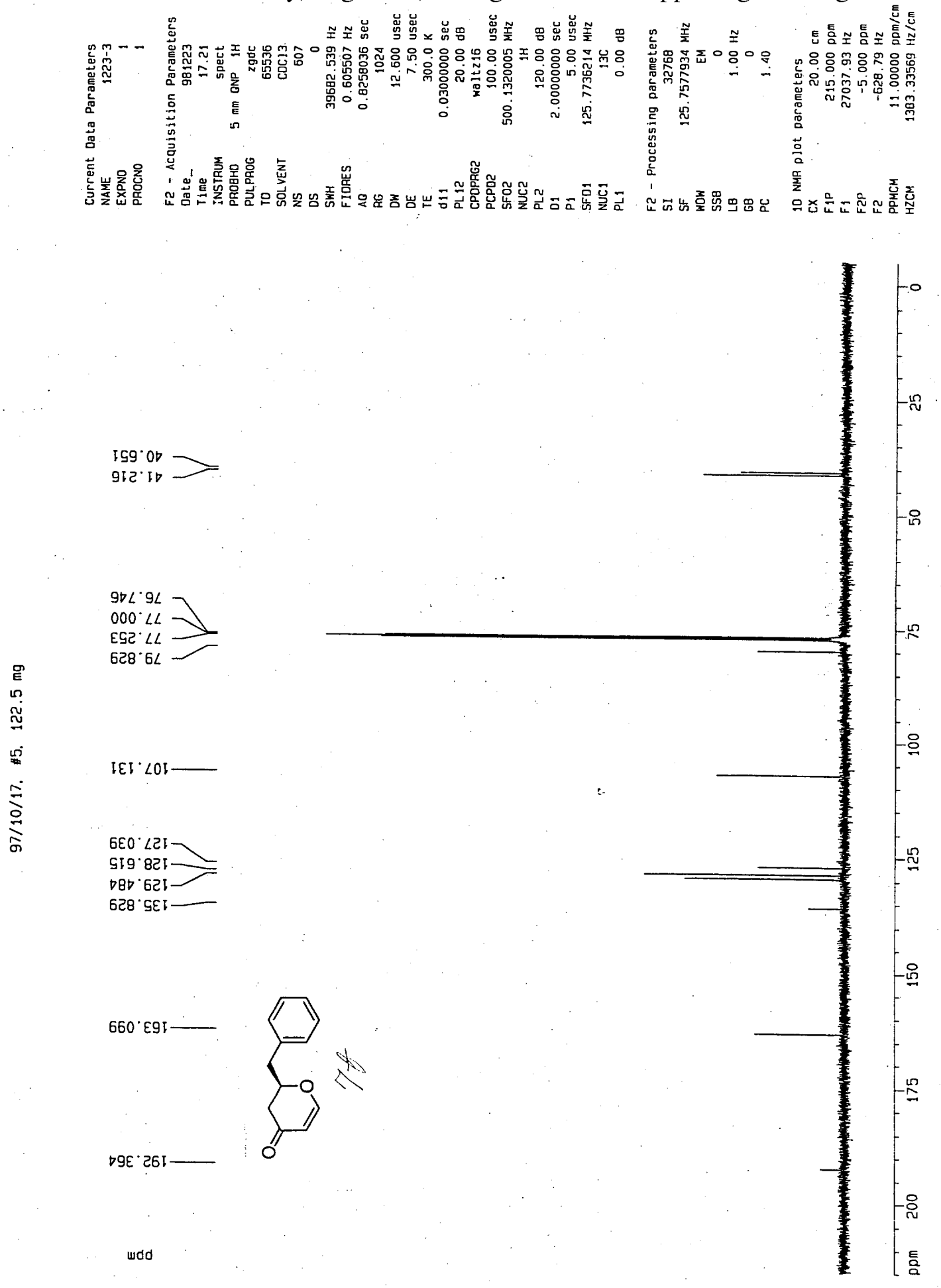


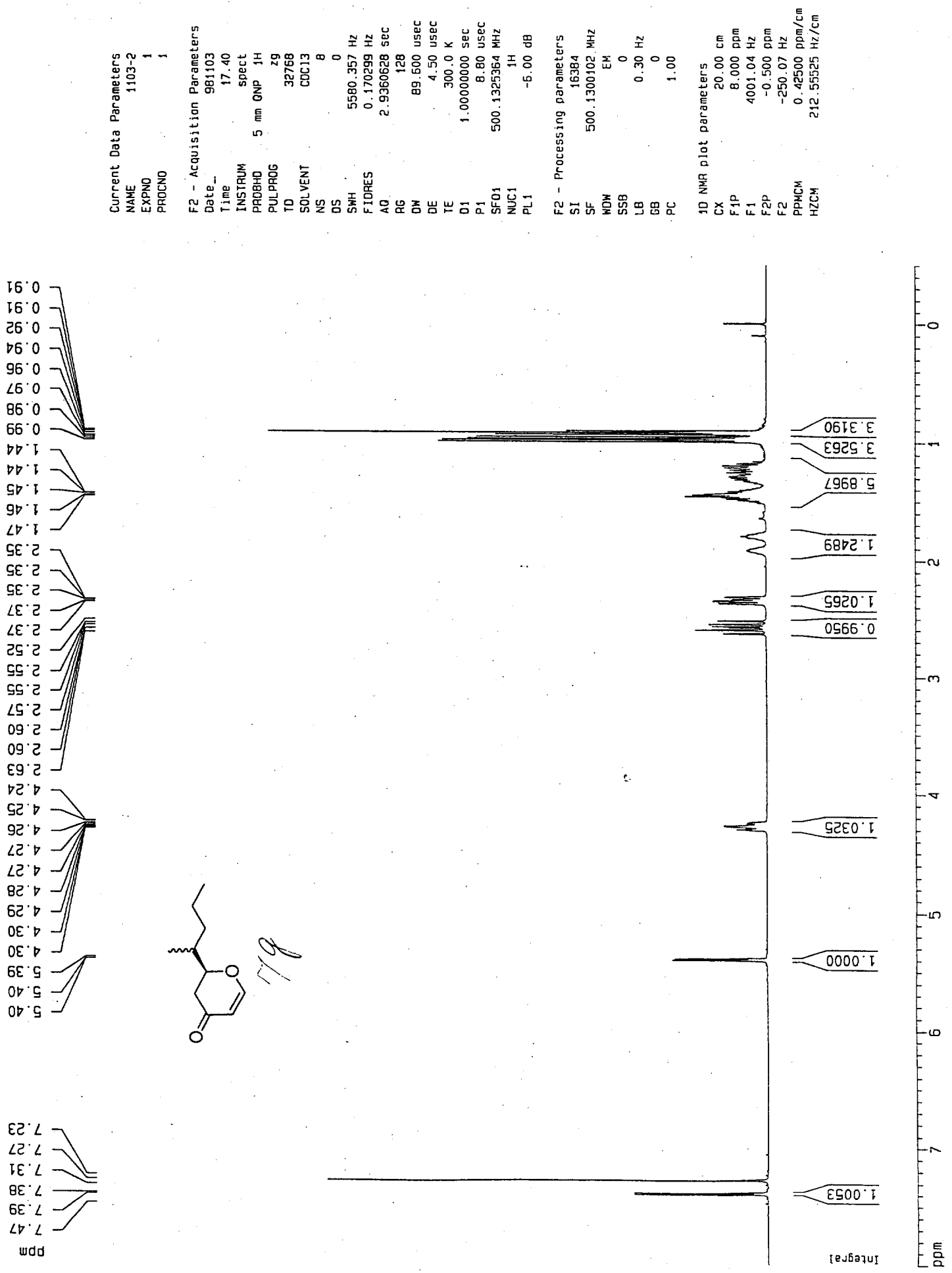


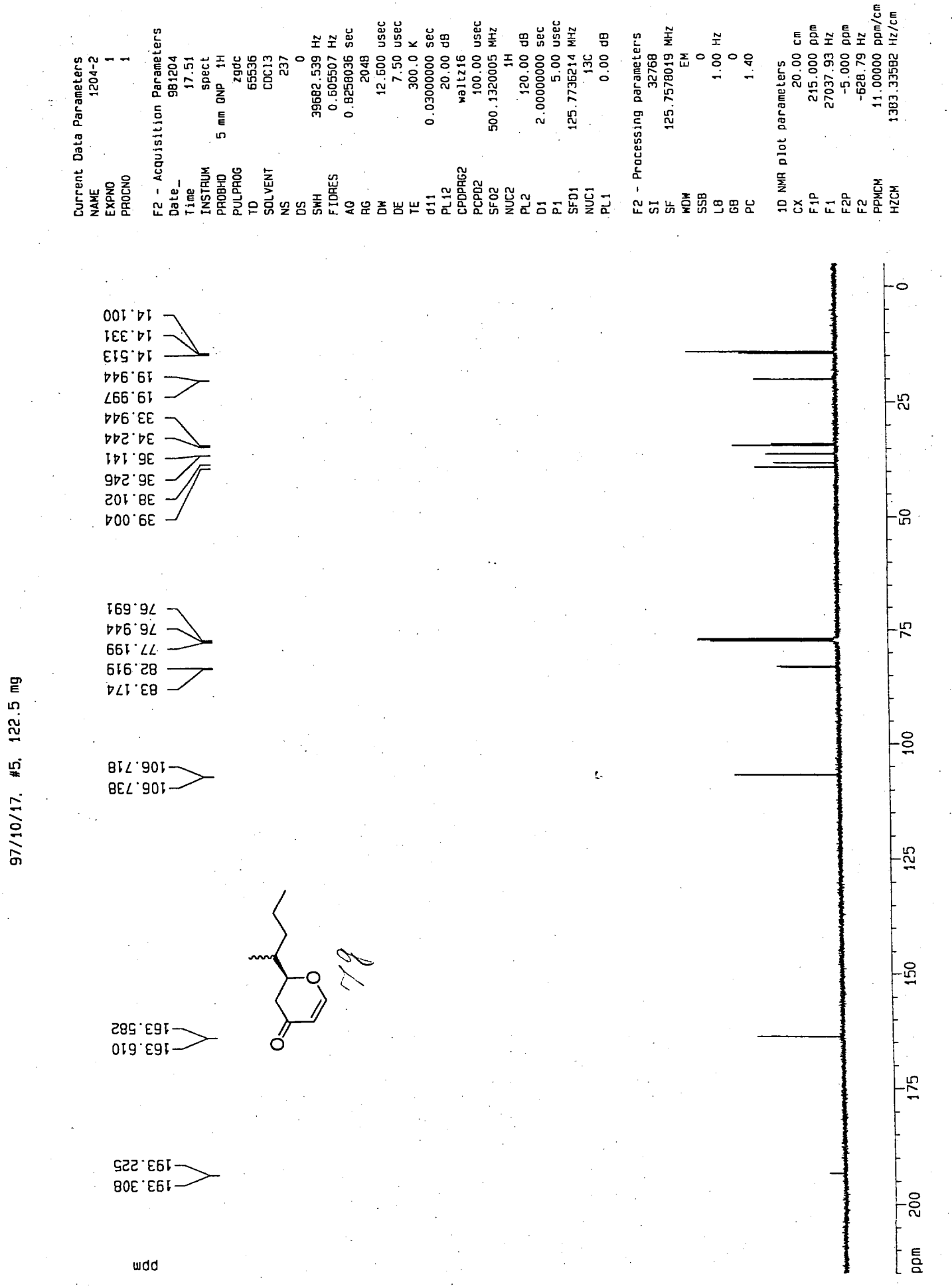


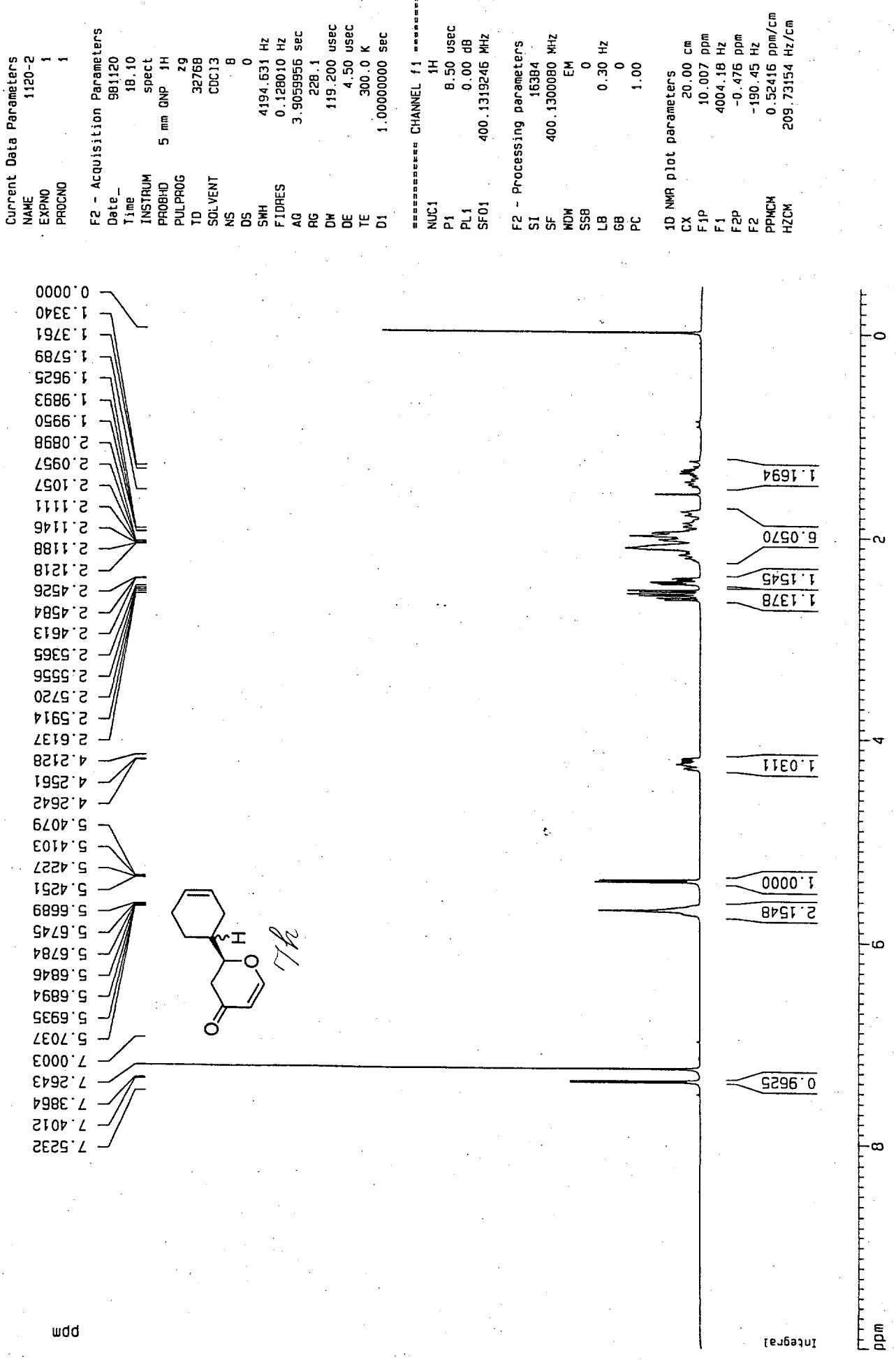


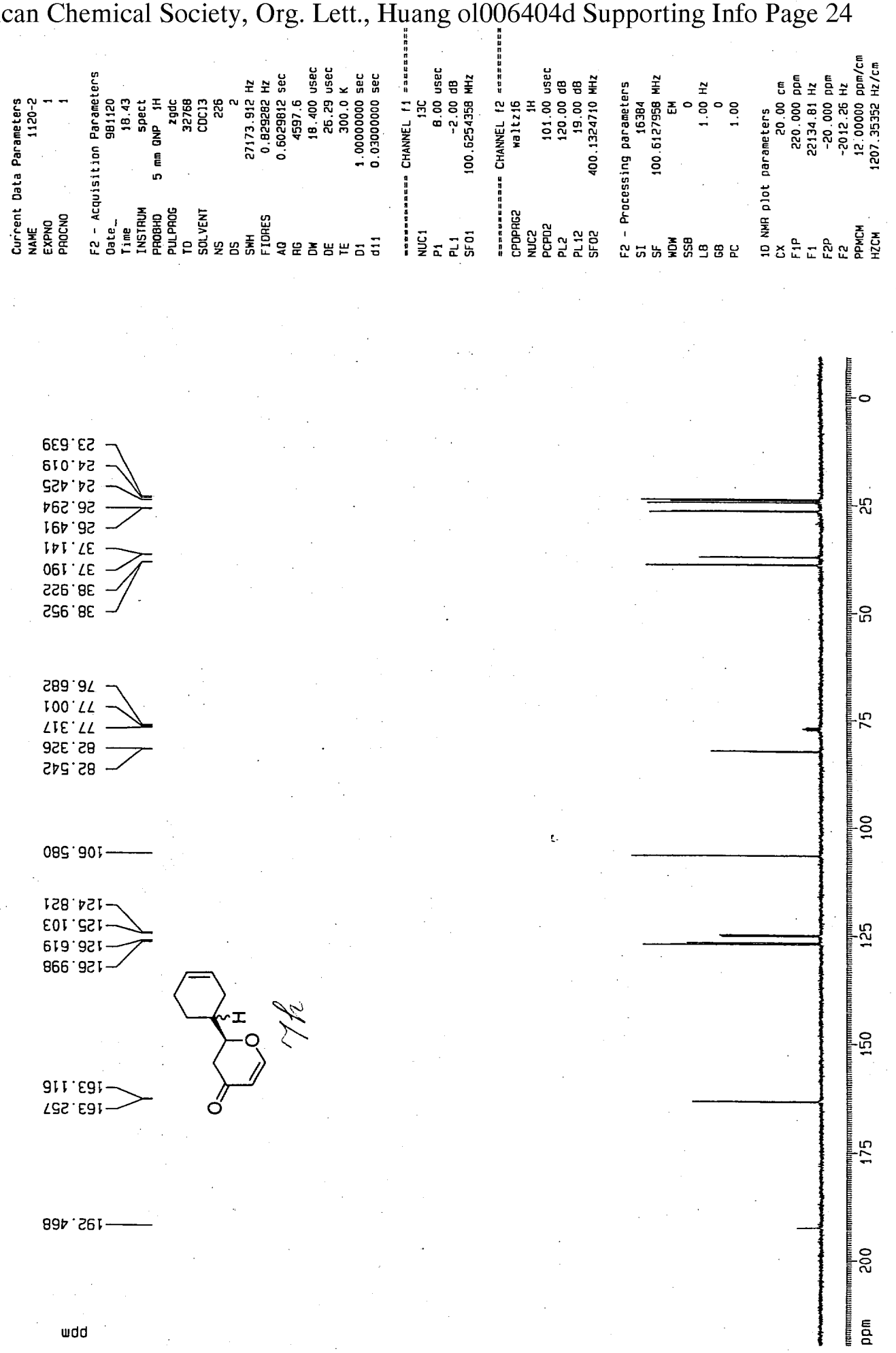


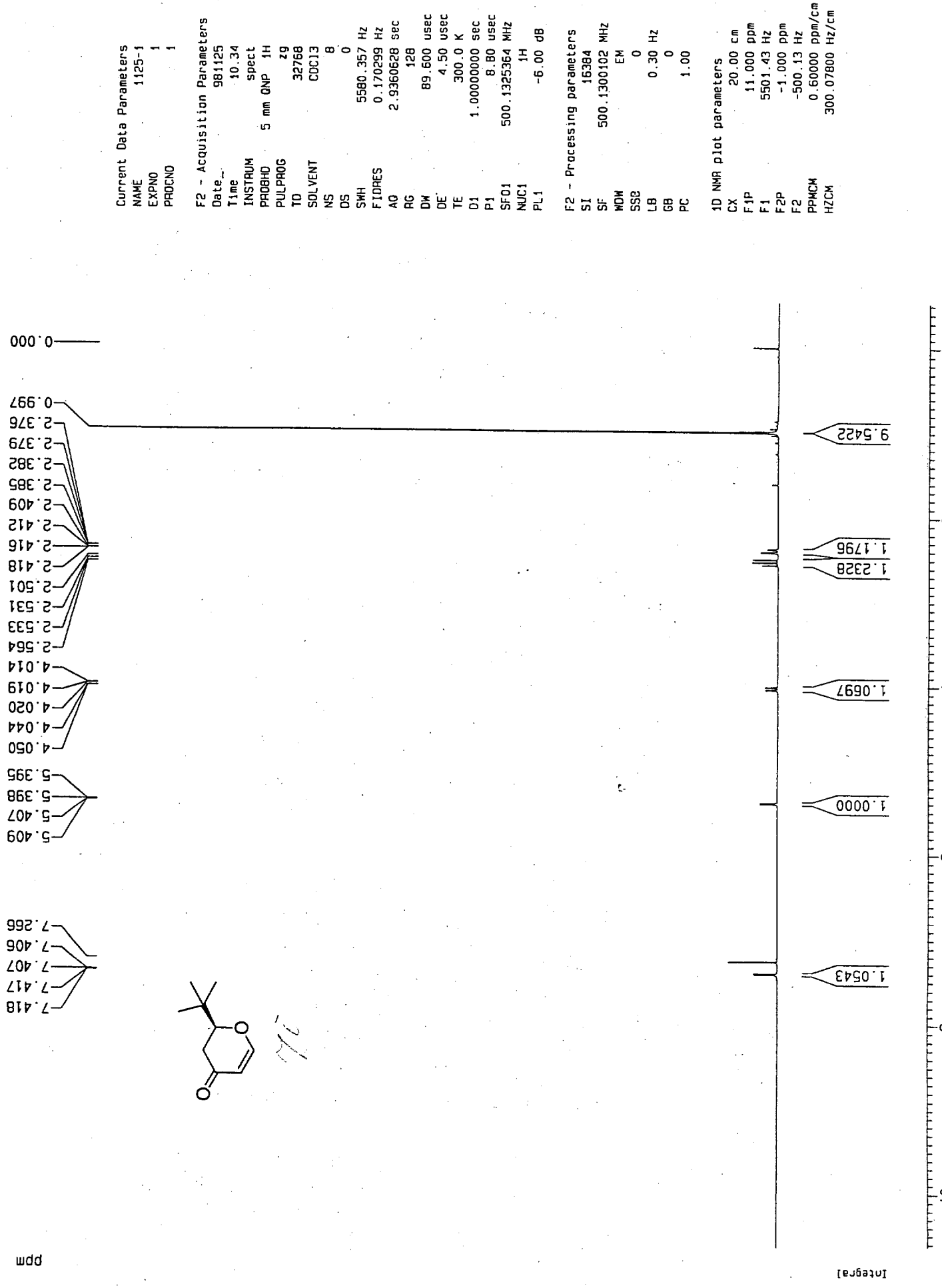


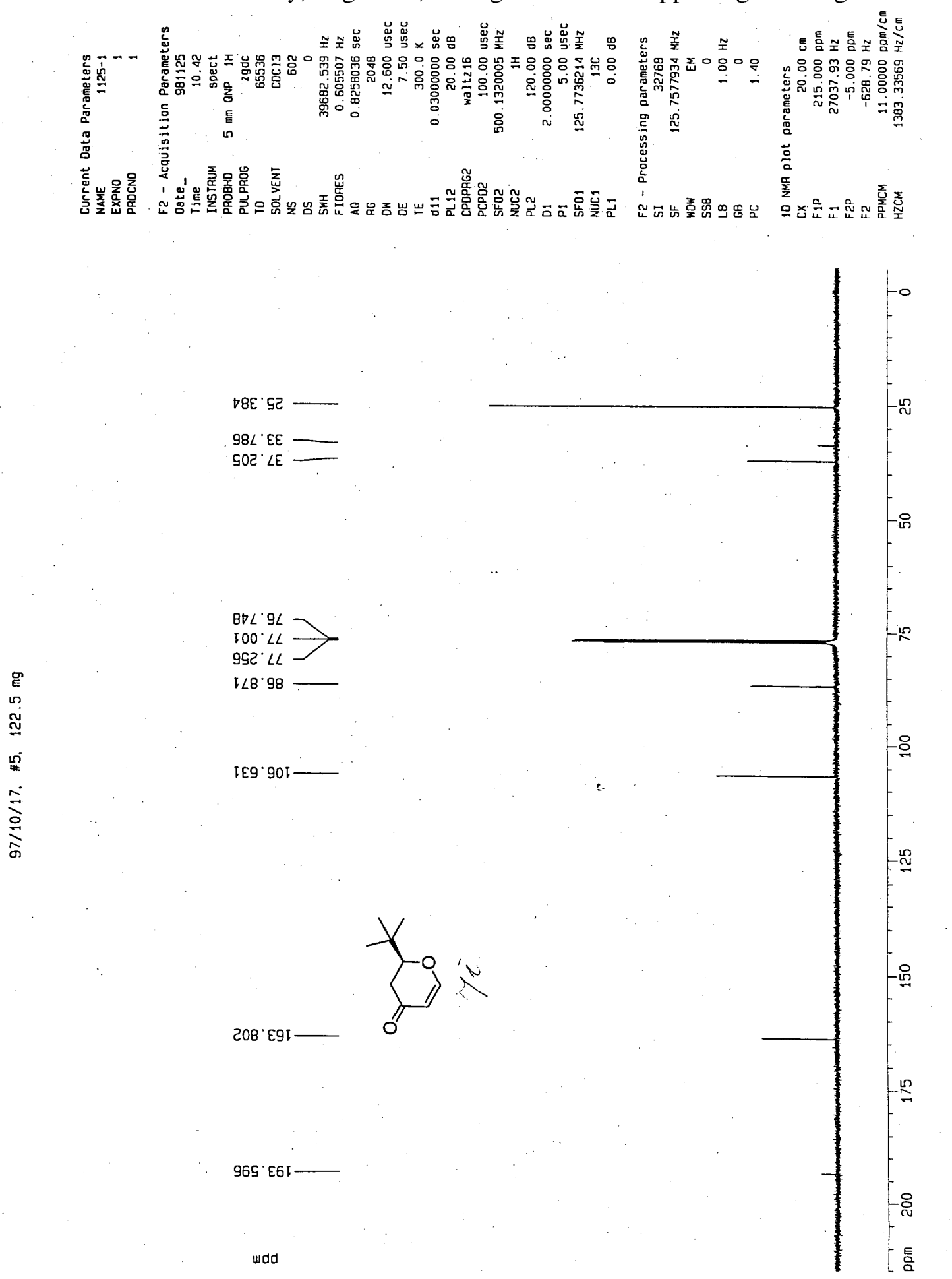


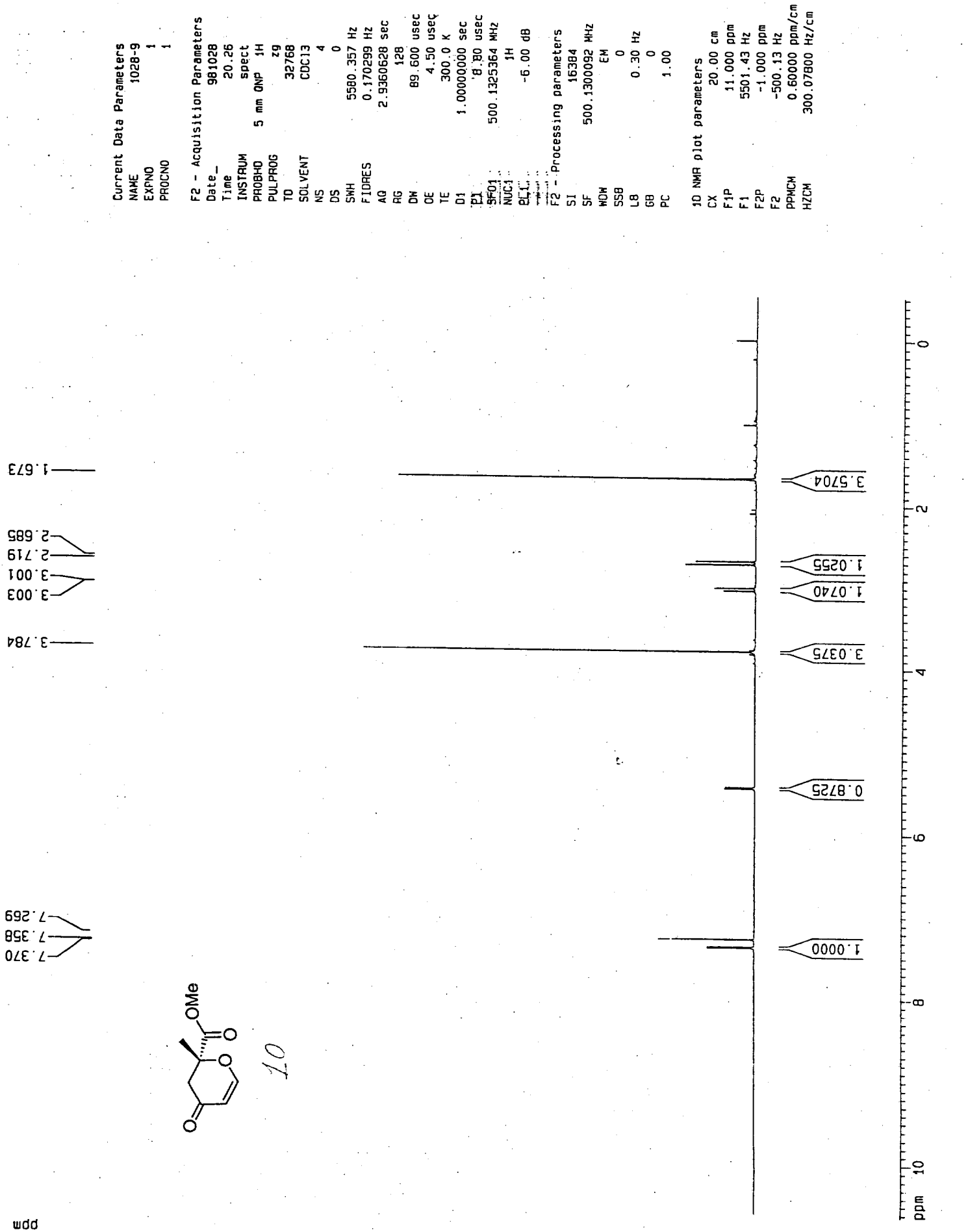


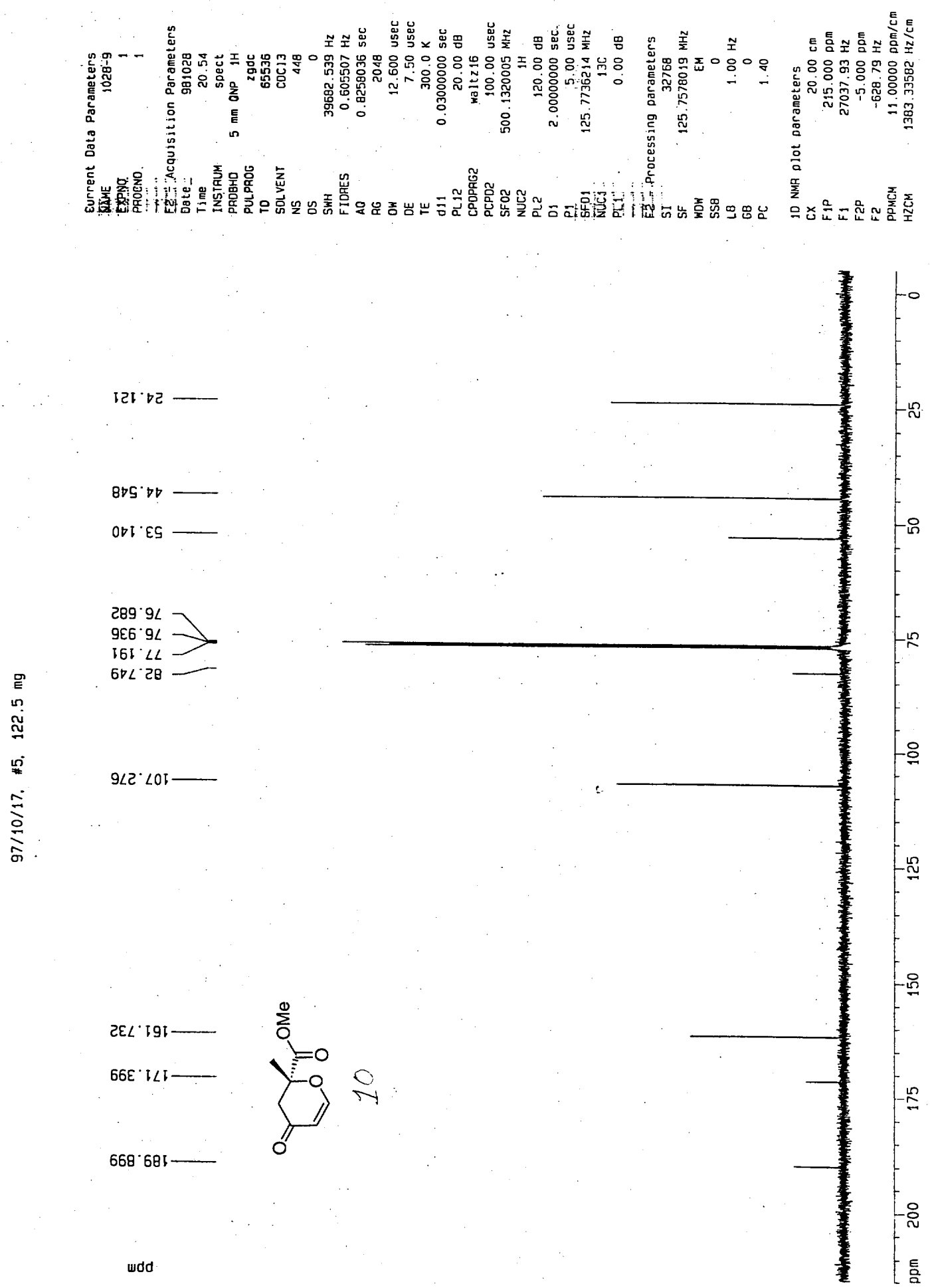


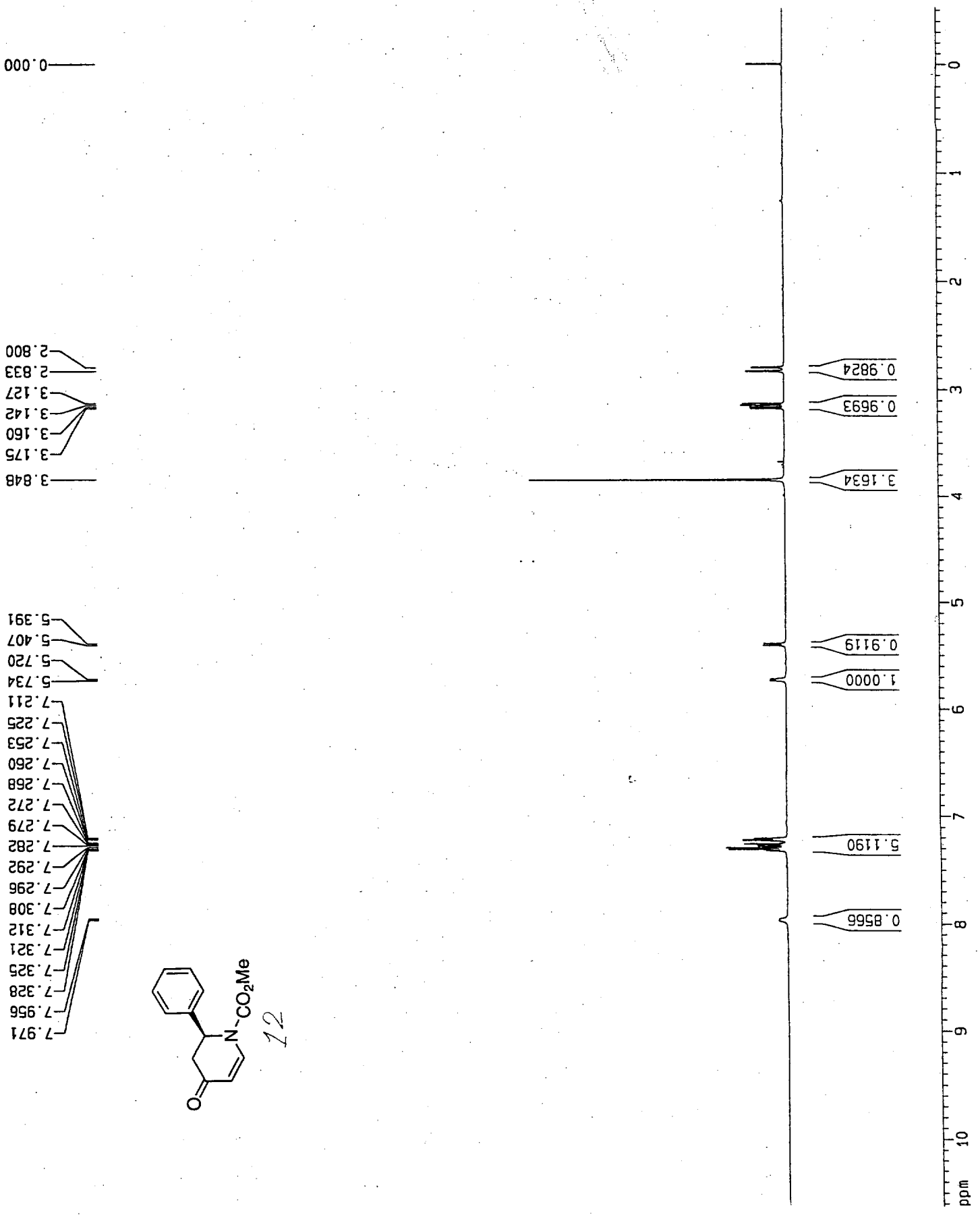




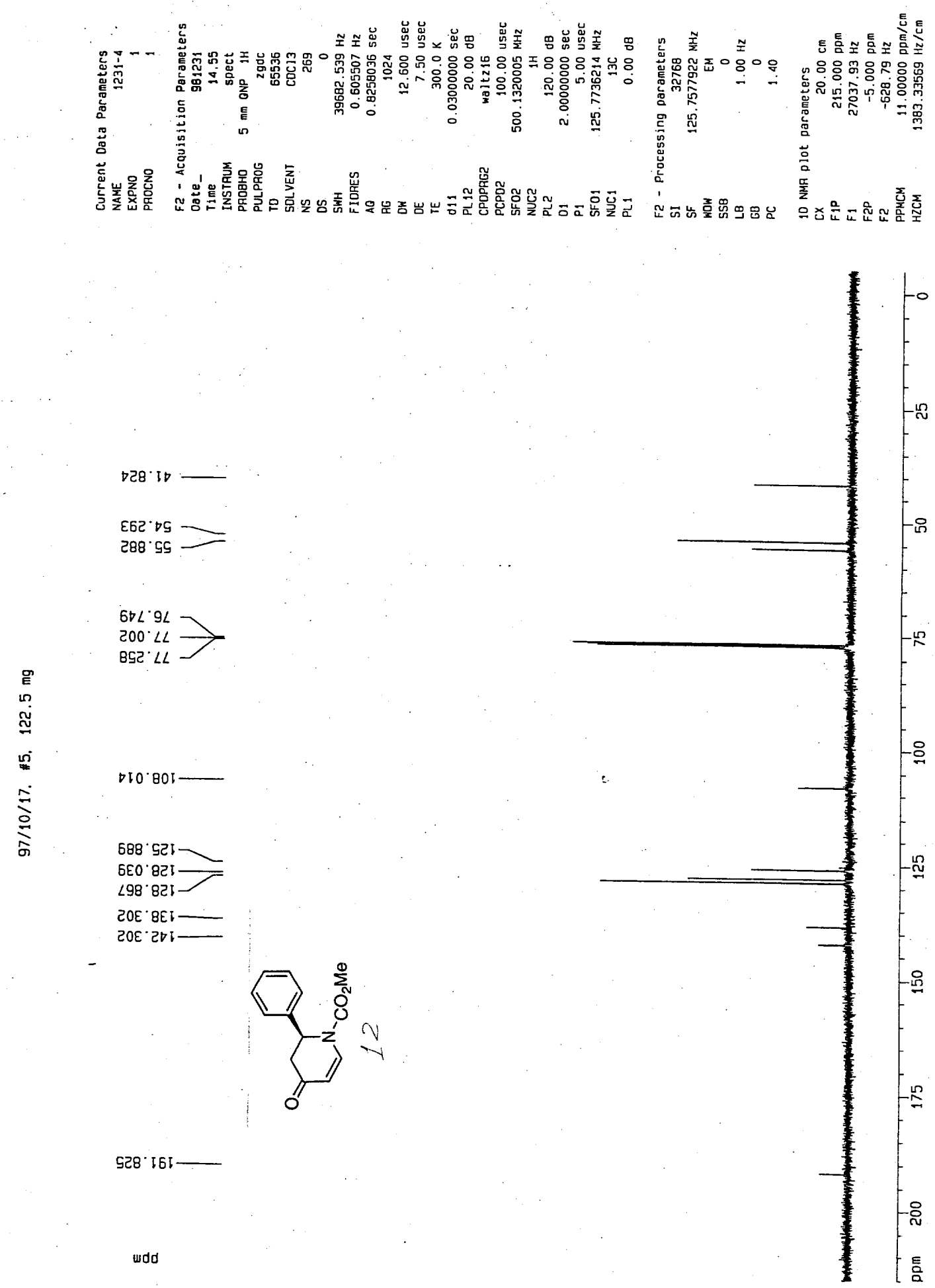


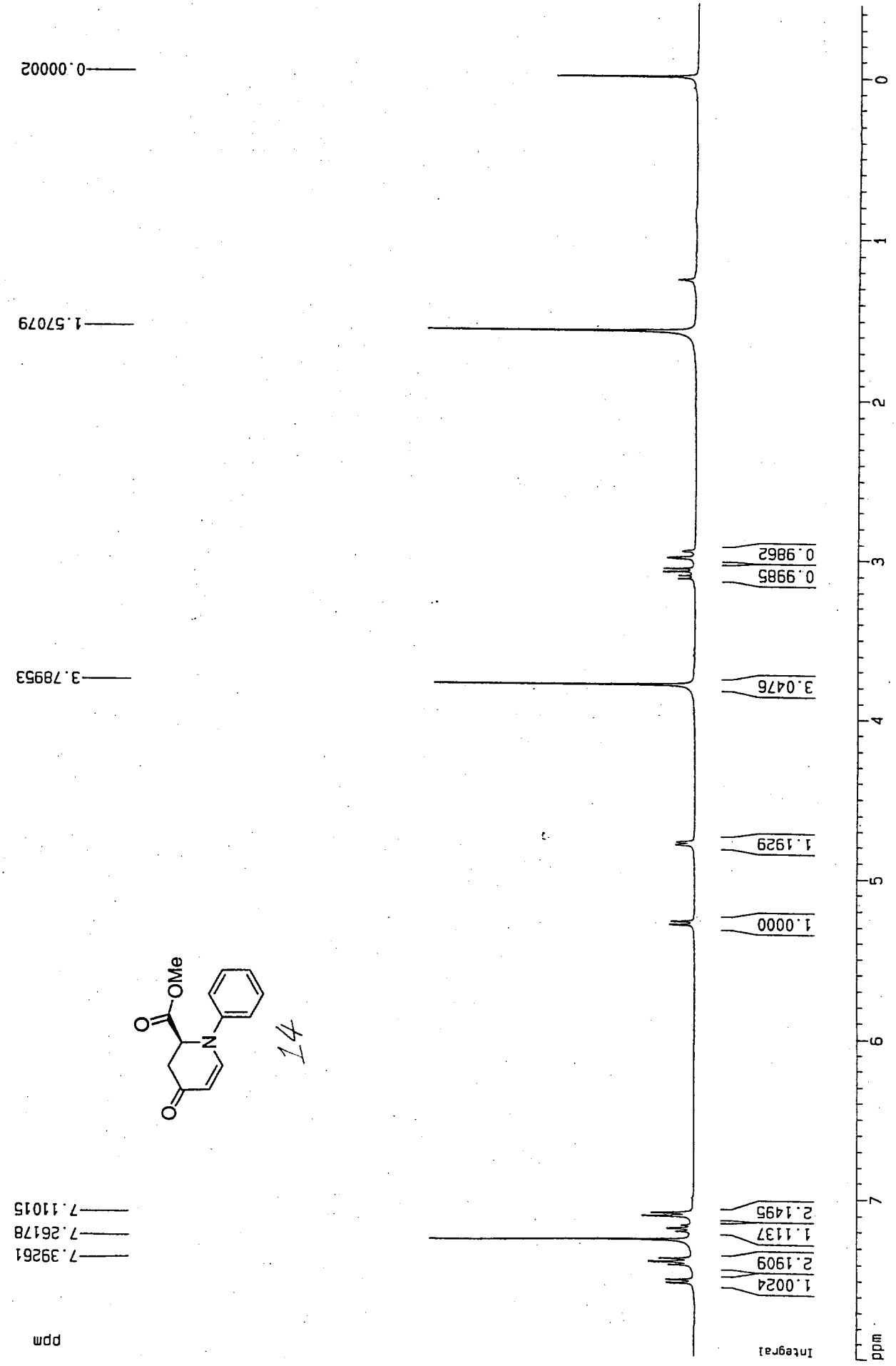


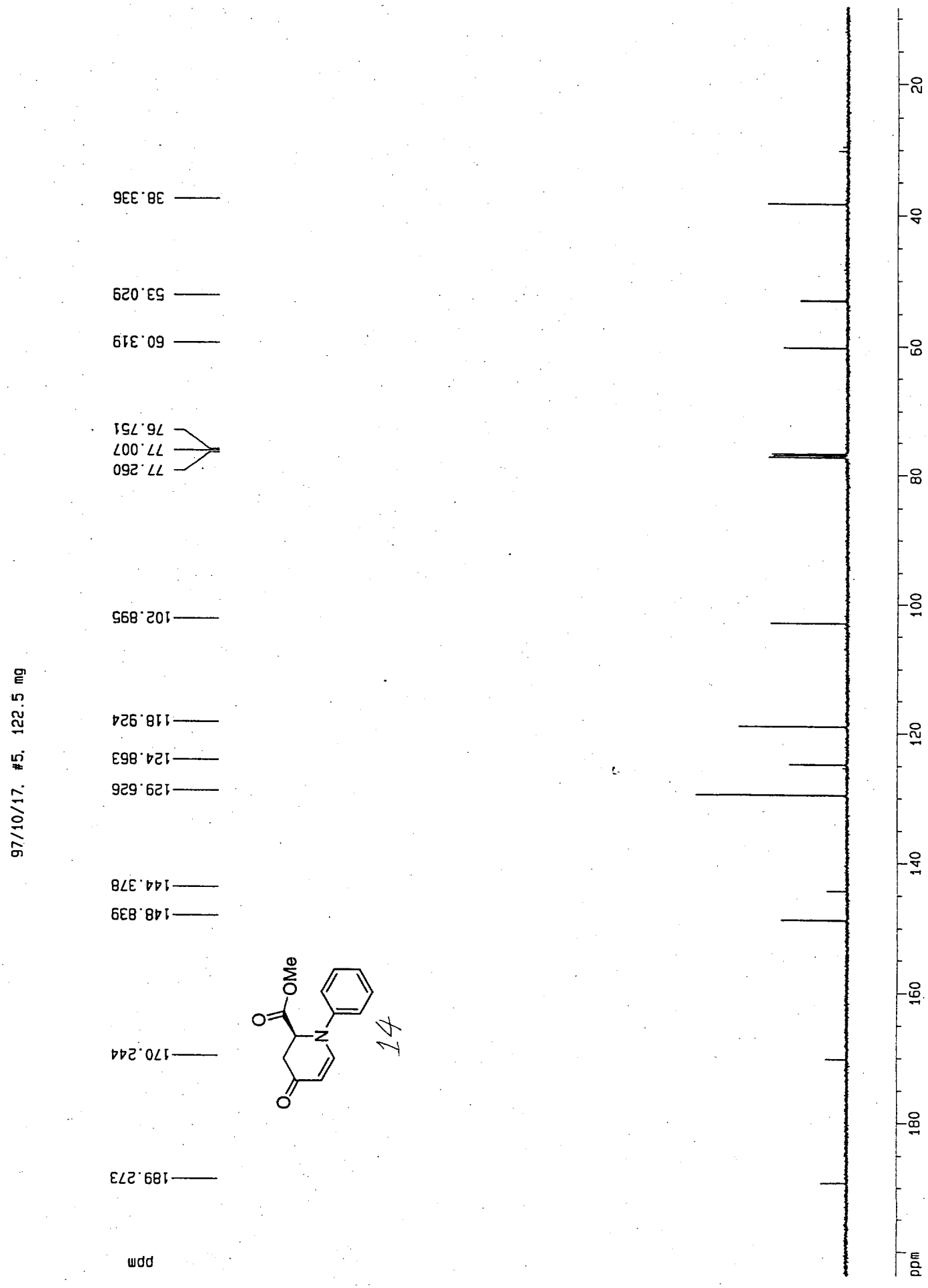




12




0.00002
1.57079
3.78953
7.39261
7.26178
7.11015
ppm
Integral
1.0024
2.1909
1.1137
2.1495
1.0000
1.1929
3.0476
0.9985
0.9862
OMe
O
N
O
14


97/10/17. #5. 122.5 mg
38.336
53.029
60.319
76.751
77.007
77.260
102.895
118.924
124.863
129.626
144.378
148.839
170.244
189.273
OMe
O
N
O
14
ppm
20
40
60
80
100
120
140
160
180
ppm