Supporting Information

For

Desymmetrization of Cyclohexadienones via Cinchonine Derived Thiourea-Catalyzed Enantioselective Aza-Michael Reaction and Total Synthesis of (-)-Mesembrine

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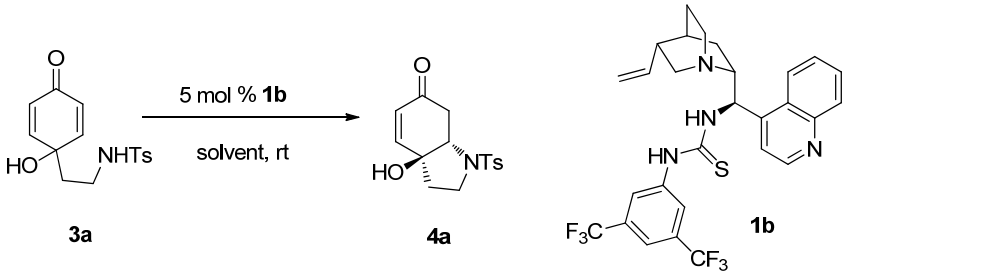
1 General Methods. Unless stated otherwise, all reactions were carried out in flame-dried glassware under a dry argon atmosphere. All solvents were purified and dried according to standard methods prior to use. ^{1}H and ^{13}C NMR spectra were recorded on a Varian instrument (300 MHz and 75 MHz, 400 MHz and 100 MHz, respectively) and internally referenced to tetramethylsilane signal or residual protio solvent signals. ^{19}F NMR chemical shifts were determined relative to $CFCl_3$ at δ 0.0. Data for ^{1}H NMR are recorded as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet or unresolved, br = broad singlet, coupling constant(s) in Hz, integration). Data for ^{13}C NMR are reported in terms of chemical shift (δ, ppm).

Alkaloid derived-thioureas **1a-h**[1], compounds **8a-l**[2], **11**[6] and allyl tosylcarbamate[7] were prepared according to the literatures.

2 Experimental Sections:

2.1 Screening the reaction conditions

Table 1 Screening of solvents[a]

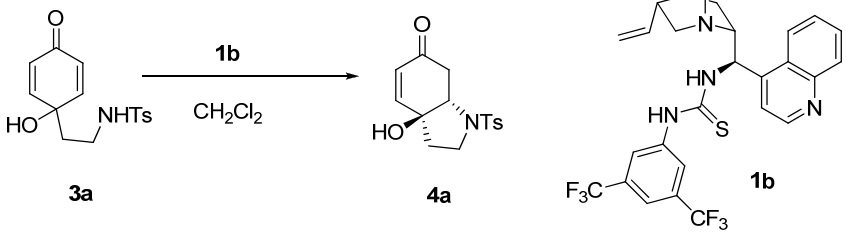


3a 4a 1b

Entry	solvent	time (h)	yield (%)[b]	*ee* (%)[c]
1	**CH_2Cl_2**	**12**	**94**	**97**
2	$CHCl_3$	8	95	88
3	DCE	12	91	96
4	CCl_4	24	82	90
5	toluene	9	92	95
6	benzene	10	96	96
7	THF	24	36	92
8	ether	10	91	86
9	CH_3CN	24	71	88

[a] Reaction conditions：5 mol % of **1b**, 0.1 mol/L **3a** in solvent at room temperature. [b] Isolated yields. [c] Determined by chiral HPLC analysis (chiralpak AD-H).

Table 2 Investigation of the reaction temperature, concentration and catalyst loadings[a]

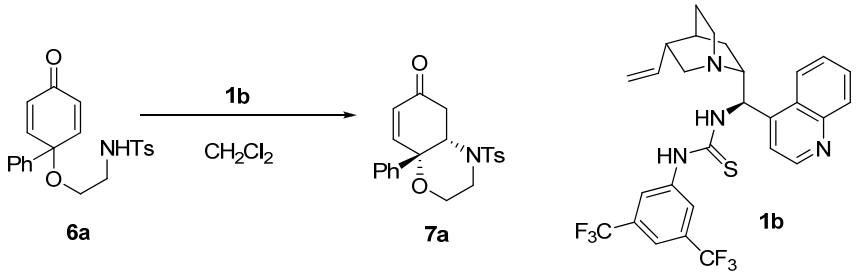


3a 4a 1b

Entry	Conc. (X mol/L)	catalyst (Y mol%)	T (℃)	time (h)	yield (%)[b]	*ee* (%)[c]
1	**0.1**	**5**	**rt**	**12**	**94**	**96.8**
2	0.2	5	rt	12	96	95.8
3	1.0	5	rt	4	96	95.1
4	0.05	5	rt	24	95	97.1
5	0.1	10	rt	5	97	97.1
6	0.1	5	-15	38	92	96.5

[a] Reaction conditions: X mol/L **3a,** Y mol % of **1b** in CH_2Cl_2. [b] Isolated yields. [c] Determined by chiral HPLC analysis (chiralpak AD-H).

Table 3 Further optimization of the reaction conditions for **6a** [a]



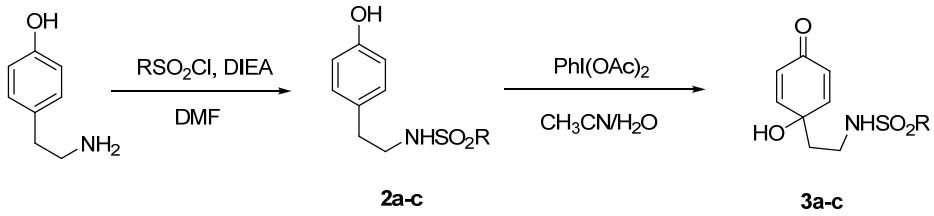
6a 7a 1b

Entry	catalyst (X mol%)	Conc. (Y mol/L)	time (h)	T (℃)	yield (%)[b]	*ee* (%)[c]
1	5	0.1	72	rt	11	98.3
2	5	0.1	48	40	22	97.7
3	5	0.5	48	rt	13	97.7
4	20	0.1	72	rt	45	97.0
5	20	0.5	144	rt	58	97.7
6	**20**	**0.5**	**72**	**40**	**82**	**96.7**

[a] Reaction conditions： X mol % of **1b**, Y mol/L **6a** in CH_2Cl_2. [b] Isolated yields. [c] Determined by chiral HPLC analysis (Chiralpak AD-H).

2.2 Preparation of substrates 3a-k.

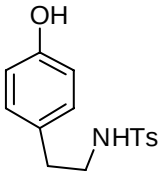
Synthesis of substrates 3a-c.



2a-c **3a-c**

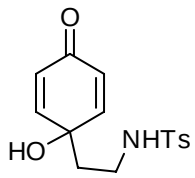
To a solution of tyramine (685 mg, 5 mmol) and corresponding sulfonyl chloride (6 mmol) in DMF (10 mL) was added DIEA (2.6 mL, 15 mmol) dropwise at 0 ℃. The reaction mixture was stirred for 2 h and diluted with H_2O, extracted with ethyl acetate for three times. The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4 and filtered. The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography to afford **2**.

To a solution of **2** (1.0 mmol) in CH_3CN/H_2O (5 mL, 4:1) was slowly added $PhI(OAc)_2$ (425 mg, 1.2 mmol) at 0 ℃. The reaction mixture was stirred for 1h, then dried over anhydrous Na_2SO_4 and filtered. The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography to afford **3**.



N-(4-Hydroxyphenethyl)-4-methylbenzenesulfonamide (2a)[4]

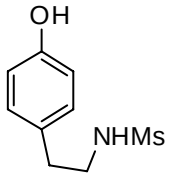
46% yield, white solid. Mp = 171.8-172.5 ℃; ^{1}H NMR (300 MHz, CD_3OD) δ 2.40 (s, 3H), 2.58 (t, J = 7.5 Hz, 2H), 2.97 (t, J = 7.5 Hz, 2H), 6.64 (d, J = 8.1 Hz, 2H), 6.89 (d, J = 8.1 Hz, 2H), 7.32 (d, J = 7.8 Hz, 2H), 7.65 (d, J = 7.8 Hz, 2H).



N-(2-(1-Hydroxy-4-oxocyclohexa-2,5-dienyl)ethyl)-4-methylbenzenesulfonamide (3a)

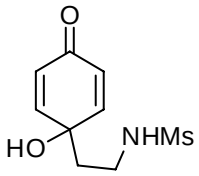
51% yield, pale yellow solid. Mp = 102.1-103.3 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.91 (t, J = 6.6 Hz, 2H), 2.43 (s, 3H), 3.03-3.09 (m, 2H), 3.26 (br, 1H), 5.40 (t, J = 6.0 Hz, 1H), 6.10 (d, J = 9.9 Hz, 2H), 6.82 (d, J = 9.9 Hz, 2H), 7.31 (d, J = 8.1 Hz, 2H), 7.71 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 38.8, 39.0, 68.9, 127.0, 128.0, 129.8, 136.2, 143.7, 150.5, 185.5; IR (film) 3331, 3281, 1662, 1618, 1307, 1151, 1089, 1016, 903, 858, 814, 662 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{15}H_{17}NO_4S$: 307.0878. Found:

307.0881.



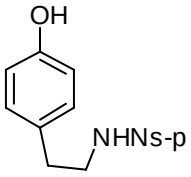
N-(4-Hydroxyphenethyl)methanesulfonamide (2b)

41% yield, yellow solid. Mp = 100.7-101.5℃; ^{1}H NMR (300 MHz, CD_3OD) δ 2.73 (t, J = 7.2 Hz, 2H), 2.80 (s, 3H), 3.25 (t, J = 7.2 Hz, 2H), 6.72 (d, J = 8.1 Hz, 2H), 7.06 (d, J = 8.1 Hz, 2H). ^{13}C NMR (75 MHz, CD_3OD) δ 36.8, 39.9, 46.0, 116.3, 130.9, 131.0, 157.0; IR (film) 3324, 2924, 2853, 1610, 1588, 1513, 1461, 1425, 1402, 1336, 1308, 1284, 1199, 1129, 1064, 976, 883, 830, 770, 739 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_9H_{13}NO_3SNa$: 238.0508. Found: 238.0510.



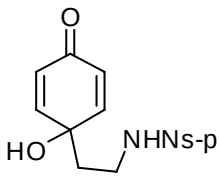
N-(2-(1-Hydroxy-4-oxocyclohexa-2,5-dienyl)ethyl)methanesulfonamide (3b)

50% yield, yellow solid. Mp = 108.6- 109.9℃; ^{1}H NMR (300 MHz, CD_3OD) δ 2.01 (t, J = 7.5 Hz, 2H), 2.94 (s, 3H), 3.15 (t, J = 7.5 Hz, 2H), 6.19 (d, J = 9.3 Hz, 2H), 7.01 (d, J = 9.3 Hz, 2H); ^{13}C NMR (75 MHz, CD_3OD) δ 39.3, 39.7, 41.4, 69.2, 128.5, 153.8, 187.6; IR (film) 3450, 3287, 1665, 1624,1445, 1293, 1141, 1079, 1008, 863, 756 cm^{-1}; HRMS (EI): Exact mass calcd for $C_9H_{13}NO_4S$: 231.0565. Found: 231.0567.



N-(4-Hydroxyphenethyl)-4-nitrobenzenesulfonamide (2c)[4]

52% yield, yellow solid. Mp = 143.6- 144.8℃; ^{1}H NMR (300 MHz, CD_3OD) δ 2.62 (t, J = 7.2 Hz, 2H), 3.12 (t, J = 7.2 Hz, 2H), 6.59 (d, J = 8.4 Hz, 2H), 6.89 (d, J = 8.4 Hz, 2H), 7.93 (d, J = 8.7 Hz, 2H), 8.31 (d, J = 8.7 Hz, 2H).

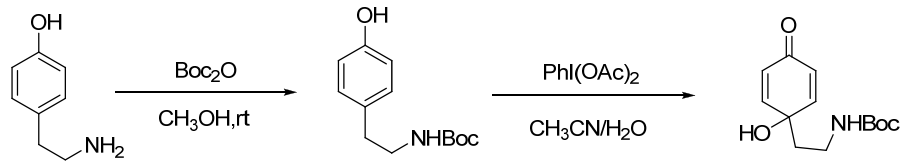


N-(2-(1-Hydroxy-4-oxocyclohexa-2,5-dienyl)ethyl)-4-nitrobenzenesulfonamide(3c)

46% yield, yellow solid. Mp = 143.6-144.8℃; ^{1}H NMR (400 MHz, CD_3OD) δ 1.92 (t, J = 7.6 Hz, 2H), 3.00 (t, J = 7.6 Hz, 2H), 6.14 (d, J = 10.0 Hz, 2H), 6.92 (d, J = 10.0 Hz, 2H), 8.08 (d, J = 8.8 Hz, 2H), 8.43 (d, J = 8.8 Hz, 2H); ^{13}C NMR (100 MHz, CD_3OD) δ 39.4, 40.9, 69.1, 125.5, 128.5, 129.4, 147.6, 151.5, 153.5, 187.4; IR (film) 3425, 3203, 1670, 1631, 1530, 1352, 1335, 1308, 1279, 1159, 1093, 1004, 869, 852, 747, 716 cm^{-1}; HRMS

(EI): Exact mass calcd for $C_{14}H_{14}N2O_6S$: 338.0573. Found: 338.0572.

***tert*-Butyl 2-(1-hydroxy-4-oxocyclohexa-2,5-dienyl)ethylcarbamate (3d)**

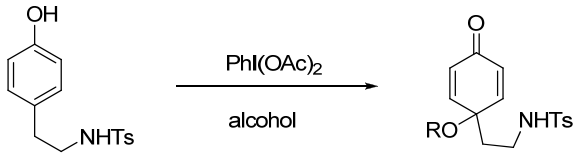


2d **3d**

To a solution of tyramine (4.11 g, 3 mmol) in methanol (50 mL) was added di-*tert*-butyl dicarbonate (7.4 g, 3.4 mmol) slowly and the reaction mixture was stirred at room temperature overnight. The solvent was evaporated, and the residue was diluted with ethyl acetate and washed with water. The organic layer was dried over anhydrous Na_2SO_4 and filtered; the solvent was removed under reduced pressure. The residue was purified by silica gel column chromatography (PE : EtOAc = 2:1) to afford **2d**.[3] 70 % yield, white solid. Mp =71.2-72.5 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.44 (s, 9H), 2.70 (t, J = 7.2 Hz, 2H), 3.30-3.36 (m, 2H), 4.65 (br, 1H), 6.37 (br, 1H), 6.78 (d, J = 8.1 Hz, 2H), 7.01 (d, J = 8.1 Hz, 2H).

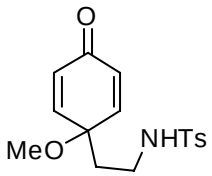
To a solution of **2d** (1.18 g, 5.0 mmol) in CH_3CN/H_2O (20 mL, 4:1) was slowly added $PhI(OAc)_2$ (1.93 g, 6.0 mmol) at 0 ℃. The reaction mixture was stirred for 1h, then dried over anhydrous Na_2SO_4 and filtered. The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography to provide **3d**. 45% yield, yellow solid. Mp = 129.2-130.9℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.43 (s, 9H), 1.93 (t, J = 6.9 Hz, 2H), 3.22-3.25 (m, 2H), 3.61 (br, 1H), 4.93 (br, 1H), 6.16 (d, J = 10.2 Hz, 2H), 6.90 (d, J = 10.2 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 28.3, 36.0, 40.2, 68.7, 79.8, 127.8, 151.0, 156.1, 185.4; IR (film) 3344, 3252, 2971, 1697, 1660, 1617, 1537, 1275, 1216, 1166, 1077, 860, 748 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{13}H_{19}NO_4Na$: 276.1206. Found: 276.1210.

Synthesis of substrates 3e-h



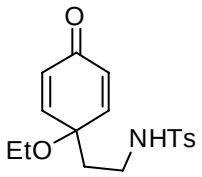
2a **3e-h**

To a solution of **2a** (1.45 g, 5.0 mmol) in the corresponding alcohol (8 mL) was added a solution of $PhI(OAc)_2$ (2.40 g, 7.5 mmol) in CH_2Cl_2 (20 mL) at 0 ℃. The mixture was stirred at room temperature for 10 min. The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography to afford **3**.



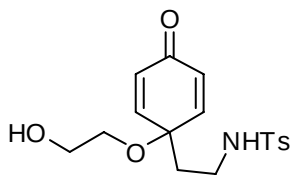
N-(2-(1-Methoxy-4-oxocyclohexa-2,5-dienyl)ethyl)-4-methylbenzenesulfonamide (3e)

24% yield, yellow solid. Mp = 97.6-98.7 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.87 (t, J = 6.6 Hz, 2H), 2.44 (s, 3H), 3.08 (dt, J = 6.0, 6.6 Hz, 2H), 3.34 (s, 3H), 5.20 (t, J = 6.0 Hz, 1H), 6.32 (d, J = 10.2 Hz, 2H), 6.68 (d, J = 10.2 Hz, 2H), 7.32 (d, J = 8.1 Hz, 2H), 7.74 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 38.8, 38.9, 53.1, 74.7, 127.0, 129.8, 131.5, 136.6, 143.6, 149.5, 184.7; IR (film) 3205, 2928, 1663, 1623, 1452, 1324, 1150, 1089, 1071, 947, 865, 833, 814, 664 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{16}H_{19}NO_4S$: 321.1035. Found: 321.1032.



N-(2-(1-Ethoxy-4-oxocyclohexa-2,5-dienyl)ethyl)-4-methylbenzenesulfonamide (3f)

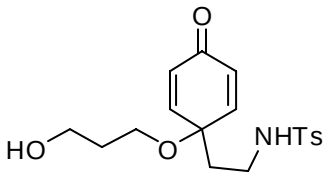
11% yield, yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.15 (t, J = 6.9 Hz, 3H), 1.87 (t, J = 6.6 Hz, 2H), 2.44 (s, 3H), 3.06 (dt, J = 6.0, 6.6 Hz, 2H), 3.32 (q, J = 6.9 Hz, 2H), 5.49 (t, J = 6.0 Hz, 1H), 6.27 (d, J = 10.2 Hz, 2H), 6.72 (d, J = 10.2 Hz, 2H), 7.32 (d, J = 8.1 Hz, 2H), 7.73 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 15.8, 21.4, 38.7, 38.8, 61.0, 74.2, 126.9, 129.6, 130.8, 136.5, 143.4, 150.2, 184.8; IR (film) 3282, 2976, 2927, 1669, 1628, 1329, 1156, 1088, 1064, 859, 814, 730, 709, 661 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{17}H_{21}NO_4S$: 335.1191. Found: 335.1189.



N-(2-(1-(2-Hydroxyethoxy)-4-oxocyclohex-2-enyl)ethyl)-4-methylbenzenesulfonamide (3g)

38% yield, colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.85-1.90 (m, 2H), 2.39 (s, 3H), 2.99-3.06 (m, 2H), 3.34-3.37 (m, 2H), 3.65-3.68 (m, 2H), 5.84 (t, J = 5.7 Hz, 1H), 6.24 (d, J = 10.2 Hz, 2H), 6.74 (d, J = 10.2 Hz, 2H), 7.26 (d, J = 8.4 Hz, 2H), 7.70 (d, J = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.4, 38.6, 38.7, 61.6, 66.5,

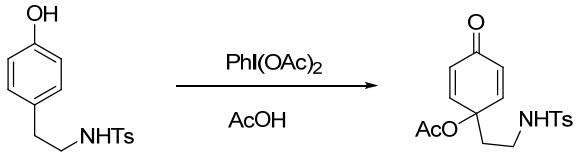
74.2, 126.9, 129.7, 130.9, 136.4, 143.5, 149.8, 184.8; IR (film) 3517, 3272, 2925, 1704, 1667, 1396, 1323, 1155, 1089, 857, 814, 659 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{17}H_{21}NO_5S$: 351.1140. Found: 351.1138.



N-(2-(1-(3-Hydroxypropoxy)-4-oxocyclohexa-2,5-dienyl)ethyl)-4-methylbenzenesulfonamide (3h)

29% yield, pale yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.79 (quintet, J = 5.7 Hz, 2H), 1.87 (t, J = 6.3 Hz, 2H), 2.33 (br, 1H), 2.44 (s, 3H), 3.07 (app q, J = 6.0 Hz, 2H), 3.43-3.47 (m, 2H), 3.76-3.79 (m, 2H), 6.03 (t, J = 6.3 Hz, 1H), 6.30 (d, J = 10.2 Hz, 2H), 6.77 (d, J = 10.2 Hz, 2H), 7.32 (d, J = 8.1 Hz, 2H), 7.35 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 32.4, 38.8, 38.9, 60.7, 63.9, 74.4, 127.0, 129.7, 131.0, 136.7, 143.4, 149.9, 184.7; IR (film) 3521, 3272, 2926, 2875, 1666, 1624, 1599, 1494, 1323, 1154, 1081, 861, 814, 659 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{18}H_{24}NO_5S$: 366.1370. Found: 366.1373.

Synthesis of 1-(2-(4-methylphenylsulfonamido)ethyl)-4-oxocyclohexa-2,5-dienyl acetate (3i)

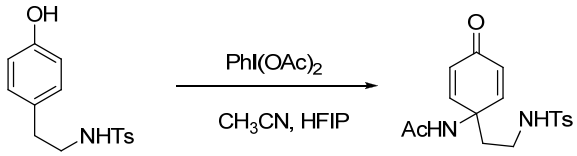


2a **3i**

A solution of $PhI(OAc)_2$ (1.06 g, 3.3 mmol) in AcOH (25 mL) was added dropwise to a vigorously stirred solution of **2a** (873 mg, 3 mmol) in AcOH (25 mL) at room temperature. The mixture was stirred for 1h, and then it was diluted with EtOAc, washed with Na_2CO_3 (aq.) and brine. The oragnic layer was separated and dried over anhydrous Na_2SO_4. The solvent was removed under reduced presure and the residue was purified by silica gel column chromatography to afford **3i**. 25% yield, yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.02 (t, J = 6.6 Hz, 2H), 2.06 (s, 3H), 2.44 (s, 3H), 3.01 (dt, J = 6.6, 7.8 Hz, 2H), 5.18 (t, J = 6.0 Hz, 1H), 6.24 (d, J = 10.2 Hz, 2H), 6.82 (d, J = 10.2 Hz, 2H), 7.31 (d, J = 8.4 Hz, 2H), 7.71 (d, J = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 20.9, 21.2, 37.8, 39.1, 75.0, 126.7, 128.7, 129.6, 136.1, 143.6, 147.4, 168.9, 184.6; IR (film) 3277, 2926, 1747, 1665, 1626, 1598, 1494, 1434, 1397, 1368, 1327, 1229, 1155, 1090, 1015,

932, 855, 814, 659 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{17}H_{19}NO_5SNa$: 372.0876. Found: 372.0883.

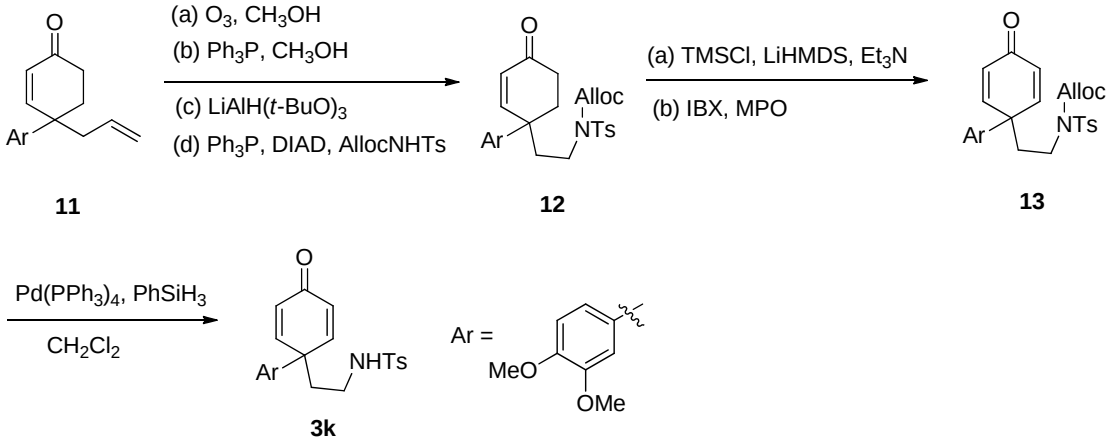
Synthesis of N-(1-(2-(4-methylphenylsulfonamido)ethyl)-4-oxocyclohexa-2,5-dienyl) acetamide (3j) [5]



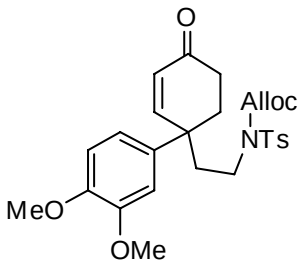
2a **3j**

A solution of $PhI(OAc)_2$ (1.9 g, 6.0 mmol) in HFIP (4 mL) was added dropwise to a vigorously stirred solution of **2a** (1.45 g, 5.0 mmol) in MeCN (17 mL) and HFIP (12 mL) at 15 °C. The mixture was stirred for 20 min and then was concentrated. The residue was purified by silica gel column chromatography to afford **3j**.[5] 37% yield, white solid. ^{1}H NMR (300 MHz, acetone-d^6) 1.82 (s, 3H), 2.08-2.13 (m, 2H), 2.38 (s, 3H), 2.83-2.86 (m, 2H), 6.08 (d, J = 10.2 Hz, 2H), 6.41 (br, 1H), 6.90 (d, J = 10.2 Hz, 2H), 7.34 (d, J = 8.4 Hz, 2H), 7.45 (br, 1H), 7.65 (d, J = 8.4 Hz, 2H); IR (film) 3375, 1659, 1626, 1593, 1529, 1395, 1320, 1288, 1274, 1185, 1152, 1094, 1037, 1008, 927, 659 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{17}H_{21}N_2O_4S$: 349.1217. Found: 349.1223.

Synthesis of N-(2-(1-(3,4-dimethoxyphenyl)-4-oxocyclohexa-2,5-dienyl)ethyl)-4-methyl benzenesulfonamide (3k)



11 **12** **13** **3k**

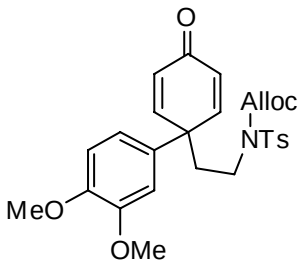


Allyl 2-(1-(3,4-dimethoxyphenyl)-4-oxocyclohex-2-enyl)ethyl (tosyl) carbamate (12)

To a solution of **11** (1.36 g, 5.0 mmol) in CH_3OH (30 mL) at -78 ℃ was bubbled O_3 until the starting material **11** disappeared. The reaction was purged with argon for 10 min at -78 ℃, and then PPh_3 (2.62 g, 10 mmol) was added. The reaction was stirred at room temperature for 30 min. The solvent was removed under reduced presure and the residue was purified by short silica gel column chromatography (PE: EtOAc = 2:1) to afford aldehyde (994 mg, 52% yield, containing 25 mol% Ph_3PO).

To a solution of the above aldehyde (902 mg, containing 25 mol% Ph_3PO) in THF was added $LiAlH(O^tBu)_3$ (955 mg, 3.75 mmol) at 0℃. The reaction mixture was stirred for 5 min. The mixture was quenched with buffer solution (300 mL, pH = 7) and extracted with EtOAc. The combined organic layer was washed with brine, dried over anhydrous Na_2SO_4. The solvent was removed under reduced presure to afford alcohol that was used directly in the next step.

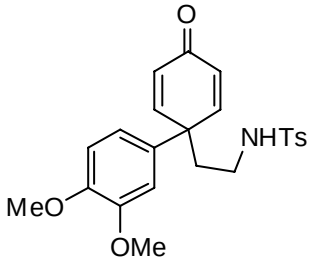
To a solution of the above alcohol in THF (20 mL) was added Ph_3P (891 mg, 3.3 mmol), allyl tosylcarbamate (763 mg, 3.0 mmol) and DIAD (687 mg, 3.3 mmol) at 0℃. The reaction mixture was stirred at room temperature for 3 h. The solvent was removed under reduced presure and the residue was purified by silica gel column chromatography (PE: EtOAc = 2:1) to afford **7** (960 mg, 69% yield over two steps). ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.04-2.52 (m, 6H), 2.42 (m, 3H), 3.65-3.78 (m, 2H), 3.88 (s, 3H), 3.93 (s, 3H), 4.55 (d, J = 5.4 Hz, 2H), 5.21-5.26 (m, 2H), 5.70-5.83 (m, 1H), 6.23 (d, J = 9.9 Hz, 1H), 6.85 (s, 2H), 6.94 (s, 1H), 7.17 (d, J = 9.9 Hz, 1H), 7.29 (d, J = 8.1 Hz, 2H), 7.76 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 34.1, 36.7, 40.3, 42.6, 43.7, 55.7, 55.8, 67.6, 109.5, 110.7, 119.1, 119.2, 128.1, 129.3, 129.8, 130.7, 133.8, 136.2, 144.7, 147.9, 149.2, 151.7, 153.6, 199.1; IR (film) 2926, 2854, 1729, 1680, 1595, 1517, 1454, 1353, 1255, 1164, 1087, 1024, 852, 811, 766, 738, 703, 667 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{27}H_{31}NO_7S$: 513.1821. Found: 513.1819.



Allyl 2-(1-(3,4-dimethoxyphenyl)-4-oxocyclohexa-2,5-dienyl) ethyl(tosyl)carbamate (13)

To a solution of **12** (1.54 g, 3.0 mmol) in THF (60 mL) at -78 ℃ under Ar atmosphere was added Et_3N (8.28 mL, 60.0 mmol), TMSCl (7.32 mL, 57.0 mmol). The reaction was stirred at -78 ℃ for 30 min. The mixture was quenched with buffer solution (pH = 7.4) and extracted with EtOAc. The conbined organic layer was washed with brine, dried over anhydrous Na_2SO_4. The solvent was removed under reduced presure to provide TMS enol ether that was used directly in the next step.

To a flask containing DMSO (12 mL) were added IBX (1.16 g, 4.2 mmol) and MPO (528 mg, 4.2 mmol). This mixture was stirred at ambient temperature to result a clear solution (about 30 min). Then this solution was added in one portion at ambient temperature to a solution of the above crude TMS enol ether in DMSO (12 mL). The reaction was stirred at room temperature for 6h. The mixture was quenched with water and extracted with EtOAc. The combined organic layer was washed with brine, dried over anhydrous Na_2SO_4. The solvent was removed under reduced presure and the residue was purified by silica gel column chromatography (PE: EtOAc = 2:1) to provide dienenone **13** (982 mg, 64% yield over two steps).^{1}H NMR (400 MHz, $CDCl_3$) δ 2.44 (s, 3H), 2.58-2.62 (m, 2H), 3.77-3.81 (m, 2H), 3.87 (s, 6H), 4.58 (d, J = 6.0 Hz, 2H), 5.22-5.28 (m, 2H), 5.74-5.80 (m, 1H), 6.41 (d, J = 6.8 Hz, 2H), 6.81-6.92 (m, 3H), 6.99 (d, J = 6.8 Hz, 2H), 7.31 (d, J = 8.4 Hz, 2H), 7.79 (d, J = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.4, 36.5, 43.8, 47.1, 55.8, 55.9, 67.7, 109.5, 111.3, 118.5, 119.3, 128.0, 128.6, 129.3, 130.5, 130.6, 136.0, 144.8, 148.6, 149.2, 151.7, 153.1, 185.6 ; IR (film) 2926, 2927, 1719, 1685, 1596, 1517, 1463, 1412, 1335, 1258, 1159, 1098, 1023, 935, 848, 806, 730, 659 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{27}H_{29}NO_7S$: 511.1665. Found: 511.1668.

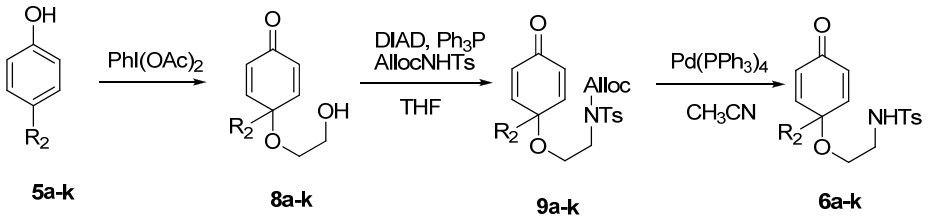


N-(2-(1-(3,4-Dimethoxyphenyl)-4-oxocyclohexa-2,5-dienyl)ethyl) -4-methylbenzenesulfonamide (3k)

To a solution of **13** (540 mg，1.06 mmol) in CH_2Cl_2 (10 mL) was added $PhSiH_3$ (571 mg, 5.28 mmol) and $Pd(PPh_3)_4$ (133 mg, 0.10 mmol). The reaction mixture was stirred at room temperature for 10 min and quenched with water. The mixture was extacted with CH_2Cl_2. The combined organic layer

was washed with brine, dried over anhydrous Na_2SO_4. The solvent was removed under reduced presure and the residue was purified by preparative TLC followed by preparative HPLC to afford **3h** (166 mg, 37% yield). ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.35-2.42 (m, 2H), 2.42 (s, 3H), 2.85-2.92 (m, 2H), 3.81 (s, 3H), 3.85 (s, 3H), 5.31 (t, J = 6.0 Hz, 1H), 6.31 (d, J = 10.2 Hz, 2H), 6.70 (s, 1H), 6.81 (s, 2H), 6.84 (d, J = 10.2 Hz, 2H), 7.29 (d, J = 8.1 Hz, 2H), 7.69 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.4, 37.4, 39.2, 47.3, 55.8, 55.9, 109.6, 111.4, 118.5, 126.9, 128.6, 129.8, 130.7, 136.5, 143.6, 148.6, 149.2, 153.4, 185.8; IR (film) 3268, 2969, 1738, 1661, 1621, 1517, 1401, 1365, 1258, 1233, 1157, 1092, 1024, 869 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{23}H_{25}NO_5S$: 427.1453. Found: 427.1454.

2.3 General procedure for preparation of substrates 6a-k

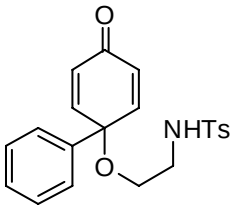


5a-k **8a-k** **9a-k** **6a-k**

Compounds **8a-k** were prepared according to the literature[2].

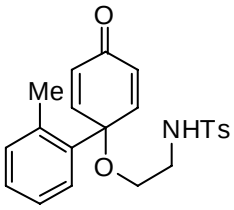
To a solution of **8** (2 mmol), AllocNHTs (2.2 mmol) and Ph_3P (2.5 mmol) in THF (8 mL) was added dropwise DIAD (2.2 mmol) at 0°C. The mixture was stirred at room temperature until the starting material **8** disappeared (monitored by TLC). Then it was diluted with water, extracted with EtOAc. The organic layer was washed with brine and dried over anhydrous Na_2SO_4. The solvent was removed under reduced presure and the residue was purified by silica gel column chromatography to provide **9** (containing diisopropyl hydrazine-1,2-dicarboxylate) that was used directly in the next step.

To a solution of **9** obtained above and piperidine (510 mg, 6 mmol) in CH_3CN (12 mL) was added $Pd(PPh_3)_4$ (50 mg, 0.04 mmol). The reaction mixture was stirred at room temperature for 10 min. Then it was diluted with water and extracted with ethyl acetate. The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4 and filtered. The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography and recrystallization from PE/ EtOAc to provide **6.**



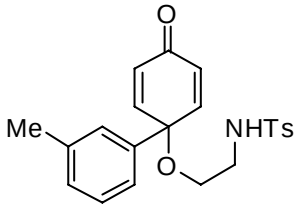
4-Methyl-N-(2-(4-oxo-1-phenylcyclohexa-2,5-dienyloxy)ethyl)benzenesulfonamide (6a)

52% yield over two steps, pale yellow solid. Mp = 146.6-147.5 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.43 (s, 3H), 3.25 (dt, J = 5.4, 5.7 Hz, 2H), 3.54 (t, J = 5.1 Hz, 2H), 5.28 (t, J = 6.3 Hz, 1H), 6.30 (d, J = 10.5 Hz, 2H), 6.67 (d, J = 10.5 Hz, 2H), 7.27-7.38 (m, 7H), 7.77 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 43.3, 63.4, 76.1, 125.5, 127.0, 128.5, 128.8, 129.7, 129.8, 137.0, 137.6, 143.6, 149.7, 185.2; IR (film) 3298, 1665, 1622, 1321, 1156, 1077, 1049, 957, 854, 731, 701, 666 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{21}H_{21}NO_4S$: 383.1191. Found: 383.1192.



4-Methyl-N-(2-(4-oxo-1-o-tolylcyclohexa-2,5-dienyloxy)ethyl)benzenesulfonamide (6b)

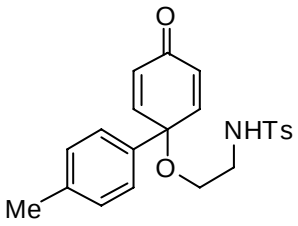
42% yield over two steps, pale yellow solid. Mp = 116.6-117.4 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.32 (s, 3H), 2.42 (s, 3H), 3.22 (dt, J = 5.1, 5.7 Hz, 2H), 3.46 (t, J = 5.4 Hz, 2H), 5.21 (t, J = 6.0 Hz, 1H), 6.35 (d, J = 10.2 Hz, 2H), 6.69 (d, J = 10.2 Hz, 2H), 7.11-7.24 (m, 3H), 7.28 (d, J = 8.4 Hz, 2H), 7.50-7.53 (m, 1H), 7.74 (d, J = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.0, 21.4, 43.2, 62.2, 75.5, 126.0, 126.4, 126.9, 128.6, 129.7, 130.6, 132.6, 135.6, 136.0, 137.0, 143.5, 147.7, 185.1; IR (film) 3271, 1662, 1624, 1380, 1349, 1330, 1164, 1092, 1068, 1017, 952, 865, 816, 760, 739, 690 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{22}H_{23}NO_4S$: 397.1348. Found: 397.1352.



4-Methyl-N-(2-(4-oxo-1-m-tolylcyclohexa-2,5-dienyloxy)ethyl)benzenesulfonamide (6c)

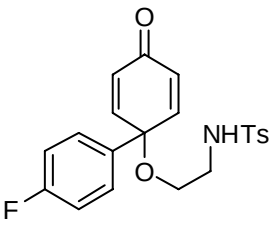
34% yield over two steps, white solid. Mp = 170.9-171.5 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.34 (s, 3H), 2.43 (s, 3H), 3.25 (dt, J = 5.4, 6.0 Hz, 2H), 3.54 (t, J = 5.4 Hz, 2H), 4.97 (d, J = 6.3 Hz, 1H), 6.31 (d, J = 10.2 Hz, 2H), 6.67 (d, J = 10.2 Hz, 2H), 7.12-7.26 (m, 4H), 7.30 (d, J = 8.4 Hz, 2H), 7.76 (d, J = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 43.3, 63.4, 76.1, 122.6, 126.1, 127.0, 128.7, 129.3, 129.7, 129.8, 137.0, 137.5, 138.6, 143.6, 149.7, 185.2; IR (film) 3264, 1666, 1624, 1600, 1329, 1163, 1080, 957, 871, 813, 735, 708, 654 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{22}H_{23}NO_4SNa$: 420.1240.

Found: 420.1251.



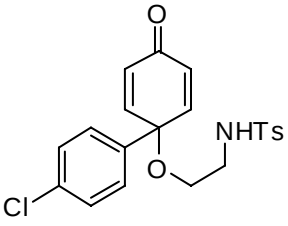
4-Methyl-N-(2-(4-oxo-1-p-tolylcyclohexa-2,5-dienyloxy)ethyl)benzenesulfonamide (6d)

42% yield over two steps, white solid. Mp = 161.5-162.2 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.33 (s, 3H), 2.43 (s, 3H), 3.25 (app q, J = 5.4 Hz, 2H), 3.53 (t, J = 5.1 Hz, 2H), 5.08 (t, J = 6.0 Hz, 1H), 6.29 (d, J = 10.2 Hz, 2H), 6.66 (d, J = 10.2 Hz, 2H), 7.14 (d, J = 8.4 Hz, 2H), 7.24 (d, J = 8.4 Hz, 2H), 7.30 (d, J = 8.1 Hz, 2H), 7.77 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.0, 21.4, 43.3, 63.3, 76.0, 125.4, 126.9, 129.4, 129.6, 129.7, 134.6, 137.0, 138.4, 143.5, 149.8, 185.2; IR (film) 3281, 1660, 1621, 1596, 1409, 1396, 1326, 1163, 1092, 1075, 954, 856, 833, 811, 708 cm^{-1}; HRMS(MALDI): Exact mass calcd for $C_{22}H_{23}NO_4SNa$: 420.1240. Found: 420.1255.



N-(2-(1-(4-Fluorophenyl)-4-oxocyclohexa-2,5-dienyloxy)ethyl)-4-methylbenzenesulfonamide (6e)

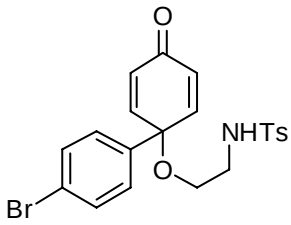
50% yield over two steps, pale yellow solid. Mp = 141.5-142.6 ℃. ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.4 (s, 3H), 3.25 (dt, J = 5.4, 5.7 Hz, 2H), 3.54 (t, J = 5.1 Hz, 2H), 5.14 (t, J = 6.0 Hz, 1H), 6.31 (d, J = 10.2 Hz, 2H), 6.64 (d, J = 10.2 Hz, 2H), 6.99-7.04 (m, 2H), 7.27-7.37 (m, 4H), 7.77 (d, J = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.4, 43.2, 63.5, 75.7, 115.5 (d, J = 21.8 Hz), 126.9, 127.4 (d, J = 8.3 Hz), 129.7, 129.8, 133.4 (d, J = 2.9 Hz), 137.0, 143.5, 149.5, 162.5 (d, J = 246.5 Hz), 185.0; ^{19}F NMR (282 MHz, $CDCl_3$) δ -113.59; IR (film) 3307, 1665, 1622, 1503, 1321, 1220, 1157, 1098, 1077, 1055, 954, 857, 841, 815, 664 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{21}H_{20}NO_4FSNa$: 424.0989. Found: 424.0999.



N-(2-(1-(4-Chlorophenyl)-4-oxocyclohexa-2,5-dienyloxy)ethyl)-4-methylbenzenesulfonamide (6f)

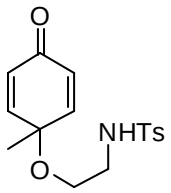
41% yield over two steps, pale yellow solid. Mp = 148.9-149.7 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.43 (s, 3H), 3.25 (dt, J = 5.1, 5.7 Hz, 2H), 3.53 (t, J = 5.1 Hz, 2H), 5.44 (t, J = 6.0 Hz, 1H), 6.31 (d, J = 10.2 Hz, 2H), 6.63 (d, J = 10.2 Hz,

2H), 7.25-7.33 (m, 6H), 7.77 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 43.2, 63.5, 75.8, 126.9, 127.0, 128.9, 129.8, 130.1, 134.3, 136.2, 137.0, 143.6, 149.2, 184.9; IR (film) 3284, 1666, 1489, 1413, 1398, 1326, 1164, 1076, 1055, 1015, 858, 827, 812, 735 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{21}H_{20}NO_4SClNa$: 440.0694. Found: 440.0707.



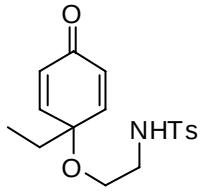
N-(2-(1-(4-Bromophenyl)-4-oxocyclohexa-2,5-dienyloxy)ethyl)-4-methylbenzenesulfonamide (6g)

40% yield over two steps, yellow solid. Mp = 129.1-130.5 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.44 (s, 3H), 3.25 (dt, J = 5.1, 5.4 Hz, 2H), 3.54 (t, J = 5.1 Hz, 2H), 5.15 (br, 1H), 6.32 (d, J = 9.9 Hz, 2H), 6.63 (d, J = 9.9 Hz, 2H), 7.23 (d, J = 8.1 Hz, 2H), 7.30 (d, J = 8.1 Hz, 2H), 7.43 (d, J = 8.1 Hz, 2H), 7.75 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 43.2, 63.6, 75.8, 122.5, 127.0, 127.4, 129.8, 130.1, 131.8, 136.7, 137.0, 143.6, 149.1, 184.9; IR (film) 3288, 2923, 1667, 1624, 1411, 1326, 1164, 1074, 1055, 1011, 975, 857, 827, 813, 689 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{21}H_{21}NO_4SBr$: 462.0369. Found: 462.0381.



4-Methyl-N-(2-(1-methyl-4-oxocyclohexa-2,5-dienyloxy)ethyl)benzenesulfonamide (6h)

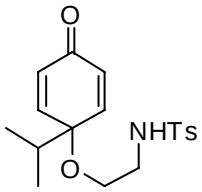
45% yield over two steps, white solid. Mp = 92.8-94.1 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.37 (s, 3H), 2.44 (s, 3H), 3.10 (dt, J = 5.4, 5.7 Hz, 2H), 3.30 (d, J = 5.7 Hz, 2H), 5.12 (br, 1H), 6.22 (d, J = 10.2 Hz, 2H), 6.64 (d, J = 10.2 Hz, 2H), 7.32 (d, J = 8.4 Hz, 2H), 7.76 (d, J = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 26.1, 43.2, 63.7, 72.4, 127.0. 129.7, 130.3, 137.0, 143.6, 151.0, 184.8; IR (film) 3210, 1660, 1620, 1441, 1325, 1155, 1089, 1077, 1055, 972, 863, 810, 663 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{16}H_{19}NO_4S$: 321.1035. Found: 321.1030.



N-(2-(1-Ethyl-4-oxocyclohexa-2,5-dienyloxy)ethyl)-4-methylbenzenesulfonamide (6i)

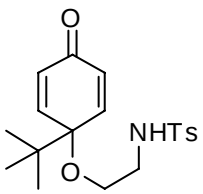
69% yield over two steps, yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.80 (t, J

= 7.5 Hz, 3H), 1.72 (q, *J* = 7.5 Hz, 2H), 2.44 (s, 3H), 3.09-3.14 (m, 2H), 3.33 (d, *J* = 5.4 Hz, 2H), 4.83 (br, 1H), 6.30 (d, *J* = 8.1 Hz, 2H), 6.57 (d, *J* = 8.1 Hz, 2H), 7.32 (d, *J* = 8.4 Hz, 2H), 7.75 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 7.6, 21.4, 31.9, 43.2, 63.4, 76.1, 127.0, 129.7, 131.4, 137.0, 143.5, 150.2, 185.2; IR (film) 3254, 2926, 1666, 1631, 1323, 1161, 1076, 952, 861, 811, 730, 653 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{17}H_{21}NO_4S$: 335.1191. Found: 335.1192.



N-(2-(1-*iso*-Propyl-4-oxocyclohexa-2,5-dienyloxy)ethyl)-4-methylbenzenesulfonamide (6j)

33% yield over two steps, white solid. Mp = 91.5-92.2 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.87 (d, *J* = 7.2 Hz, 6H), 1.90 (heptet, *J* = 7.2 Hz, 1H), 2.44 (s, 3H), 3.09-3.14 (m, 2H), 3.28-3.32 (m, 2H), 5.12 (t, *J* = 5.7 Hz, 1H), 6.31 (d, *J* = 7.5 Hz, 2H), 6.59 (d, *J* = 7.5 Hz, 2H), 7.32 (d, *J* = 8.4 Hz, 2H), 7.76 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 16.9, 21.5, 36.4, 43.3, 63.3, 78.0, 127.0, 129.7, 132.1, 137.0, 143.5, 149.3, 185.3; IR (film) 3232, 2967, 1659, 1621, 1328, 1156, 1087, 1063, 1017, 950, 876, 849, 804, 663 cm^{-1}; HRMS (ESI): Exact mass calcd for $C_{18}H_{23}NO_4SNa$: 372.1240. Found: 372.1248.



N-(2-(1-*tert*-Butyl-4-oxocyclohexa-2,5-dienyloxy)ethyl)-4-methylbenzenesulfonamide (6k)

31% yield over two steps, white solid. Mp = 90.6-91.8 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.95 (s, 9H), 2.44 (s, 3H), 3.14 (dt, *J* = 5.4, 6.0 Hz, 2H), 3.28 (t, *J* = 5.4 Hz, 2H), 4.99 (t, *J* = 6.0 Hz, 1H), 6.31 (d, *J* = 8.7 Hz, 2H), 6.74 (d, *J* = 8.7 Hz, 2H), 7.32 (d, *J* = 8.1 Hz, 2H), 7.76 (d, *J* = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 25.5, 39.4, 43.5, 63.4, 79.3, 127.0, 129.7, 132.1, 137.1, 143.6, 149.5, 184.6; IR (film) 3225, 2958, 2872, 1661, 1619, 1328, 1155, 1063, 858, 810, 660 cm^{-1}; HRMS (ESI): Exact mass calcd for $C_{19}H_{25}NO_4SNa$: 386.1397. Found: 386.1406.

References:

1 Vakulya, B.; Varga, S.; Csampai, A.; Soos, T. *Org. Lett.* **2005**, *7*, 1967.

2 Gu, Q.; Rong, Z.-Q.; Zheng, C.; You, S.-L. *J. Am. Chem. Soc.* **2010**, *132*, 4056.

3 Kuglstatter, A.; Stahl, M.; Peters, J.-U.; Huber, W.; Stihle, M.; Schlatter, D.; Benz, J.; Ruf, A.;

Roth, D.; Enderle, T.; Hennig, M. *Bioorg. Med. Chem. Lett.* **2008**, *18*, 1304.

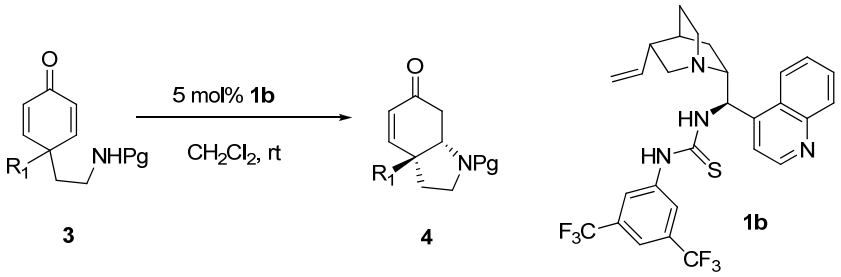
4 Cuny, G. D. *Tetrahedron Lett.* **2004**, *45*, 5167.

5 Liang, H.; Ciufolini, M. A. *J. Org. Chem.* **2008**, *73*, 4299.

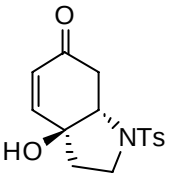
6 Taber, D. F.; He, Y. *J. Org. Chem.* **2005**, *70*, 7711.

7 Xing, D.; Yang, D. *Org. Lett.* **2010**, *12*, 1068.

2.4 General procedure for asymmetric aza-Michael reaction

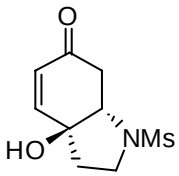


To a flame dried Schlenk flask were added compound **3** (0.2 mmol), CH_2Cl_2 (2 mL) and catalyst **1b** (5.64 mg, 0.01 mmol). The mixture was stirred at room temperature until the starting material disappeared (monitored by TLC). The solvent was removed under reduced pressure, and the residue was purified by preparative TLC to afford product **4**.



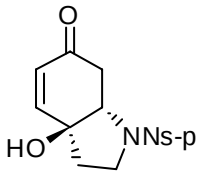
(3aS,7aS)-3a-Hydroxy-1-tosyl-3,3a,7,7a-tetrahydro-1H-indol-6(2H)-one (4a)

White solid, 94% yield, 97% *ee*. $[\alpha]_D^{20}$ = + 320° (*c* = 0.5, acetone); Mp = 127.8-128.9 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.03 (s, 1H), 2.06-2.16 (m, 2H), 2.43 (s, 3H), 2.55 (dd, *J* = 10.5, 16.8 Hz, 1H), 3.04 (dd, *J* = 6.3, 16.8 Hz, 1H), 3.45-3.52 (m, 1H), 3.61-3.68 (m, 1H), 3.95 (dd, *J* = 6.0, 10.5 Hz, 1H), 5. 97 (d, *J* = 10.2 Hz, 1H), 6.69 (d, *J* = 10.2 Hz, 1H), 7.32 (d, *J* = 7.8 Hz, 2H), 7.73 (d, *J* = 7.8 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 36.0, 44.4, 47.1, 66.3, 76.2, 127.5, 129.0, 129.7, 133.7, 143.9, 148.4, 196.7; IR (film) 3358, 1658, 1341, 1160, 1144, 1118, 1088, 1046, 1030, 892, 743, 718 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{15}H_{17}NO_4S$: 307.0878. Found: 307.0876. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (minor) = 10.81 min, t_R (major) = 24.55 min.



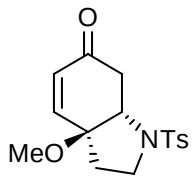
(3aS,7aS)-3a-hydroxy-1-(methylsulfonyl)-3,3a,7,7a-tetrahydro-1H-indol-6(2H)-one (4b)

White solid, 26% yield, 80% *ee*. $[\alpha]_D^{20}$ = + 75.0° (*c* = 0.25, CH_3OH); Mp = 155.0-156.1 ℃; ^{1}H NMR (300 MHz, CD_3OD) δ 2.18-2.34 (m, 2H), 2.62-2.71 (m, 1H), 2.78-2.85 (m, 1H), 2.93 (s, 3H), 3.58-3.63 (m, 2H), 3.96 (dd, *J* = 6.0, 10.5 Hz, 1H), 5.98 (d, *J* = 10.2 Hz, 1H), 6.88 (d, *J* = 10.2 Hz, 1H); ^{13}C NMR (75 MHz, CD_3OD) δ 34.2, 37.0, 45.5, 67.7, 77.1, 129.2, 151.3, 199.0; IR (film) 3474, 1673, 1318, 1287, 1253, 1195, 1150, 1103, 1086, 1052, 1024, 979, 967, 890, 818, 759 cm^{-1}; HRMS (EI): Exact mass calcd for $C_9H_{13}NO_4S$: 231.0565. Found: 231.0561. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (minor) = 8.81 min, t_R (major) = 13.19 min.



(3aS,7aS)-3a-Hydroxy-1-(4-nitrophenylsulfonyl)-3,3a,7,7a-tetrahydro-1H-indol-6(2H)-one (4c)

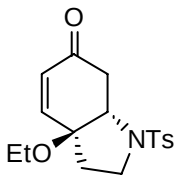
White solid, 75% yield, 87% *ee*.. $[\alpha]_D^{20}$ = + 338° (*c* = 0.2, CH_3OH); Mp = 212.8-213.4 ℃; ^{1}H NMR (300 MHz, CD_3OD) δ 1.97-1.99 (m, 1H), 2.21-2.24 (m, 1H), 2.67-2.76 (m, 1H), 2.88-2.95 (m, 1H), 3.40-3.43 (m, 1H), 3.65-3.68 (m, 1H), 3.92-3.95 (m, 1H), 5.92 (d, *J* = 10.2 Hz, 1H), 5.72 (d, *J* = 10.2 Hz, 1H), 8.09 (d, *J* = 9.0 Hz, 2H), 8.40 (d, *J* = 9.2 Hz, 2H); ^{13}C NMR (75 MHz, CD_3OD) δ 36.7, 45.5, 68.0, 76.8, 125.2, 129.2, 130.3, 143.8, 151.1, 198.6; IR (film) 3327, 2472, 1662, 1532, 1346, 1300, 1171, 1145, 1116, 1105, 1092, 1051, 1032, 1007, 988, 892, 738, 683, 628 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{14}H_{14}N_2O_6S$: 338.0573. Found: 338.0575. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (minor) = 19.84 min, t_R (major) = 36.28 min.



(3aS,7aS)-3a-Methoxy-1-tosyl-3,3a,7,7a-tetrahydro-1H-indol-6(2H)-one (4e)

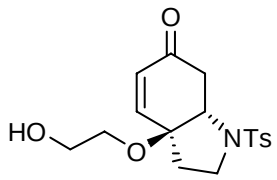
Yellow oil, 83% yield, 94% *ee*. $[\alpha]_D^{20}$ = + 320.0° (*c* = 0.5, acetone); ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.08-2.16 (m, 2H), 2.44 (s, 3H), 2.60 (dd, *J* = 10.5, 16.5 Hz, 1H), 2.75 (s, 3H), 3.12 (dd, *J* = 6.6, 10.5 Hz, 1H), 3.38-3.47 (m, 1H), 3.66-3.71 (m, 1H), 4.10

(dd, *J* = 6.6, 10.5 Hz, 1H), 6.10 (d, *J* = 10.5 Hz, 1H), 6.65 (d, *J* = 10.5 Hz, 1H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.75 (d, *J* = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 35.5, 45.3, 47.4, 50.9, 59.4, 81.8, 127.5, 129.6, 132.0, 134.1, 143.9, 147.0, 196.2; IR (film) 2940, 1683, 1597, 1443, 1383, 1159, 1084, 1068, 1029, 1015, 927, 730, 708, 660, 612 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{16}H_{19}NO_4S$: 321.1035. Found: 321.1032. The enantiomeric ratio was determined by Daicel Chiralcel OD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 19.87 min, t_R (minor) = 26.75 min.



(3aS,7aS)-3a-Ethoxy-1-tosyl-3,3a,7,7a-tetrahydro-1H-indol-6(2H)-one (4f)

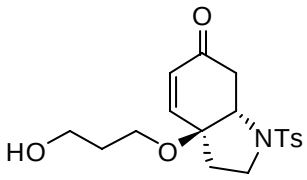
White solid, 89% yield, 90% *ee*. $[\alpha]_D^{20}$ = + 219.0° (*c* = 0.5, acetone); Mp = 102.3-103.5 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.68 (t, *J* = 6.9 Hz, 3H), 2.09-21.15 (m, 2H), 2.43 (s, 3H), 2.56-2.65 (m, 1H), 2.80-2.85 (m, 1H), 3.07-3.18 (m, 2H), 3.40-3.45 (m, 1H), 3.67-3.72 (m, 1H), 4.08 (dd, *J* = 6.6, 10.5 Hz, 1H), 6.07 (d, *J* = 10.2 Hz, 1H), 6.66 (d, *J* = 10.2 Hz, 1H), 7.33 (d, *J* = 8.1 Hz, 2H), 7.75 (d, *J* = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 14.9, 21.4, 35.5, 45.5, 47.5, 58.8, 60.1, 81.3, 127.5, 129.6, 131.4, 134.1, 143.7, 147.5, 196.4; IR (film) 2926, 1687, 1595, 1444, 1330, 1290, 1196, 1156, 1086, 1066, 1034, 1016, 810, 781, 737, 710, 660 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{17}H_{21}NO_4S$: 335.1191. Found: 335.1197. The enantiomeric ratio was determined by Daicel Chiralcel OD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 18.44 min, t_R (minor) = 24.05 min.



(3aS,7aS)-3a-(2-Hydroxyethoxy)-1-tosyl-3,3a,7,7a-tetrahydro-1H-indol-6(2H)-one (4g)

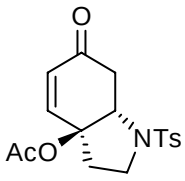
Yellow oil, 88% yield, 89% *ee*. $[\alpha]_D^{20}$ = + 279.4° (*c* = 0.5, acetone); ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.88 (br, 1H), 2.14-2.20 (m, 2H), 2.44 (s, 3H), 2.53-2.62 (m, 1H), 2.96-3.12 (m, 2H), 3.19-3.32 (m, 3H), 3.44-3.47 (m, 1H), 3.63-3.66 (m, 1H), 4.12 (dd, *J* = 6.6, 10.8 Hz, 1H), 6.09 (d, *J* = 10.5 Hz, 1H), 6.72 (d, *J* = 10.5 Hz, 1H), 7.34 (d, *J* = 8.4 Hz, 2H), 7.74 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.4, 34.9, 45.1, 47.3, 60.9, 61.2, 64.8, 81.5, 127.5, 129.6, 131.4, 134.2, 144.0, 146.5, 196.0; IR (film) 3527, 2927, 1682, 1597, 1383, 1159, 1087, 1016, 908, 815, 729, 661 cm^{-1}; HRMS (EI): Exact mass calcd for

$C_{17}H_{21}NO_5S$: 351.1140. Found: 351.1138. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 20.32 min, t_R (minor) = 23.52 min.



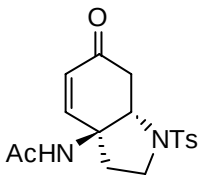
(3aS,7aS)-3a-(3-Hydroxypropoxy)-1-tosyl-3,3a,7,7a-tetrahydro-1 H-indol-6(2H)-one (4h)

Colorless oil, 80% yield, 97% *ee*. $[\alpha]_D^{20}$ = + 220.0^o (*c* = 0.5, acetone). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.36-1.39 (quintet, *J* = 6.0 Hz, 2H), 1.67 (br, 1H), 2.13-2.16 (m, 2H), 2.44 (s, 3H), 2.52-2.59 (m, 1H), 3.04-3.11 (m, 2H), 3.25-3.28 (m, 1H), 3.46-3.52 (m, 3H), 3.63-3.66 (m, 1H)，4.18 (dd, *J* = 6.4, 10.8 Hz, 1H), 6.10 (d, *J* = 10.4 Hz, 1H), 6.70 (d, *J* = 10.4 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 2H), 7.75 (d, *J* = 8.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.5, 32.1, 35.6, 45.2, 47.3, 59.8, 60.0, 61.1, 81.6, 127.5, 129.7, 131.7, 134.7, 143.9, 147.2, 196.1; IR (film) 3541, 2951, 1681, 1597,1475, 1444, 1384, 1340, 1159, 1086, 1066, 1032, 1015, 815, 777, 733, 710, 661 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{18}H_{23}NO_5S$: 365.1297. Found: 365.1294. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 19.65 min, t_R (minor) = 27.47 min.



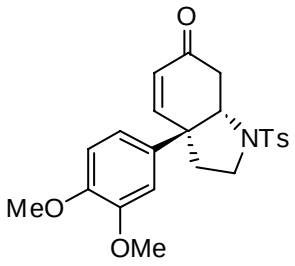
(3aS,7aS)-6-Oxo-1-tosyl-2,3,3a,6,7,7a-hexahydro-1H-indol-3a-yl acetate (4i)

White solid, 75% yield, 89% *ee*. $[\alpha]_D^{20}$ = + 227.0 ^{o} (*c* = 0.5, acetone); Mp = 159.6-160.8 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.46 (s, 3H), 2.24-2.31 (m, 1H), 2.40-2.44 (m, 1H), 2.43 (s, 3H), 2.60 (dd, *J* = 10.2, 17.1 Hz, 1H), 3.18 (dd, *J* = 7.5, 17.1 Hz, 1H), 3.34-3.39 (m, 1H), 3.73-3.79 (m, 1H), 4.46 (dd, *J* = 7.5, 10.2 Hz, 1H), 6.03 (d, *J* = 10.5 Hz, 1H), 6.81 (d, *J* = 10.5 Hz, 1H), 7.35 (d, *J* = 8.4 Hz, 2H), 7.74 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 20.8, 21.4, 35.0, 44.8, 46.8, 62.4, 83.5, 127.7, 129.8, 133.9, 143.8, 144.5, 169.6, 195.2; IR (film) 3052, 2959, 2027, 2854, 2349, 1740, 1687, 1346, 1259, 1233, 1192, 1158, 1088, 1032, 817, 745, 663 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{17}H_{19}NO_5SNa$: 372.0876. Found: 372.0880. The enantiomeric ratio was determined by Daicel Chiralcel OD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (minor) = 26.30 min, t_R (major) = 29.43 min.



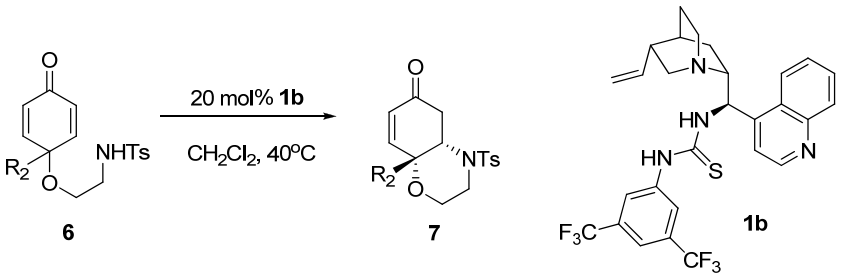
N-((3aS,7aS)-6-oxo-1-tosyl-2,3,3a,6,7,7a-hexahydro-1H-indol-3a-yl)acetamide (4j)

White solid, 70% yield, 99% *ee*. $[\alpha]_D^{20}$ = + 320.0° (*c* = 0.5, CH_3OH); Mp = 245.3-246.5 ℃; ^{1}H NMR (300 MHz, CD_3OD) δ 1.42 (s, 3H), 2.10-2.11 (m, 1H), 2.30-2.34 (m, 1H), 2.43 (s, 3H), 2.79 (dd, *J* = 9.9, 16.5 Hz, 1H), 2.93 (dd, *J* = 6.3, 16.5 Hz, 1H), 3.40-3.43 (m, 1H), 3.66-3.72 (m, 1H), 4.55 (dd, *J* = 6.3, 9.9 Hz, 1H), 5.95 (d, *J* = 10.2 Hz, 1H), 6.60 (d, *J* = 10.2 Hz, 1H), 7.41 (d, *J* = 8.4 Hz, 2H), 7.70 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, CD_3OD) δ 21.4, 22.8, 35.5, 45.3, 47.9, 61.6, 63.4, 128.8, 129.6, 131.1, 135.4, 145.4, 150.9, 173.5, 198.7; IR (film) 3360, 1666, 1593, 1536, 1335, 1288, 1269, 1148, 1095, 1026, 1011, 931, 901, 846, 822, 796, 656 cm^{-1}; HRMS (ESI): Exact mass calcd for $C_{17}H_{21}N_2O_4S$: 349.1217. Found: 349.1218. The enantiomeric ratio was determined by Daicel Chiralpak OJ-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 24.08 min, t_R (minor) = 50.55 min.

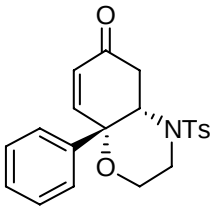


(3aR,7aS)-3a-(3,4-Dimethoxyphenyl)-1-tosyl-3,3a,7,7a-tetrahydro-1H-indol-6(2H)-one (4k)

Colorless oil, 91% yield, 97% *ee*. $[\alpha]_D^{20}$ = +190.3 ° (*c* = 0.6, acetone); ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.92-1.98 (m, 1H), 2.11-2.19 (m, 1H), 2.44 (s, 3H), 2.63 (dd, *J* = 3.6, 16.8 Hz, 1H), 3.10 (dd, *J* = 3.6, 16.8 Hz, 1H), 3.31-3.40 (m, 1H), 3.72-3.77 (m, 1H), 3.77 (s, 3H), 3.86 (s, 3H), 3.86-4.09 (m, 1H), 6.25 (d, *J* = 10.2 Hz, 1H), 6.51 (d, *J* = 2.1 Hz, 1H), 6.62 (d, *J* = 10.2 Hz, 1H), 6.67-6.79 (m, 2H), 7.30 (d, *J* = 8.1 Hz, 2H), 7.68 (d, *J* = 8.1 Hz, 2H); ^{13} C NMR (75 MHz, $CDCl_3$) δ 21.5, 36.9, 39.3, 48.0, 51.3, 55.8, 55.9, 65.9, 109.2, 111.2, 119.0, 127.4, 129.7, 130.4, 131.0, 134.8, 143.8, 148.7, 149.3, 149.8, 196.5; IR (film) 2962, 1685, 1596, 1517, 1463, 1412, 1334, 1258, 1158, 1097, 1023, 934, 847, 805, 728, 658 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{23}H_{25}NO_5S$: 427.1453. Found: 427.1458. The enantiomeric ratio was determined by Daicel Chiralcel AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 26.65 min, t_R (minor) = 33.64 min.

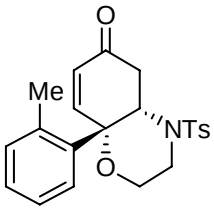


To a flame dried Schlenk flask were added compound **6** (0.2 mmol), CH_2Cl_2 (0.2 mL) and catalyst **1b** (22.6 mg, 0.04 mmol). The mixture was stirred at 40℃ until the starting material disappeared (monitored by TLC). The solvent was removed under reduced pressure, and the residue was purified by preparative TLC to afford product **7**.



(4aS,8aS)-8a-Phenyl-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin -6(8aH)-one (7a)

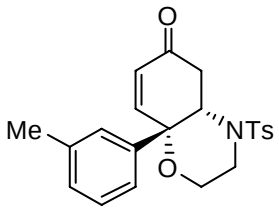
Semisolid, 82% yield, 97 % *ee*. $[\alpha]_D^{20}$ = + 142.0º (*c* = 0.5, acetone); ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.32 (dd, *J* = 4.2, 15.3 Hz, 1H), 2.43 (s, 3H), 3.07-3.25 (m, 2H), 3.33-3.38 (m, 1H), 3.65-3.73 (m, 2H), 5.12 (dd, *J* = 4.2, 13.2 Hz, 1H), 5.97 (d, *J* = 10.2 Hz, 1H), 6.66 (d, *J* = 10.2 Hz, 1H), 7.36-7.49 (m, 5H), 7.62-7.64 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 35.7, 39.0, 50.6, 60.0, 74.5, 127.0, 127.1, 128.3, 128.4, 129.2, 130.0, 136.2, 139.0, 144.1, 150.3, 197.2; IR (film) 3057, 3029 2866, 1683, 1313, 1303, 1277, 1263, 1101, 1089, 1079, 971, 953, 908, 853, 812, 772, 759, 697, 671, 634, 619 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{21}H_{21}NO_4S$: 383.1191. Found: 383.1195. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 18.57 min, t_R (minor) = 23.38 min.



(4aS,8aS)-8a-o-Tolyl-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin -6(8aH)-one (7b)

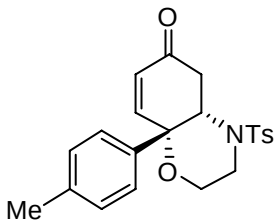
White solid, 76% yield, 95% *ee*. $[\alpha]_D^{20}$ = + 187.7º (*c* = 0.5, acetone); Mp = 167.5-168.4 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.31 (dd, *J* = 4.2, 15.6 Hz, 1H), 2.43 (s, 3H), 2.50 (s, 3H), 3.14-3.33 (m, 3H), 3.49-3.58 (m, 1H), 3.73 (dd, *J* = 3.3, 11.4 Hz, 1H), 5.12-5.23 (m, 1H), 6.02 (d, *J* = 10.2 Hz, 1H), 6.85 (d, *J* = 10.2 Hz, 1H), 7.28-7.33 (m, 5H), 7.66-7.71 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 21.7, 35.7, 38.9, 51.7, 59.7, 75.8, 126.6,

127.3, 128.6, 128.8, 129.6, 130.0, 133.5, 135.7, 136.0, 137.1, 144.2, 148.6, 197.3; IR (film) 2960, 2921, 2861, 1689, 1380, 1337, 1327, 1155, 1114, 1087, 1070, 1041, 977, 964, 949, 908, 855, 813, 766, 657, 625 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{22}H_{23}NO_4S$: 397.1348. Found: 397.1354. The enantiomeric ratio was determined by Daicel Chiralpak IC (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (minor) = 94.27 min, t_R (major) = 114.81 min.



(4aS,8aS)-8a-m-tolyl-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin-6(8aH)-one (7c)

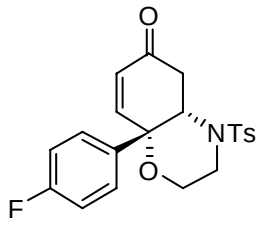
White solid, 79% yield, 98% *ee*. $[\alpha]_D^{20}$ = + 141.4° (*c* = 0.5, acetone); Mp = 147.6-148.8 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.30-2.37 (m, 1H), 2.40 (s, 3H), 2.43 (s, 3H), 3.08-3.26 (m, 2H), 3.31-3.36 (m, 1H), 3.70-3.72 (m, 2H), 5.10 (dd, *J* = 4.2, 12.0 Hz, 1H), 5.96 (d, *J* = 10.2 Hz, 1H), 6.65 (d, *J* = 10.2 Hz, 1H), 7.18 (d, *J* = 6.9 Hz, 1H), 7.29-7.43 (m, 5H), 7.63 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 21.6, 35.8, 39.0, 50.7, 60.1, 74.5, 124.0, 127.2, 127.6, 128.3, 129.1, 129.2, 130.0, 136.3, 138.9, 139.0, 144.0, 150.4, 197.4; IR (film) 2960, 2926, 2851, 1687, 1607, 1449, 1319, 1291, 1260, 1188, 1157, 1105, 1088, 1077, 1050, 1016, 976, 787, 772, 703, 687 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{22}H_{23}NO_4S$: 397.1348. Found: 397.1347. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 0.3 mL/min^{-1}, λ = 214 nm, t_R (major) = 60.24 min, t_R (minor) = 63.35 min.



(4aS,8aS)-8a-p-Tolyl-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin-6(8aH)-one (7d)

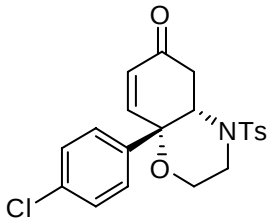
White solid, 96% yield, 96% *ee*. $[\alpha]_D^{20}$ = + 190.0° (*c* = 0.5, acetone); Mp = 151.2-152.1 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.30 (dd, *J* = 3.9, 15.6 Hz, 1H), 2.38 (s, 3H), 2.43 (s, 3H), 3.06 -3.23 (m, 2H), 3.33-3.37 (m, 1H), 3.68-3.71 (m, 2H), 5.08 (dd, *J* = 4.2, 12.3 Hz, 1H), 5.94 (d, *J* = 9.9 Hz, 1H), 6.64 (d, *J* = 9.9 Hz, 1H), 7.24-7.30 (m, 4H), 7.50 (d, *J* = 8.1 Hz, 2H), 6.63 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.0, 21.5, 35.7, 39.0, 50.6, 59.9, 74.4, 126.9, 127.1, 128.1, 129.9, 130.0, 135.8, 136.3, 138.2, 144.0, 150.4, 197.3; IR (film) 2910, 2864, 1693, 1379, 1327, 1265, 1151, 1106, 1093, 1074, 992, 972, 917, 821, 810, 798, 764, 706, 659 cm^{-1}; HRMS (EI): Exact mass calcd for

$C_{22}H_{23}NO_4S$: 397.1348. Found: 397.1352. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 13.54 min, t_R (minor) = 31.06 min.



(4aS,8aS)-8a-(4-Fluorophenyl)-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin-6(8aH)-one (7e)

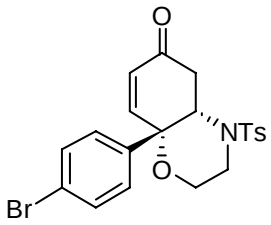
White solid, 97% yield, 98% *ee*. $[\alpha]_D^{20}$ = + 134.5° (*c* = 0.5, acetone); Mp = 73.4-74.6 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.28 (dd, *J* = 4.2, 15.6 Hz, 1H), 2.44 (s, 3H), 3.04-3.23 (m, 2H), 3.38-3.43 (m, 1H), 3.62-3.74 (m, 2H), 5.06 (dd, *J* = 4.2, 12.6 Hz, 1H), 5.97 (d, *J* = 10.2 Hz, 1H), 6.62 (d, *J* = 10.2 Hz, 1H), 7.11-7.27 (m, 2H), 7.31 (d, *J* = 8.1 Hz, 2H), 7.59-7.65 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 35.6, 39.0, 50.7, 60.0, 74.2, 116.2 (d, *J* = 20.9 Hz), 127.1, 128.5, 129.0 (d, *J* = 8.6 Hz), 130.1, 134.7 (d, *J* = 3.1 Hz), 136.2, 144.2, 150.0, 162.5 (d, *J* = 247.1 Hz), 197.0; ^{19}F NMR (282 MHz, $CDCl_3$) δ -113.59; IR (film) 2963, 2925, 2873, 1687, 1599, 1508, 1337, 1262, 1224, 1156, 1101, 1086, 1045, 1016, 962, 910, 858, 835, 679, 653 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{21}H_{20}NO_4FS$: 401.1097. Found: 401.1102. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 16.03 min, t_R (minor) = 22.72 min.



(4aS,8aS)-8a-(4-Chlorophenyl)-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin-6(8aH)-one (7f)

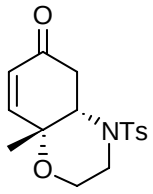
White solid, 96% yield, 96% *ee*. $[\alpha]_D^{20}$ = + 162.6° (*c* = 0.5, acetone); Mp = 207.6-208.4 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.28 (dd, *J* = 4.2, 15.3 Hz, 1H), 2.45 (s, 3H), 3.04-3.24 (m, 2H), 3.39-3.44 (m, 1H), 3.65-3.75 (m, 2H), 5.04 (dd, *J* = 4.2, 12.6 Hz, 1H), 5.97 (d, *J* = 10.2 Hz, 1H), 6.58 (d, *J* = 10.2 Hz, 1H), 7.31 (d, *J* = 8.1 Hz, 2H), 7.42 (d, *J* = 8.4Hz, 2H), 7.56 (d, *J* = 8.4 Hz, 2H), 7.63 (d, *J* = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.6, 35.6, 38.9, 50.7, 60.1, 74.2, 127.0, 128.5, 128.7, 129.5, 130.1, 134.4, 136.2, 137.6, 144.3, 149.7, 197.0; IR (film) 2911, 2865, 1692, 1487, 1456, 1378, 1327, 1299, 1265, 1249, 1153, 1107, 1092, 1072, 1046, 1010, 991, 971, 915, 738, 708 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{21}H_{20}NO_4SCl$: 417.0802. Found: 417.0799. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 18.00

min, t_R (minor) = 30.87 min.



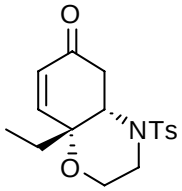
(4aS,8aS)-8a-(4-Bromophenyl)-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin-6(8aH)-one (7g)

White solid, 84% yield, 93% *ee*. $[\alpha]_D^{20}$ = + 140.6° (*c* = 0.5, acetone); Mp = 233.1-234.3 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.28 (dd, *J* = 3.9, 15.6 Hz, 1H)，2.45 (s, 3H), 3.04-3.22 (m, 2H), 3.39-3.44 (m, 1H), 3.61-3.76 (m, 2H), 5.03 (dd, *J* = 4.2, 12.3 Hz, 1H), 5.97 (d, *J* = 10.2 Hz, 1H), 6.58 (d, *J* = 10.2 Hz, 1H), 7.31 (d, *J* = 7.8 Hz, 2H), 7.49 (d, *J* = 8.1 Hz, 2H), 7.56-7.64 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 35.5, 38.9, 50.6, 60.1, 74.3, 122.6, 127.0, 128.7, 128.8, 130.1, 132.4, 136.2, 138.1, 144.2, 149.6, 197.0; IR (film) 3058, 2948, 2912, 2865, 1691, 1378, 1327, 1299, 1267, 1250, 1153, 1108, 1092, 1073, 1046, 990, 823, 651, cm^{-1}; HRMS (EI): Exact mass calcd for $C_{21}H_{20}NO_4SBr$: 461.0296. Found: 461.0297. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 18.13 min, t_R (minor) = 31.64 min.



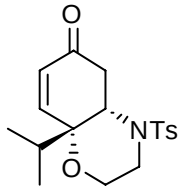
(4aS,8aR)-8a-methyl-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin-6(8aH)-one (7h)

White solid, 96% yield, 97% *ee*. $[\alpha]_D^{20}$ = + 49.0° (*c* = 0.5, acetone); Mp = 171.6-172.4 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.56 (s, 3H), 2.05-2.11 (m, 1H), 2.45 (s, 3H), 2.84-2.93 (m, 1H), 3.13-3.10 (m, 1H), 3.62-3.76 (m, 2H), 3.91-3.99 (m, 1H), 4.07-4.13 (m, 1H), 6.02 (d, *J* = 10.2 Hz, 1H), 6.66 (d, *J* = 10.2 Hz, 1H), 7.33 (d, *J* = 8.1 Hz, 2H), 7.67 (d, *J* = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.2, 21.5, 35.3, 38.8, 53.8, 59.5, 69.3, 126.8, 129.4, 130.1, 137.0, 144.0, 149.4, 197.5; IR (film) 2924, 2854, 1680, 1368, 1275, 1153, 1119, 1009, 880, 848, 824, 802, 790, 769, 708, 662 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{16}H_{19}NO_4S$: 321.1035. Found: 321.1036. The enantiomeric ratio was determined by Daicel Chiralcel OD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 12.44 min, t_R (minor) = 17.29 min.



(4aS,8aR)-8a-Ethyl-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin-6(8aH)-one (7i)

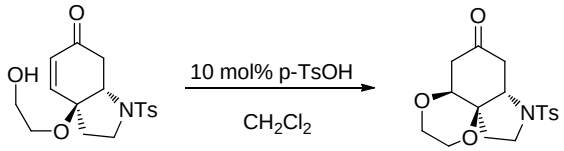
Yellow oil, 97% yield, 97% *ee*. $[\alpha]_D^{20}$ = + 58.6° (*c* = 0.5, acetone); ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.89 (t, *J* = 7.5 Hz, 3H), 1.91 (q, *J* = 7.5 Hz, 2H), 2.01-2.08 (m, 1H), 2.41 (s, 3H), 2.84-2.93 (m, 1H), 3.07-3.13 (m, 1H), 3.58-3.70 (m, 2H), 3.81-3.86 (m, 1H), 4.14 (dd, *J* = 4.2, 12.6 Hz, 1H), 6.03 (d, *J* = 10.2 Hz, 1H), 6.68 (d, *J* = 10.2 Hz, 1H), 7.30 (d, *J* = 8.7 Hz, 2H), 7.64 (d, *J* = 8.7 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 7.04, 21.5, 24.7, 35.2, 38.4, 51.6, 59.4, 71.6, 126.7, 130.0, 130.4, 136.9, 143.9, 147.7, 197.6; IR (film) 2970, 2937, 2880, 1686, 1456, 1337, 1273, 1154, 1119, 1081, 1030, 975, 948, 922, 815, 766, 690 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{17}H_{21}NO_4S$: 335.1191. Found: 335.1195. The enantiomeric ratio was determined by Daicel Chiralcel OD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 17.84 min, t_R (minor) = 24.73 min.



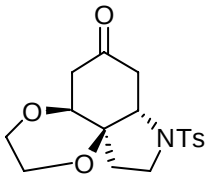
(4aS,8aR)-8a-*iso*-Propyl-4-tosyl-3,4,4a,5-tetrahydro-2H-benzo[b][1,4]oxazin-6(8aH)-one (7j)

Yellow oil, 73% yield, 96% *ee*. $[\alpha]_D^{20}$ = + 47.8° (*c* = 0.5, acetone); ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.87 (d, *J* = 6.9 Hz, 3H), 1.03 (d, *J* = 6.9 Hz, 3H), 2.05 (dd, *J* = 4.8, 15.3 Hz, 1H), 2.45 (s, 3H), 2.83 (heptet, *J* = 6.9 Hz, 1H), 2.89-2.98 (m, 1H), 3.14-3.19 (m, 1H), 3.64-3.71 (m, 2H), 3.83-3.89 (m, 1H), 4.39 (dd, *J* = 4.5, 12.9 Hz, 1H), 6.12 (d, *J* = 10.2 Hz, 1H), 6.71 (d, *J* = 10.2 Hz, 1H), 7.33 (d, *J* = 8.1 Hz, 2H), 7.67 (d, *J* = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 14.5, 17.6, 21.5, 25.7, 35.4, 38.3, 50.4, 59.2, 73.8, 126.8, 130.1, 131.6, 137.0, 144.0, 145.2, 197.7; IR (film) 2964, 2933, 2878, 1711, 1686, 1348, 1336, 1263, 1155, 1118, 1091, 1078, 1050, 1025, 969, 953, 929, 815, 767, 684, 656, 612 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{18}H_{23}NO_4S$: 349.1348. Found: 349.1359. The enantiomeric ratio was determined by Daicel Chiralcel OD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 8.84 min, t_R (minor) = 10.38 min.

3 Derivatization of the aza-Michael adducts

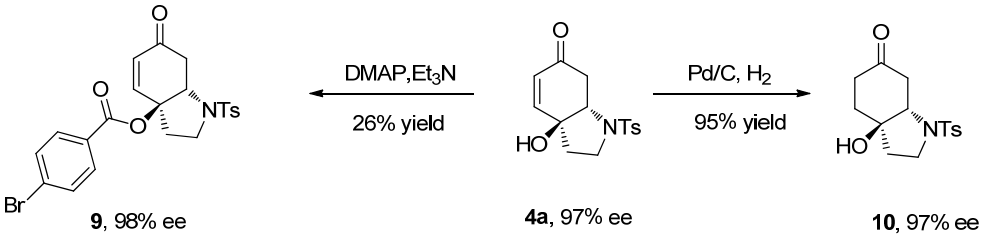


4g, 89 % ee **8,** 89 % ee



(4^1R,7aS,10aS)-7-tosyloctahydro-[1,4]dioxino[2,3-d]indol-9(5H)-one (8)

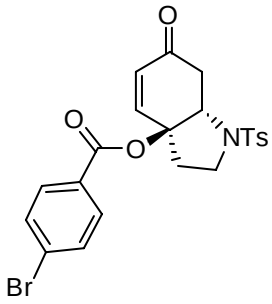
To a solution of **4g** (17.6 mg, 0.05 mmol, 89% *ee*) in CH_2Cl_2 (1 mL) was added *p*-TsOH (1 mg, 0.005 mmol). After the reaction was stirred for 5 min, the solvent was removed and the residue was purified by preparative TLC (CH_2Cl_2/ EtOH =30/1) to provide **8**. White solid, 92% yield, 89% *ee*. $[\alpha]_D^{20}$ = + 79.0° (*c* = 0.5, acetone); Mp = 162.2-163.1 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.86-1.92 (m, 1H), 2.14-2.24 (m, 1H), 2.43 (s, 3H), 2.43-2.51 (m, 1H), 2.61-2.67 (m, 2H), 3.03-3.13 (m, 2H), 3.20-3.29 (m, 1H), 3.34-3.43 (m, 1H), 3.50-3.58 (m, 1H), 3.62-3.70 (m, 2H), 3.86-3.88 (m, 1H), 4.15-4.20 (m, 1H), 7.33 (d, *J* = 8.1 Hz, 2H), 7.74 (d, *J* = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 33.4, 43.2, 46.1, 46.7, 58.1, 60.3, 66.6, 75.2, 80.4, 127.6, 129.6, 134.2, 143.7, 204.6; IR (film) 2956, 1718, 1596, 1446, 1337, 1304, 1189, 1104, 1086, 1040, 1025, 997, 972, 905, 813, 723, 707, 662 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{17}H_{21}NO_5S$: 351.1140. Found: 351.1146. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 22.15 min, t_R (minor) = 27.05 min



9, 98% ee
>99% ee after recrystallization

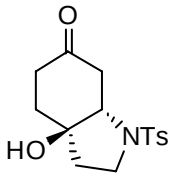
4a, 97% ee

10, 97% ee



(3aS,7aS)-6-oxo-1-tosyl-2,3,3a,6,7,7a-hexahydro-1H-indol-3a-yl 4-bromobenzoate (9)

To a solution of **4a** (20 mg, 0.065 mmol, 97% *ee*) and 4-bromobenzoyl chloride (38 mg, 0.174 mmol) in CH_2Cl_2 (1 mL) were added DMAP (1.5 mg, 0.013 mmol) and Et_3N (18 mg, 0.18 mmol). The reaction mixture was stirred at room temperature for 5h. The mixture was then quenched with water and extracted with CH_2Cl_2. The organic layer was washed with brine and dired over anhydrous Na_2SO_4. The solvent was removed under reduced presure and the residue was purified by silica gel column chromatography (PE/ EtOAc =2/1) to provide **9** (8.4 mg, 26% yield). White solid, 26% yield, 98% *ee* (>99% *ee* after one recrystallization). Analytical data for **9** (99% *ee*): $[\alpha]_D^{20}$ = + 138.0° (*c* = 0.5, acetone); Mp = 245.6-246.7℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.01 (s, 3H), 2.37-2.44 (m, 1H), 2.50-2.57 (m, 1H), 2.63-2.72 (m, 1H), 3.31 (dd, *J* = 6.9, 17.1 Hz, 1H), 3.40-3.49 (m, 1H), 3.86-3.92 (m, 1H), 4.75 (dd, *J* = 7.5, 10.2 Hz, 1H), 6.10 (d, *J* = 10.2 Hz, 1H), 6.78 (d, *J* = 10.2 Hz, 1H), 6.93 (d, *J* = 8.1 Hz, 2H), 7.40 (d, *J* = 8.7 Hz, 2H), 7.48 (d, *J* = 8.7 Hz, 2H), 7.59 (d, *J* = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.3, 35.7, 45.5, 47.0, 62.2, 84.3, 127.2, 127.7, 128.8, 129.6, 129.8, 130.8, 131.6, 133.4, 143.7, 144.6, 164.0, 195.1; IR (film) 2961, 2923, 2853, 1709, 1680, 1586, 1388, 1340, 1283, 1258, 1160, 1090, 1048, 1033, 1008, 938, 854, 846, 755, 664 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{22}H_{20}NO_5SBrNa$: 512.0138. Found: 512.1023. The enantiomeric ratio was determined by Daicel Chiralcel OD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 32.00 min, t_R (minor) = 43.83 min.

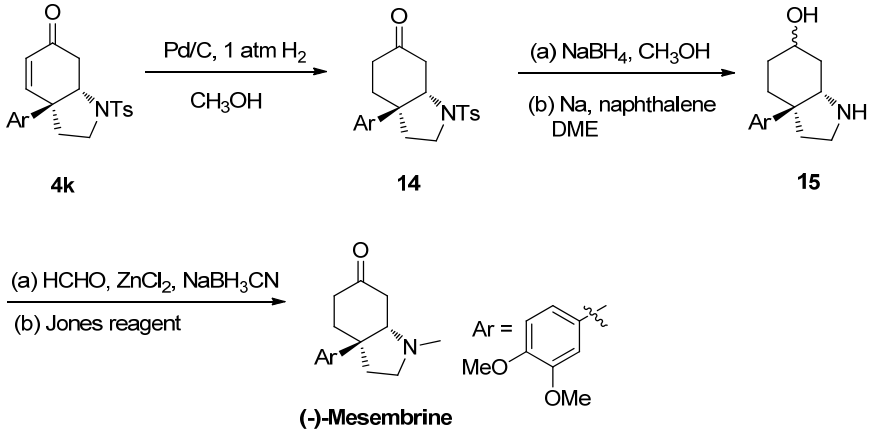


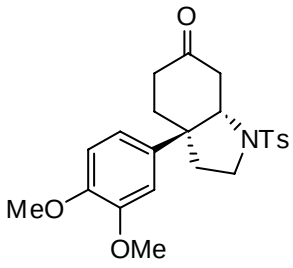
(3aR,7aS)-3a-hydroxy-1-tosylhexahydro-1H-indol-6(2H)-one (10)

To a solution of **4a** (80 mg, 0.26 mmol, 97% *ee*) in MeOH (2 mL) under argon, 5% Pd/C (4 mg) was added. Then the reaction was charged with 1 atm of hydrogen, the reaction mixture was stirred at room temperature for 10 h. The reaction mixture was filtered through a pad of celite, washed with methanol. The filtrate was concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (CH_2Cl_2/ EtOH =30/1) to provide compound **10**. White solid, 95% yield, 97% *ee*. $[\alpha]_D^{20}$ = + 194.3° (*c* = 0.5, acetone); Mp = 127.5-128.2 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ

1.87-2.07 (m, 5H), 2.30-2.54 (m, 3H), 2,43 (s, 3H), 2.91-2.98 (m, 1H), 3.21-3.30 (m, 1H), 3.50-3.55 (m, 2H), 7.32 (d, J = 8.1 Hz, 2H), 7.70 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5, 32.6, 35.4, 37.0, 45.1, 47.1, 65.4, 78.3, 127.7, 130.0, 132.9, 143.9, 209.7; IR (film) 3492, 2931, 2880, 1720, 1595, 1320, 1154, 1120, 1086, 1042, 1015, 995, 981, 942, 863, 734, 706, 662 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{15}H_{19}NO_4S$: 309.1035. Found: 309.1032. The enantiomeric ratio was determined by Daicel Chiralpak AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (minor) = 15.98 min, t_R (major) = 45.90 min.

4 Total synthesis of (-)-Mesembrine

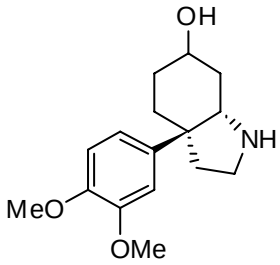




(3aS,7aS)-3a-(3,4-Dimethoxyphenyl)-1-tosylhexahydro-1H-indol-6 (2H)-one (14)

To a solution of **4k** (33.6 mg, 0.079 mmol) in MeOH (2 mL) under argon, 10% Pd/C (3.4 mg) was added. Then the reaction was charged with 1 atm of hydrogen, the reaction mixture was stirred at room temperature for 10h. The reaction mixture was filtered through a pad of celite, washed with methanol. The filtrate was concentrated under reduced pressure. The crude product was purified by preparative TLC (PE: EtOAc = 3:1) to provide compound **14** (30.7 mg, 91% yield, 97% *ee*). $[\alpha]_D^{20}$ = +71.6.0 ^{o} (c = 0.5, acetone); ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.06-2.21 (m, 6H), 2.40 (s, 3H), 2.93 (d, J = 6.3 Hz, 2H), 3.31-3.35 (m, 1H), 3.54-3.56 (m, 1H), 3.81 (s, 3H), 3.85 (s, 3H), 4.30 (t, J = 6.3 Hz, 1H), 6.56-6.66 (m, 3H), 7.22 (d, J = 8.1 Hz, 2H), 7.61 (d, J = 8.1 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.3, 33.1, 36.1, 36.7, 44.8, 46.8, 48.6, 55.6, 55.7, 63.1, 109.1, 110.5,

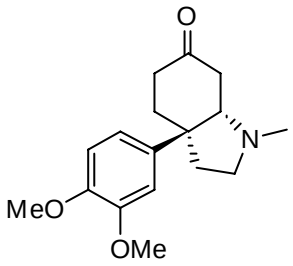
117.5, 127.2, 129.4, 134.1, 136.0, 143.5, 147.7, 148.9, 209.4; IR (film) 2931, 1715, 1588, 1514, 1438, 1329, 1255, 1149, 1086, 1024, 882, 809, 794, 704 cm^{-1}; HRMS (EI): Exact mass calcd for $C_{23}H_{27}NO_5S$: 429.1610. Found: 429.1615. The enantiomeric ratio was determined by Daicel Chiralcel AD-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (major) = 33.18 min, t_R (minor) = 40.49min.



(3aS,7aS)-3a-(3,4-Dimethoxyphenyl)octahydro-1H-indol-6-ol (15)

To a solution of **14** (14.5 mg, 0.034 mmol) in MeOH (2 mL) was added $NaBH_4$ (2.6 mg, 0.068 mmol) at 0 ℃. The reaction was stirred for 10 min and quenched with water. The mixture was extracted with with EtOAc for three times. The combined organic layer was washed with brine, dried over anhydrous Na_2SO_4. The solvent was removed under reduced presure and the residue was purified by silica gel column chromatography (PE/ EtOAc =1/2) to provide the alcohol (12.7 mg, 88% yield).

To a solution of naphthalene (64 mg, 0.50 mmol) in DME (1 mL) was added sodium (11 mg, 0.48 mmol). The mixture was stirred at room temperature for 3 h. Then a solution of the above obtained alcohol (21 mg, 0.049 mmol) in DME (0.5 mL) was added dropwise at –78 ℃. The reaction was quenched with saturated $NaHCO_3$ (0.5 mL), dried over Na_2SO_4 and concentrated. Purification of the residue via a short silica gel column chromatography (PE: EtOAc = 10 :1~ $CH_2Cl_2/CH_3OH/NEt_3$ = 3:1:0.5) provided **15** as a colorless oil (12.1 mg , 89% yield). ^1H NMR (300 MHz, $CDCl_3$) δ 1.34-1.35 (m, 1H), 1.68-2.29 (m, 7H), 3.04-3.19 (m, 2H), 3.74 (s, 1H), 3.82 (s, 3H), 3.83 (s, 3H), 3.96 (s, 1H), 5.50 (br, 2H), 6.75-6.84 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 25.9, 28.9, 30.8, 41.5, 42.3, 46.2, 55.6, 55.8, 60.4, 66.0, 110.0, 110.6, 118.3, 136.9, 147.1, 148.6; IR (film) 2933, 1669, 1588, 1518, 1463, 1409, 1248, 1148, 1098, 1024, 921, 853, 805, 765, 730 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{16}H_{24}NO_3$: 278.1749. Found: 278.1751.

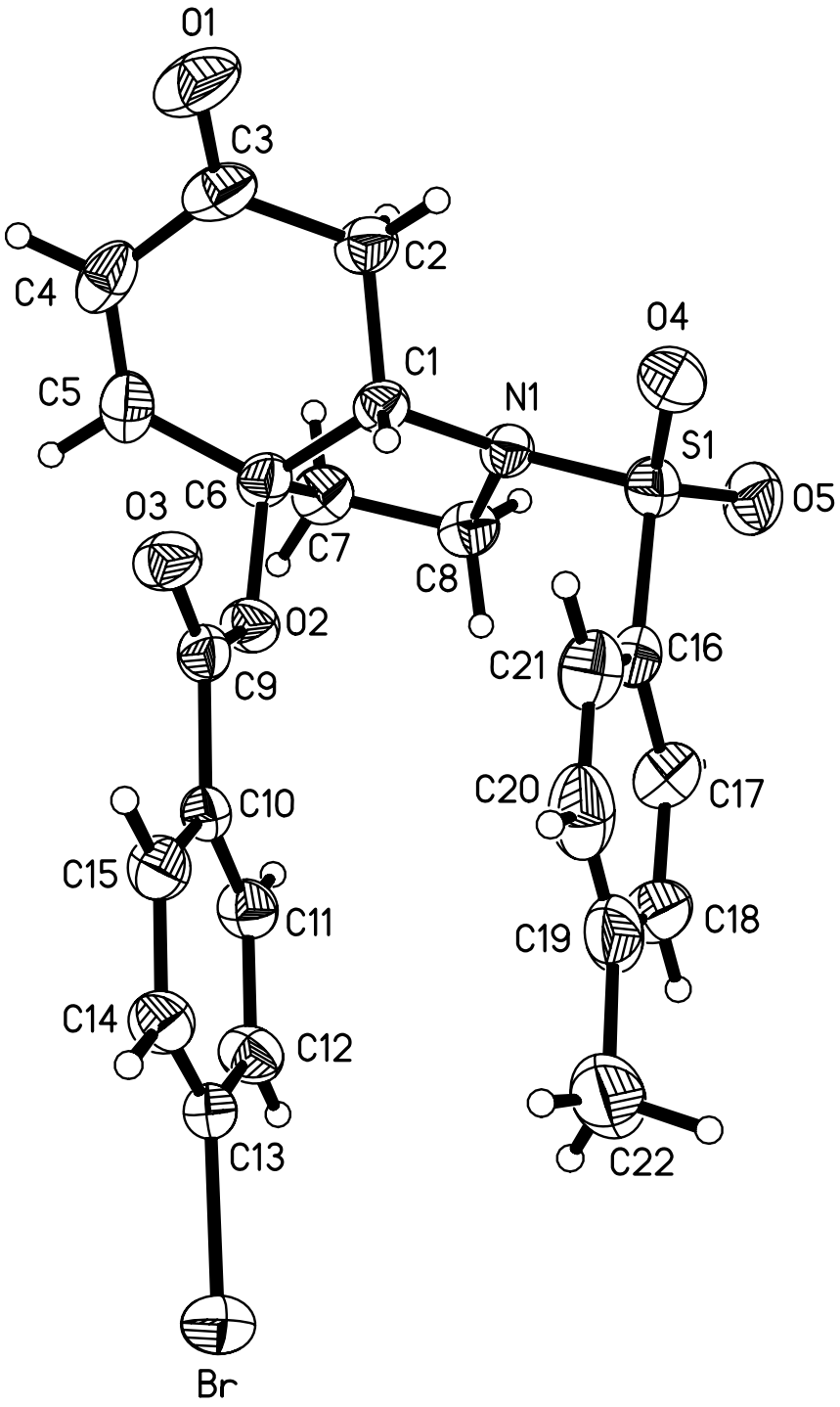


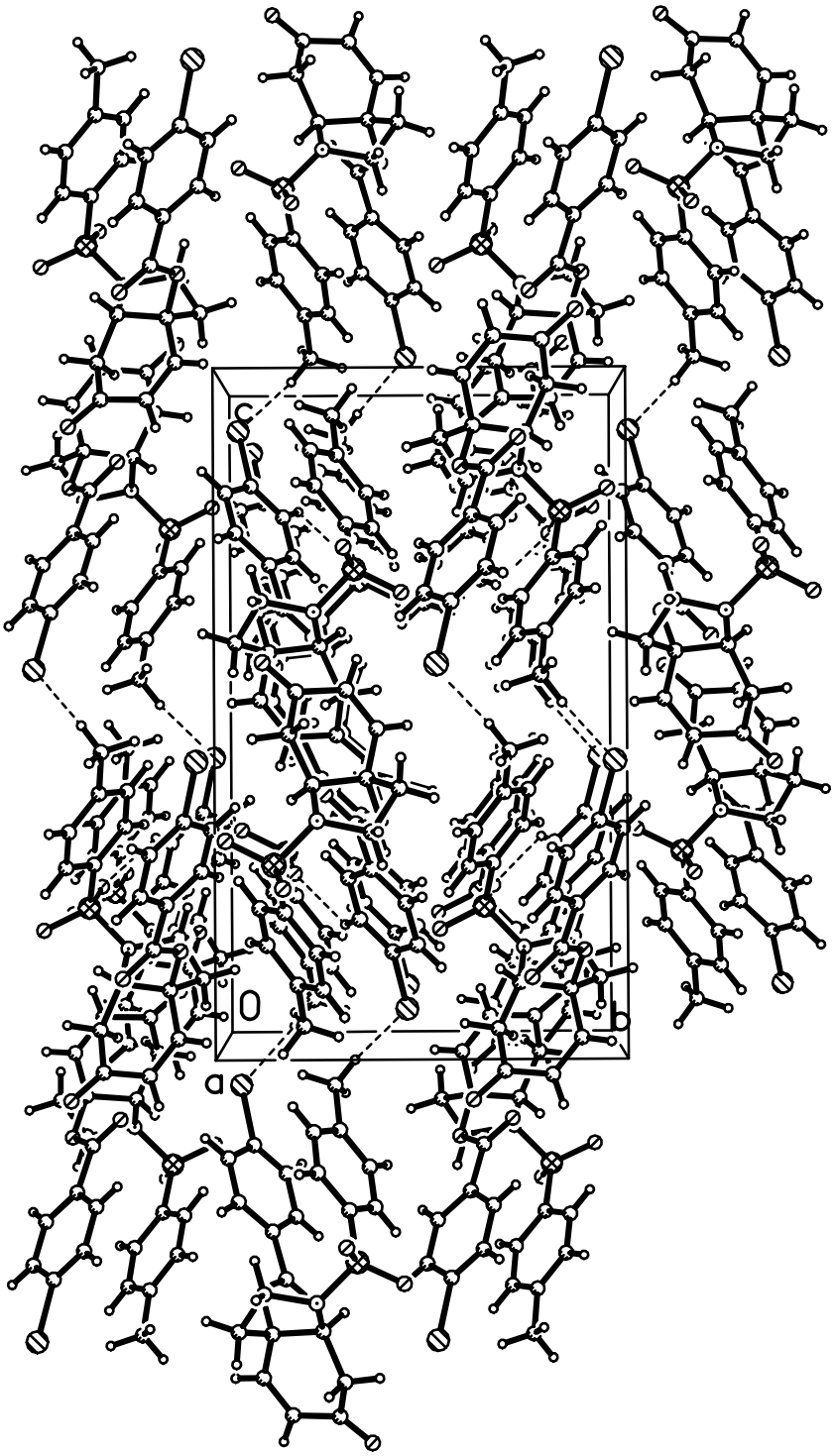
(-)- Mesembrine

To a solution of **15** (12.1 mg, 0.044 mmol) in CH_3OH (1 mL) was added 37% aqueous HCHO (13 ul, 0.13mmol), $ZnCl_2$ (3.5 mg, 0.026 mmol) and $NaBH_3CN$ (4 mg, 0.063 mmol) at room temperature. The reaction was stirred for 10 min and quenched with 0.1 N NaOH (0.5 mL). Methanol was removed under reduced pressure and the residue was extracted with ether. The organic layer was washed with brine, dried over anhydrous Na_2SO_4. The solvent was removed and the residue was purified by silica gel column chromatography (CH_2Cl_2/ CH_3OH =6/1) to provide N-methyl product.

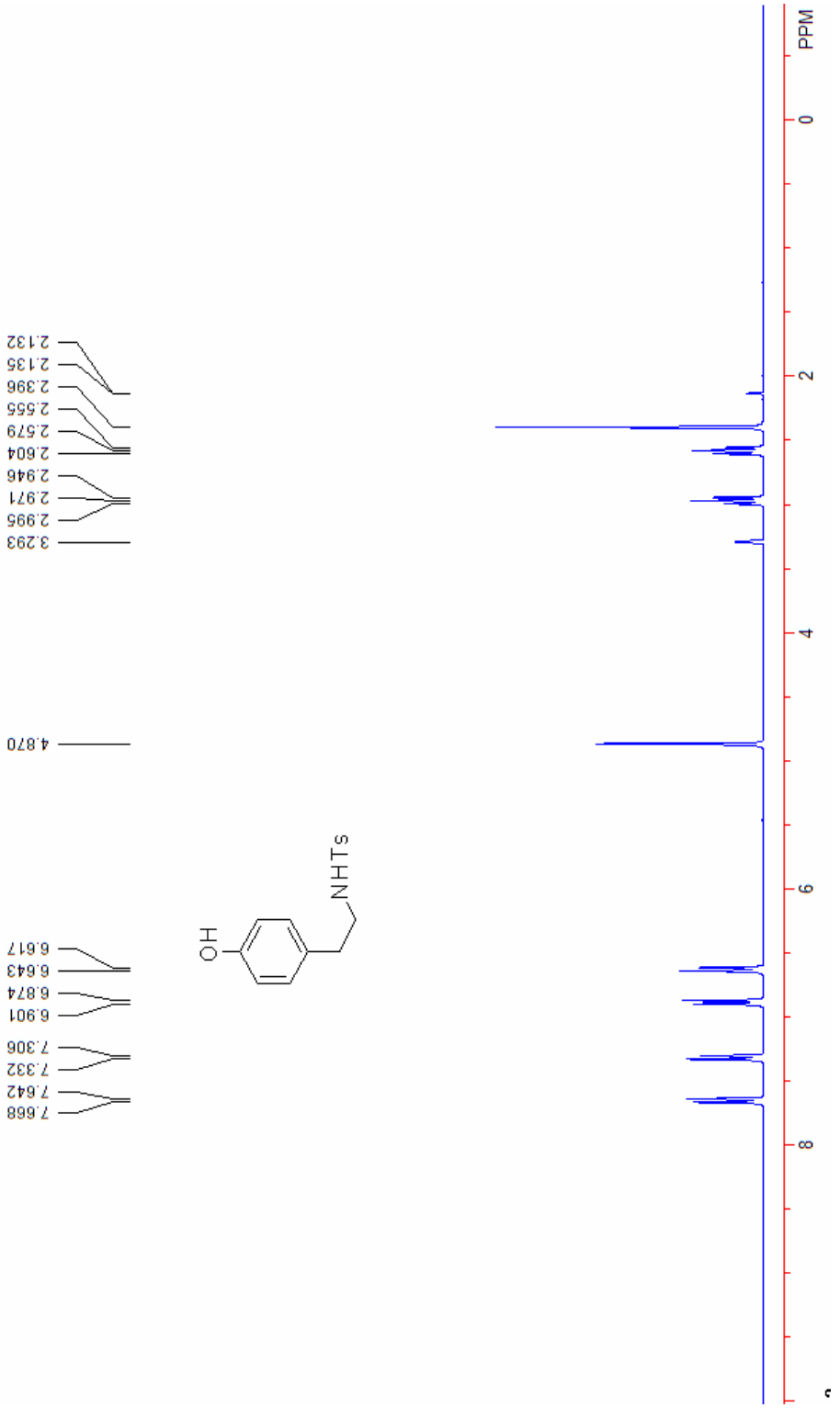
To a solution of the above obtained *N*-methyl product in acetone (1 mL) was added Jones reagent (13 μL) at 0 ℃. The reaction was stirred at room temperature for 10 min and quenched with 0.1 N NaOH (1 mL). The mixture was extracted with ether. The combined organic layer was washed with with brine, dried over anhydrous Na_2SO_4. The solvent was removed and the residue was purified by preparative TLC (CH_2Cl_2/ acetone = 2/1) to provide **(-)-Mesembrine** (5.4 mg, 45% yield over two steps). Analytical data for **(-)- Mesembrine** (98 % *ee*): $[\alpha]_D^{20}$ = -61.0 ^{o} (*c* = 0.2, CH_3OH); ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.08-2.25 (m, 5H), 2.33 (s, 3H), 2.30-2.46 (m, 2H), 2.62 (d, *J* = 3.3 Hz, 2H), 2.96-2.98 (m, 1H), 3.13-3.18 (m, 1H), 3.89 (s, 3H), 3.91 (s, 3H), 6.84-6.95 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 35.2, 36.1, 38.7, 40.0, 40.5, 47.4, 54.8, 55.8, 55.9, 70.3, 109.6, 110.7, 117.8, 139.9, 147.3, 148.8, 211.5; IR (film) 2929, 1716, 1588, 1518, 1453, 1409, 1252, 1174, 1146, 1025, 909, 850, 804, 731 cm^{-1}; HRMS (MALDI): Exact mass calcd for $C_{17}H_{24}NO_3$: 290.1751. Found: 290.1756. The enantiomeric ratio was determined by Daicel Chiralcel AS-H (25 cm), Hexanes / IPA = 80 / 20, 1.0 mL/min^{-1}, λ = 220 nm, t_R (minor) = 24.67 min, t_R (major) = 27.96 min.

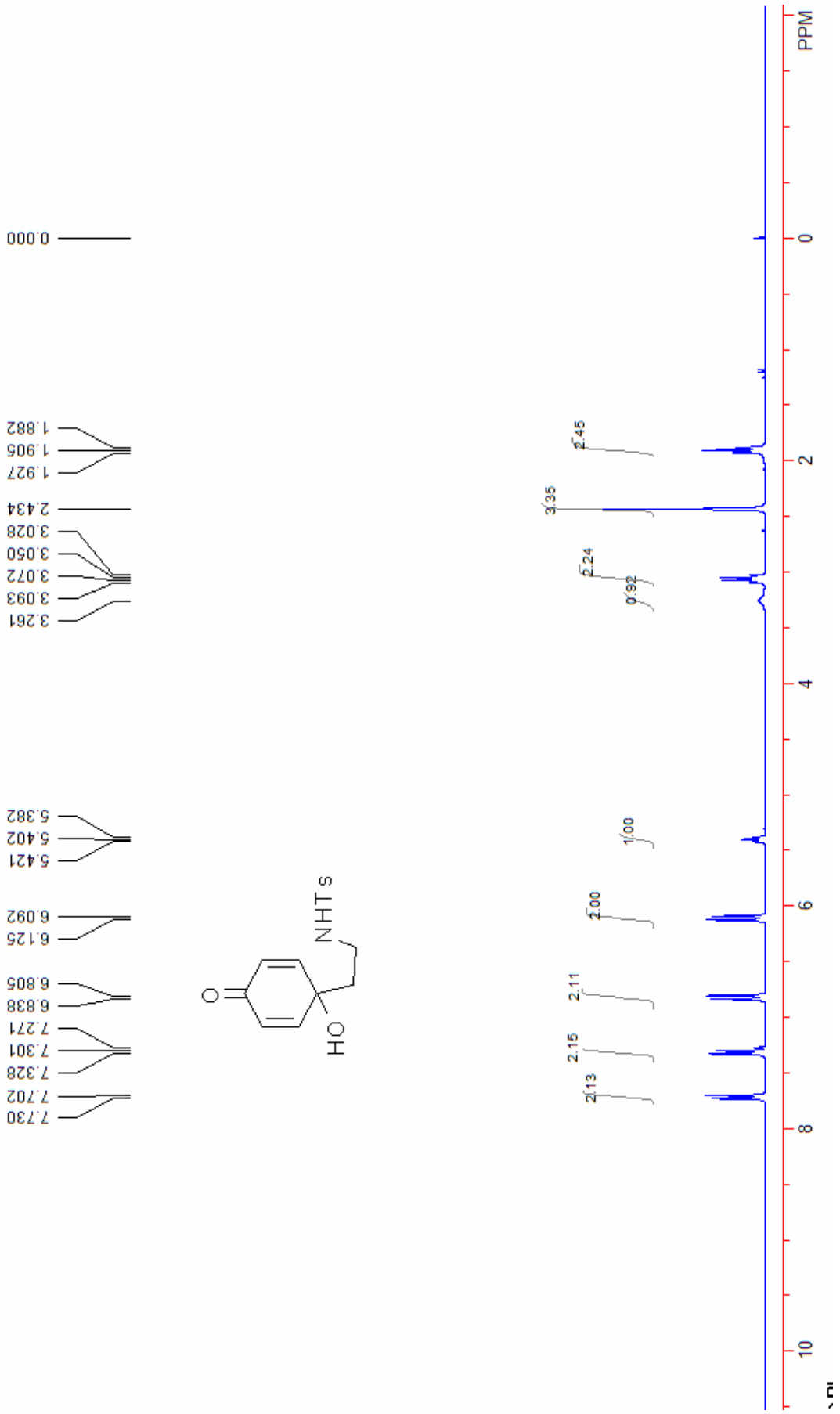
X-ray structure of enantiopure 6-oxo-1-tosyl-2,3,3a,6,7,7a-hexahydro-1H-indol-3a-yl 4-bromobenzoate **9** [CCDC 805906 contains the supplementary crystallographic data. These data can be obtained free of charge from the Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk /data request/cif.]





4 NMR and HPLC Spectra

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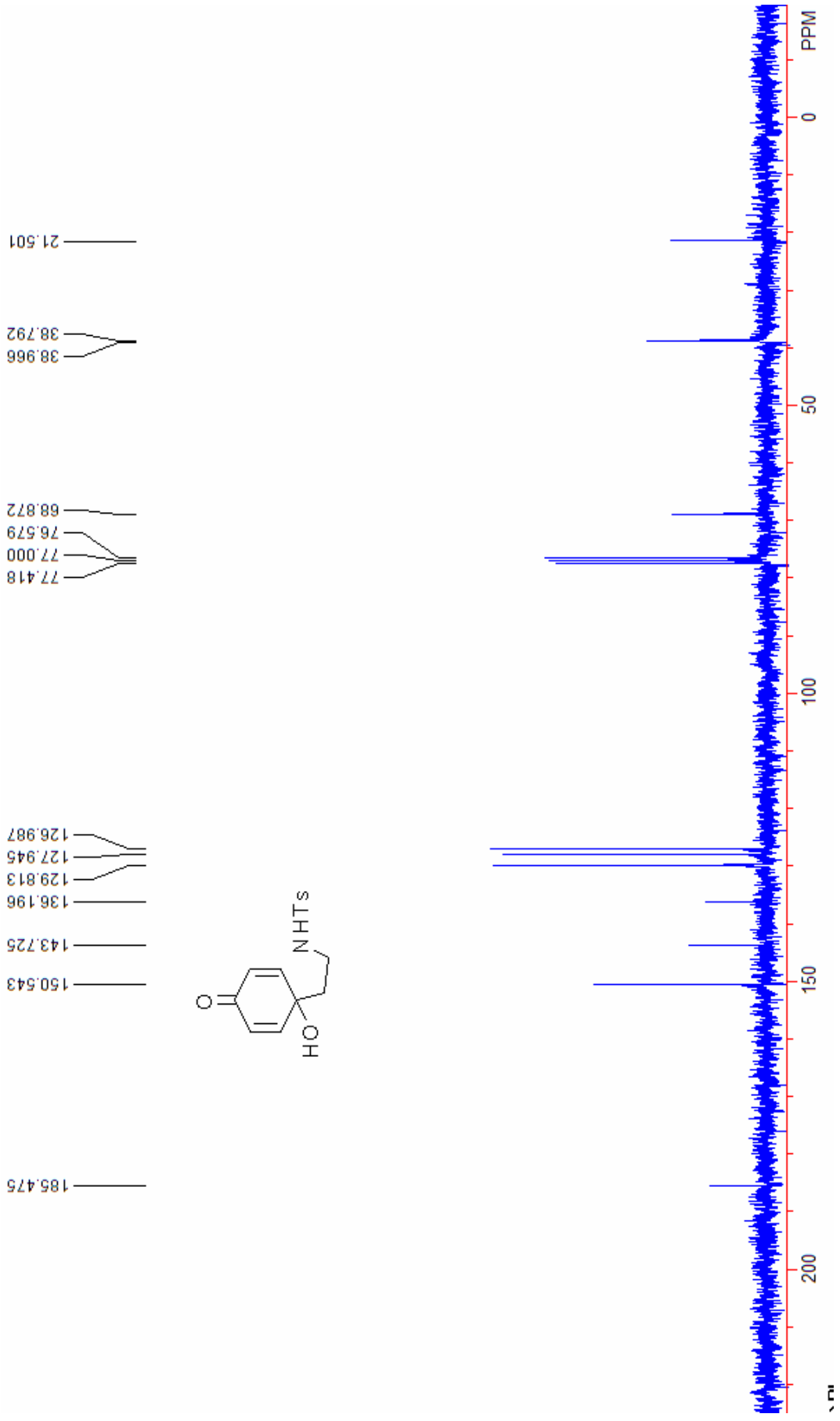
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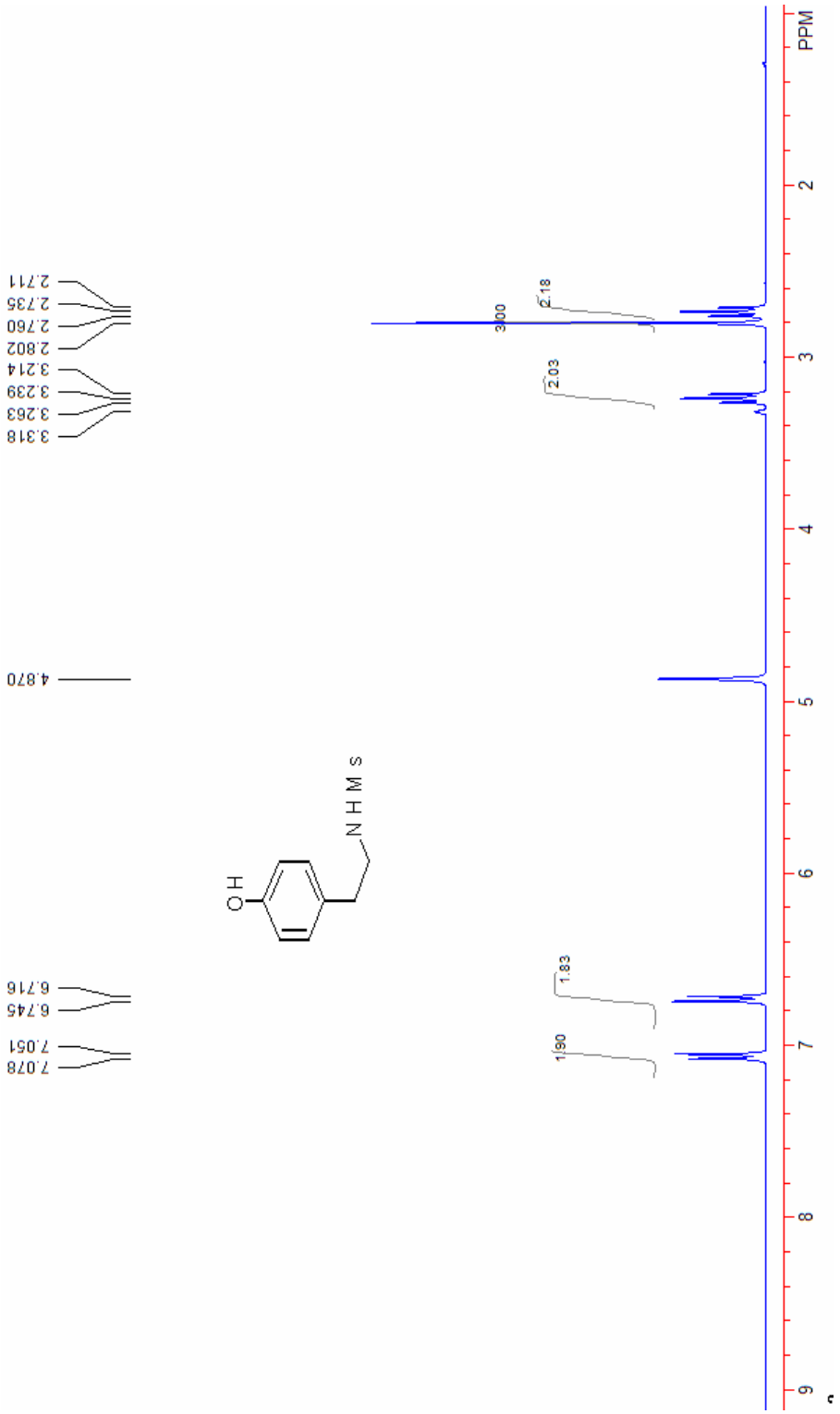
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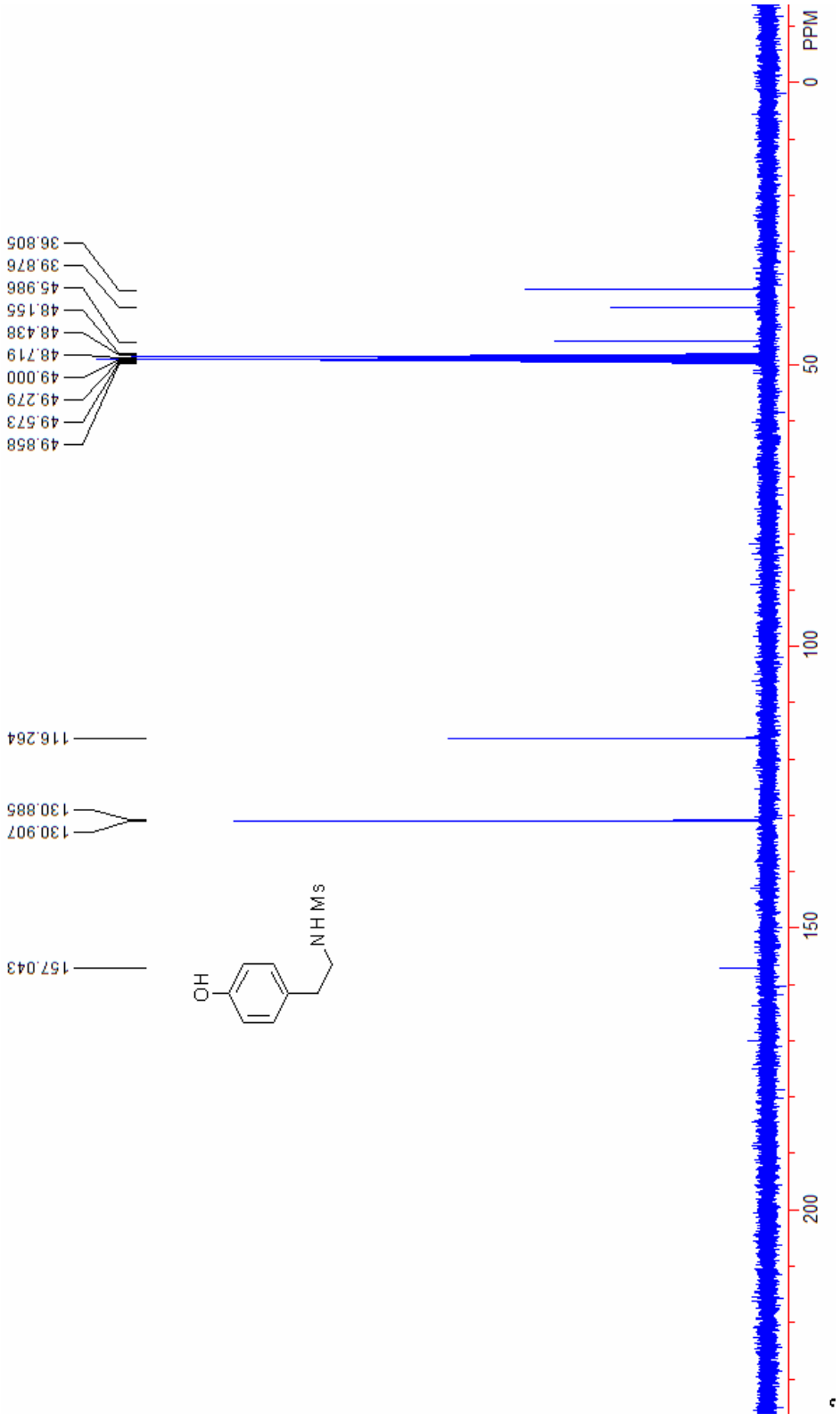
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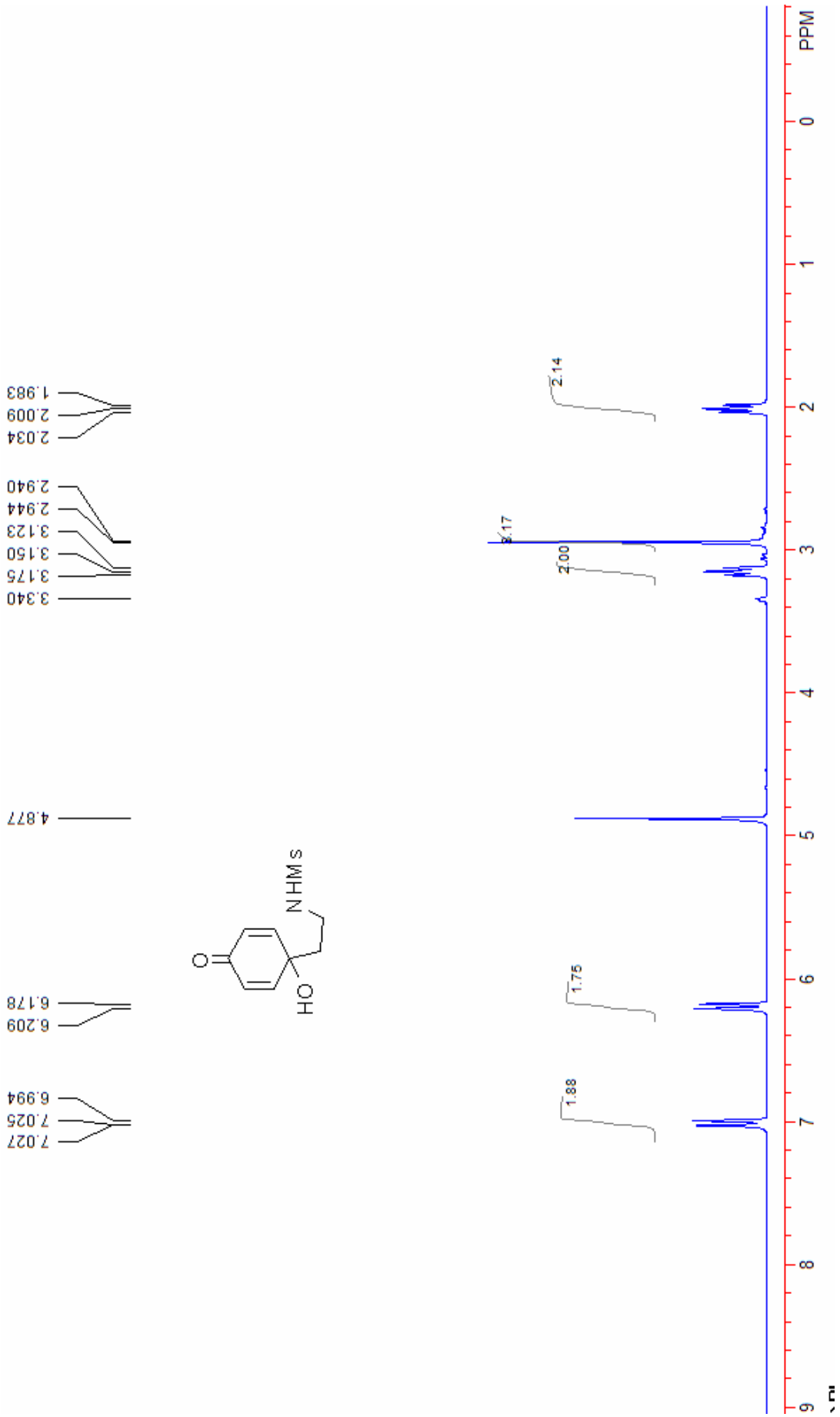
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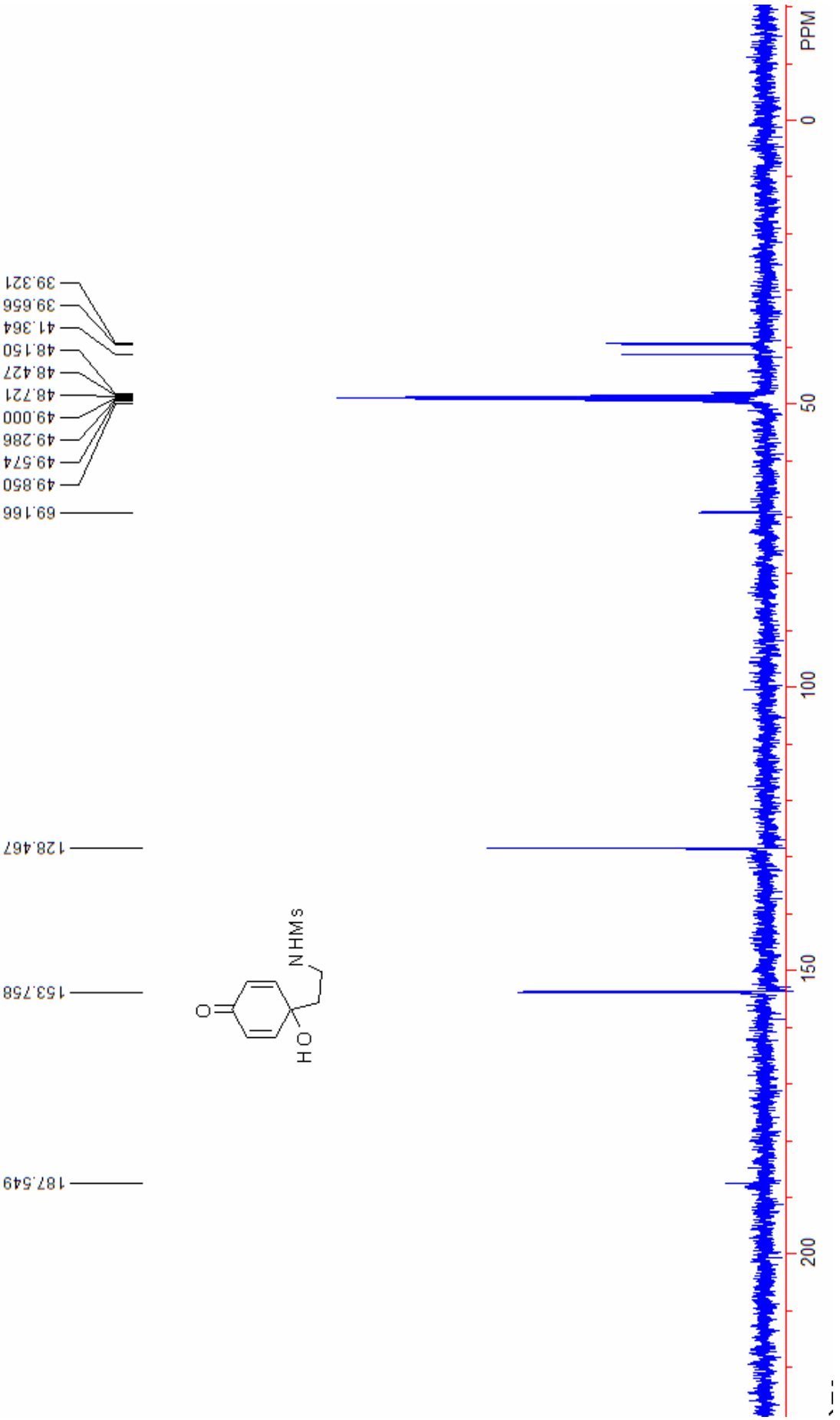

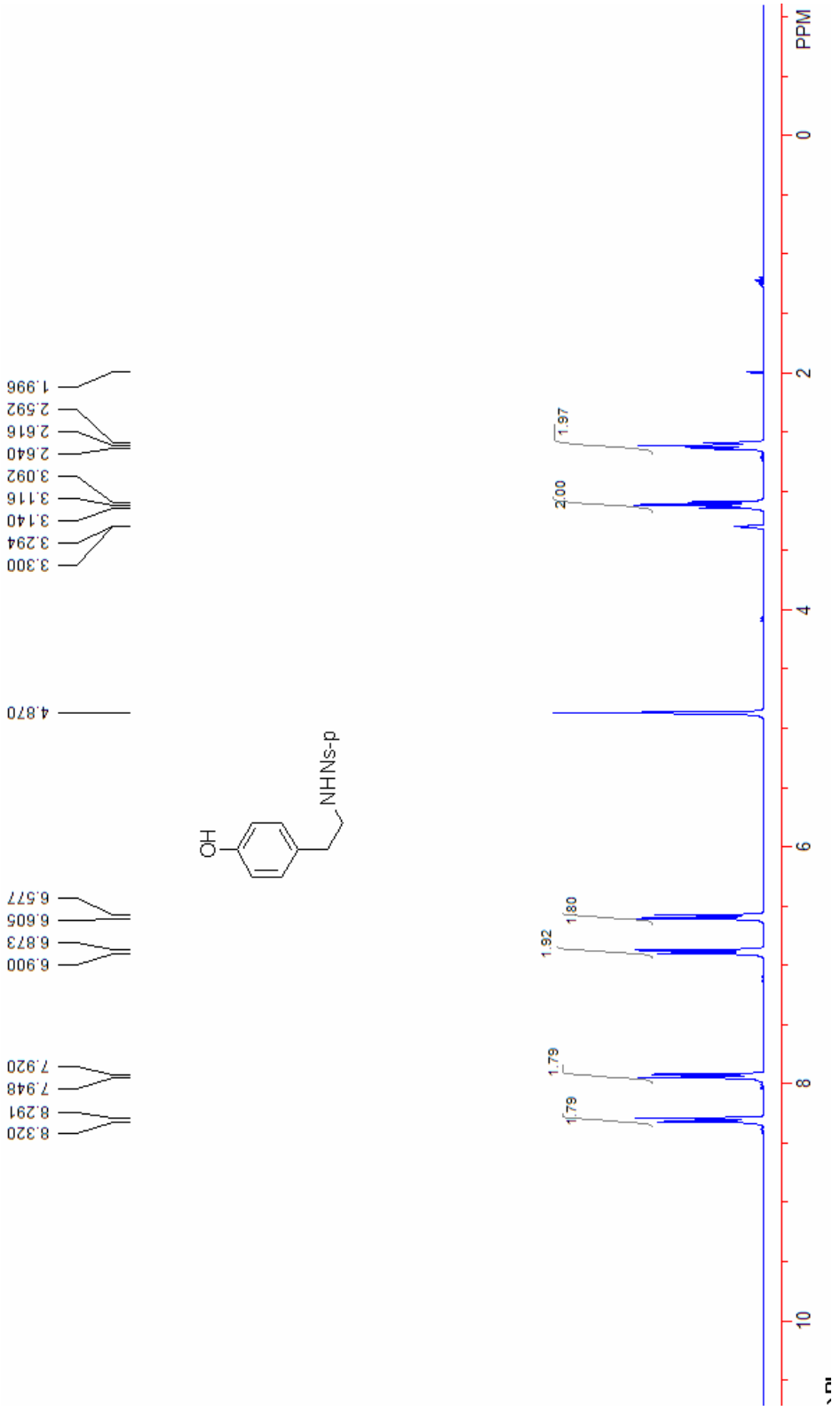
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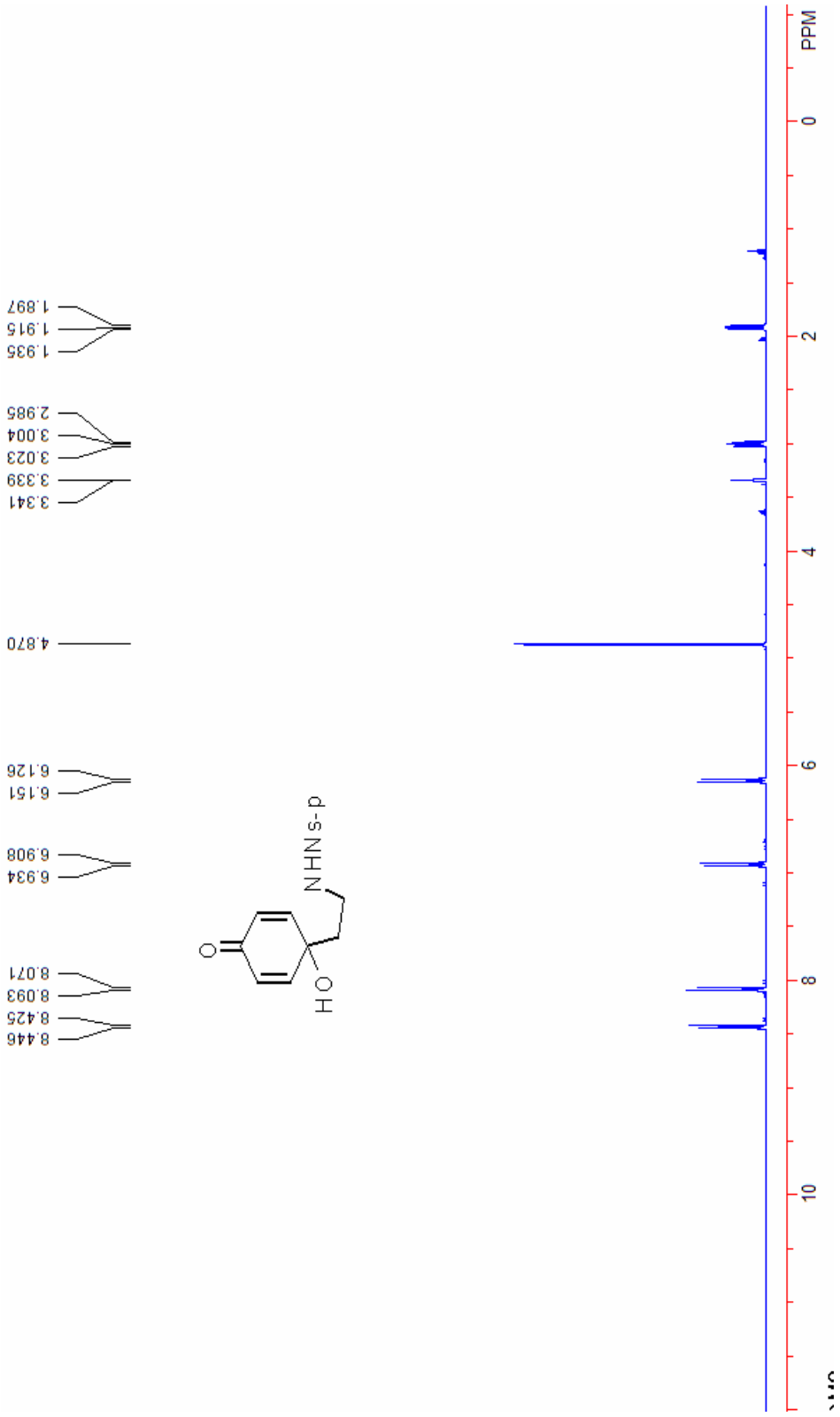
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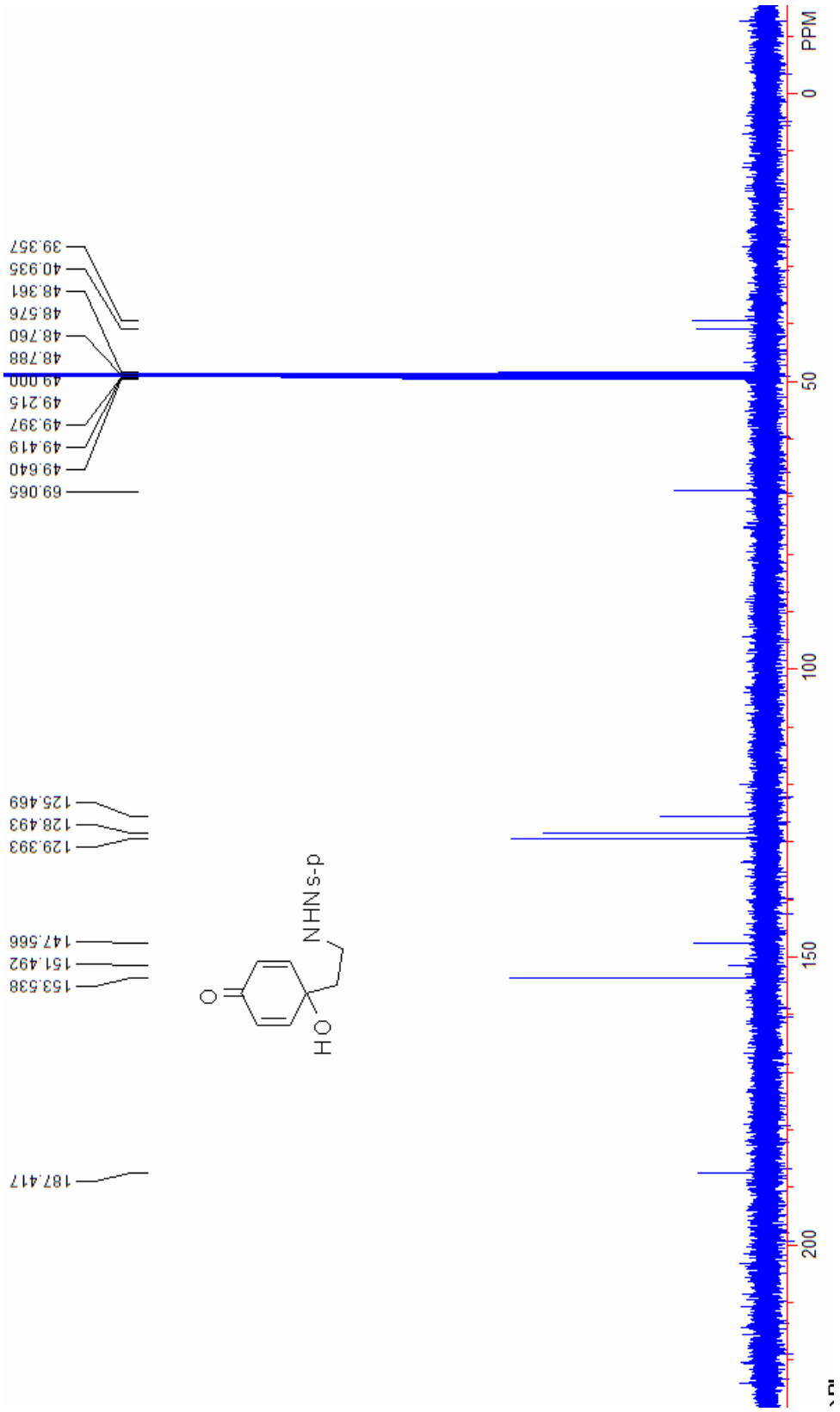

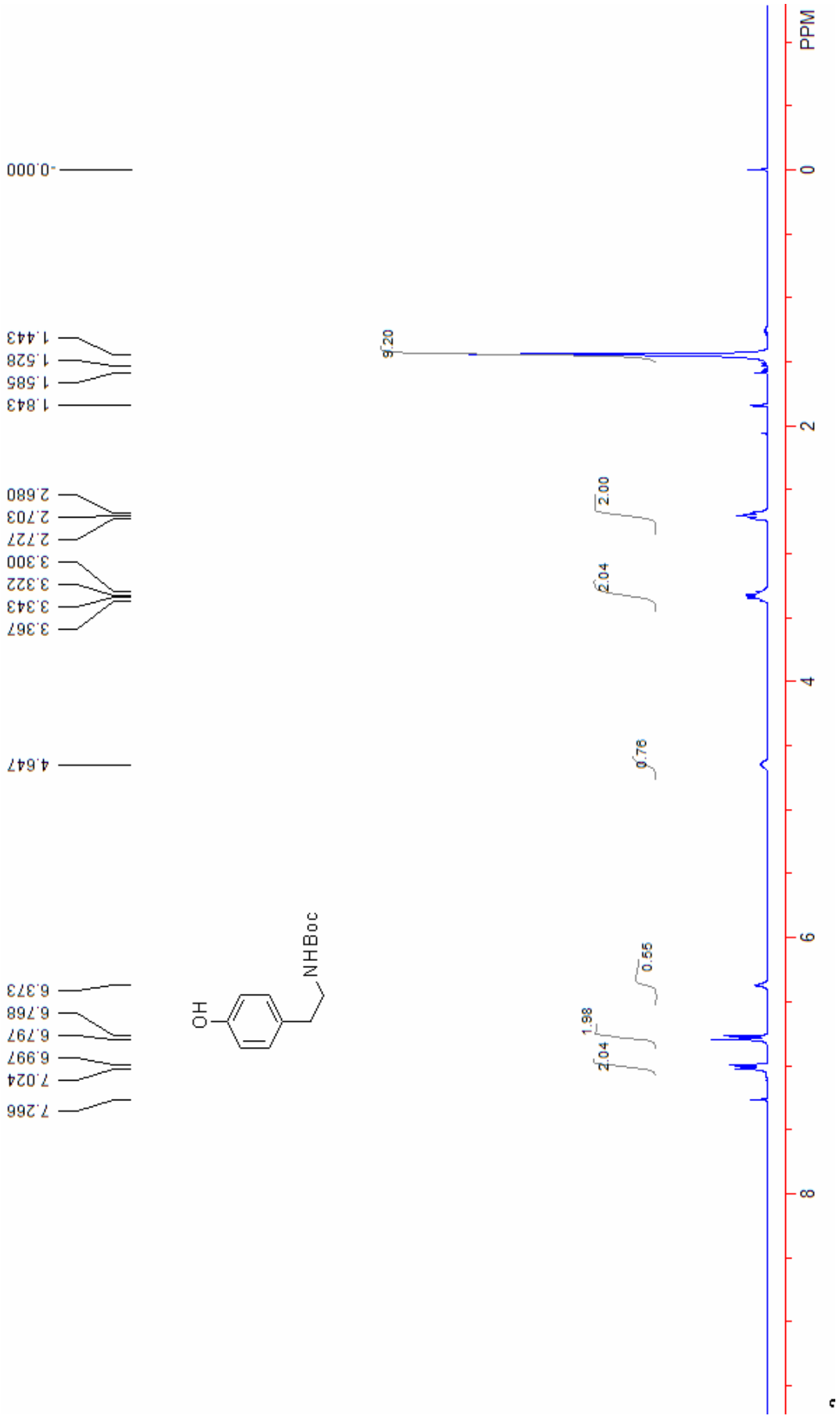
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7.024
6.997
6.797
6.768
6.373
4.647
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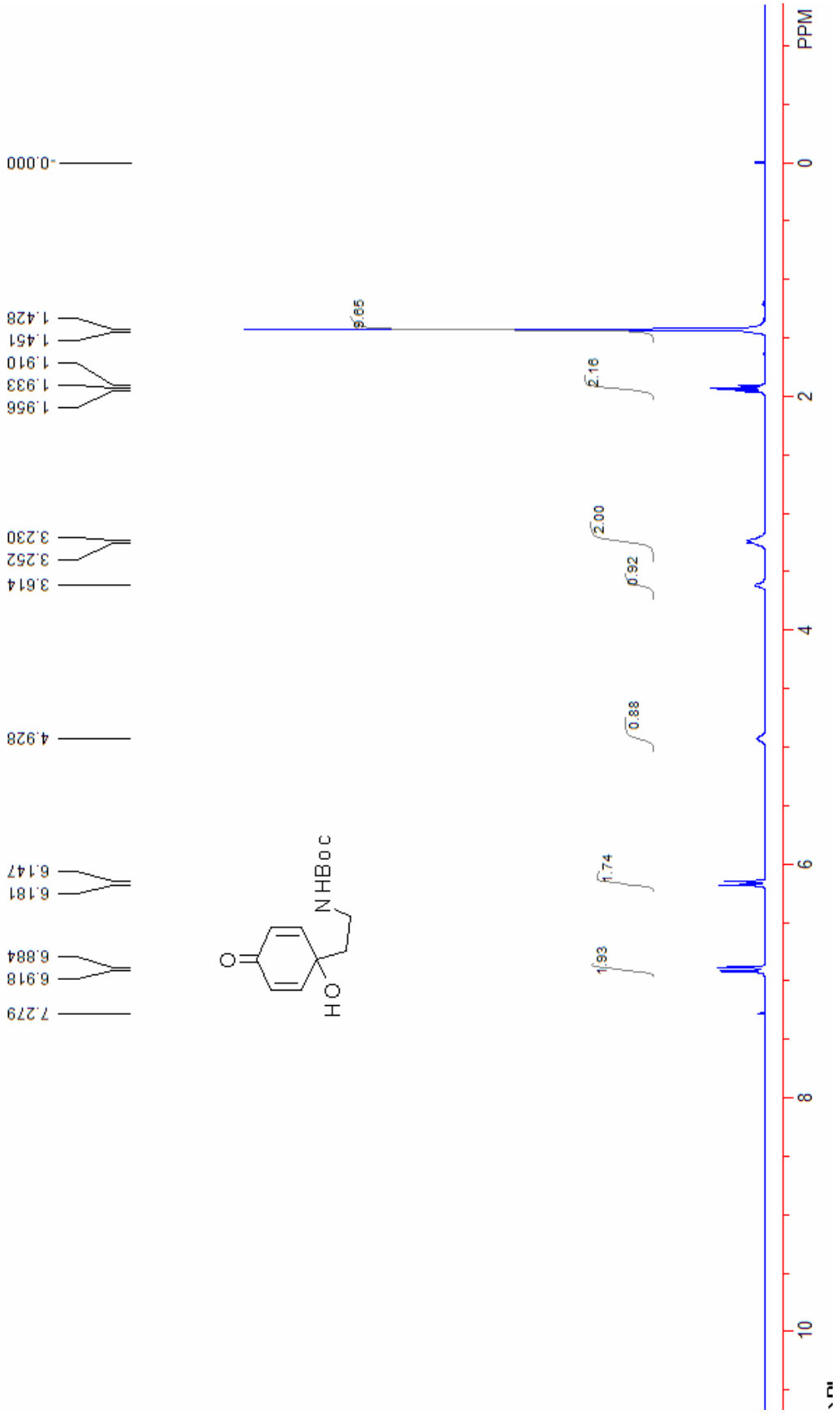
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6.884
6.918
7.279
9.65
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O
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8
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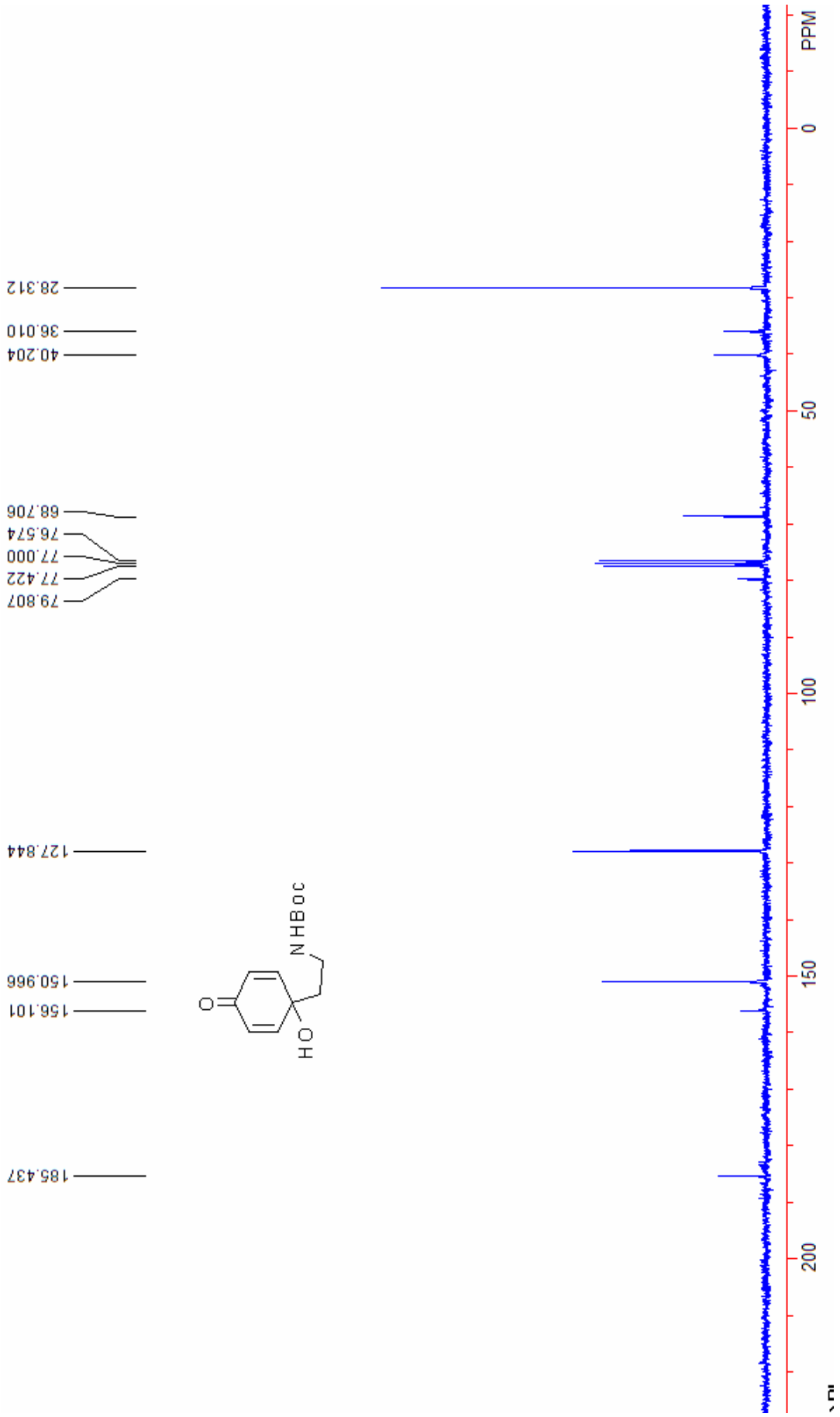
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HO
O
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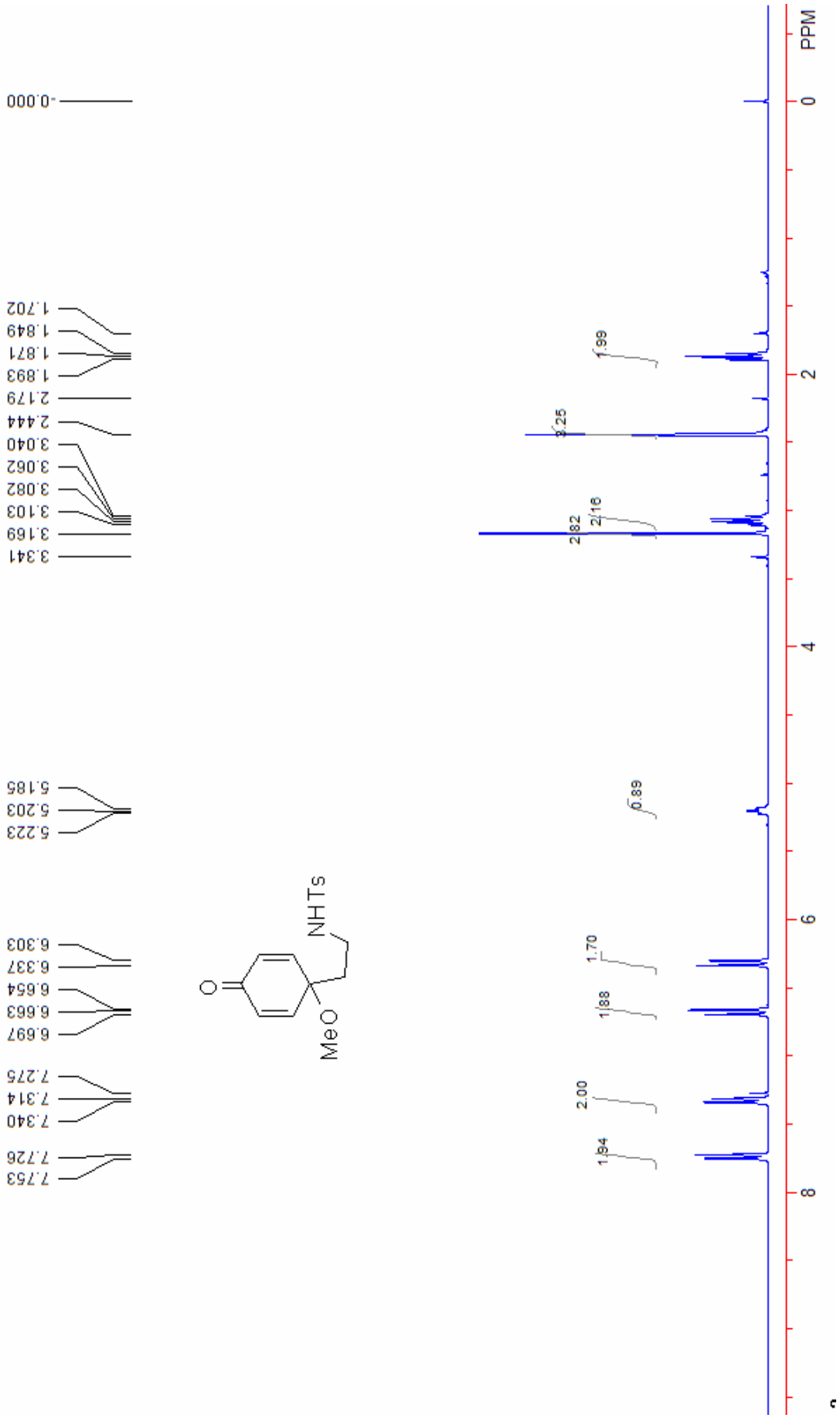
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6.303
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7.314
7.340
7.726
7.753
NHTs
MeO
O
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1.84
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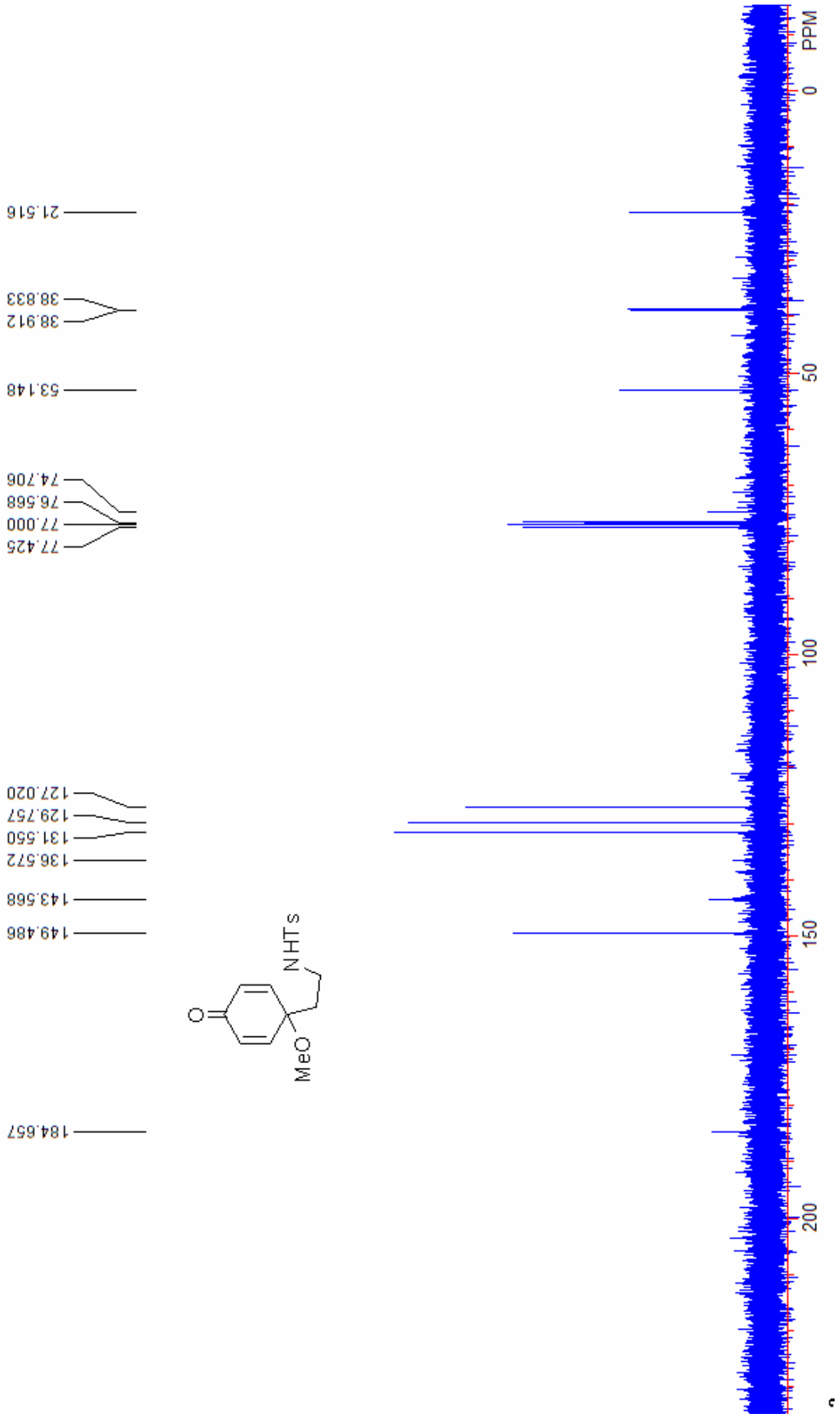

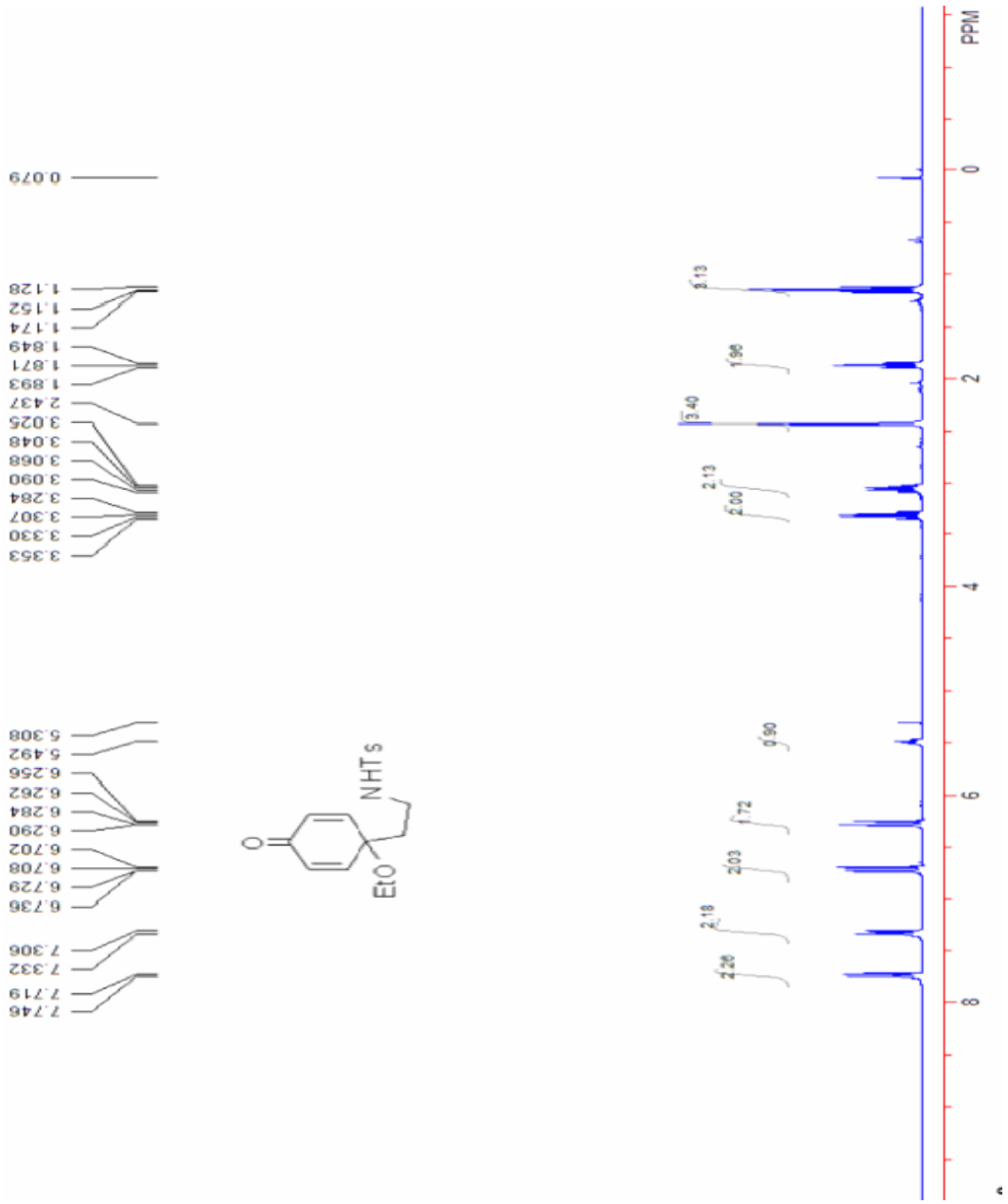
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3.284
3.307
3.330
3.353
5.308
5.492
6.256
6.262
6.284
6.290
6.702
6.708
6.729
6.736
7.306
7.332
7.719
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NHTs
EtO
O
PPM
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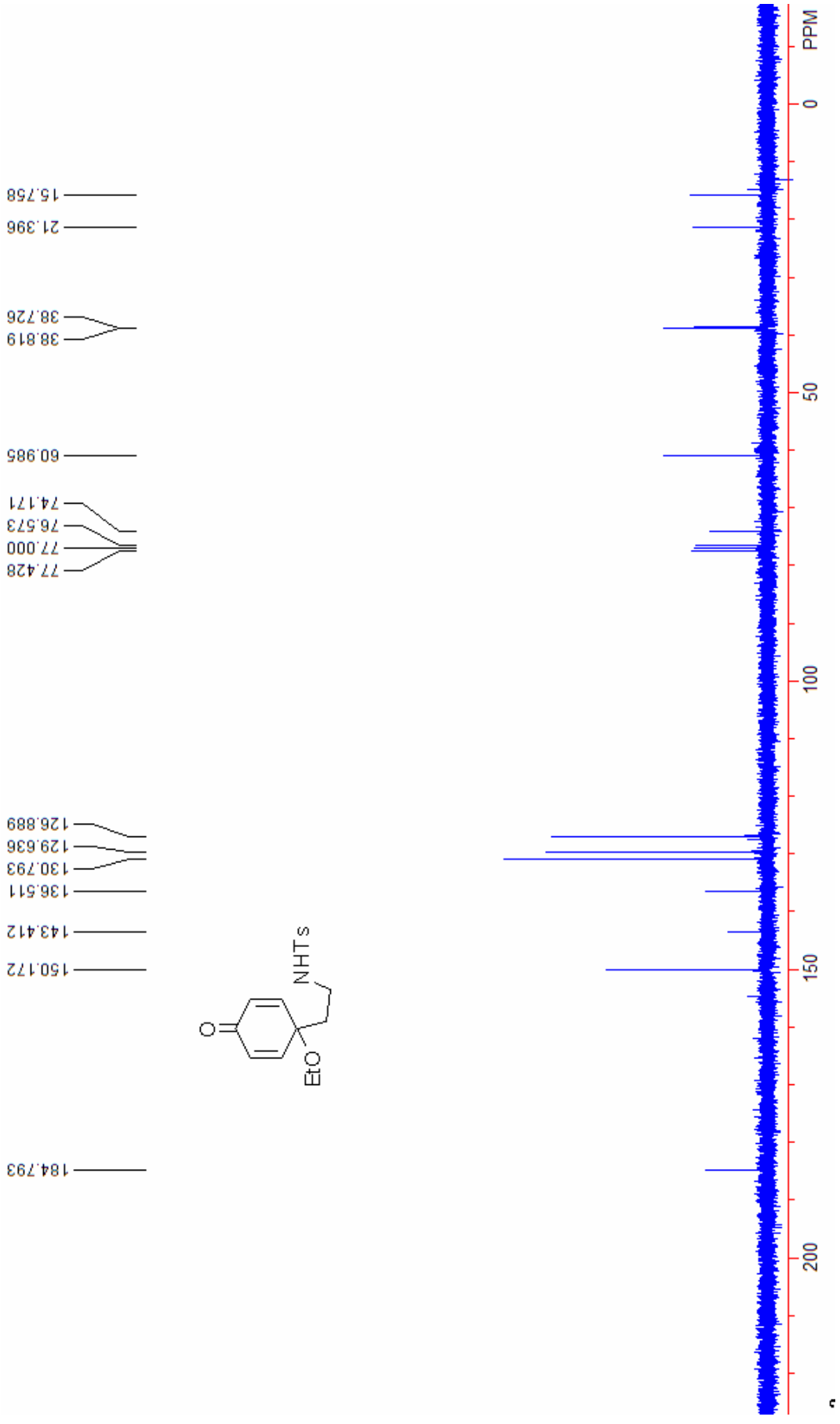
4.26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143.412
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NHTs
EtO
O
PPM
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50
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150
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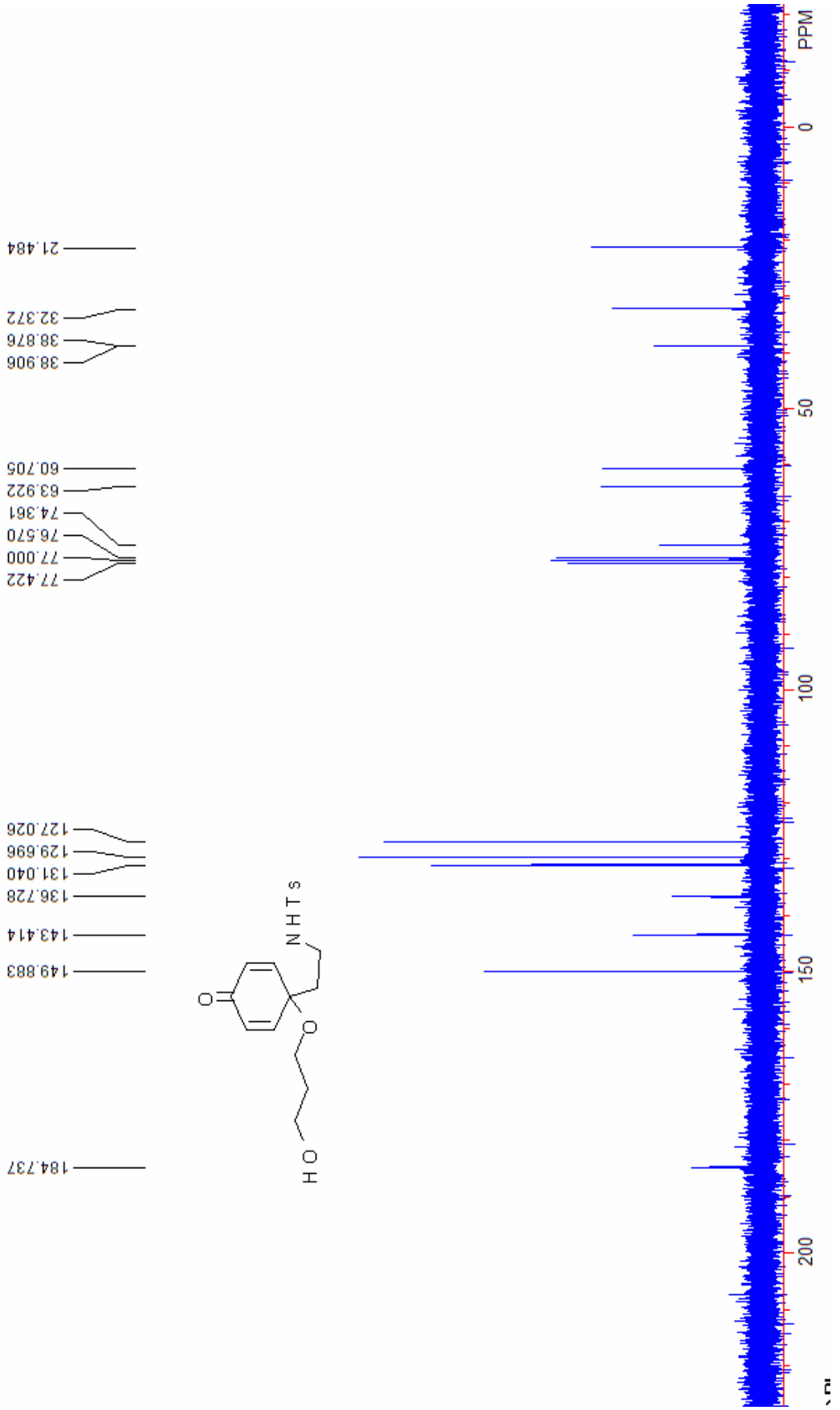
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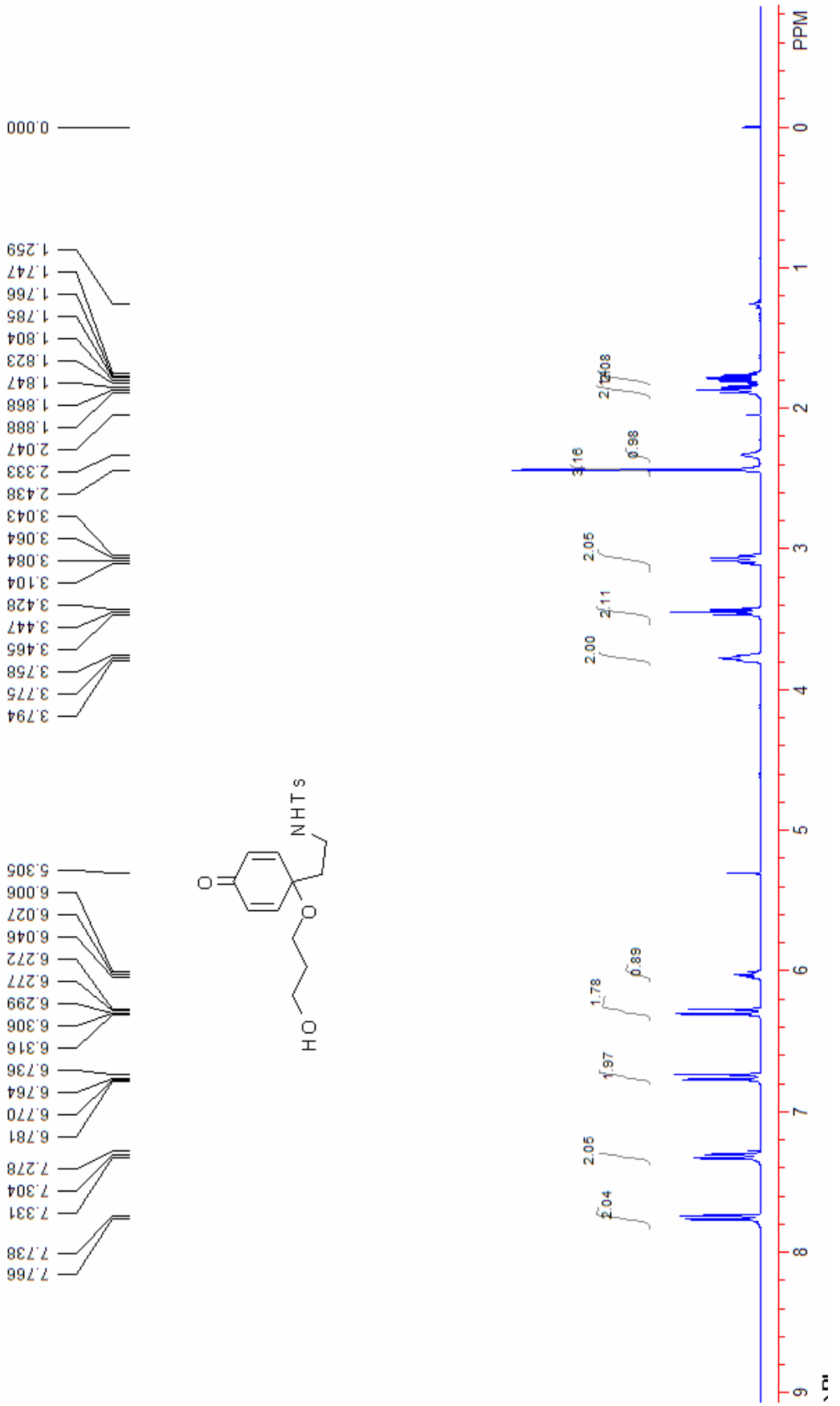
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1.847
1.868
1.888
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2.333
2.438
3.043
3.064
3.084
3.104
3.428
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3.465
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6.272
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6.299
6.306
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6.764
6.770
6.781
7.278
7.304
7.331
7.738
7.766
NHTs
O
O
HO
PPM
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1
2
3
4
5
6
7
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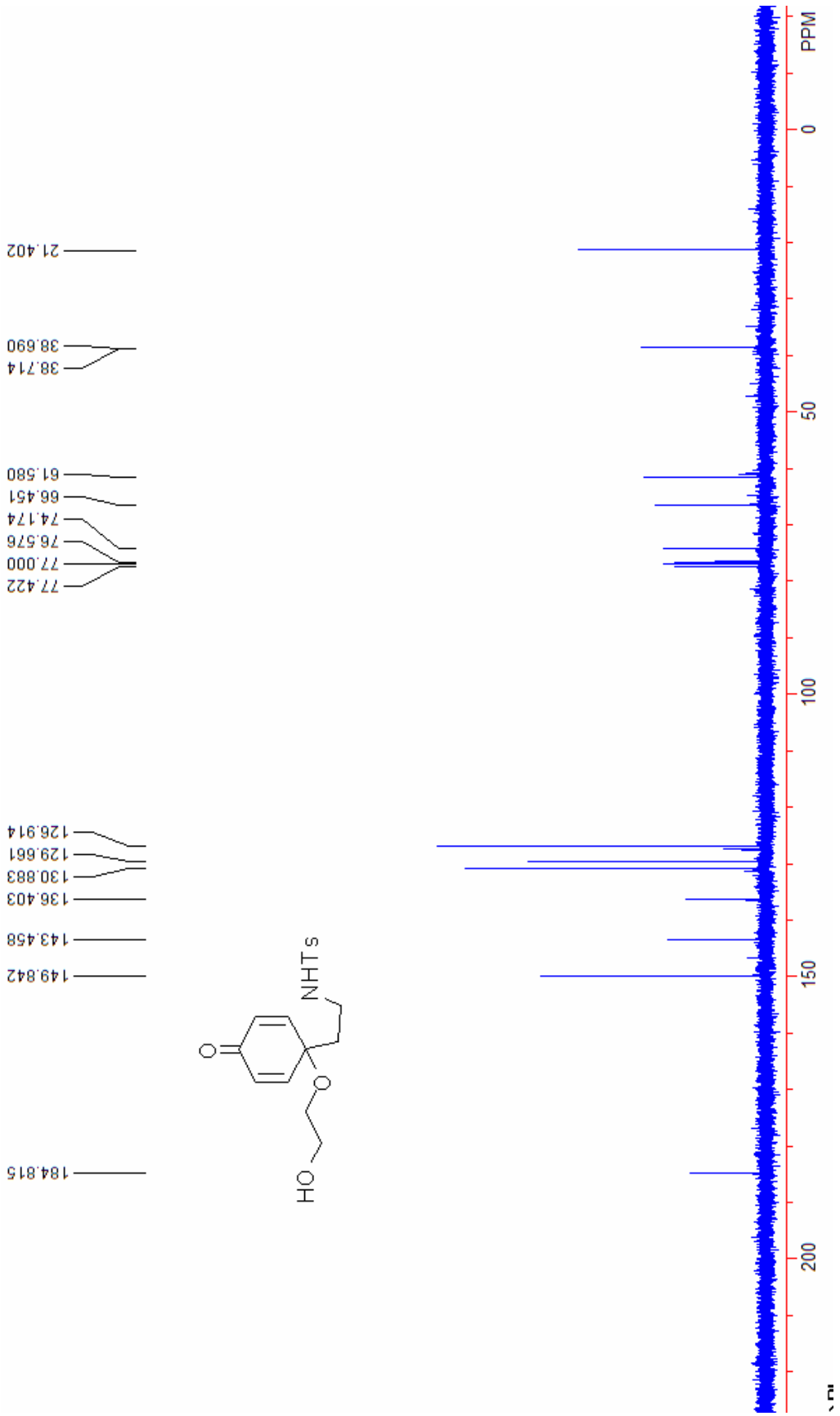
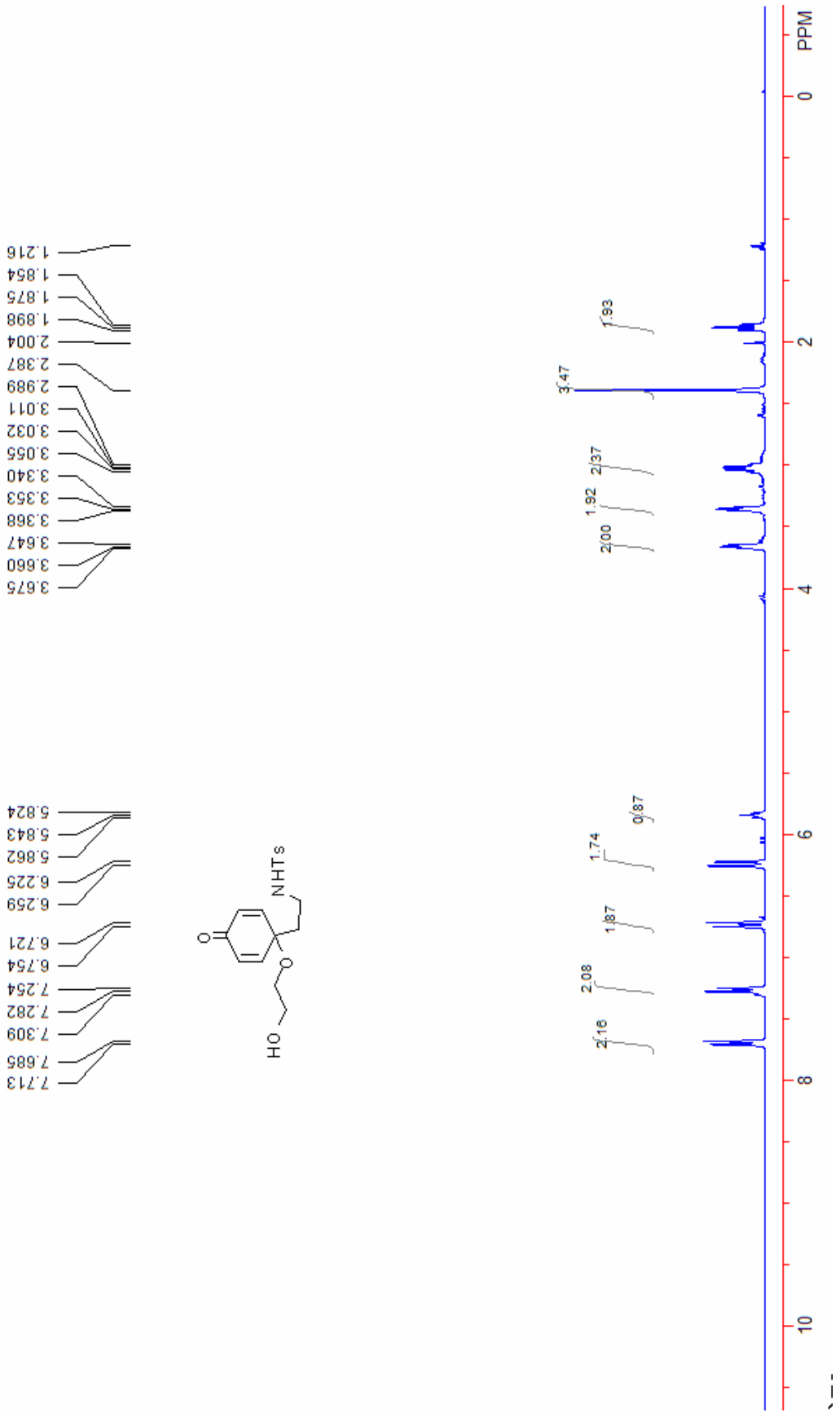
2.05
2.04

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3.647
3.660
3.675
5.824
5.843
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6.225
6.259
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6.754
7.254
7.282
7.309
7.685
7.713
NHTs
O
O
HO
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1.87
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PPM
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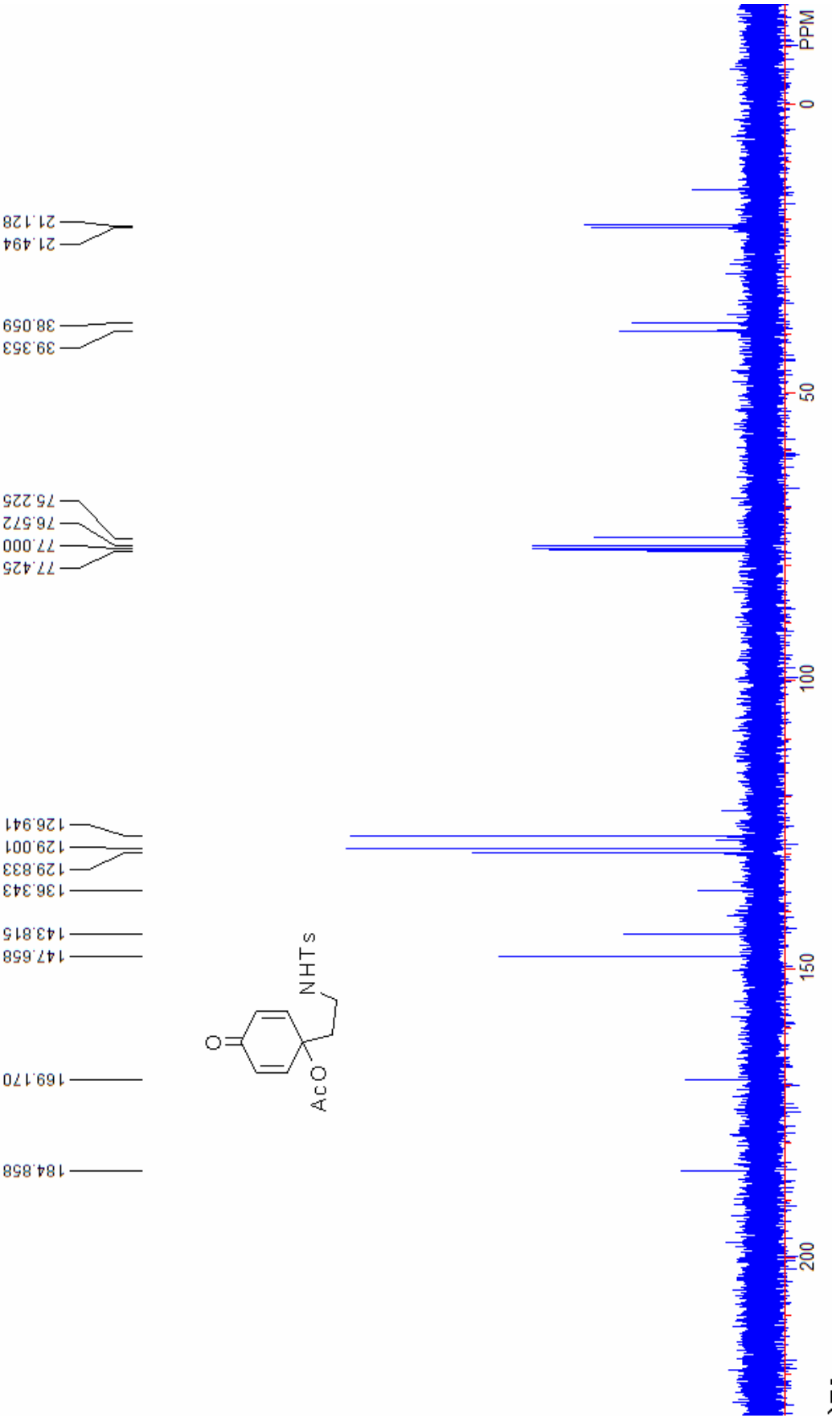
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O
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150
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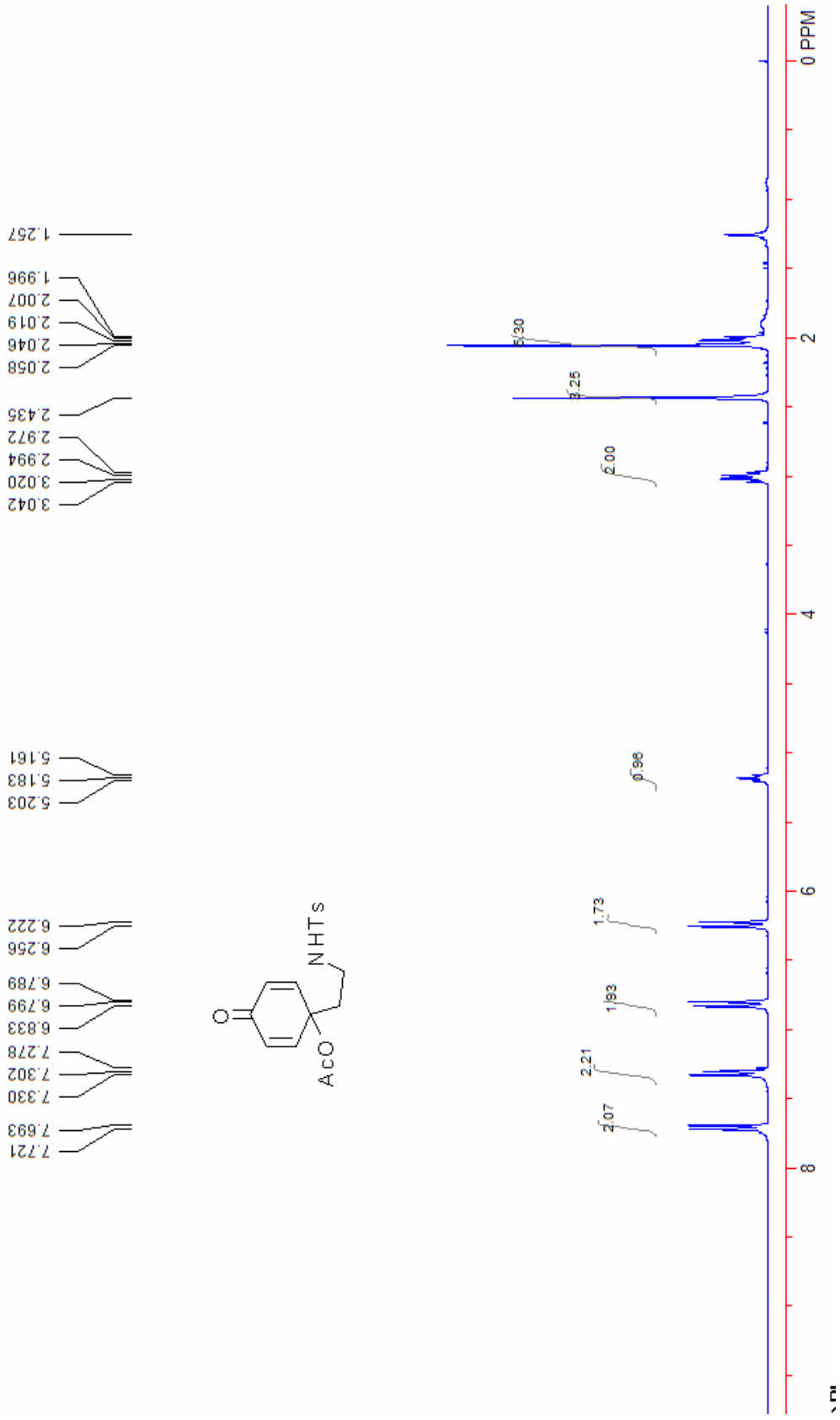
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3.042
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5.183
5.203
6.222
6.256
6.789
6.799
6.833
7.278
7.302
7.330
7.693
7.721
NHTs
AcO
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2
4
6
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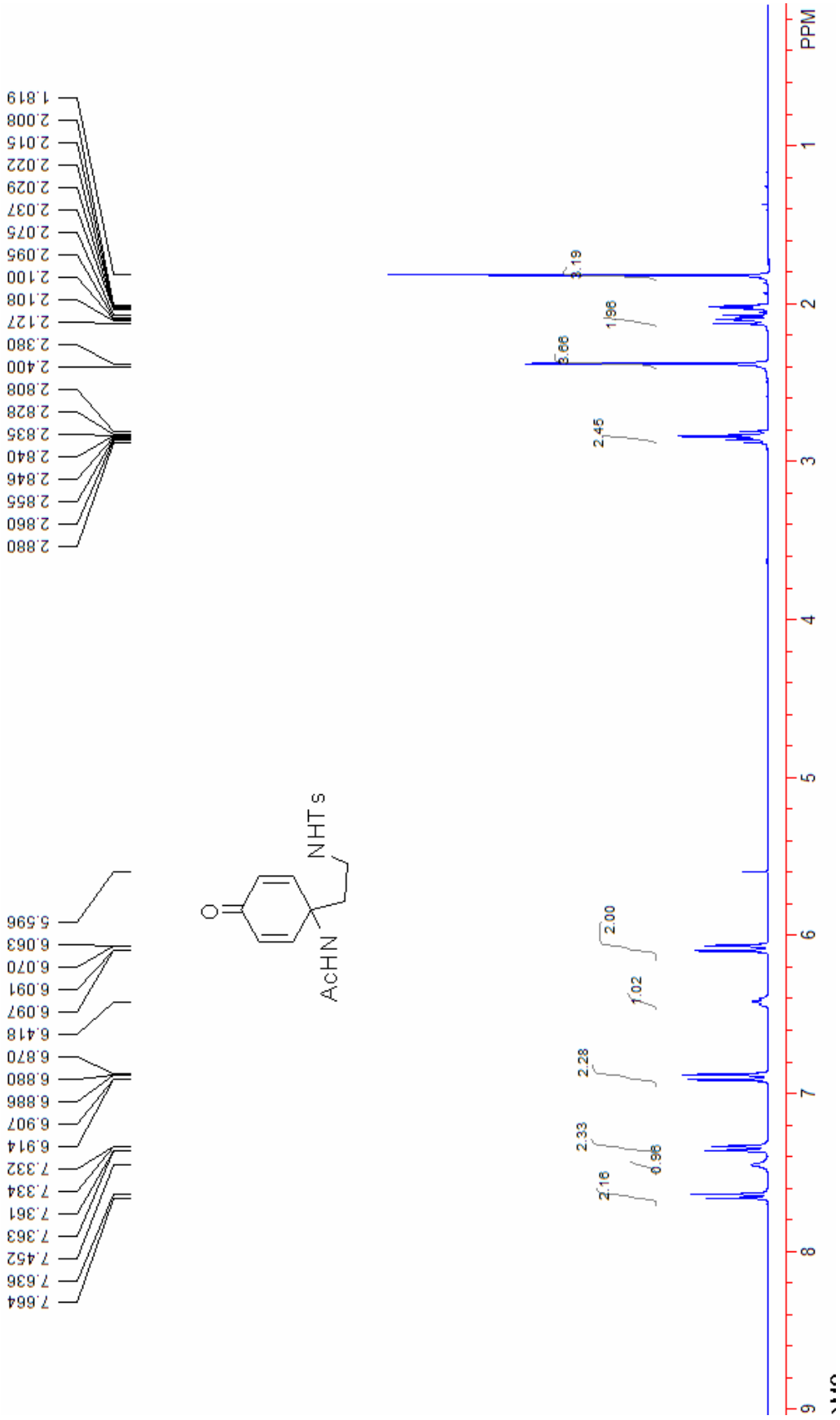
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2.380
2.400
2.808
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2.840
2.846
2.855
2.860
2.880
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6.063
6.070
6.091
6.097
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6.870
6.880
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6.907
6.914
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7.334
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7.452
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7.664
O
AcHN
NHTs
3.19
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3.66
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2
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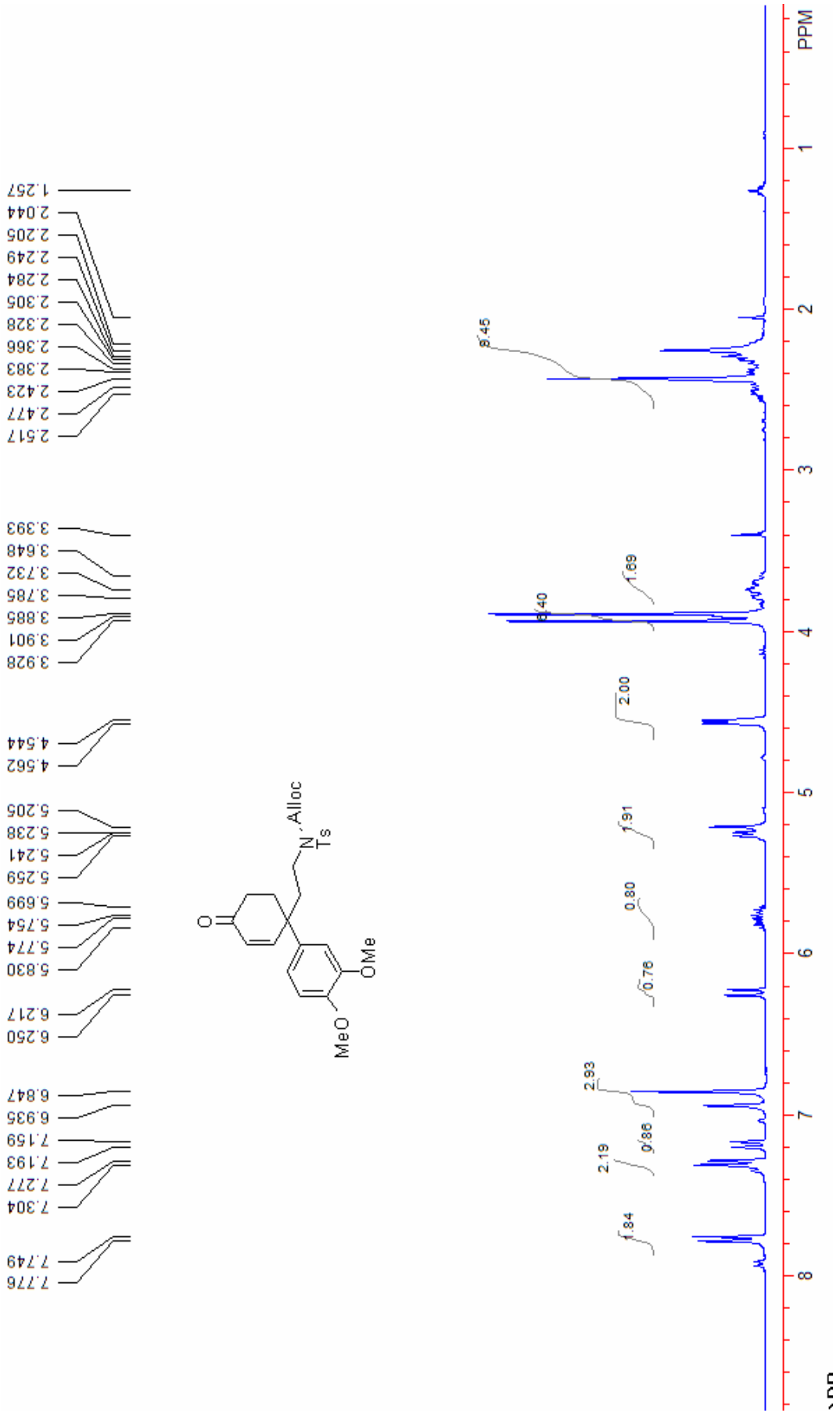
7
8
9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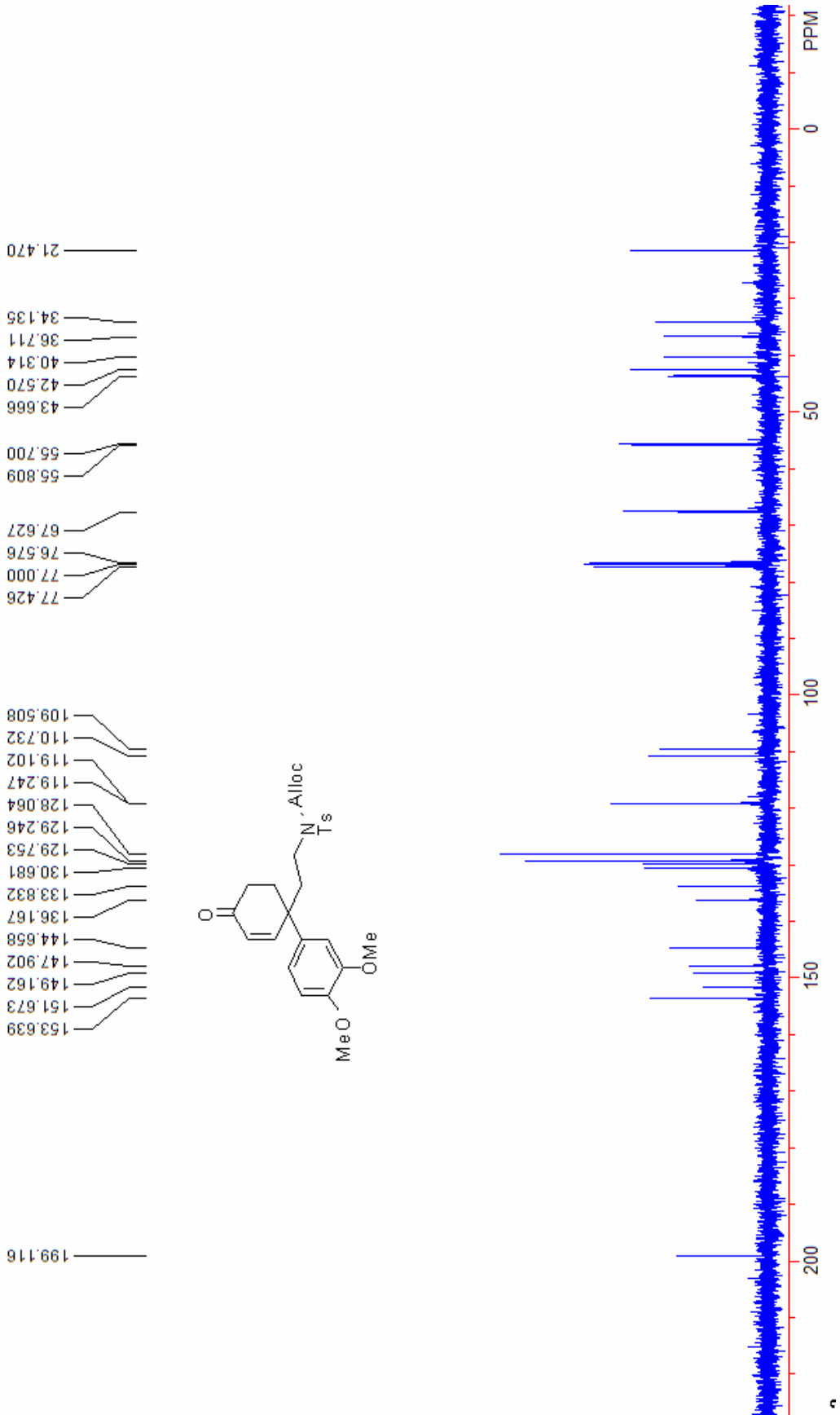
Ts
O
MeO
OMe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MeO
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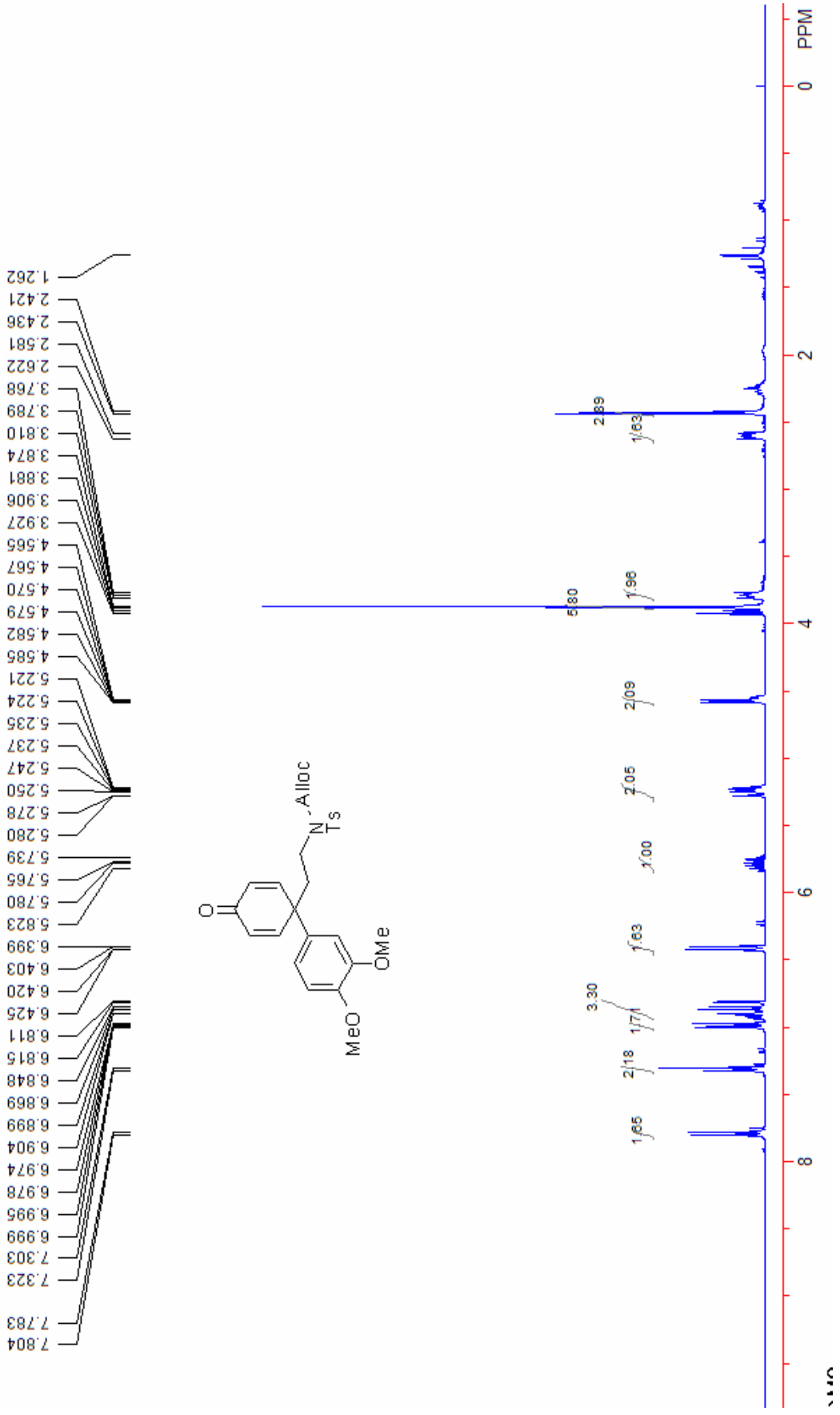
150
200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4.570
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4.585
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5.237
5.247
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5.280
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5.765
5.780
5.823
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6.403
6.420
6.425
6.811
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6.869
6.899
6.904
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6.999
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7.323
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7.804
Alloc
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Ts
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OMe
MeO
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6
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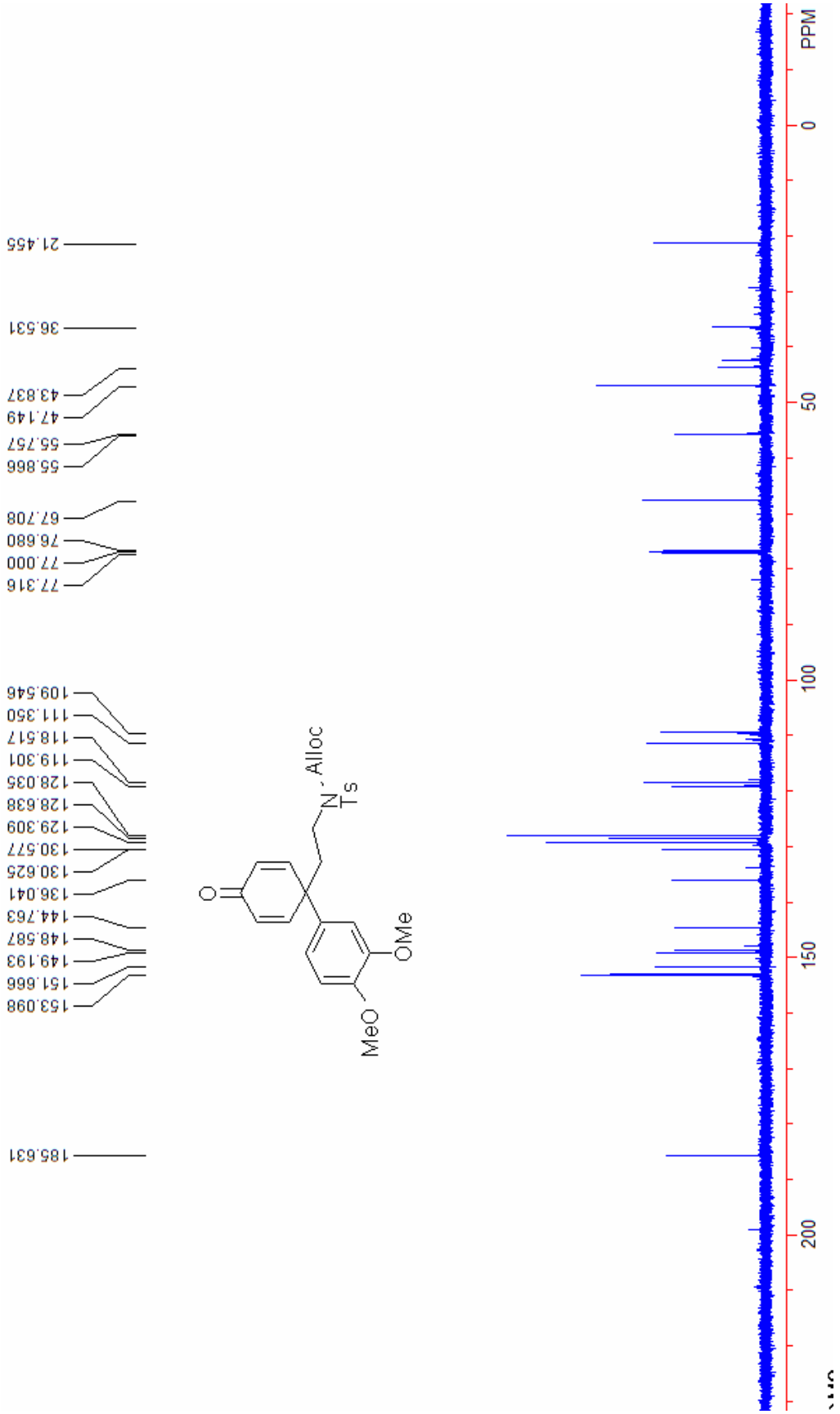

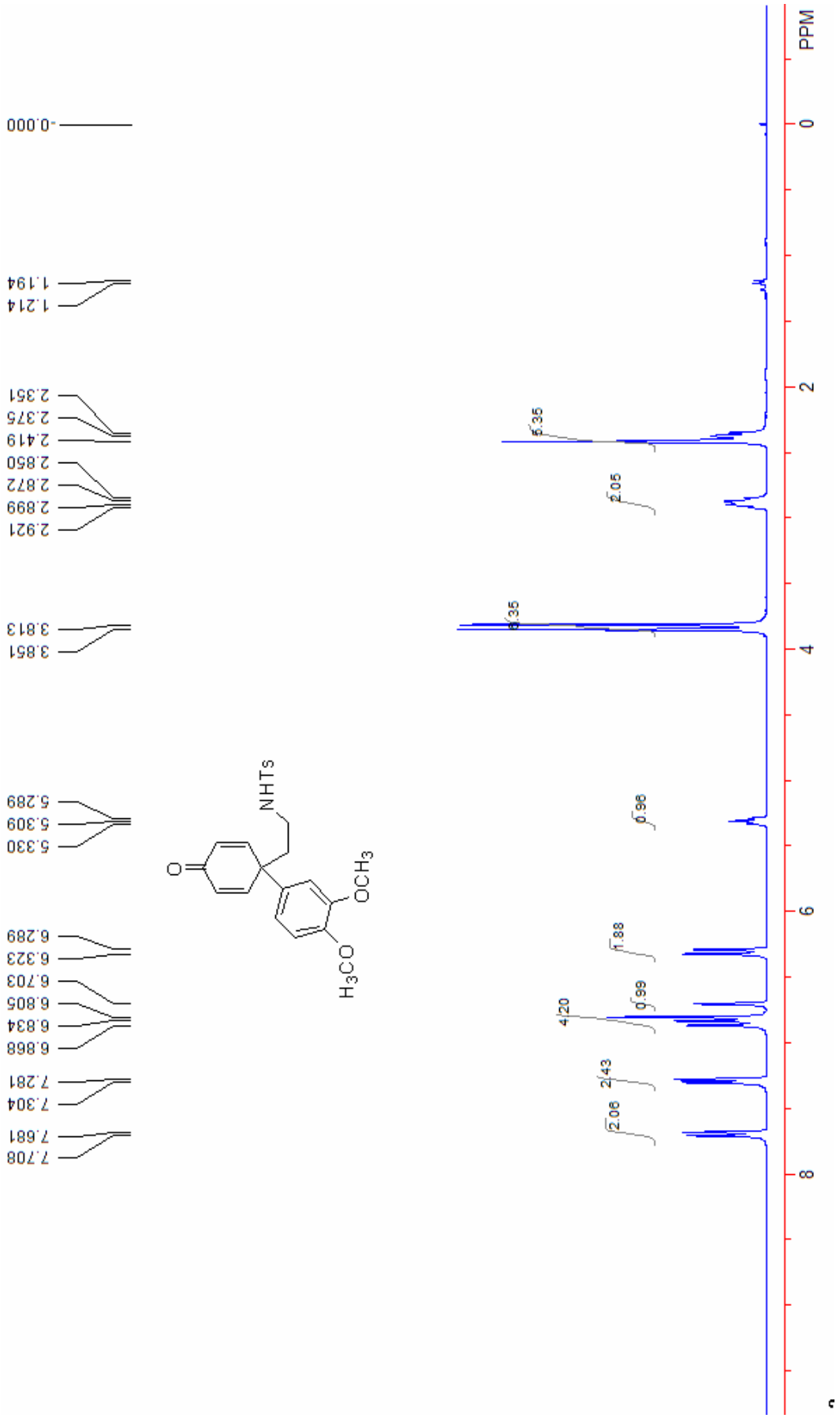
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2.06
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O
OCH3
H3CO
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5.309
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6.805
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6.868
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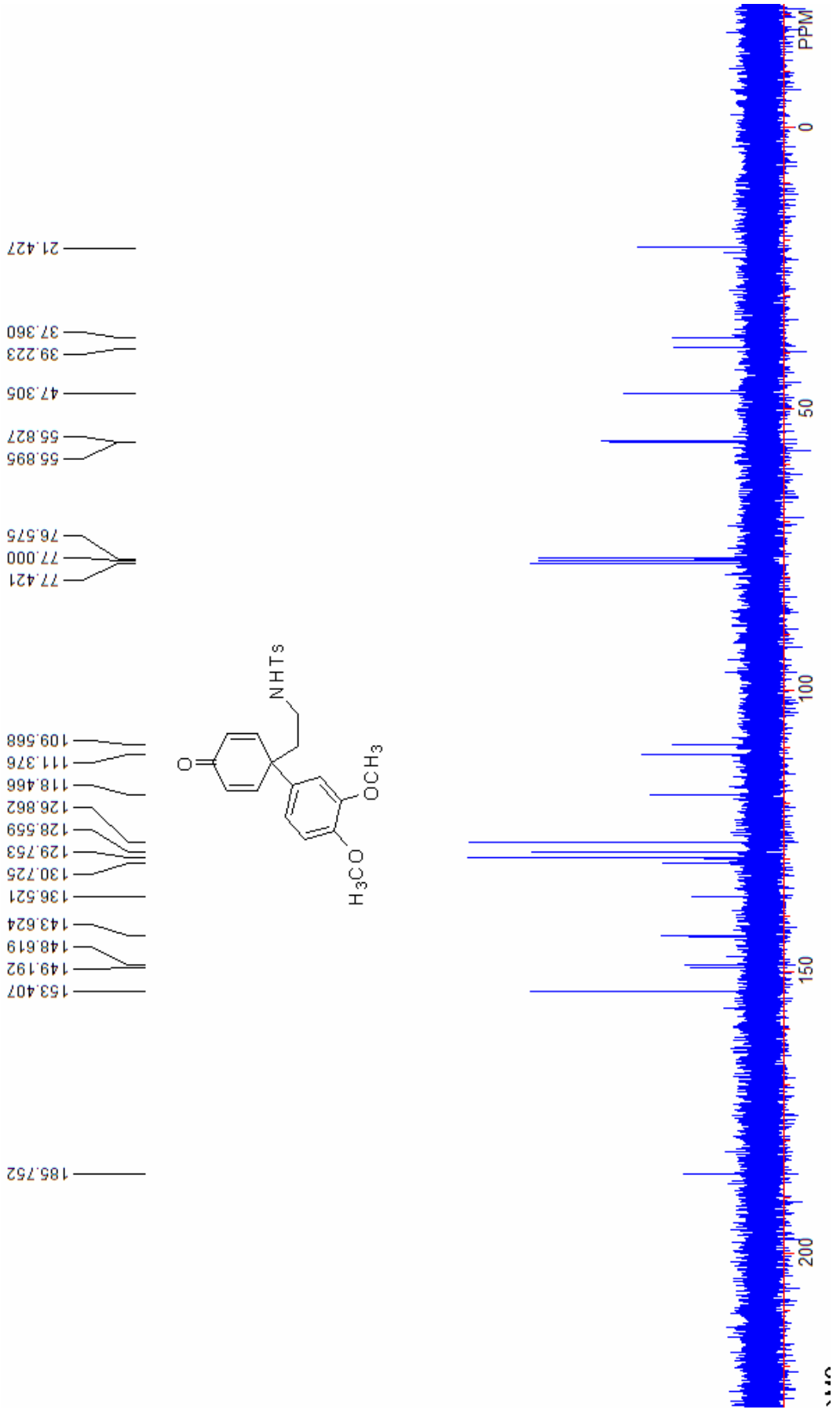

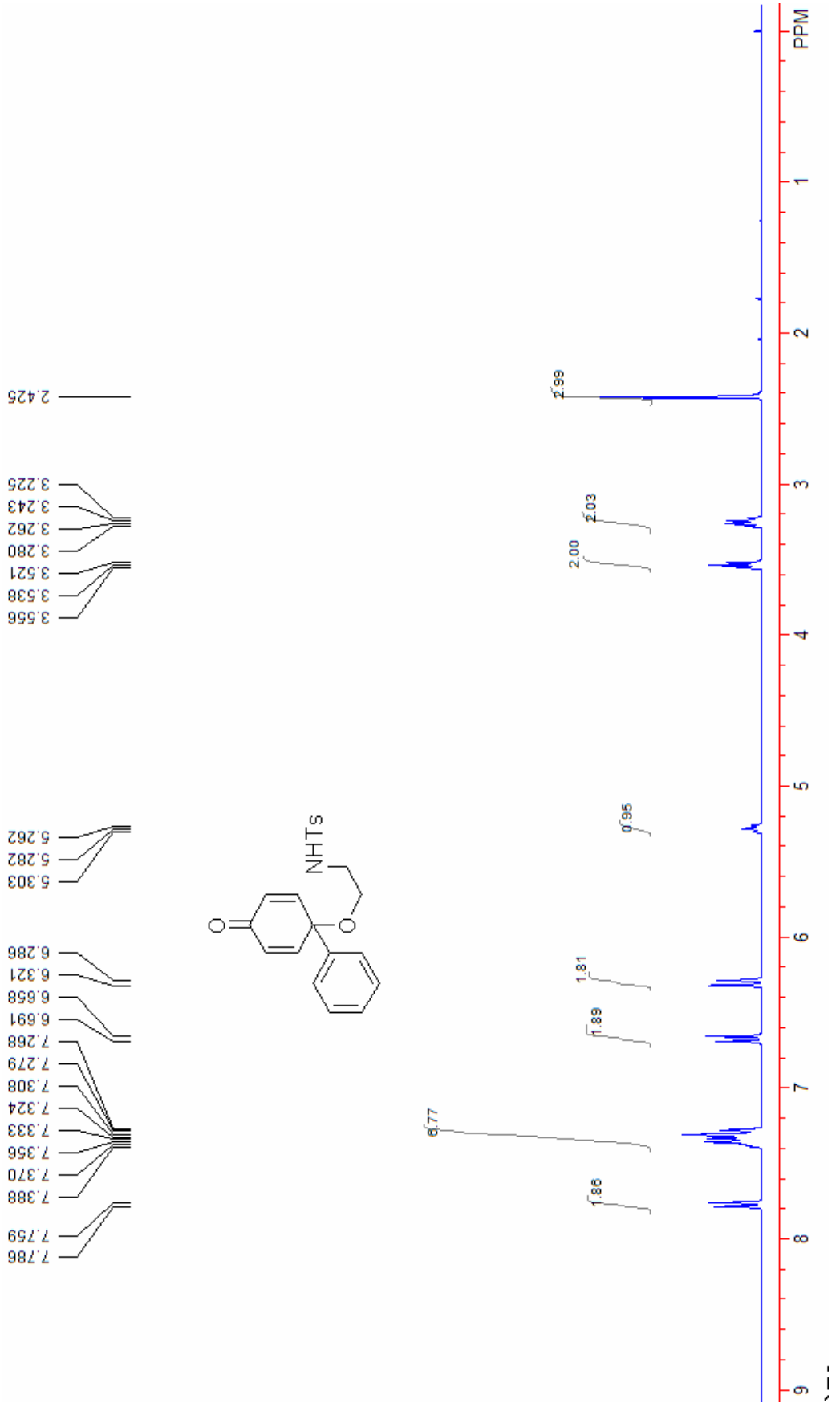
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6.286
6.321
6.658
6.691
7.268
7.279
7.308
7.324
7.333
7.356
7.370
7.388
7.759
7.786
NHTs
O
O
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2.03
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1.89
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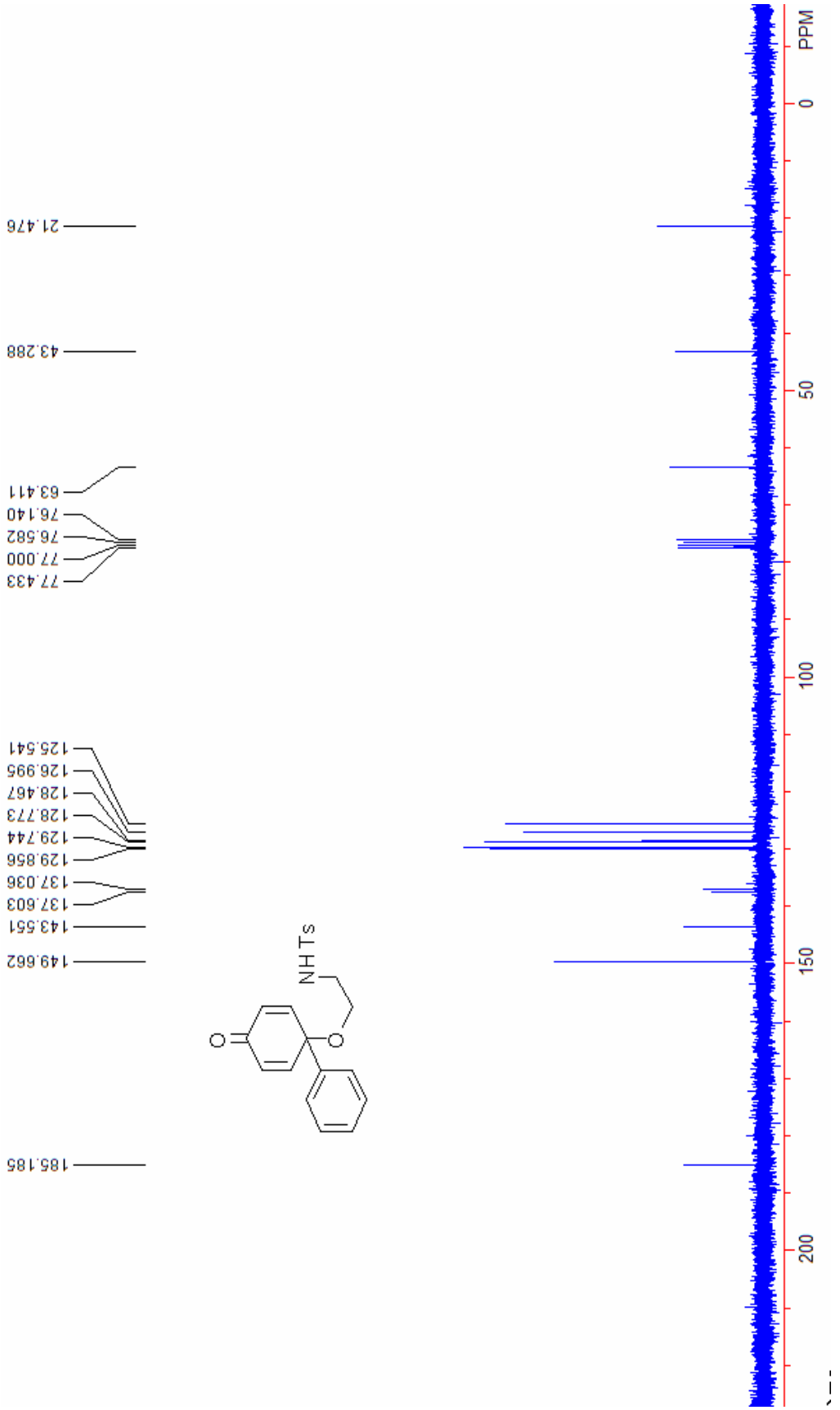
9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O
O
PPM
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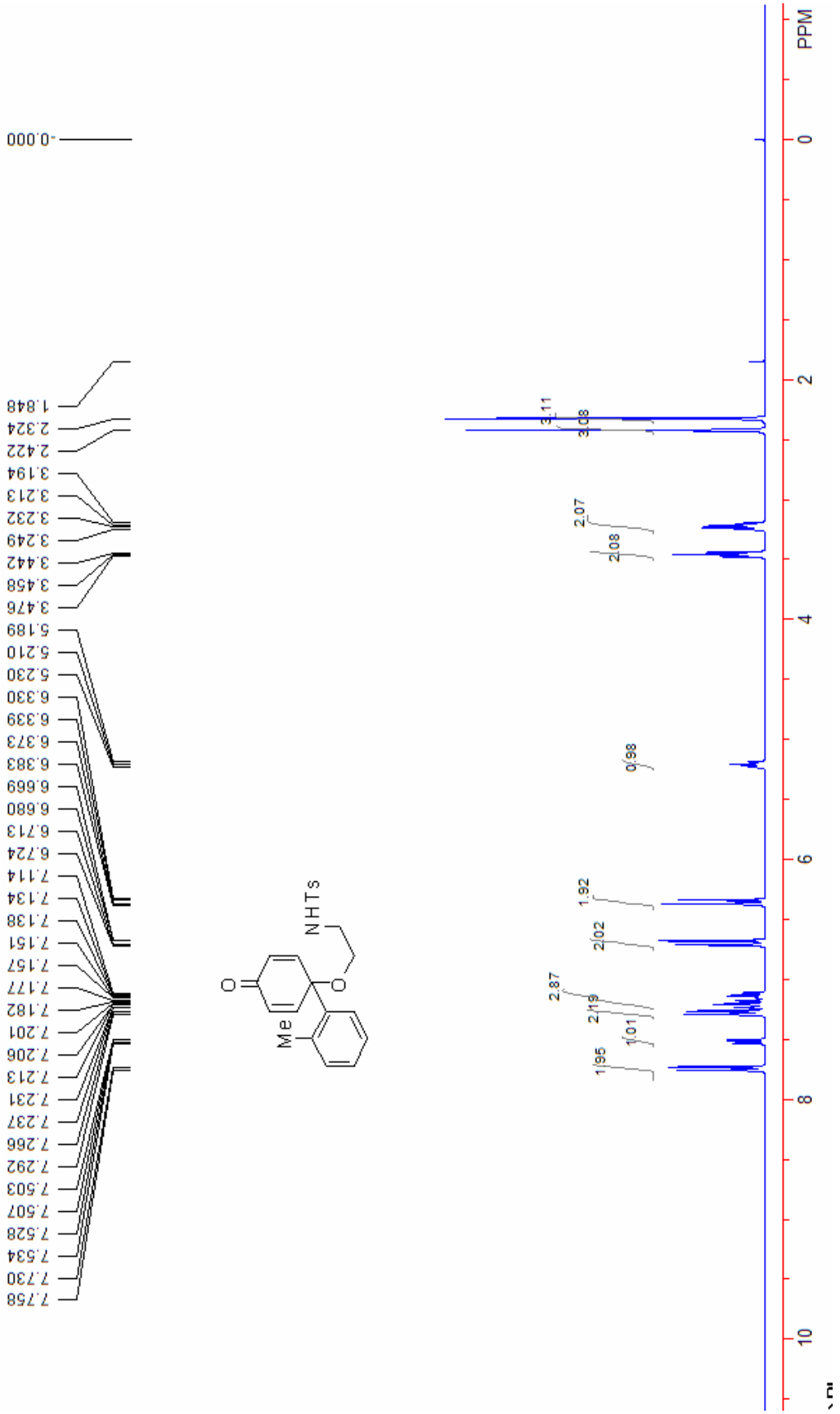
100
150
200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1.01
1.95
NHTs
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O
Me
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3.232
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7.177
7.182
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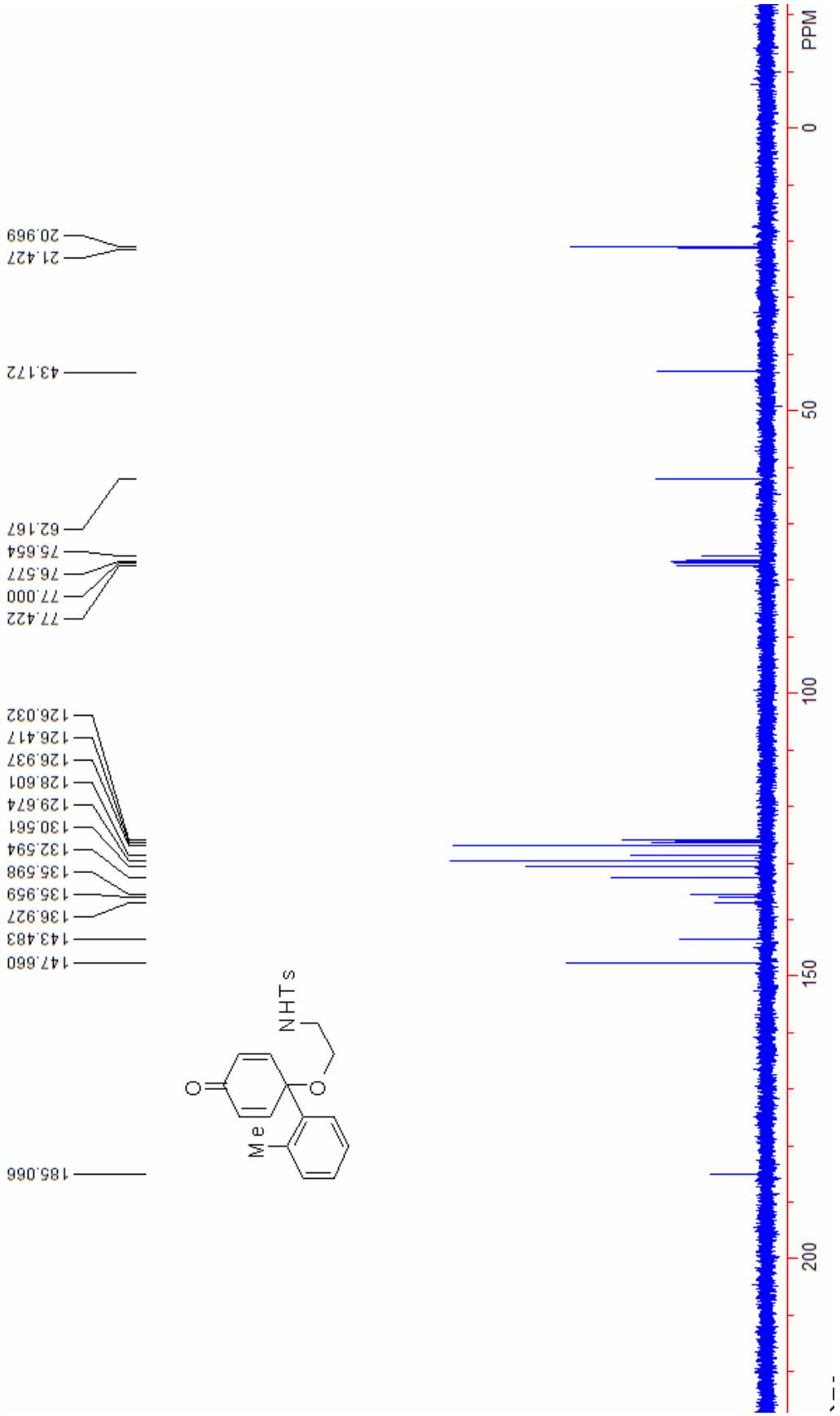
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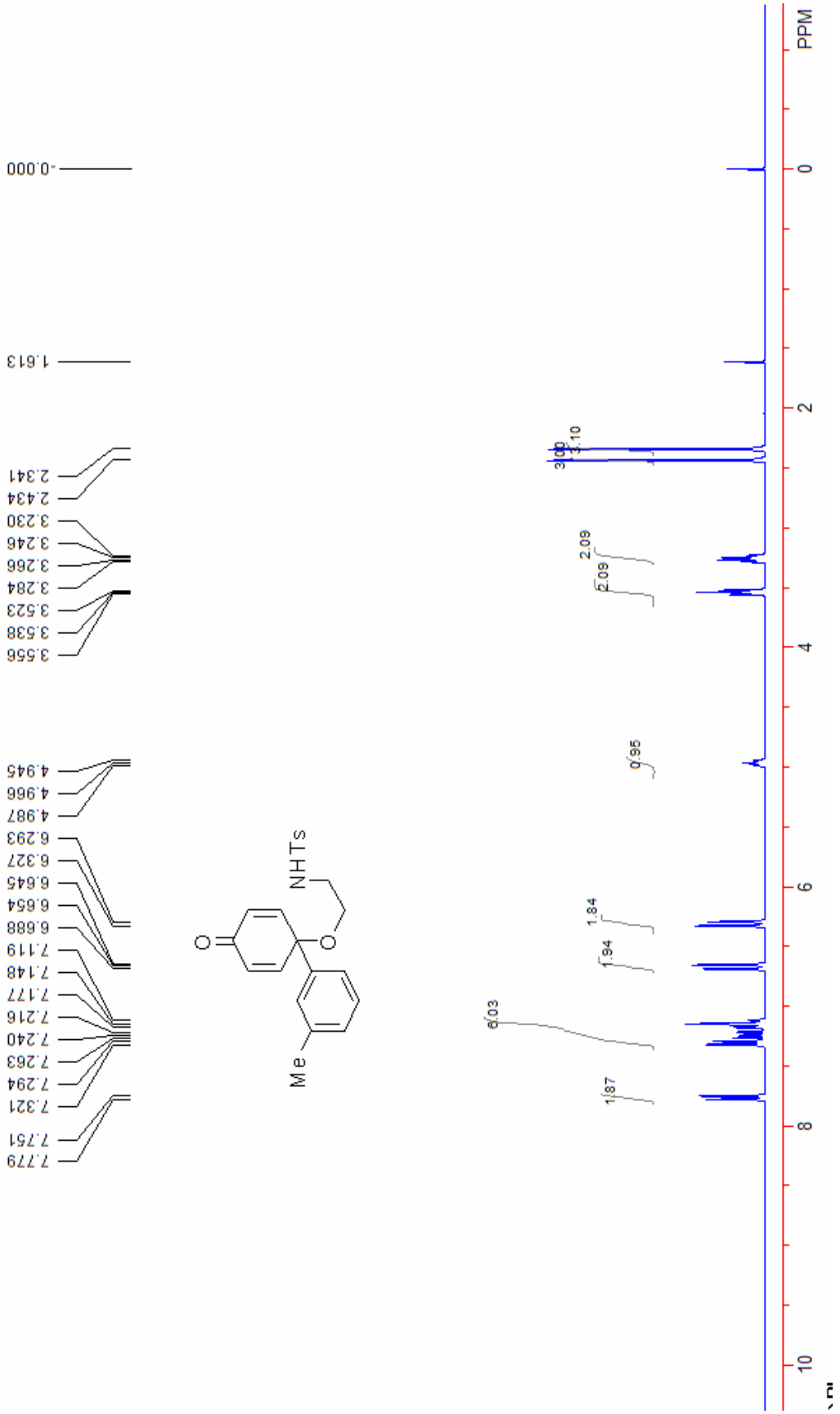
O
Me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1.87
NHTs
Me
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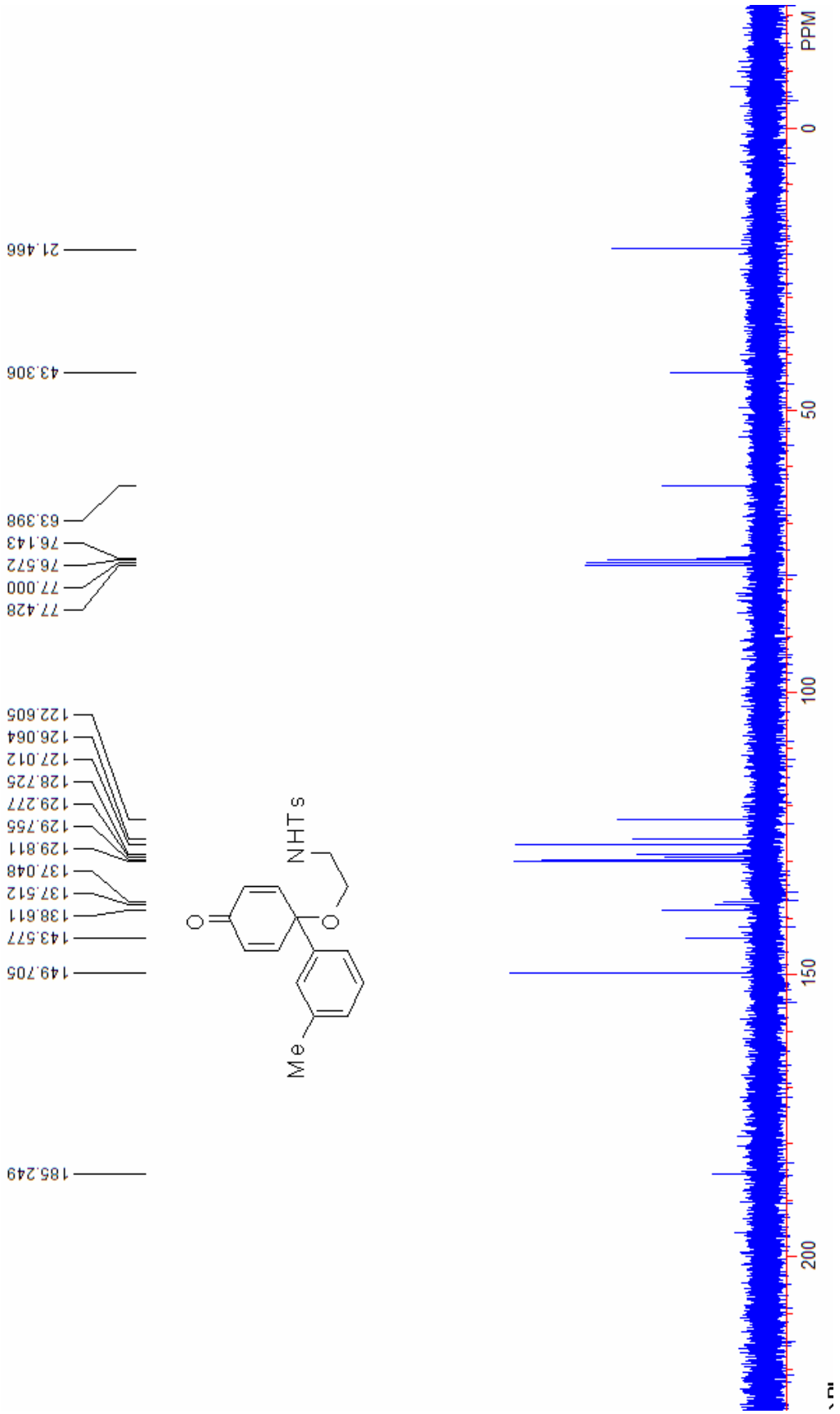
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O
O
PPM
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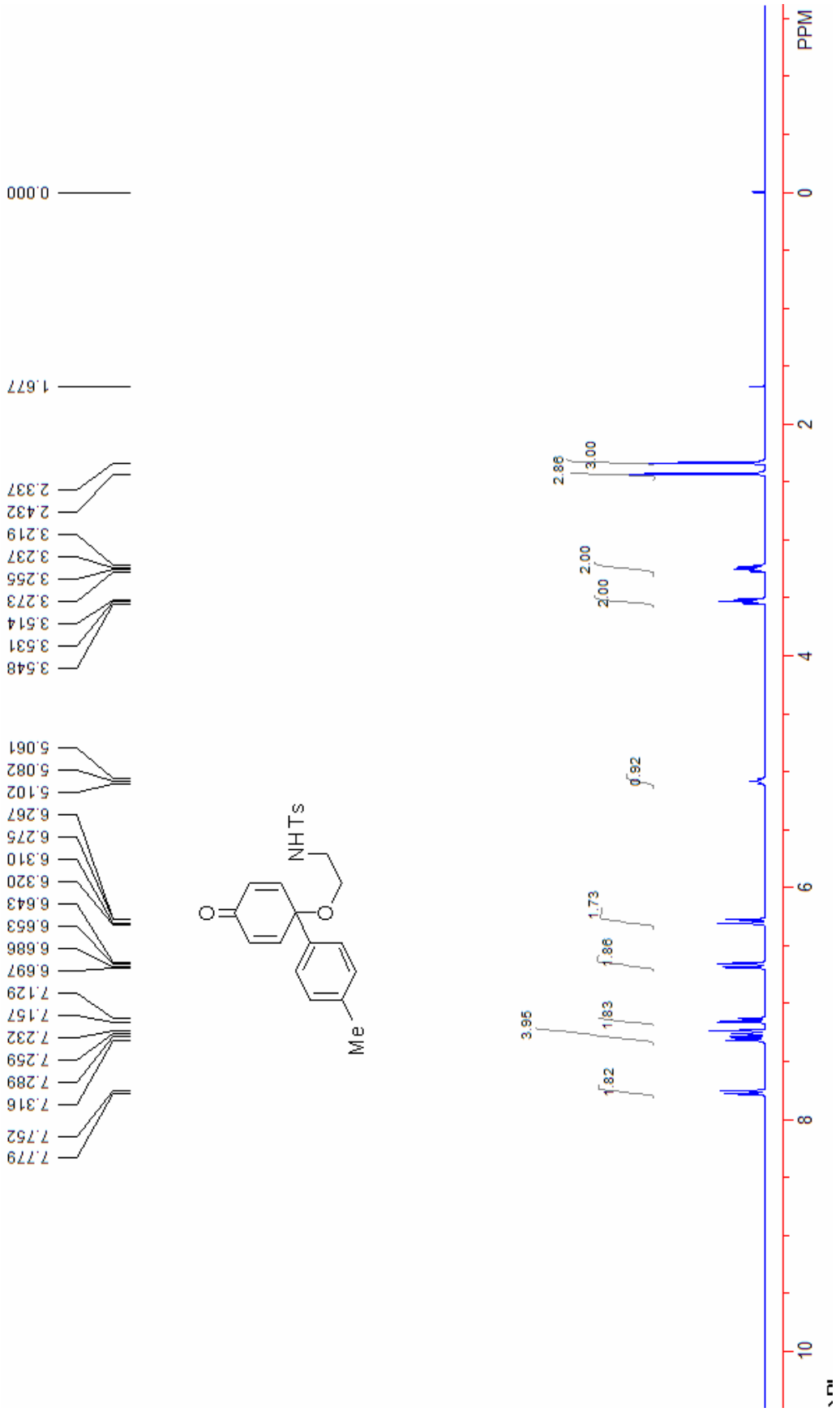
50
100
150
200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1.83
1.82
NHTs
O
O
Me
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2.337
2.432
3.219
3.237
3.255
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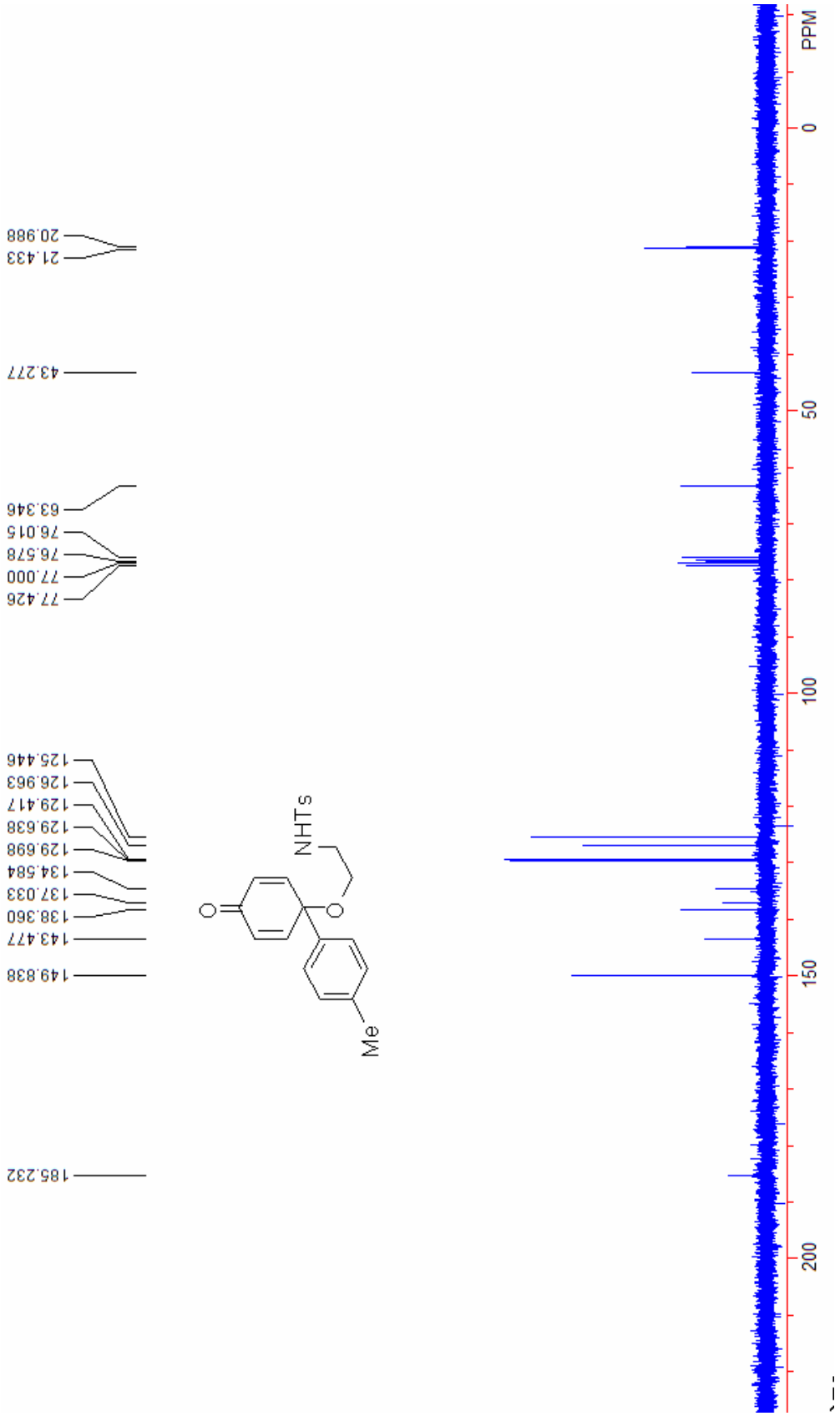
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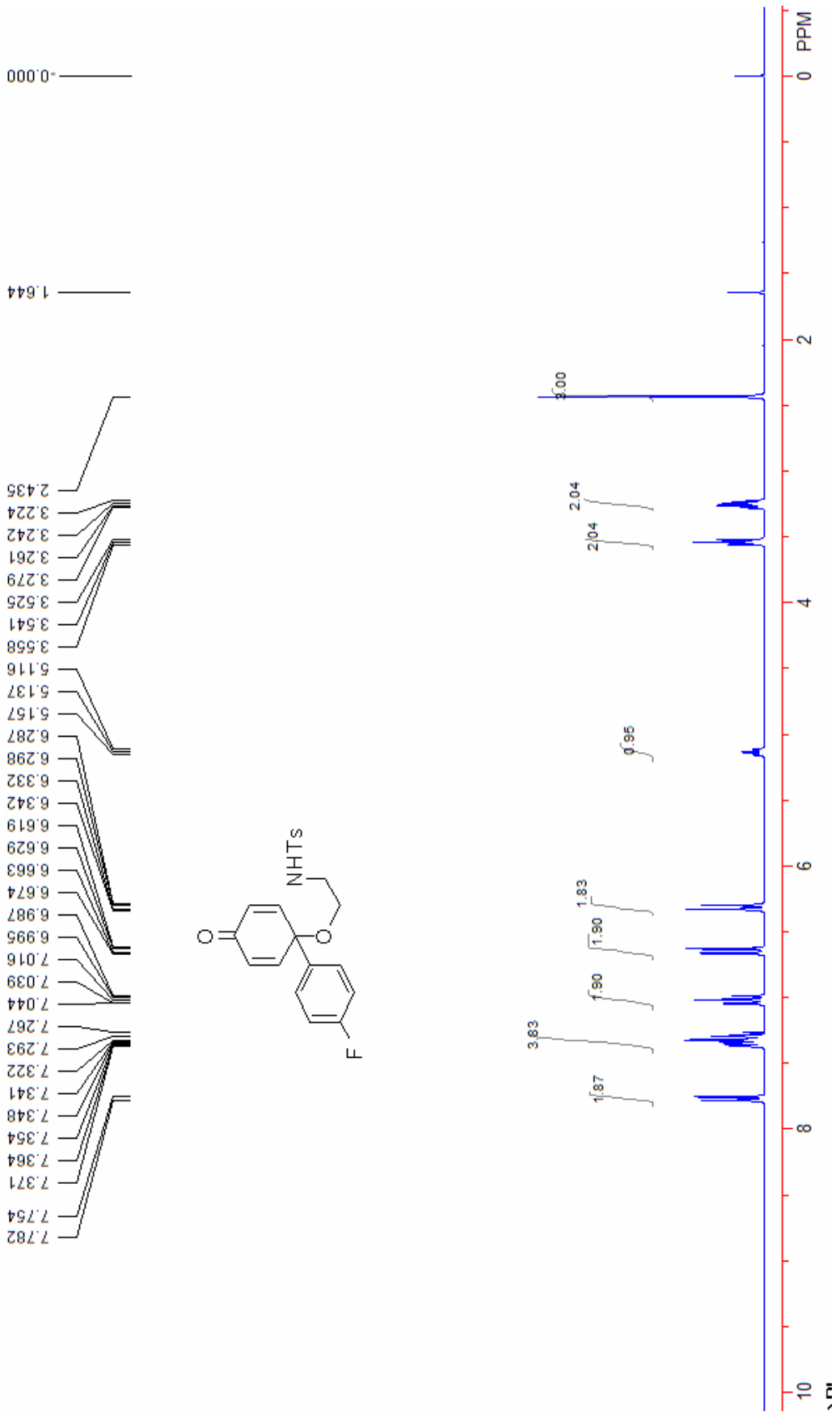
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6.629
6.663
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7.322
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O
F
PPM
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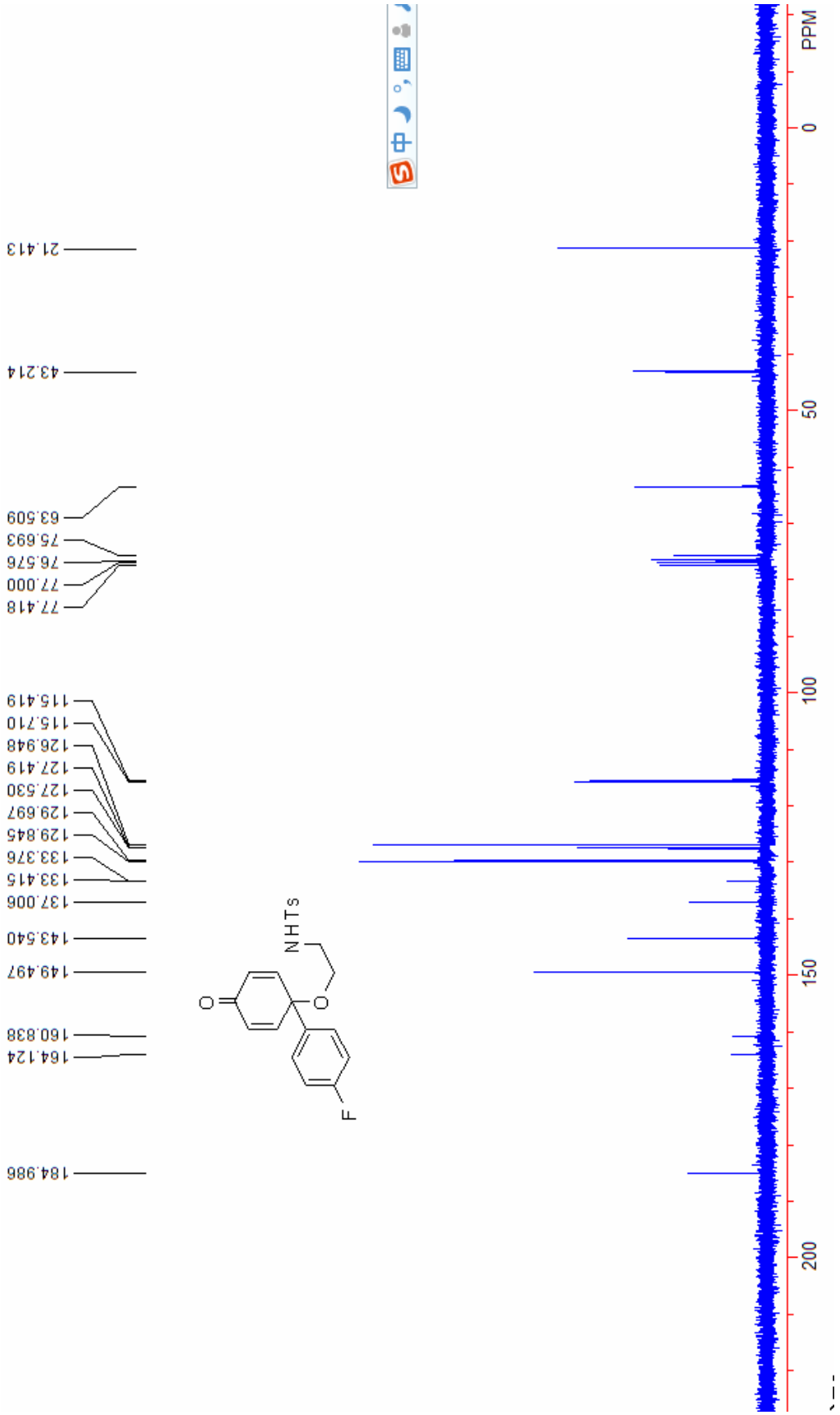
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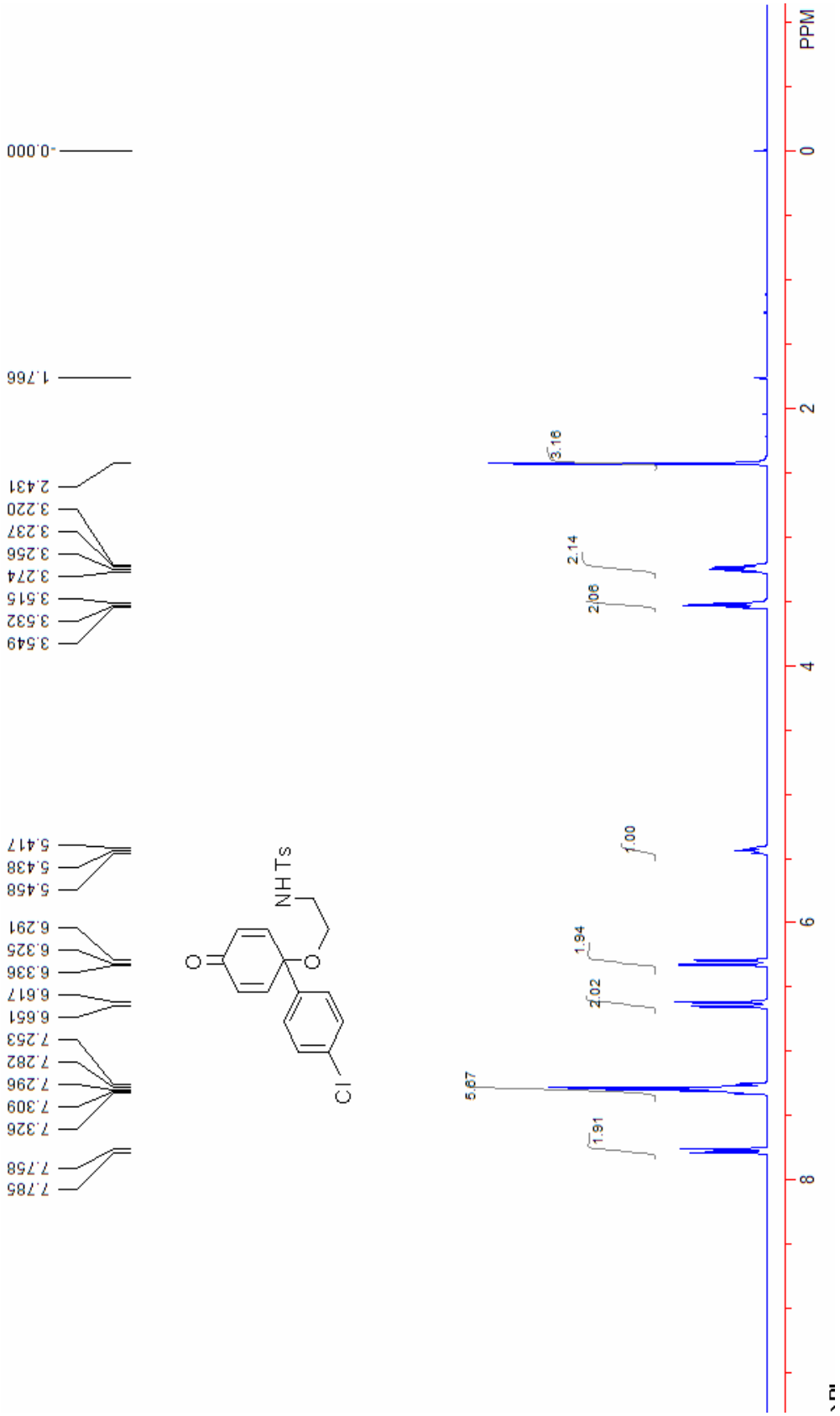
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1.94
2.02
5.67
1.91
NHTs
O
O
Cl
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3.220
3.237
3.256
3.274
3.515
3.532
3.549
5.417
5.438
5.458
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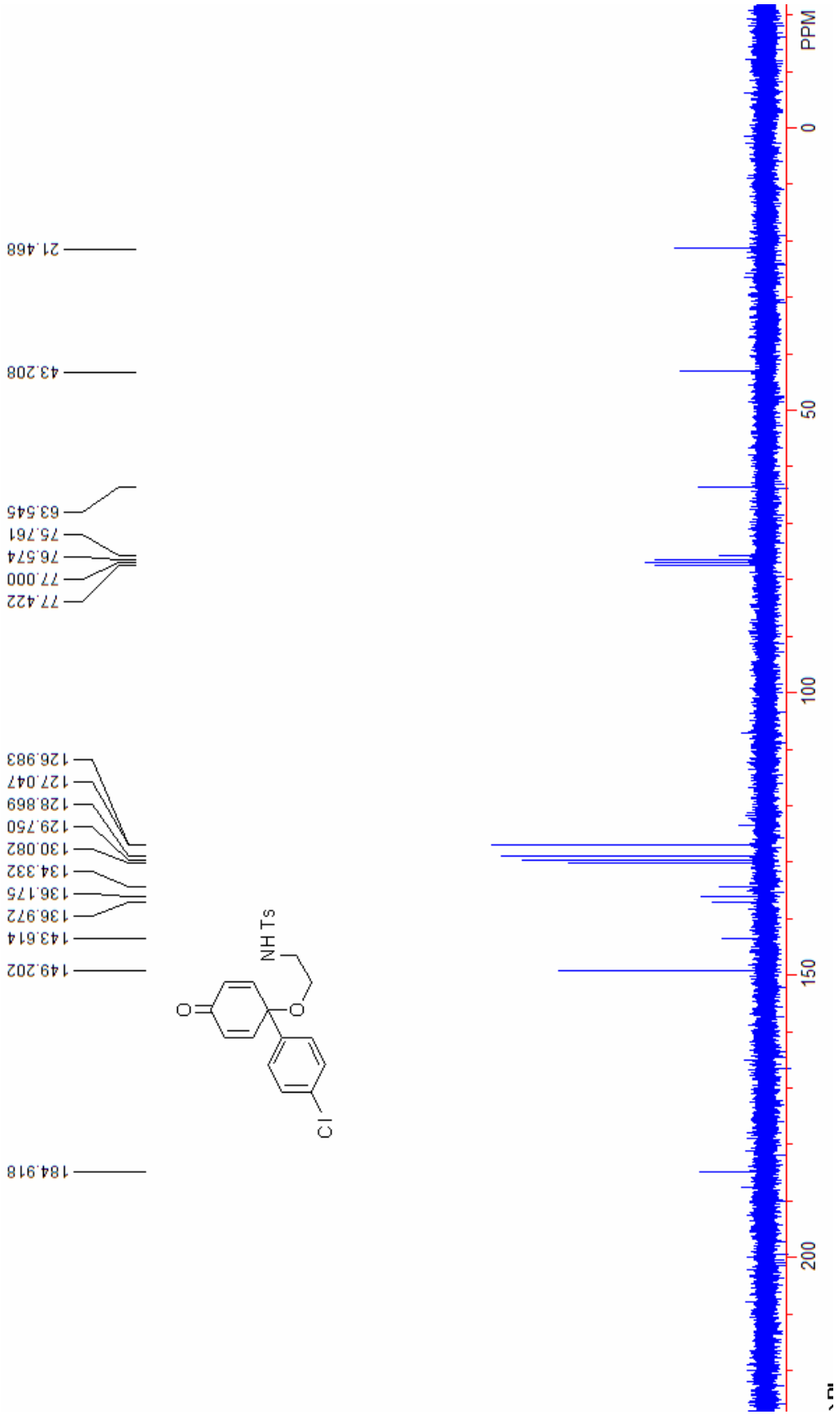
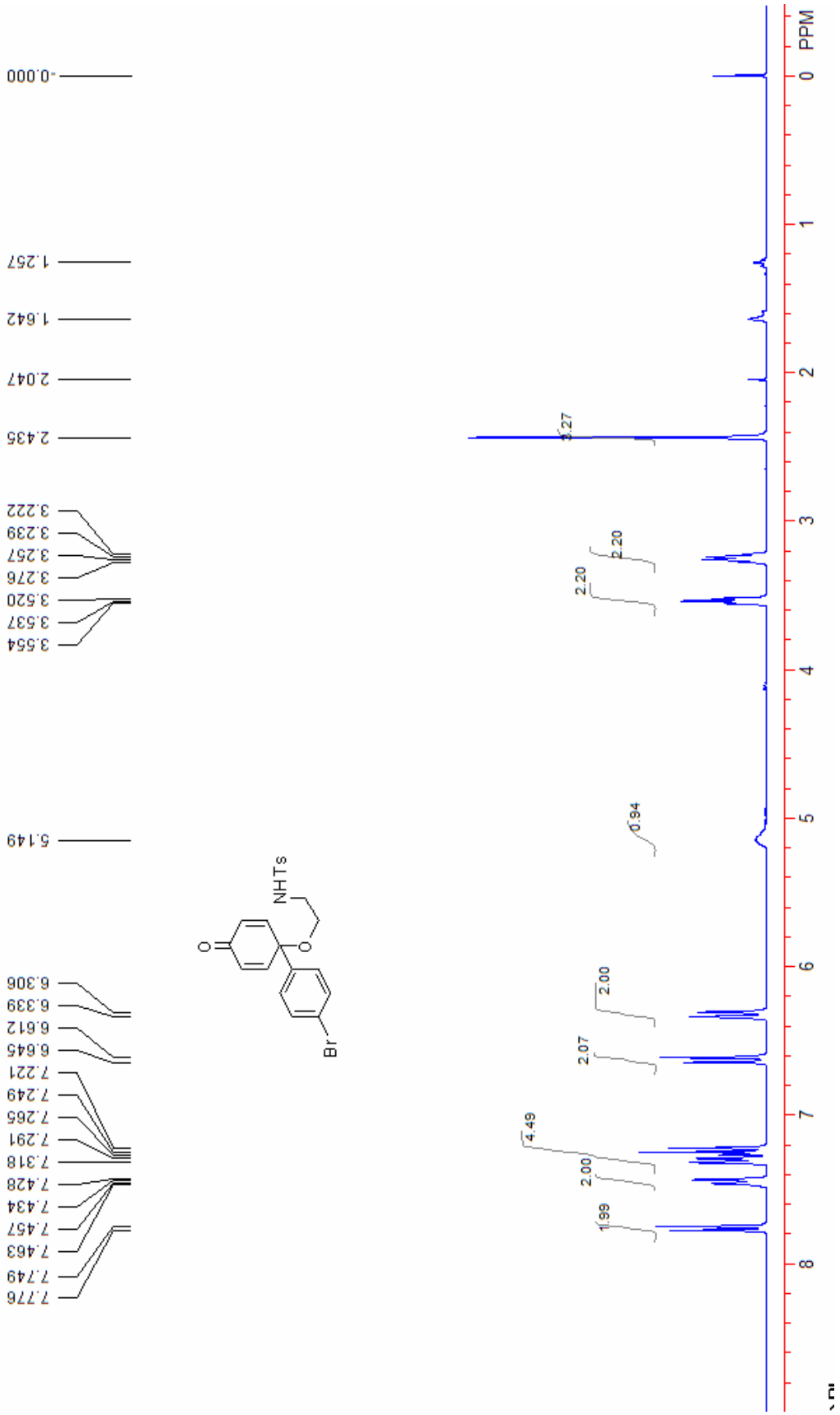
7.785

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NHTs
O
O
Br
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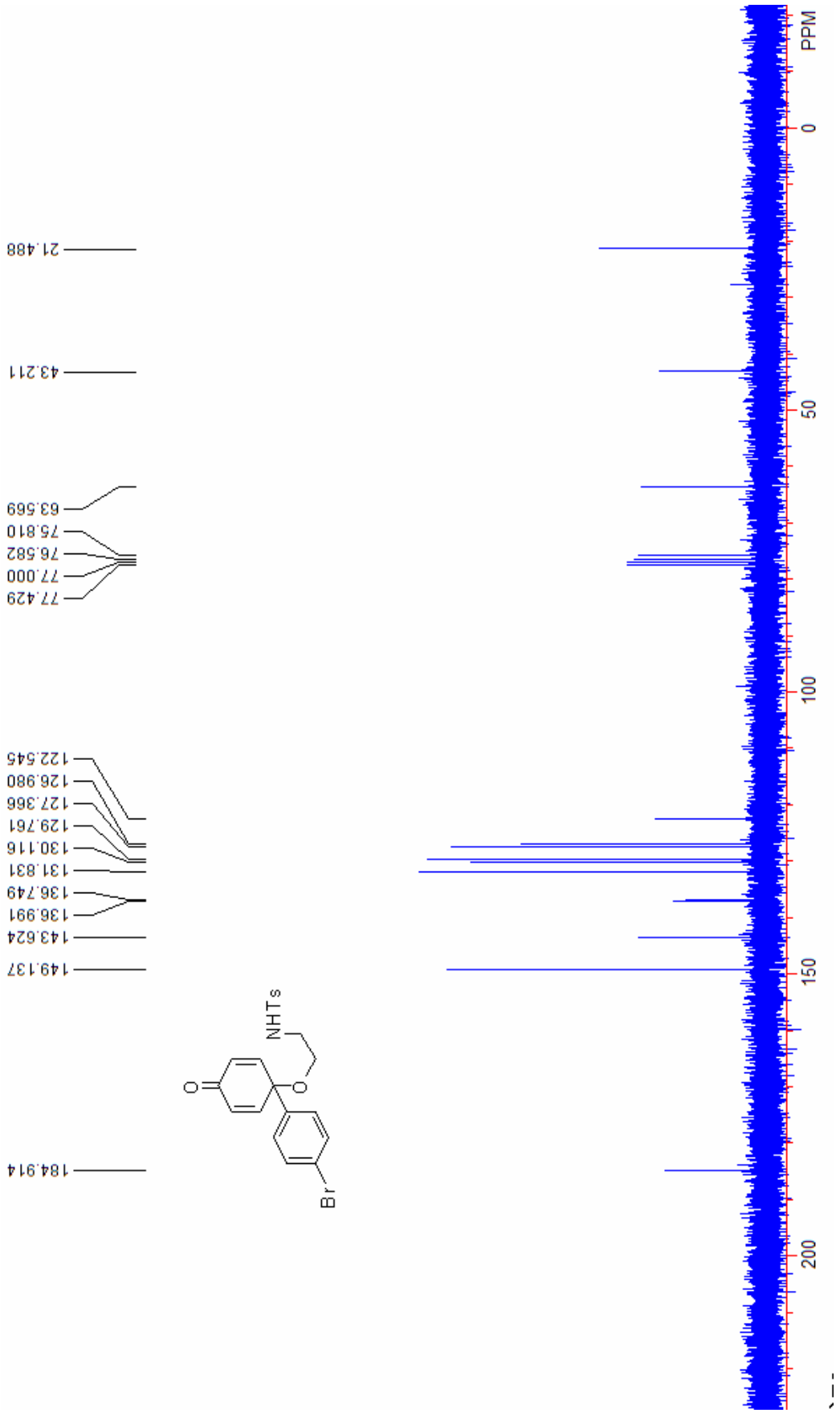

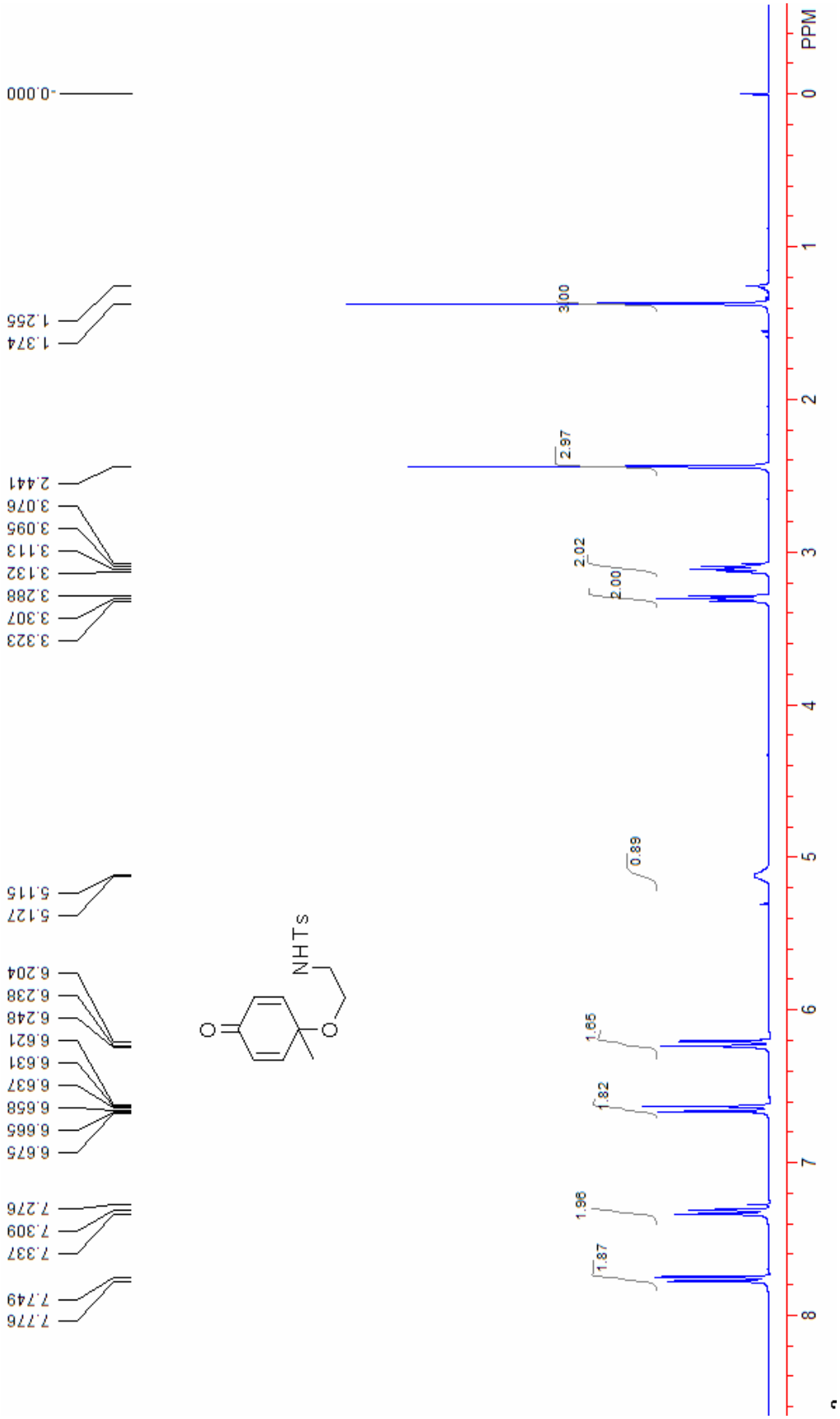

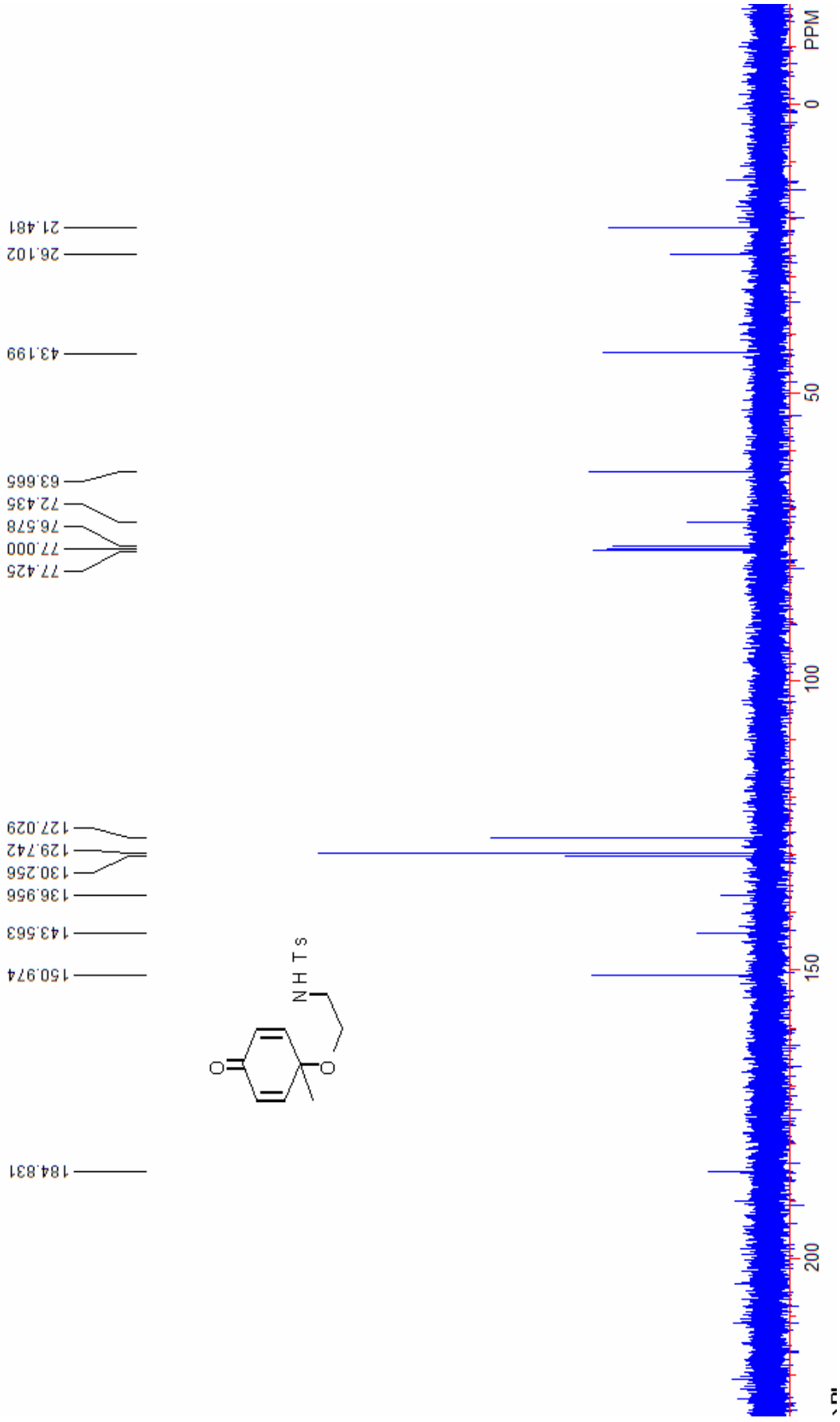
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O
PPM
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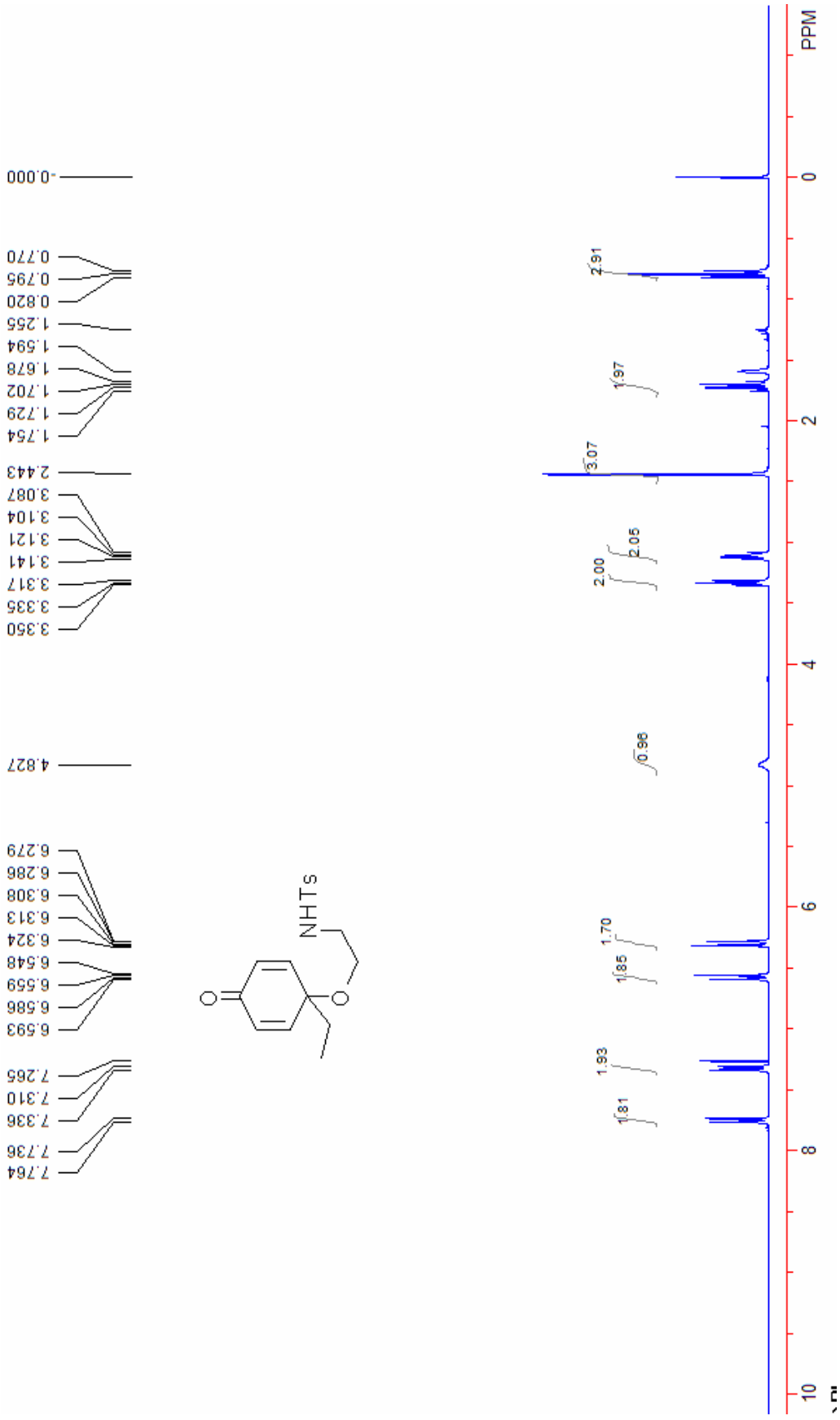

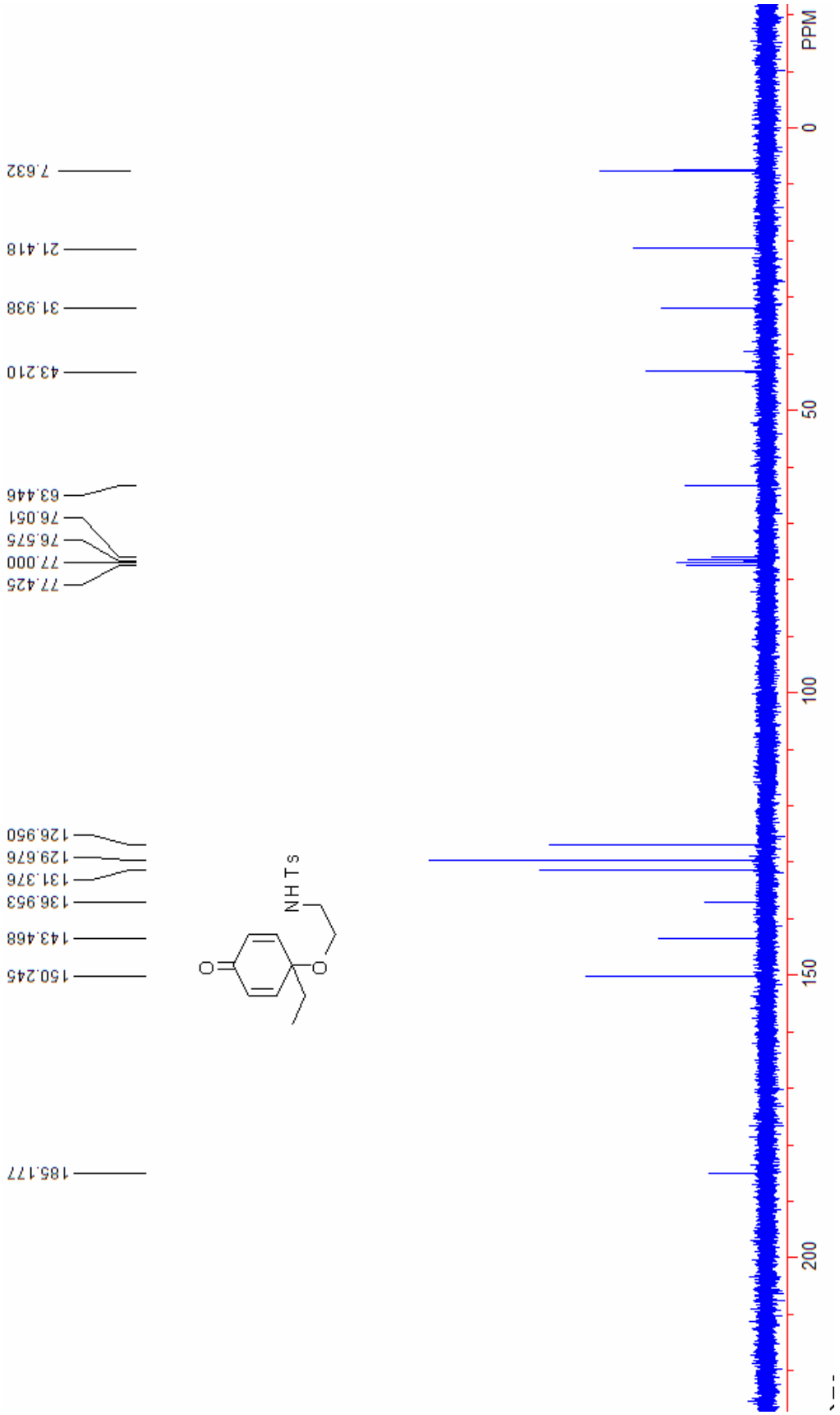
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O
PPM
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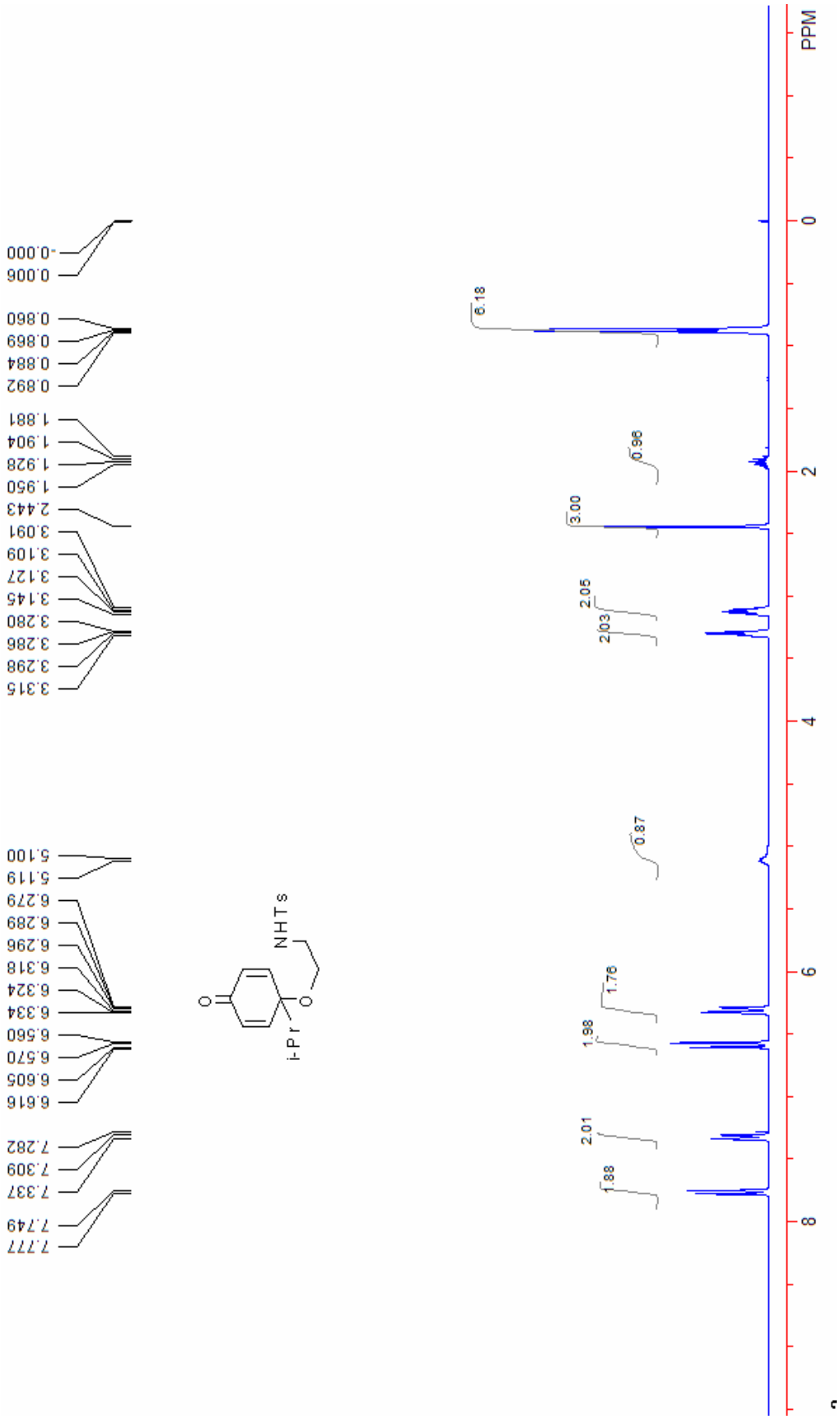
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3.109
3.127
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3.280
3.286
3.298
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6.605
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NHTs
O
O
i-Pr
PPM
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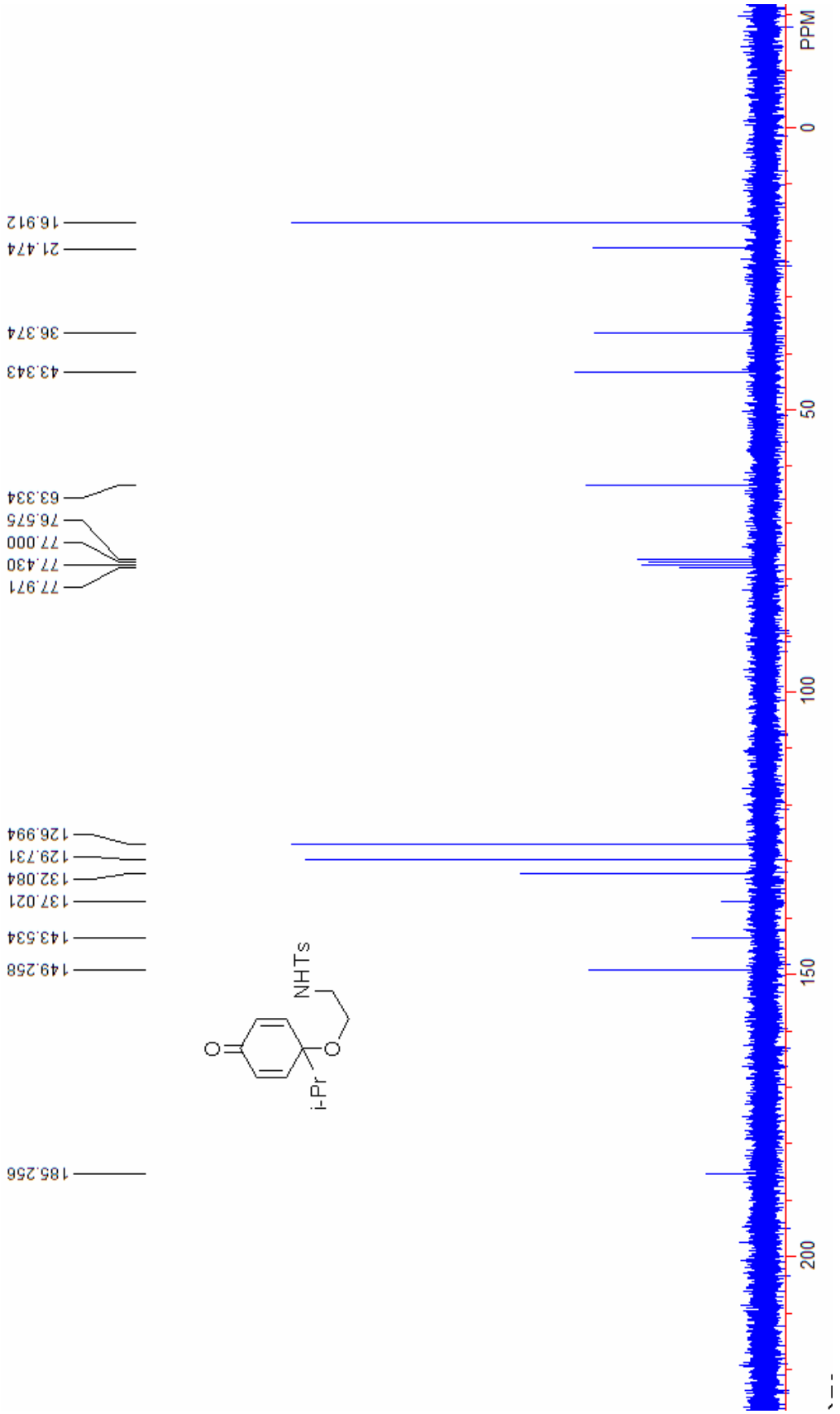
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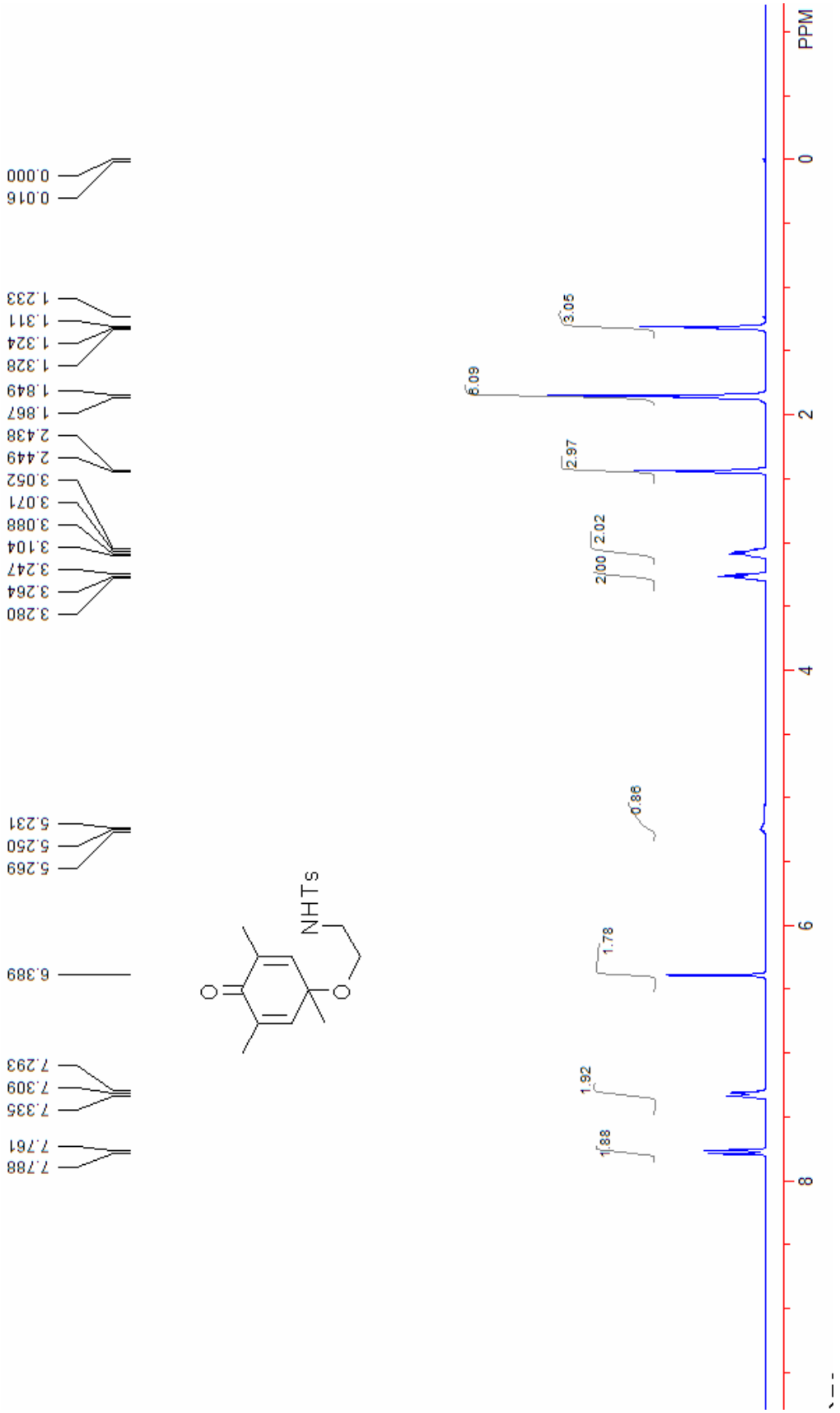
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O
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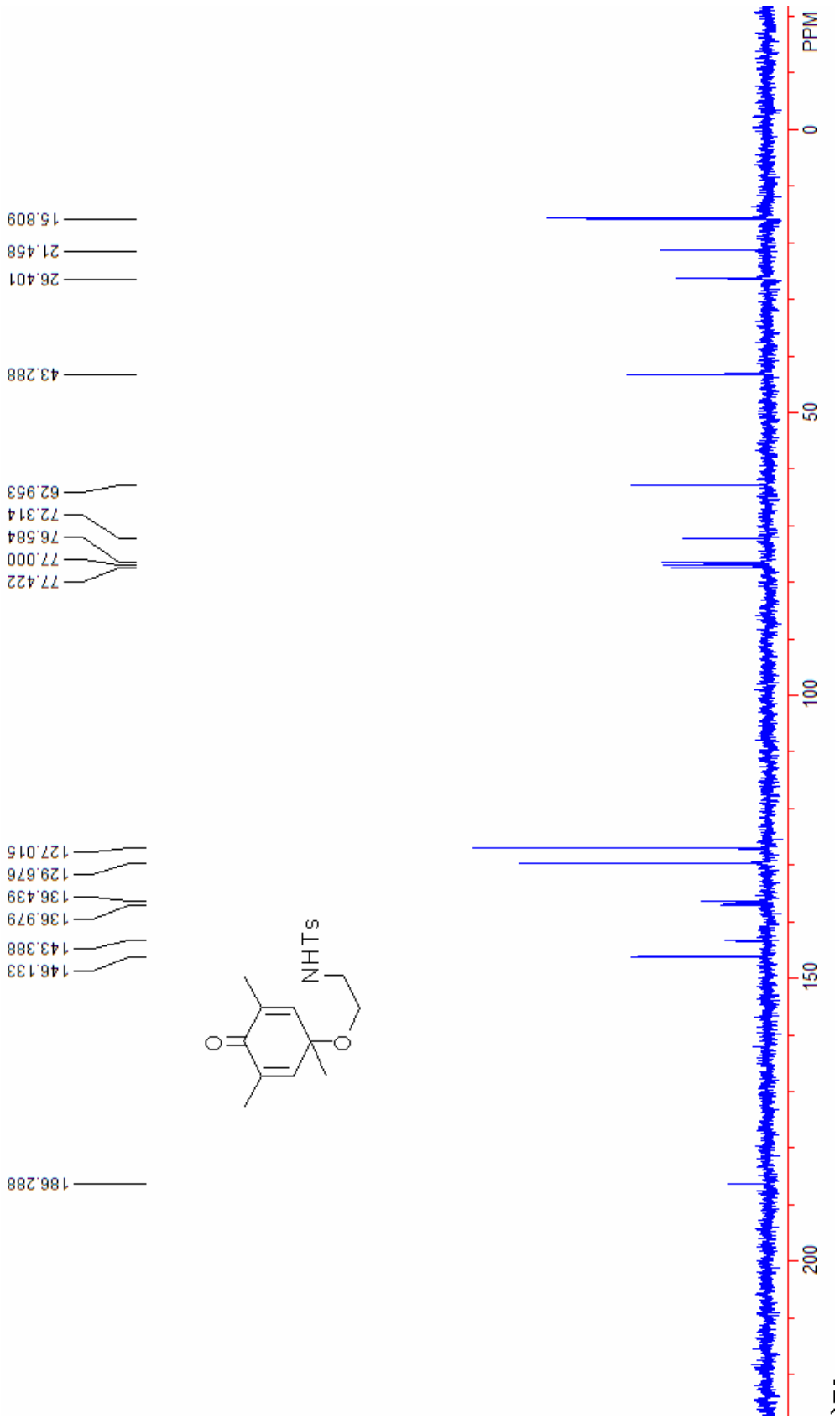

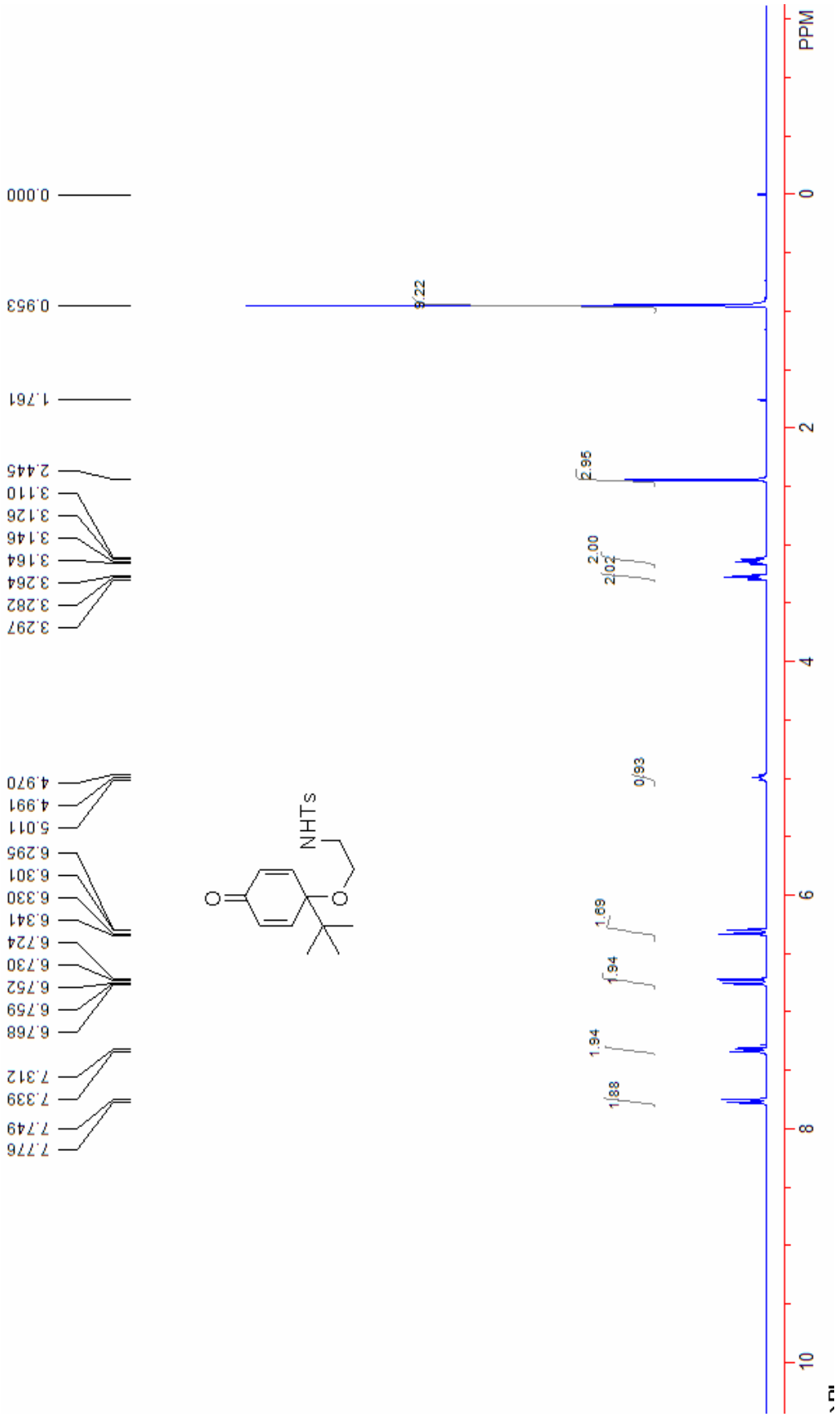
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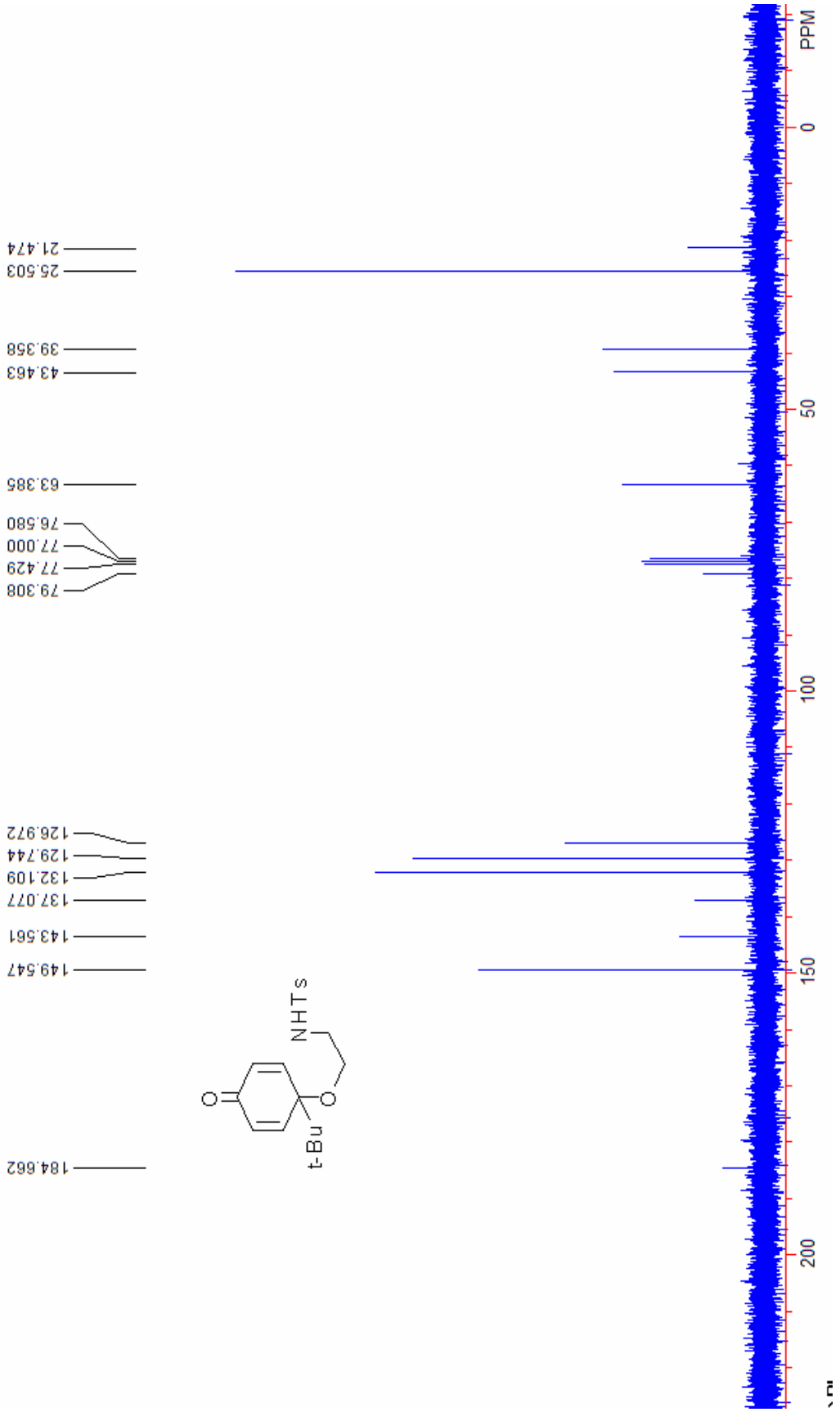
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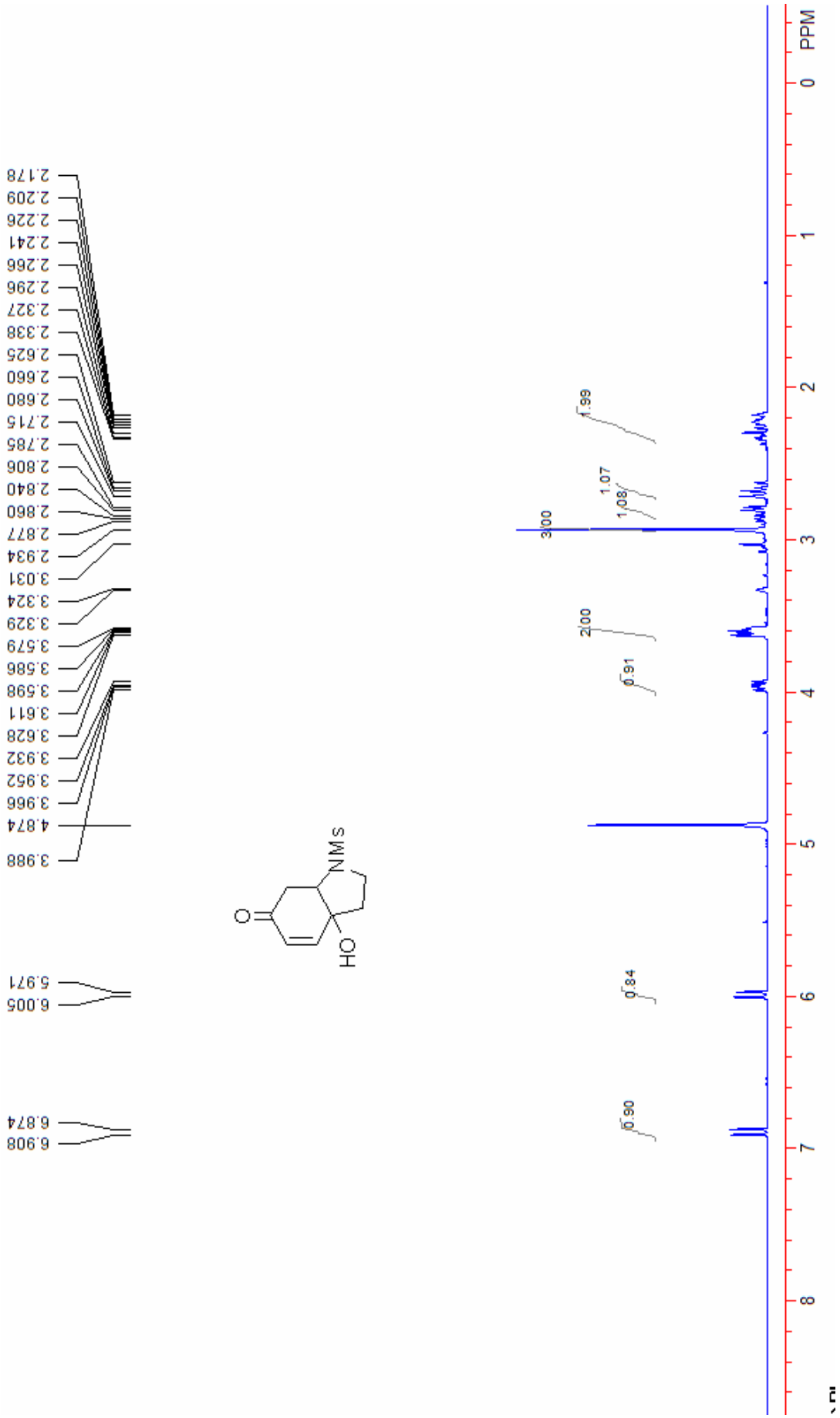
O
O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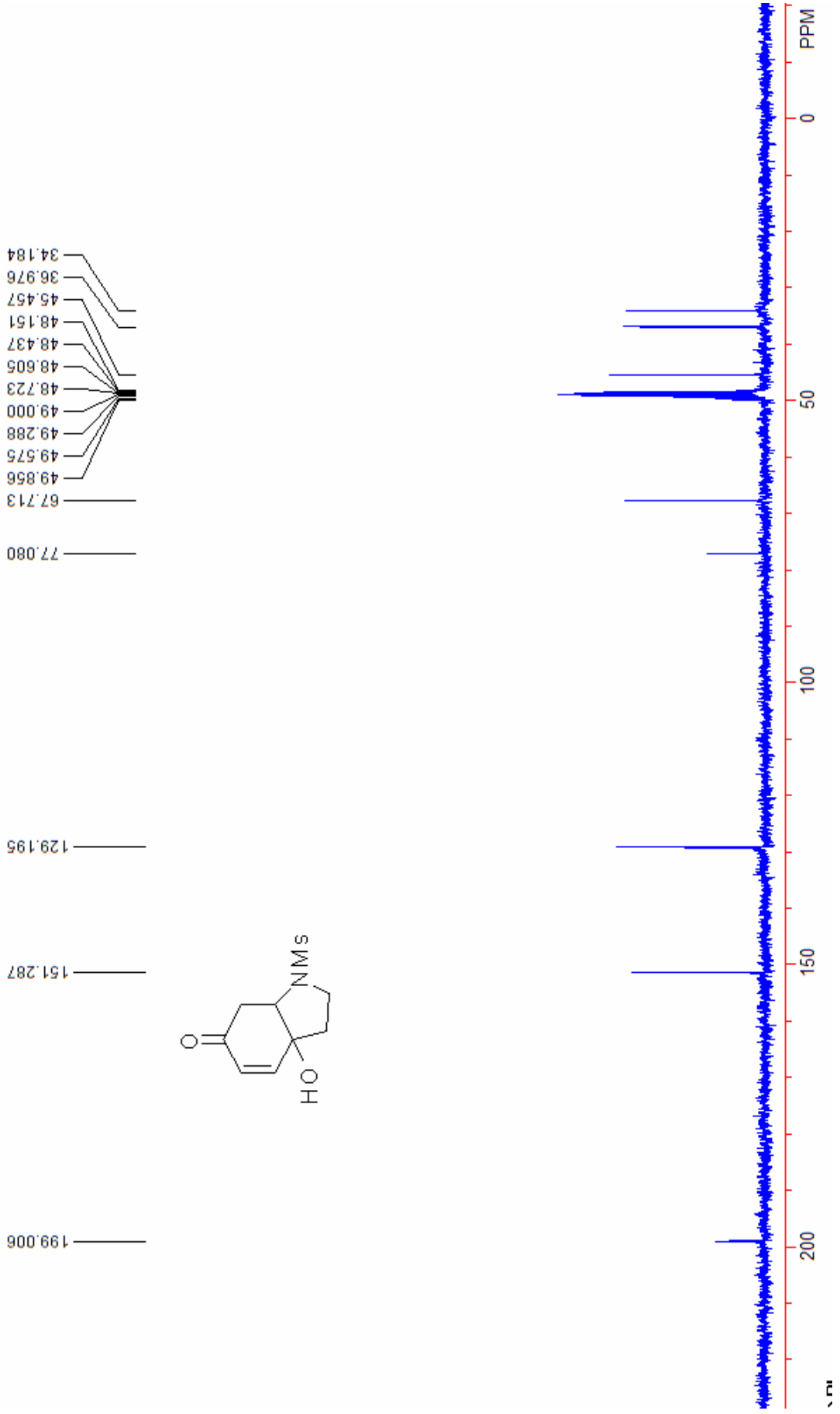
PPM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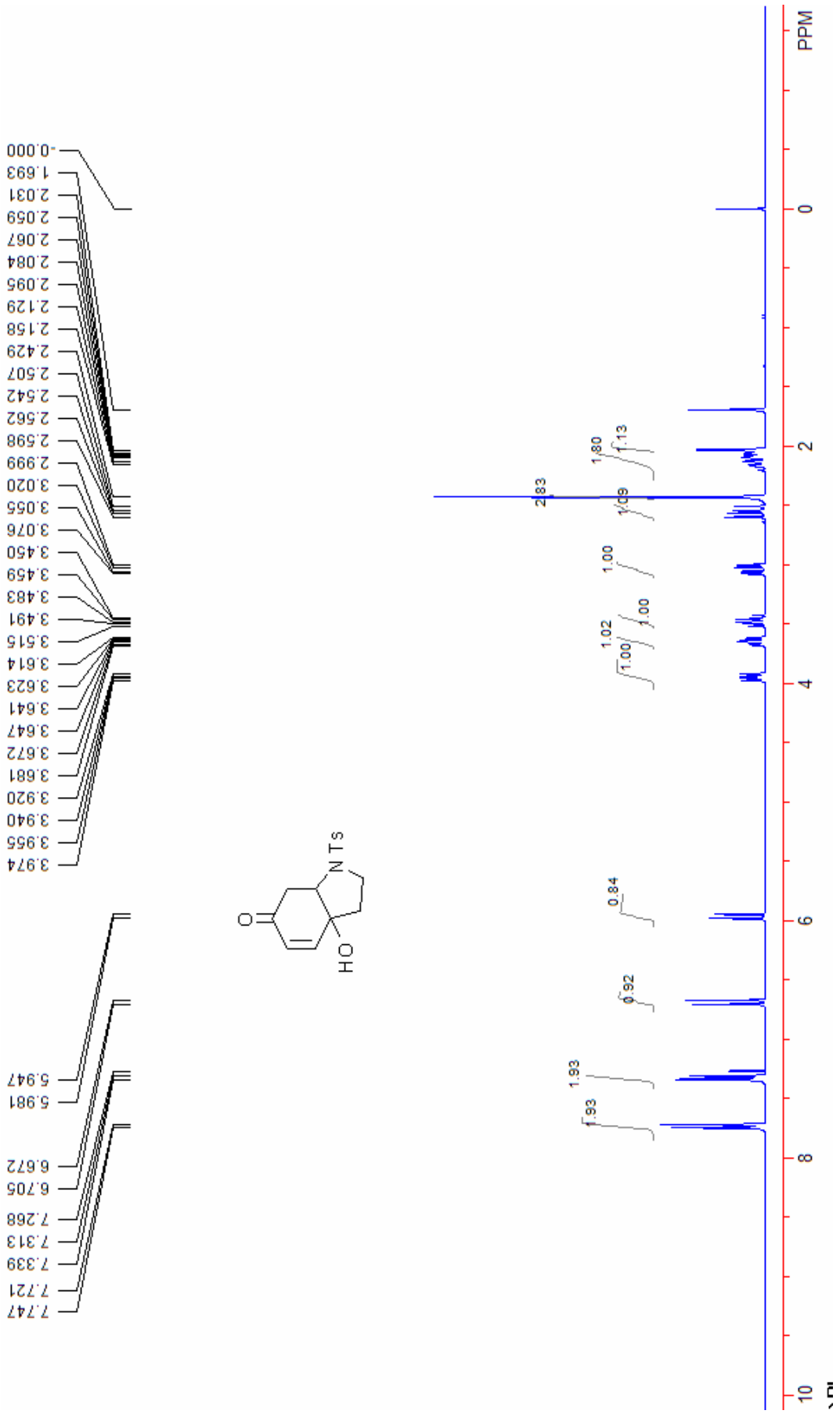
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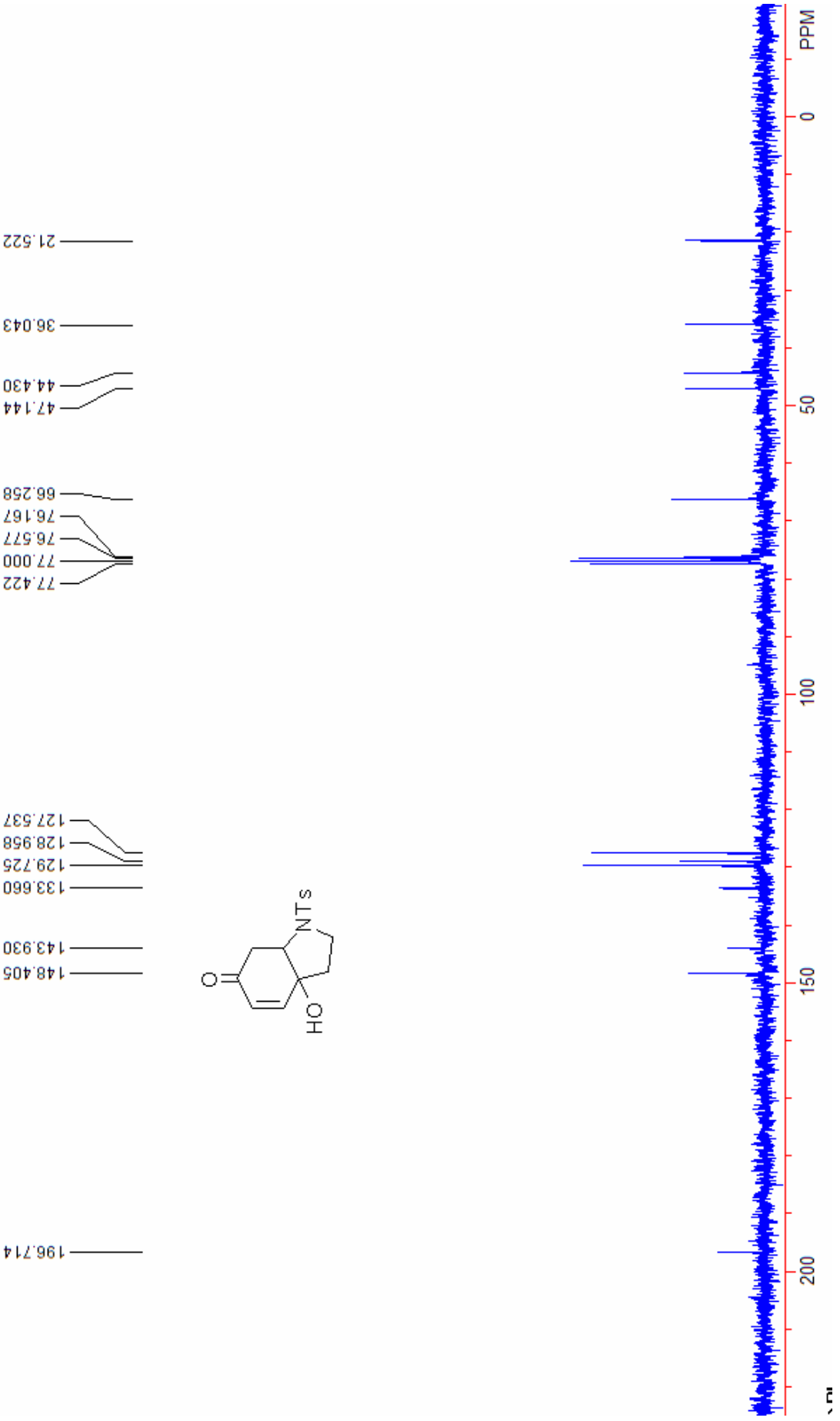
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PPM
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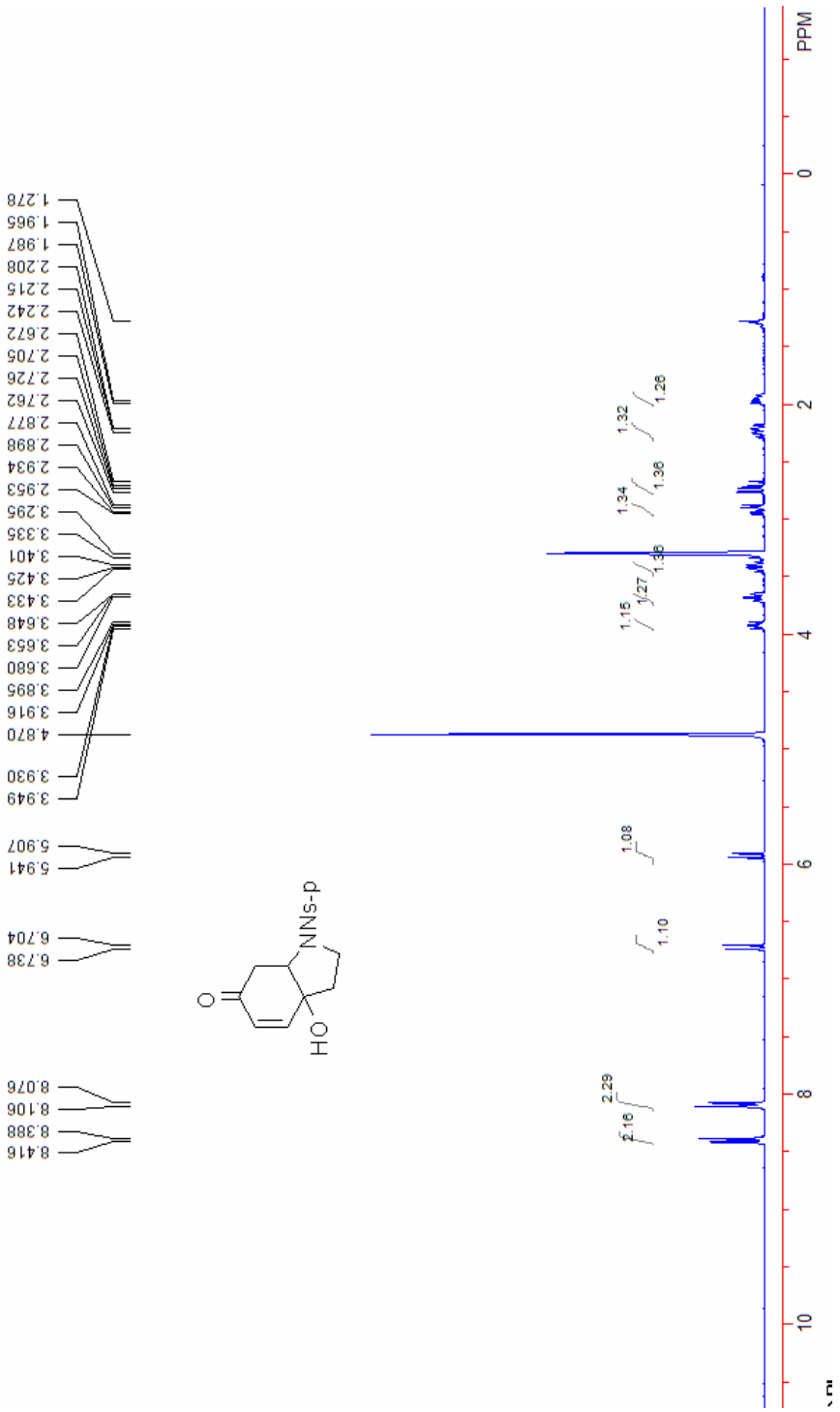
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1.10
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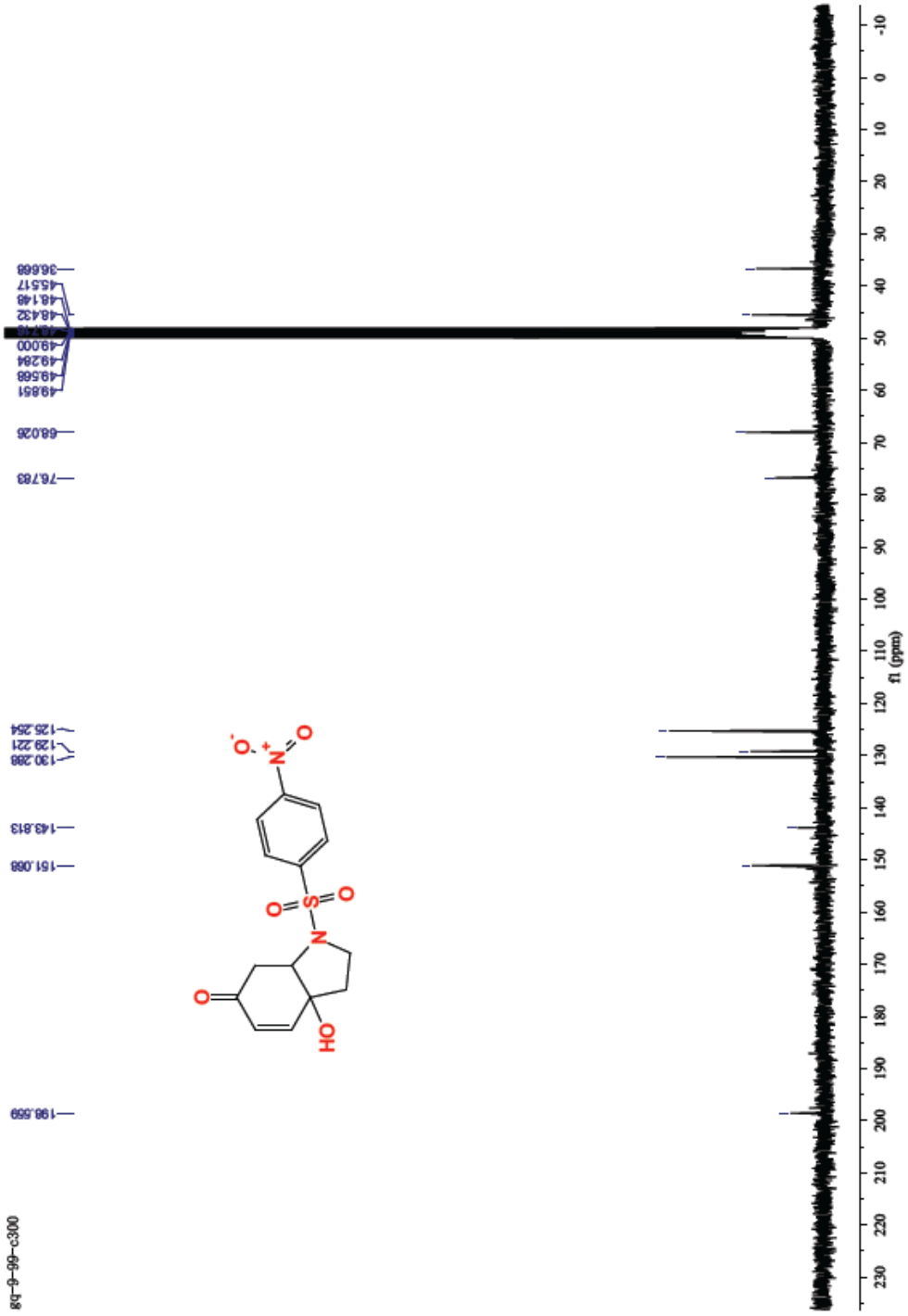
O
HO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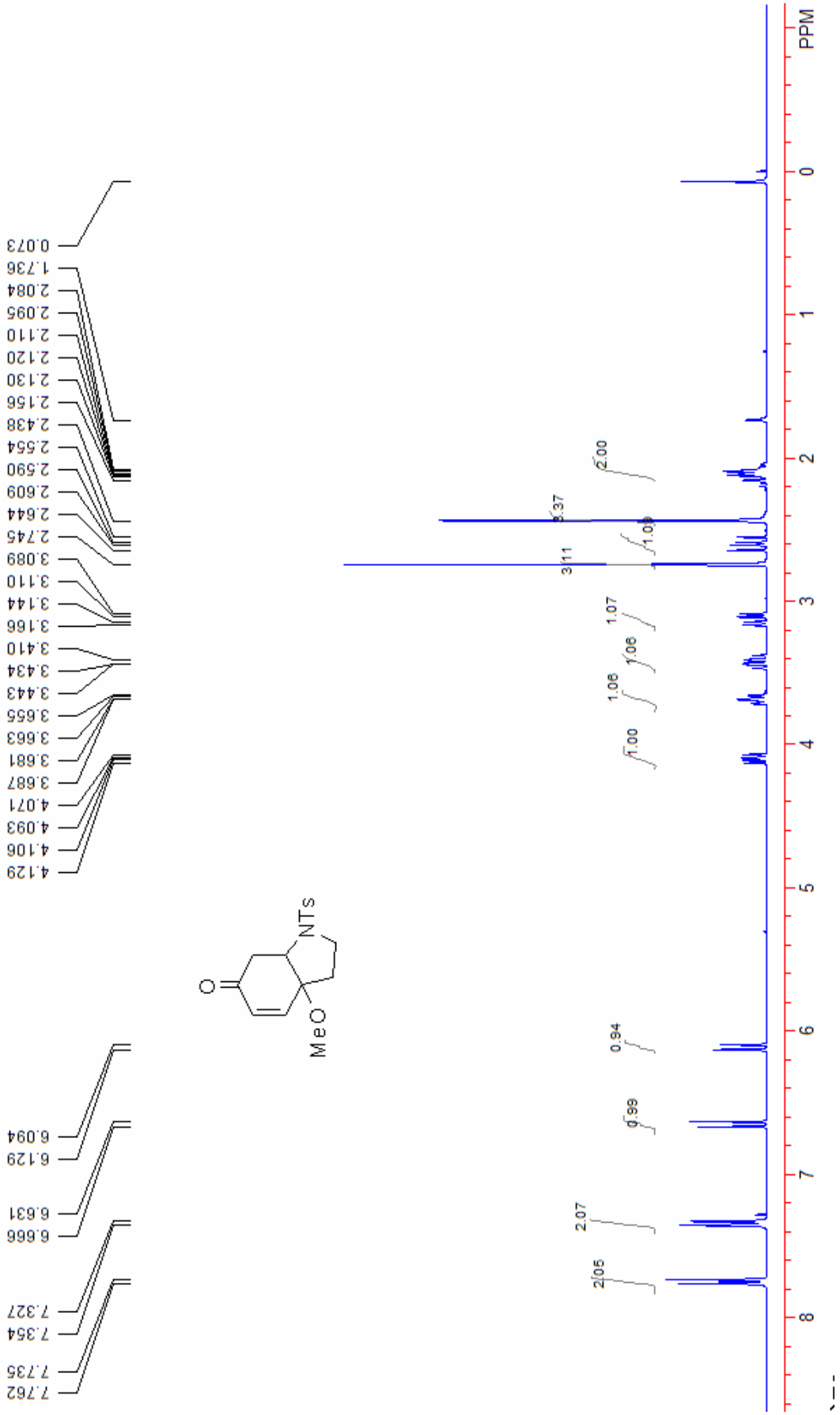
f1 (ppm)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6.094
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6.631
6.666
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NTs
O
MeO
PPM
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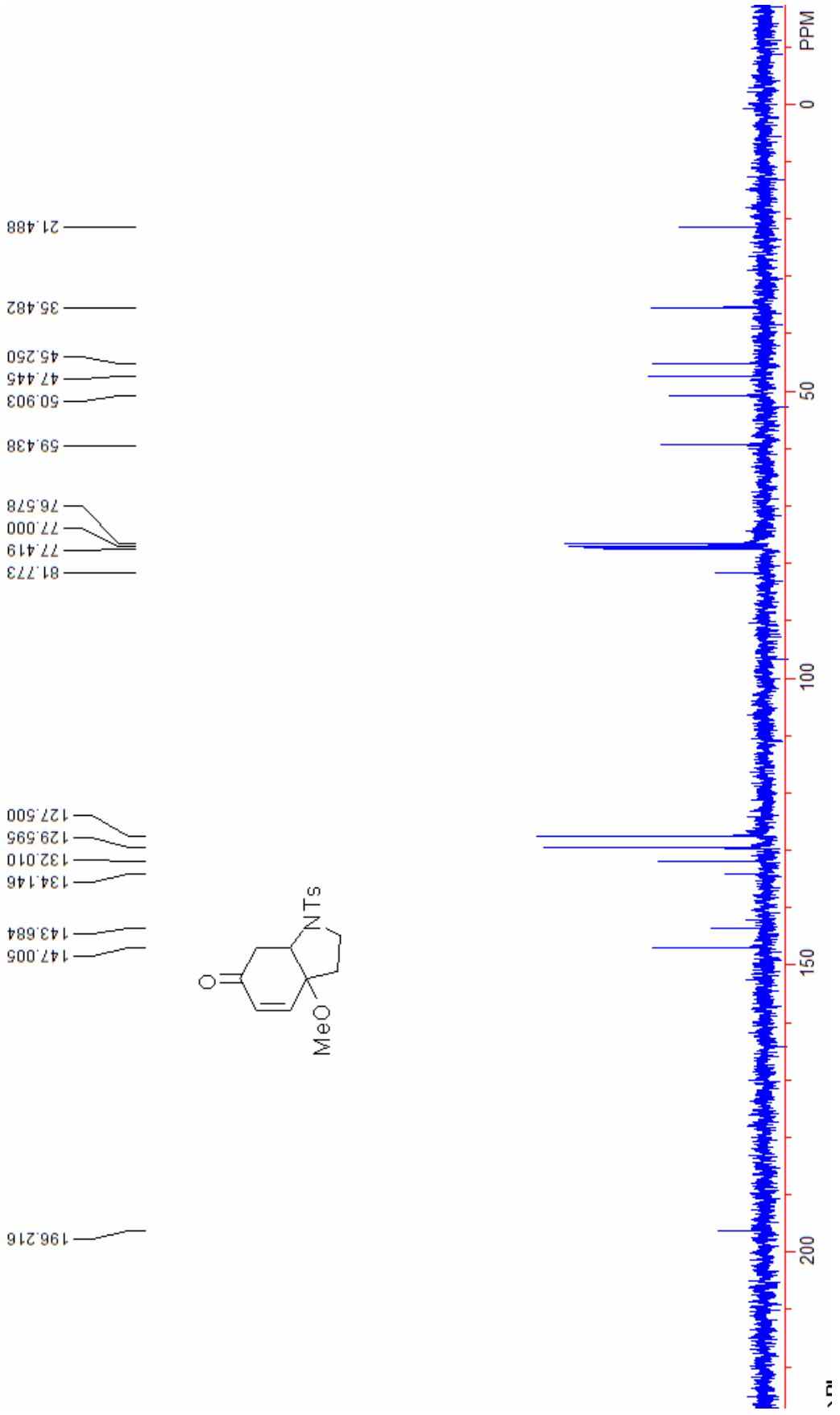

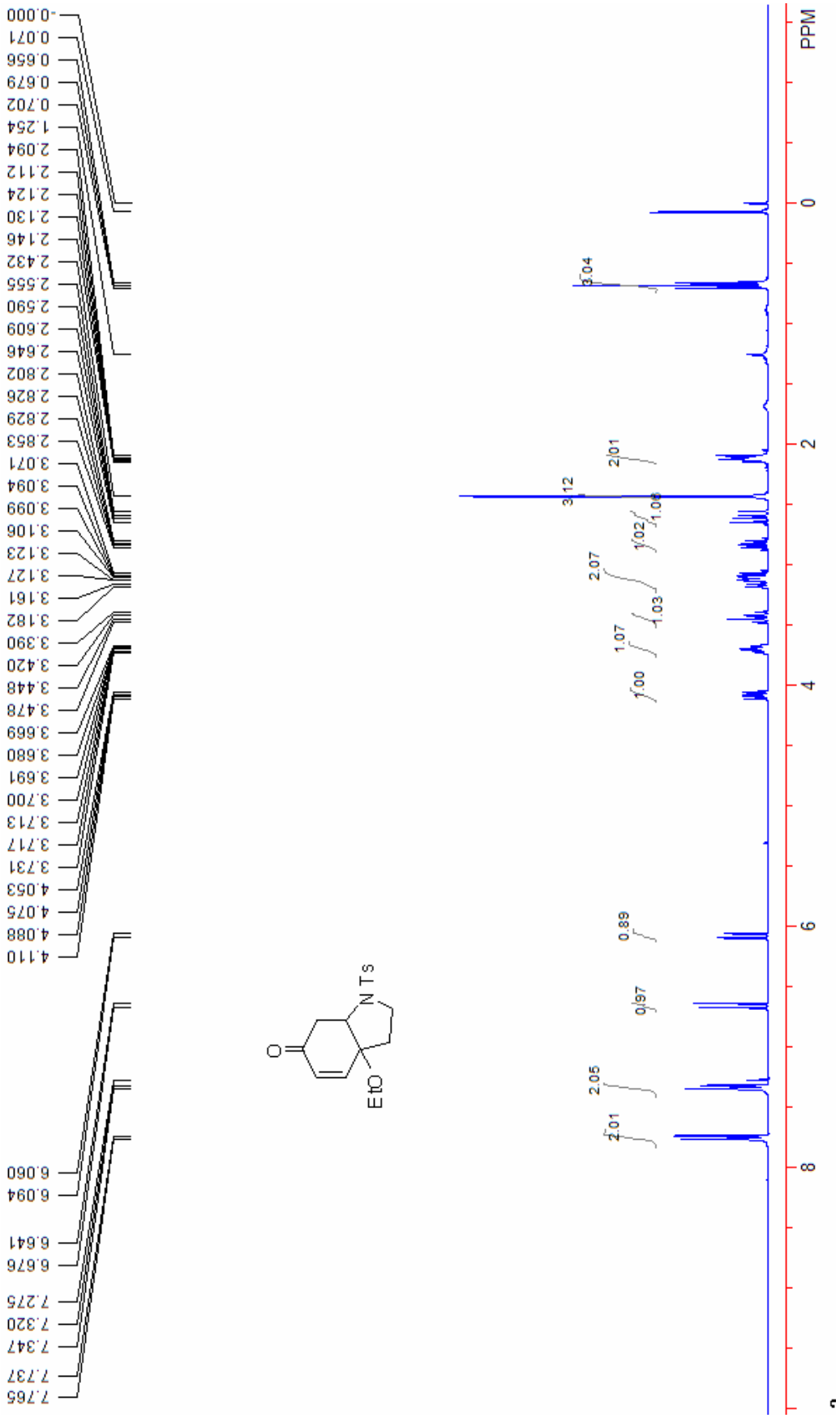
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O
N Ts
EtO
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PPM
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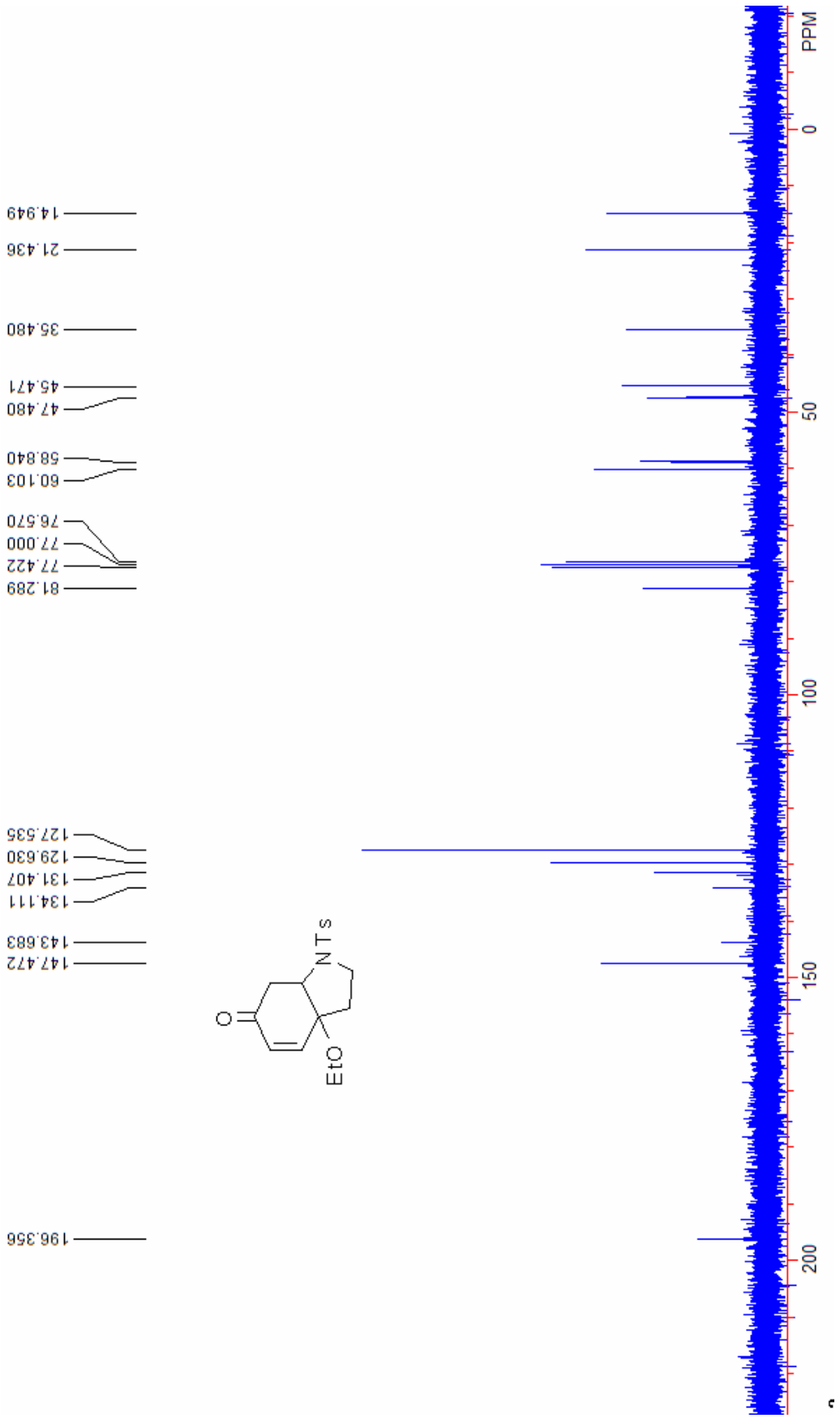
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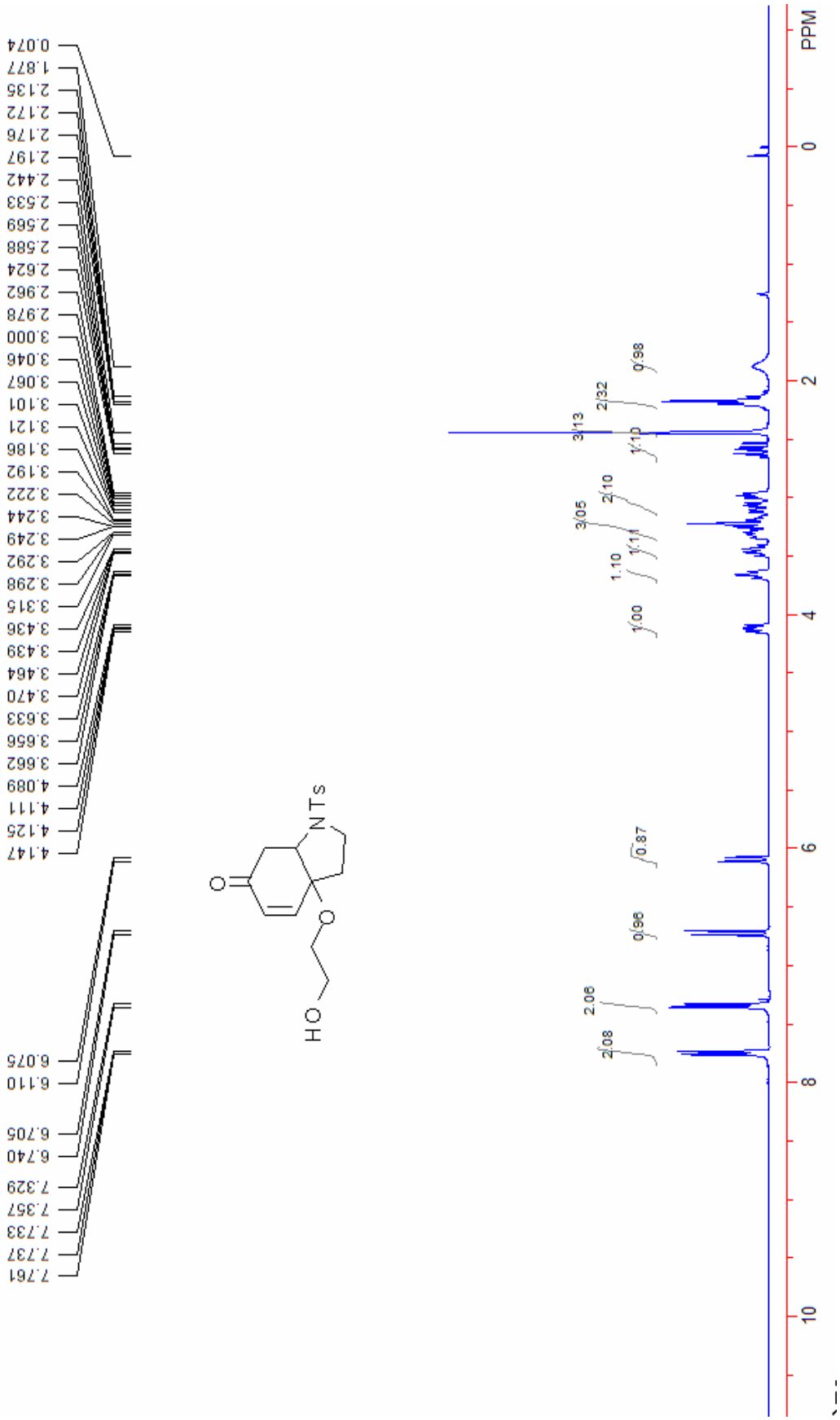
NTs
EtO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NTs
O
O
HO
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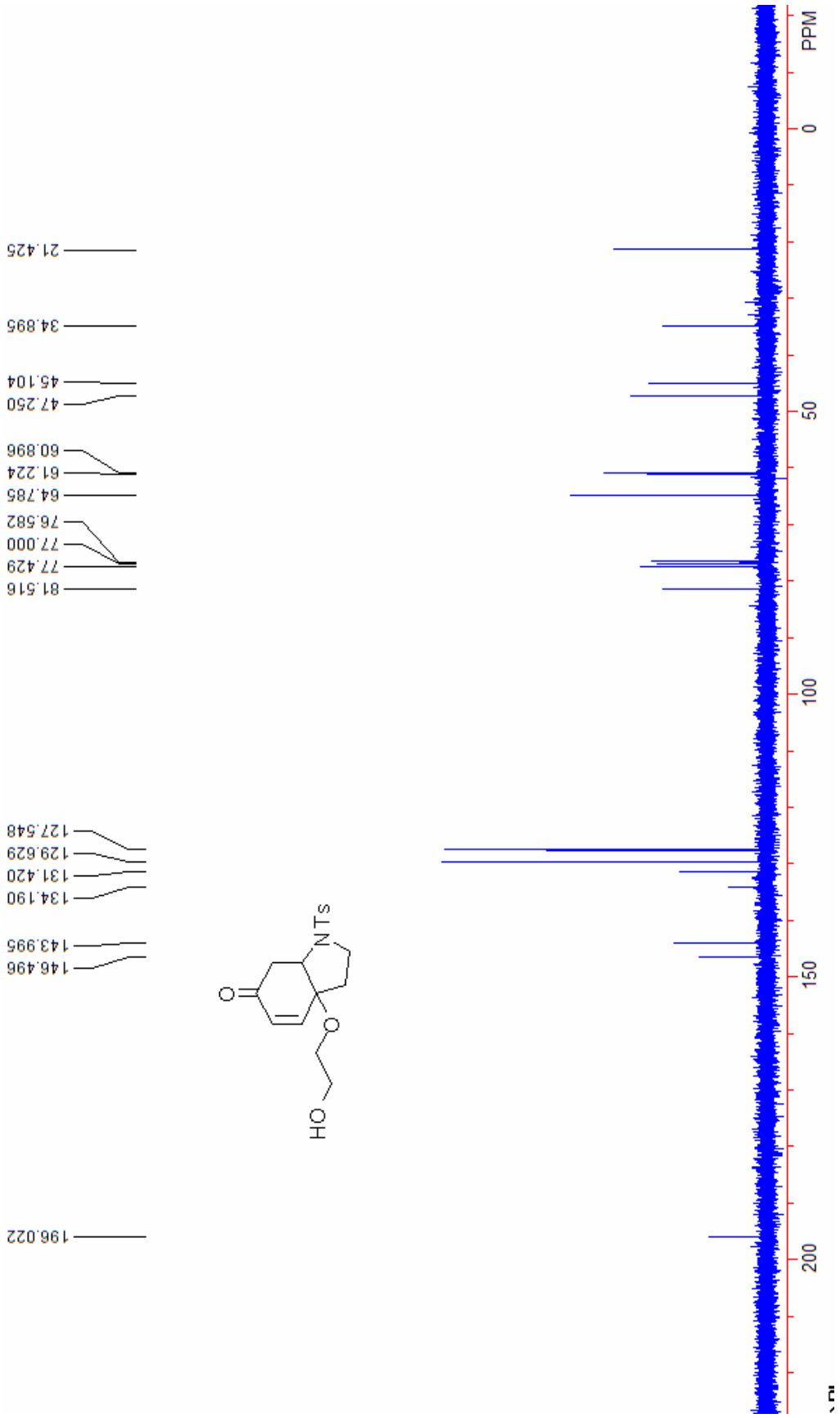
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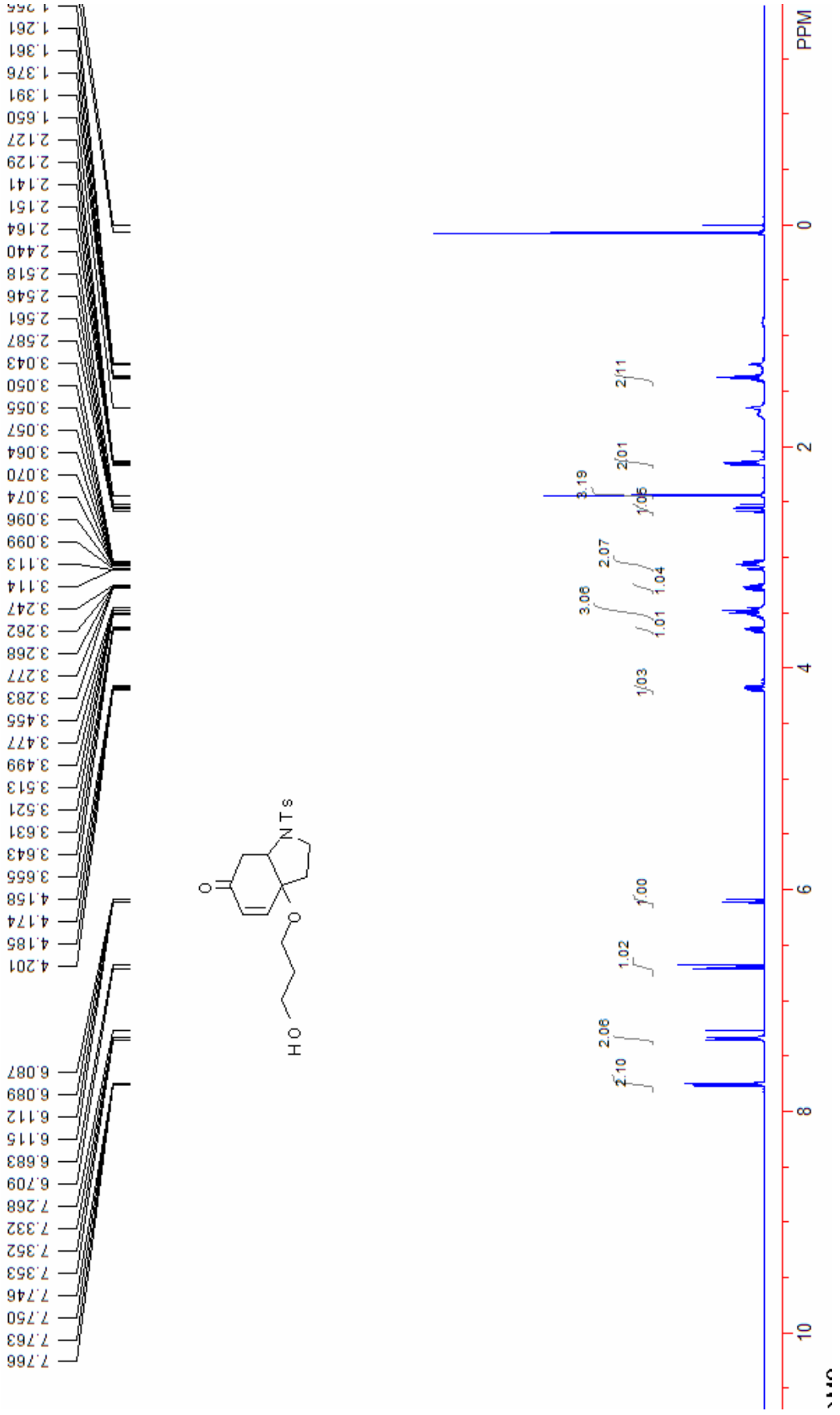
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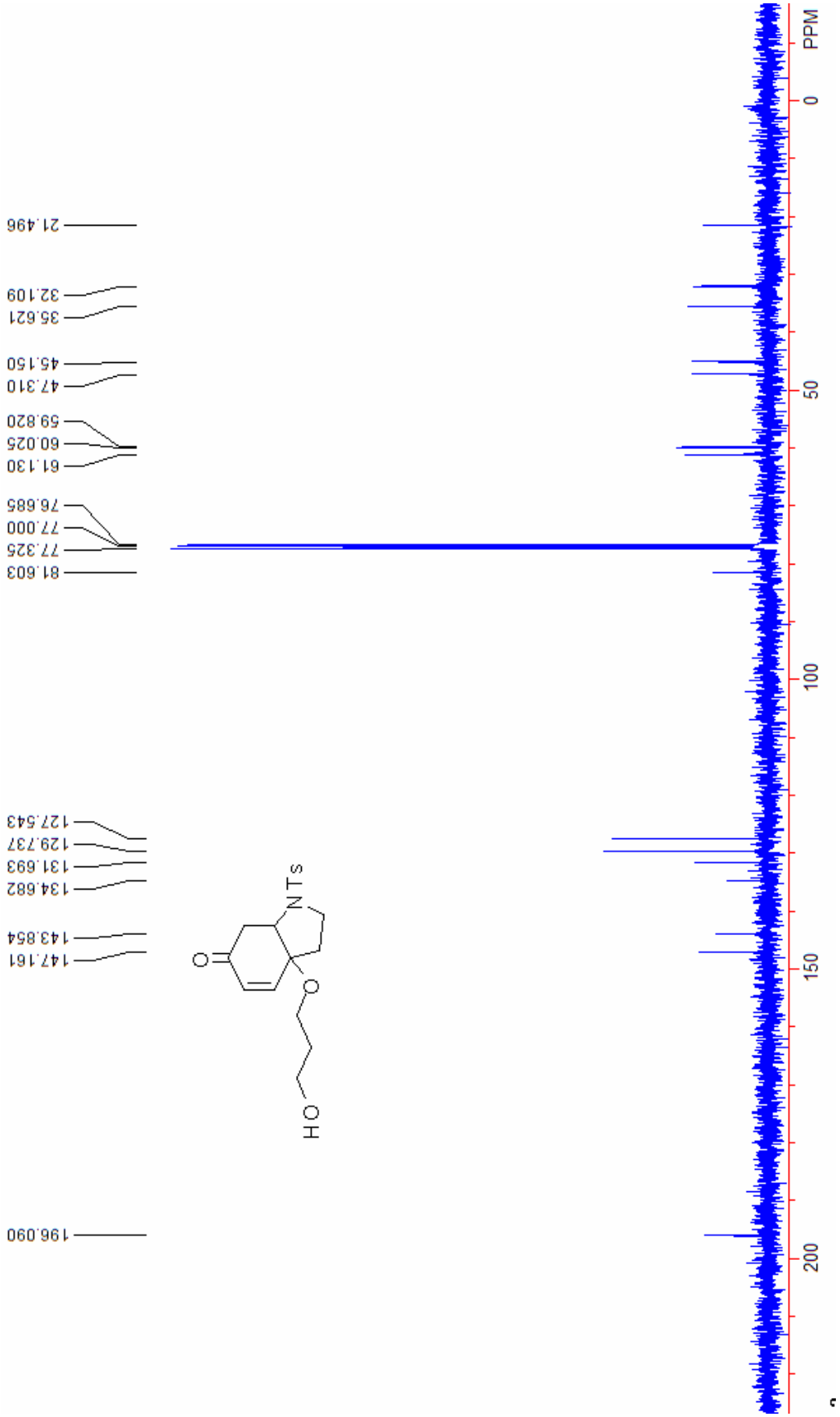
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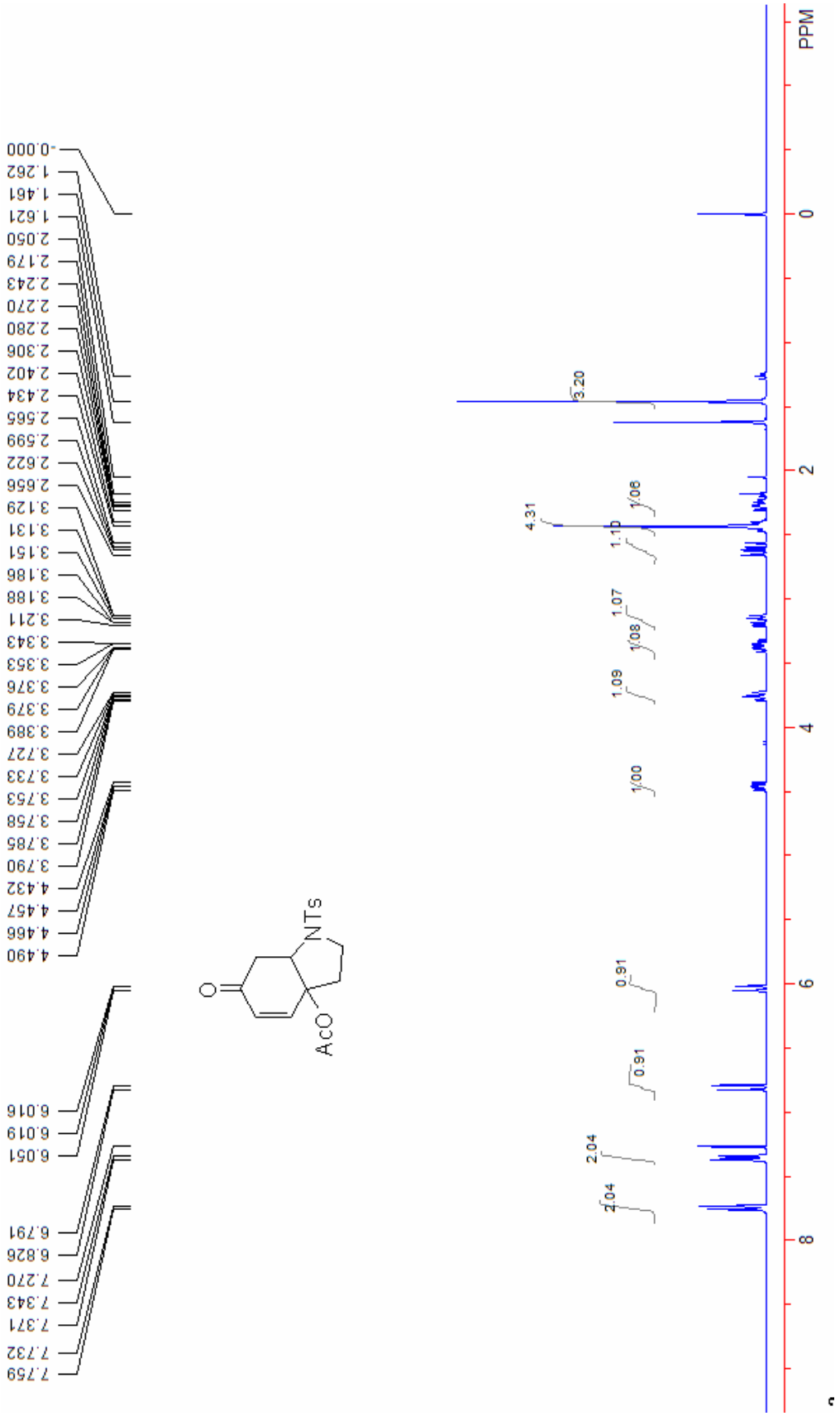
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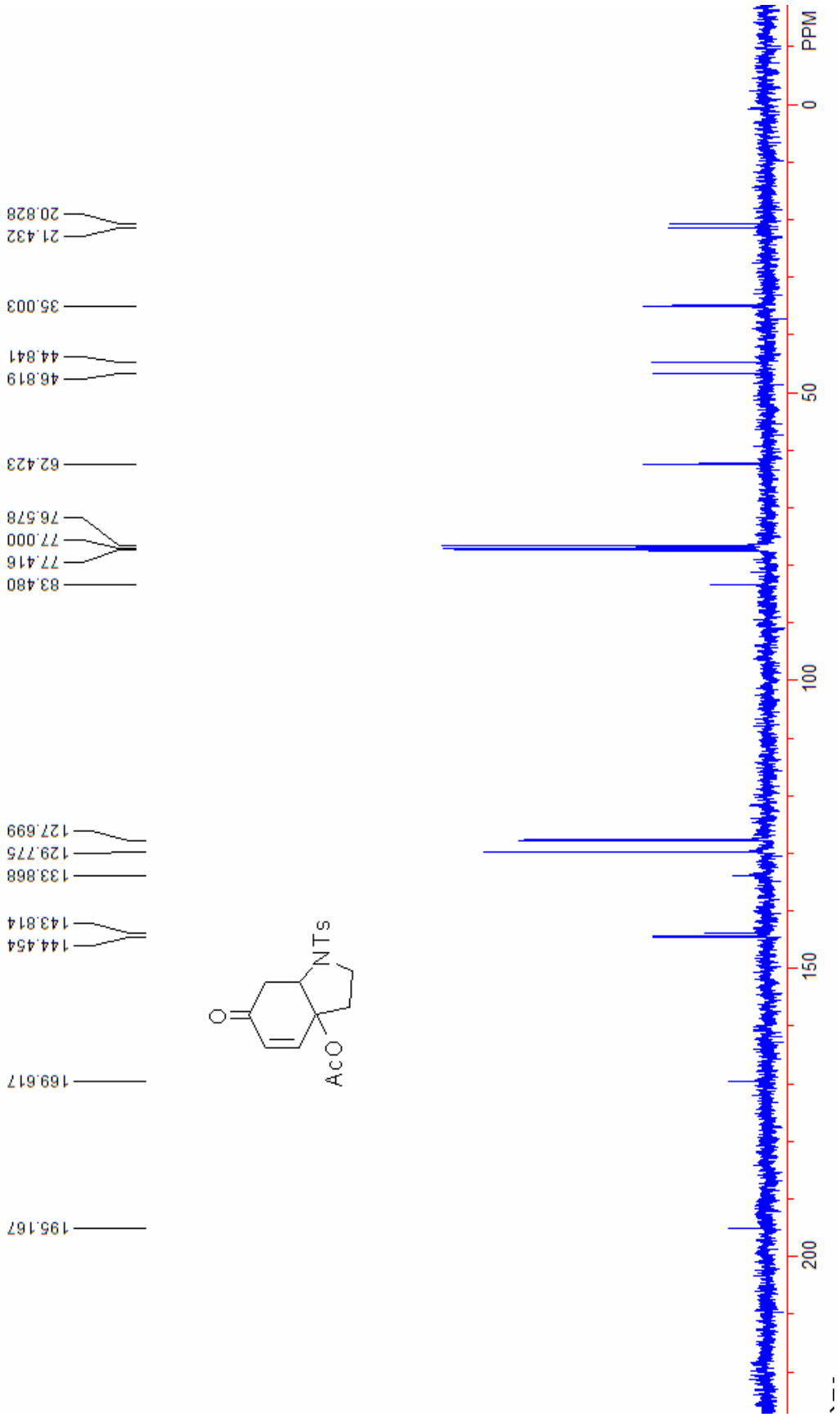

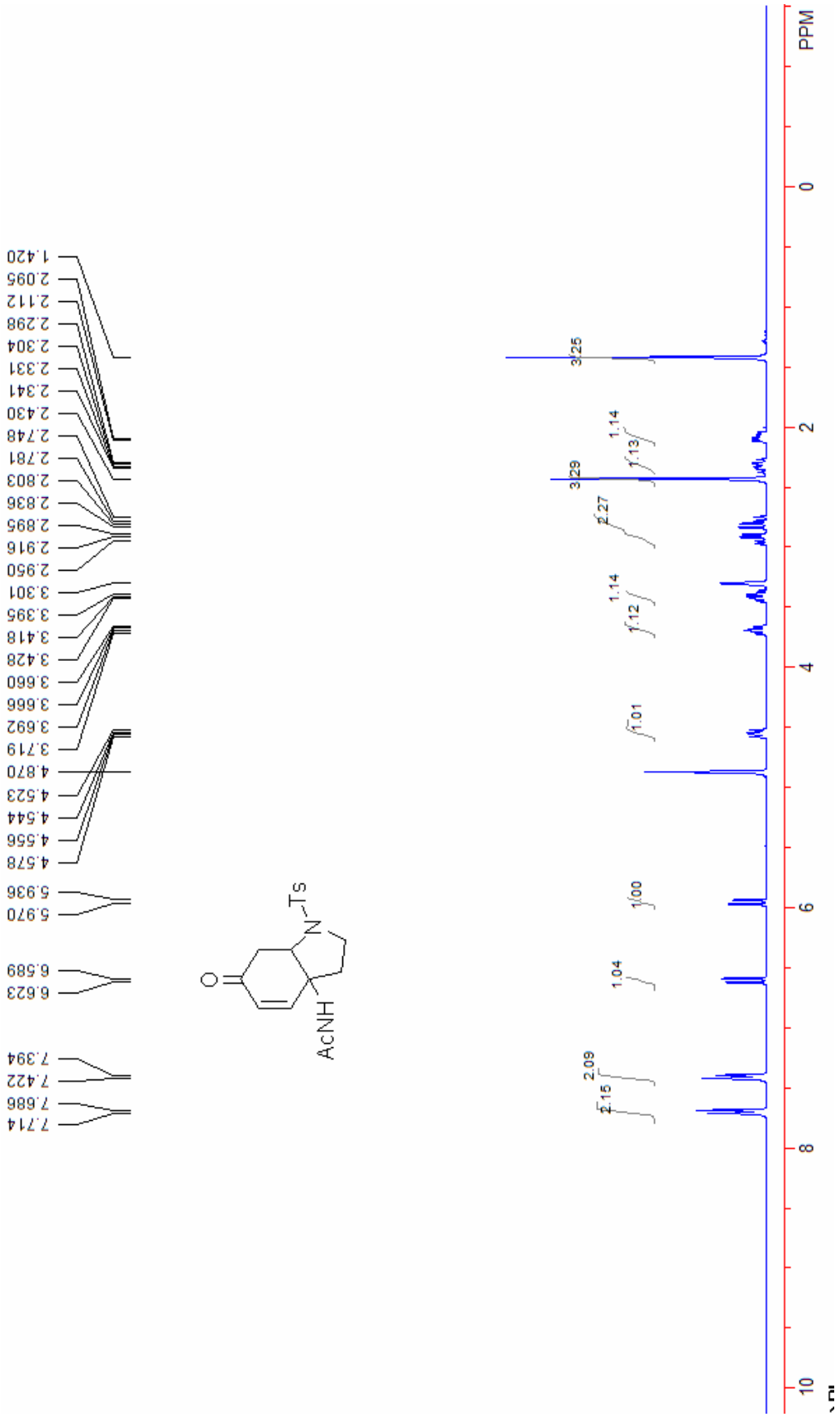
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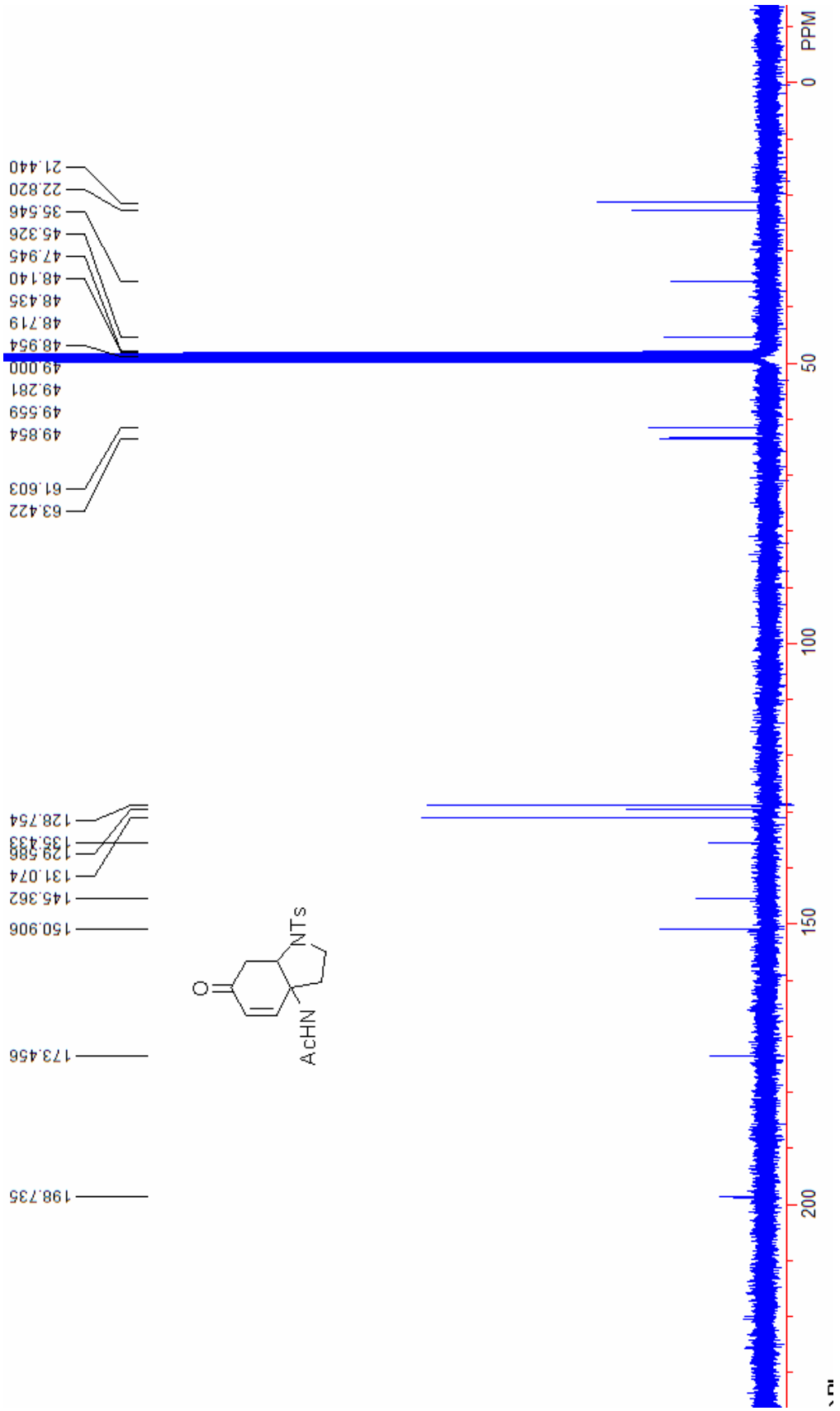
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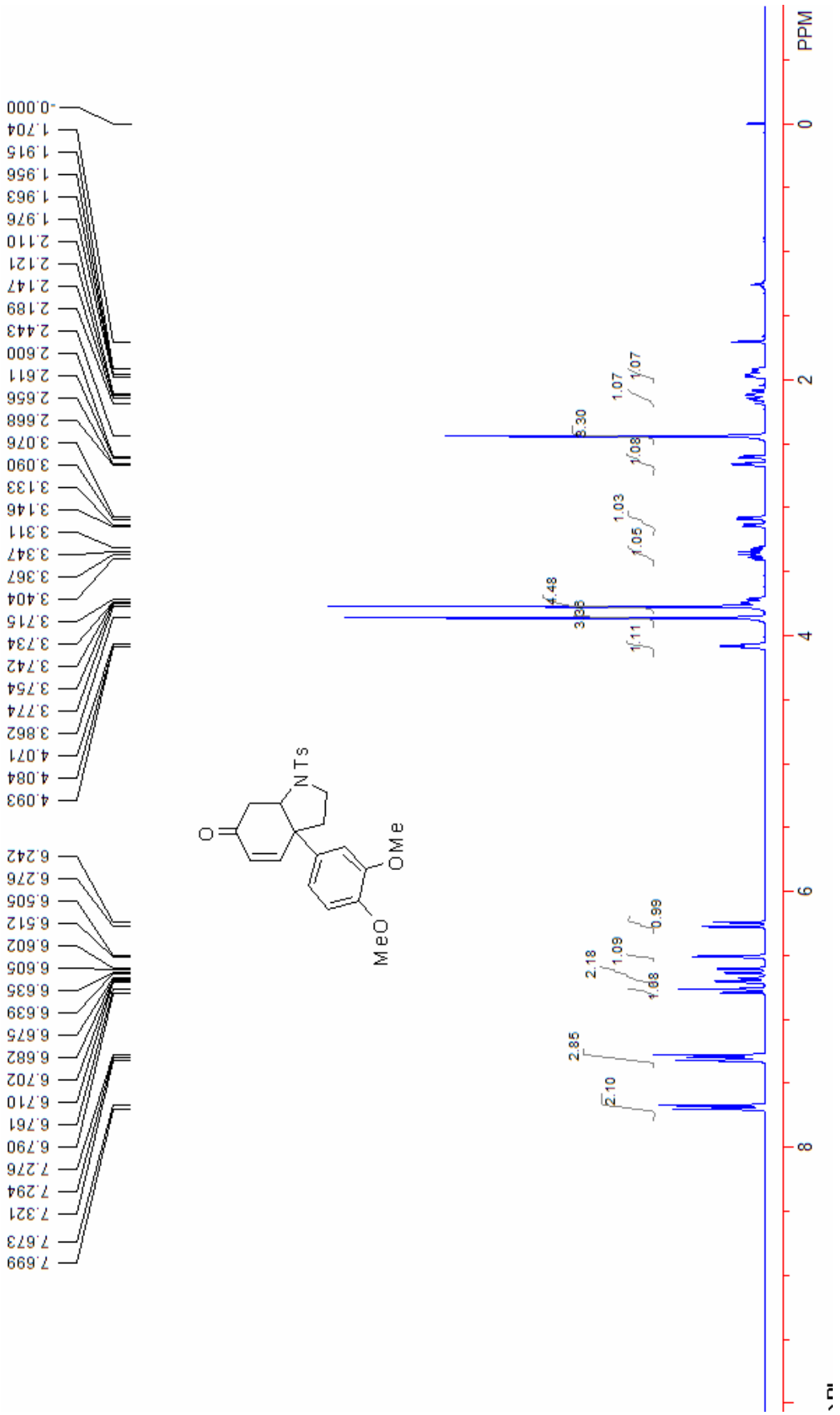
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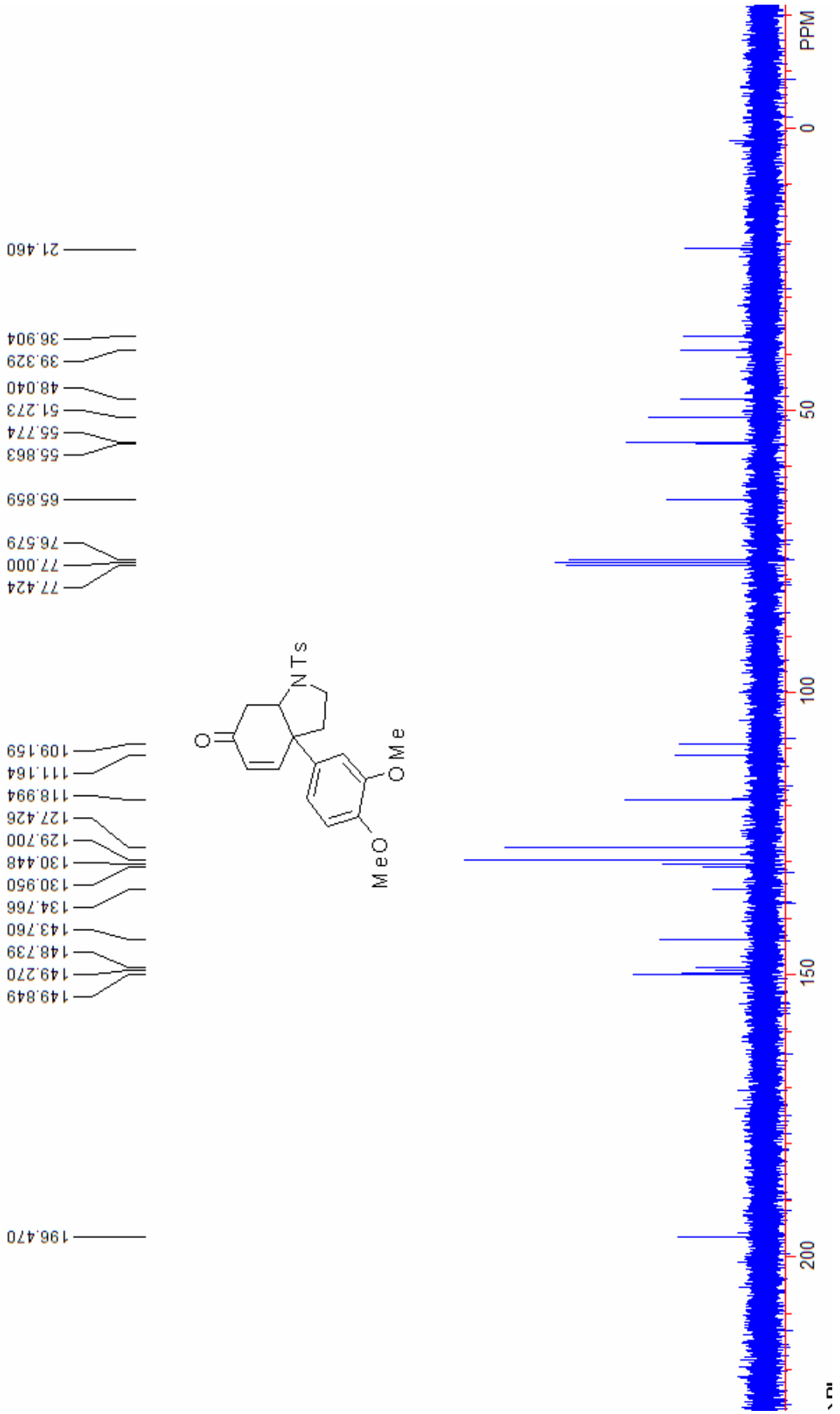

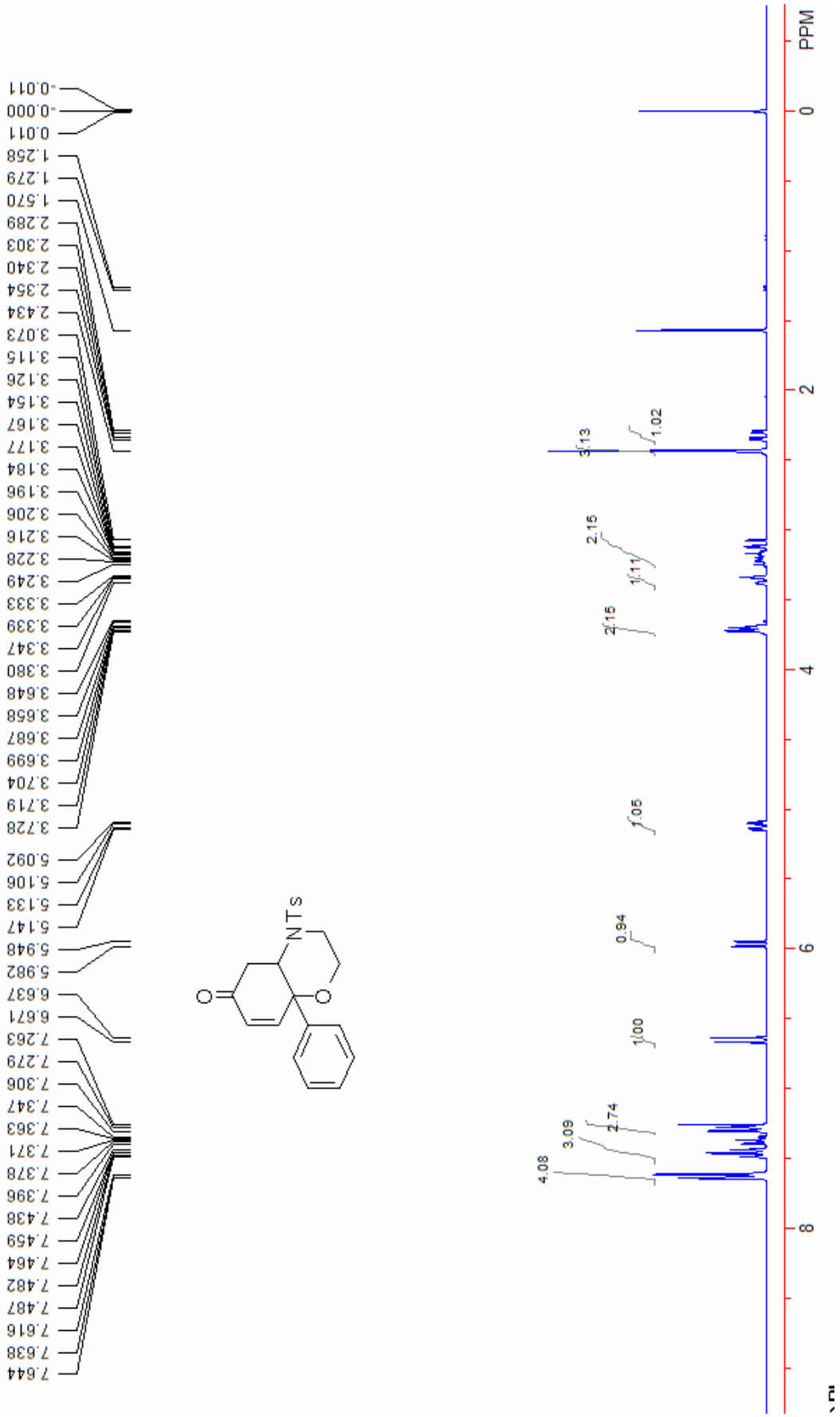
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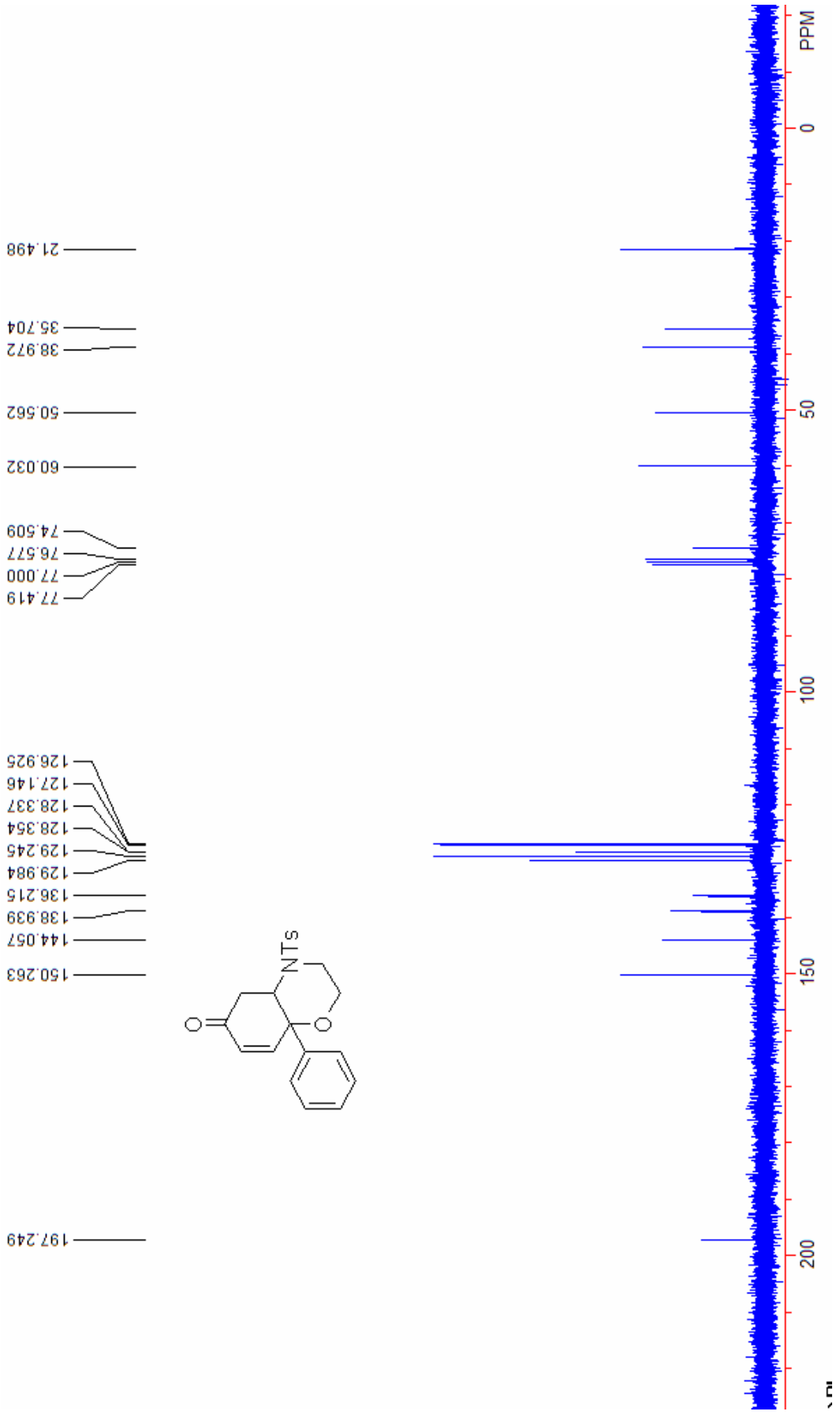
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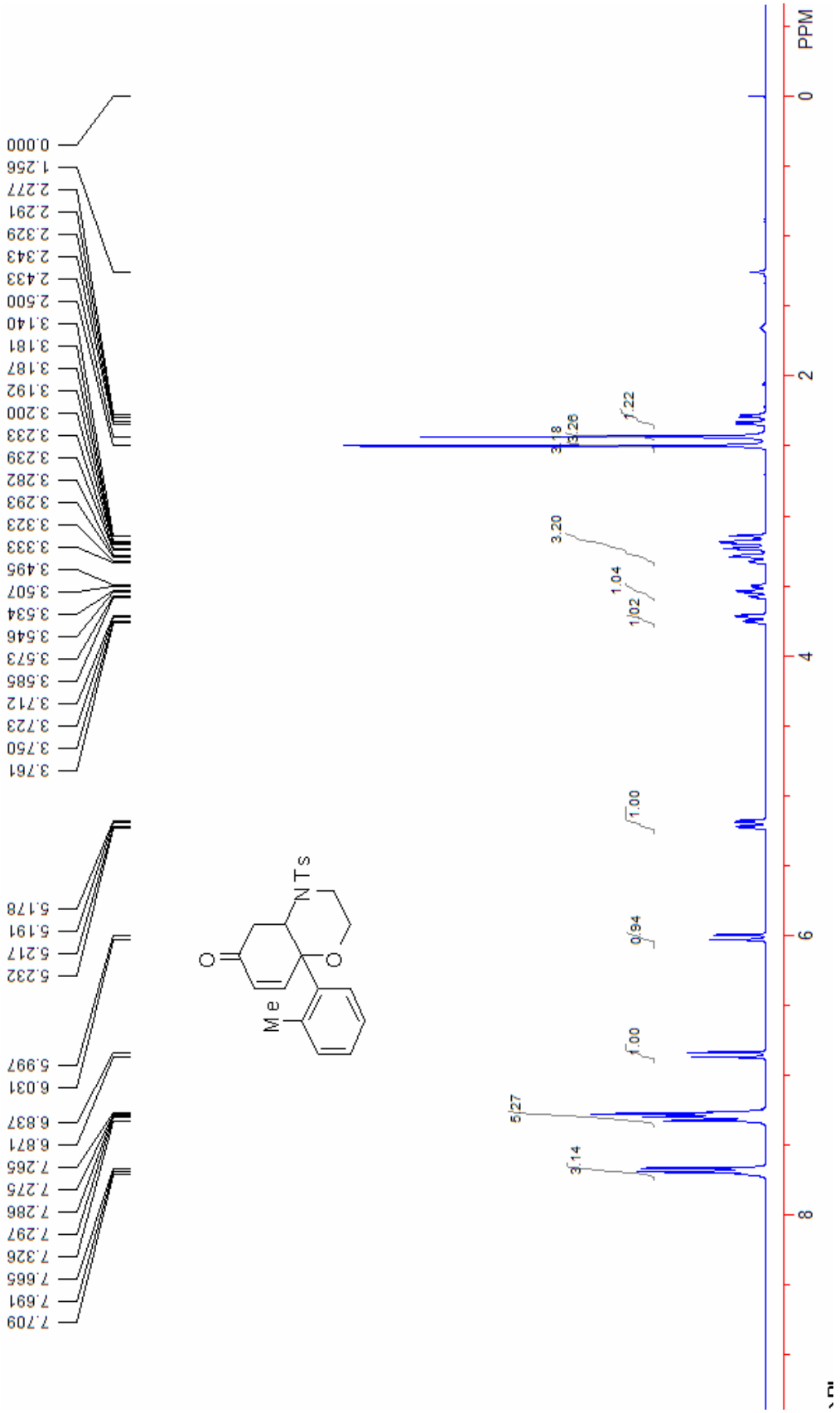
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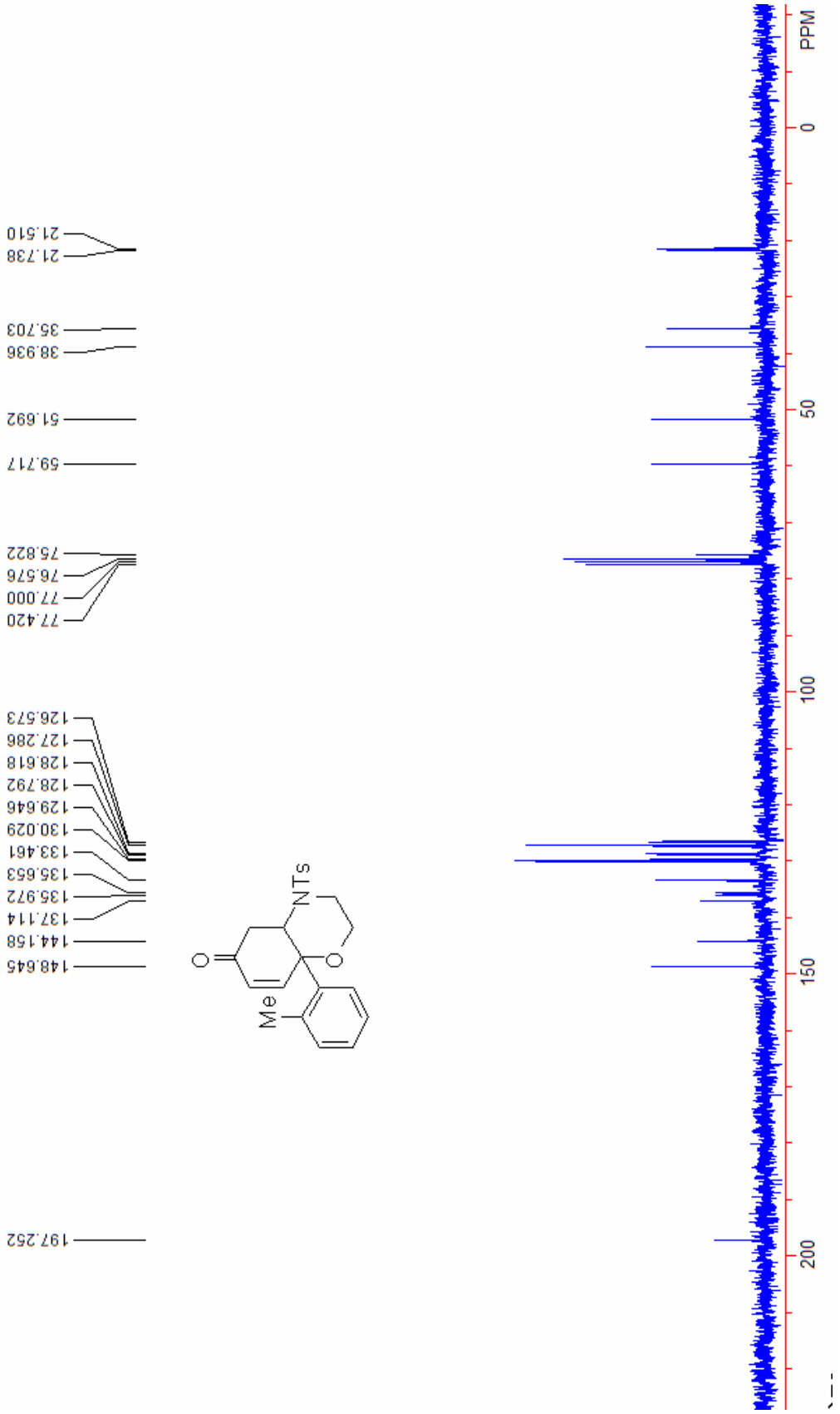

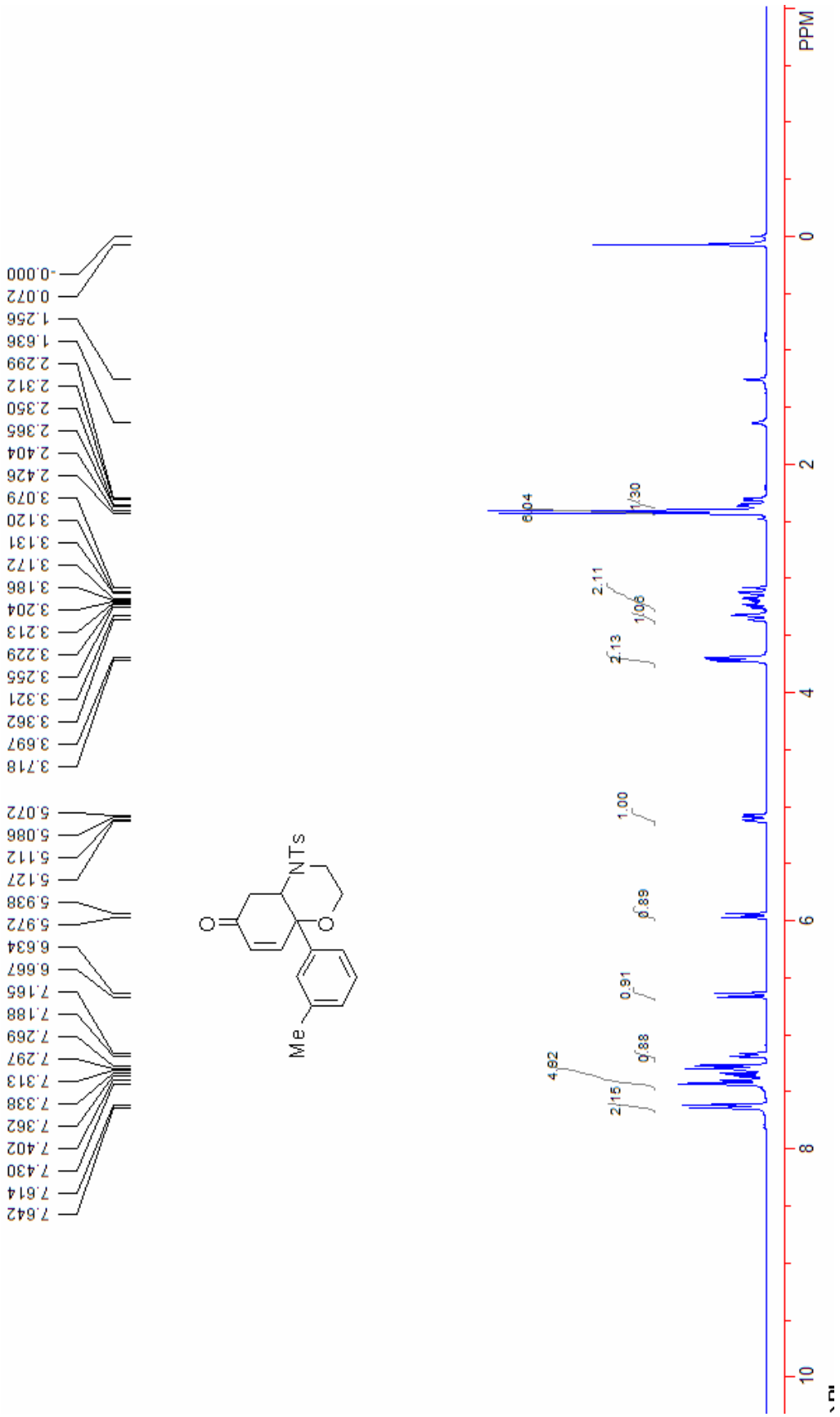

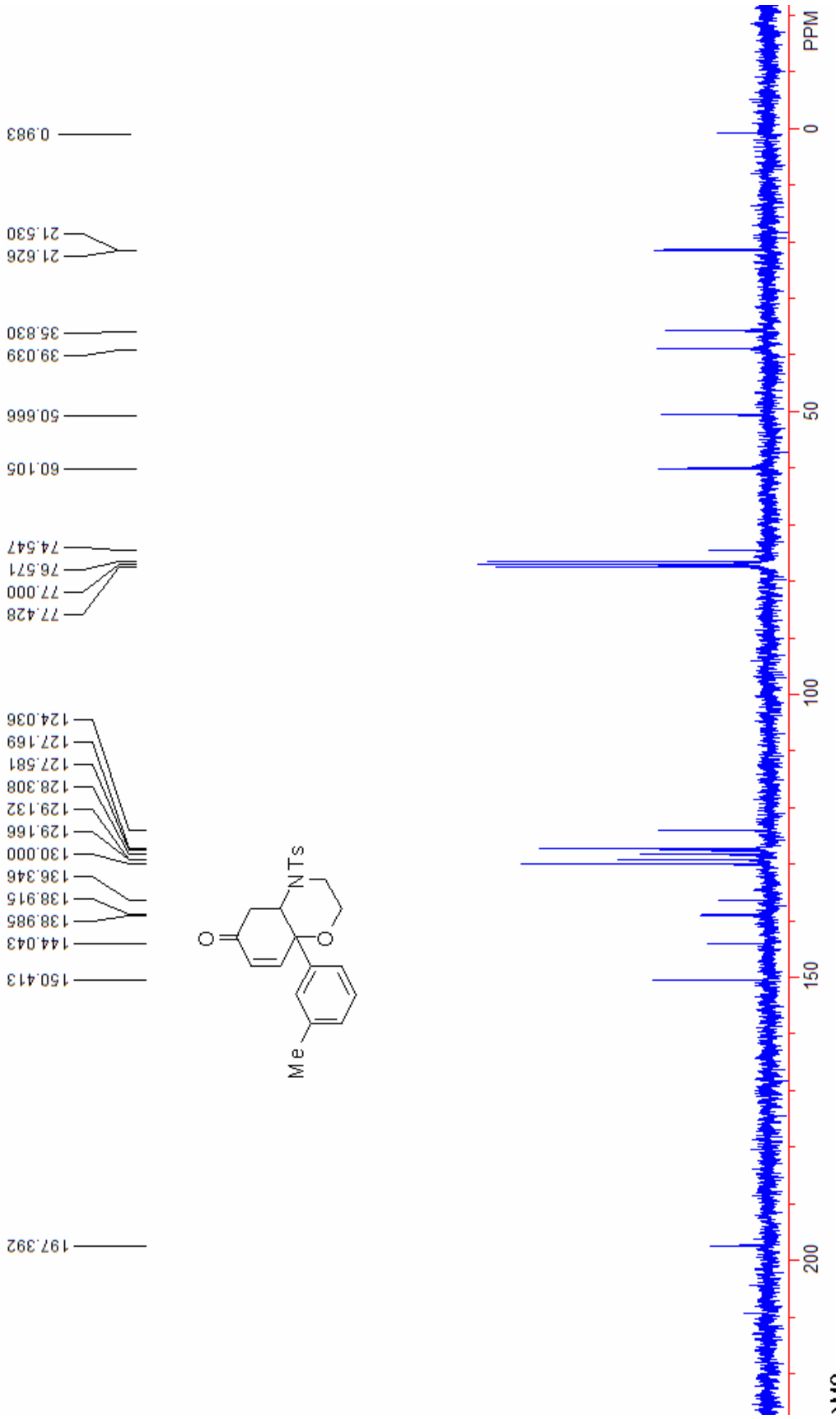
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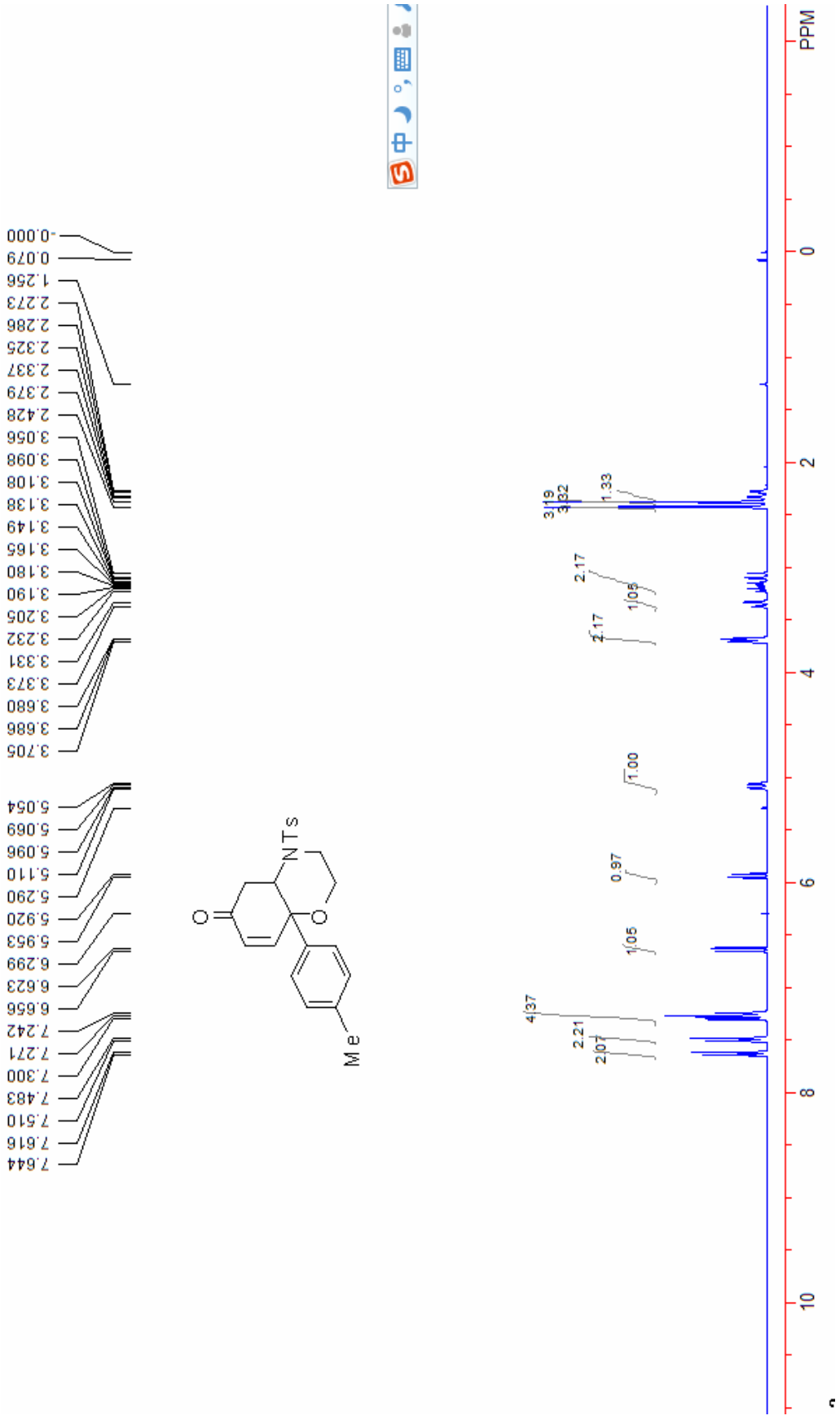
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O
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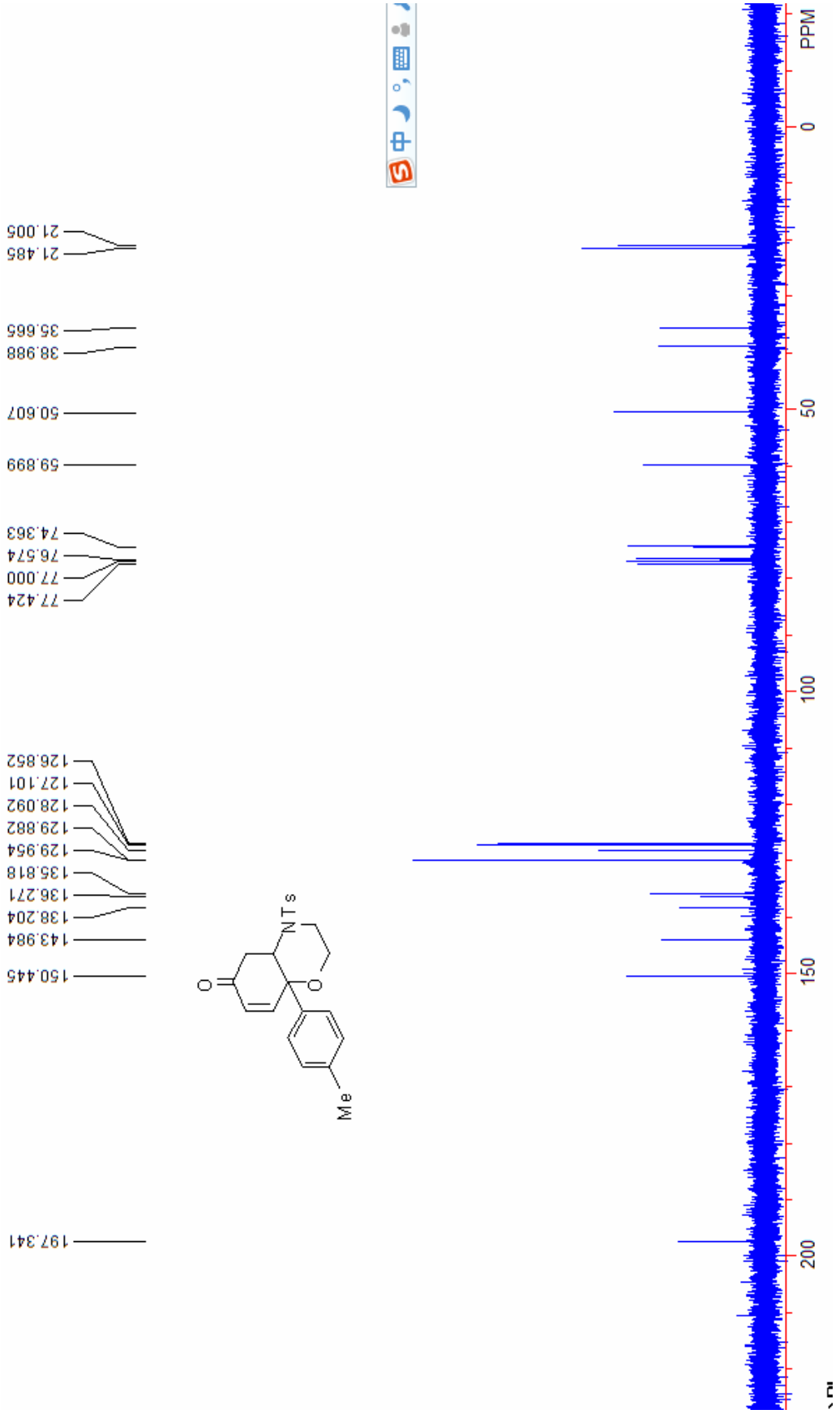
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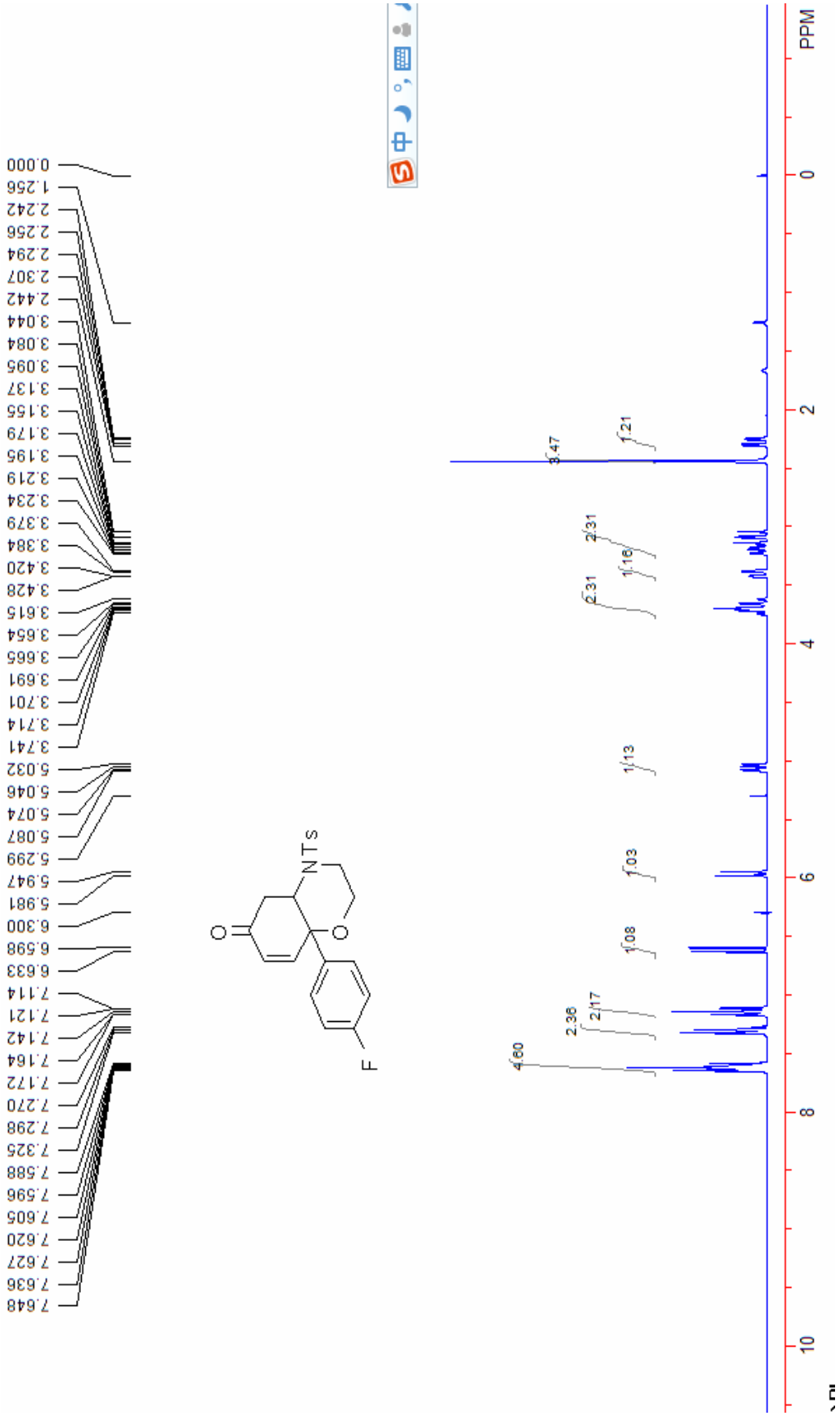
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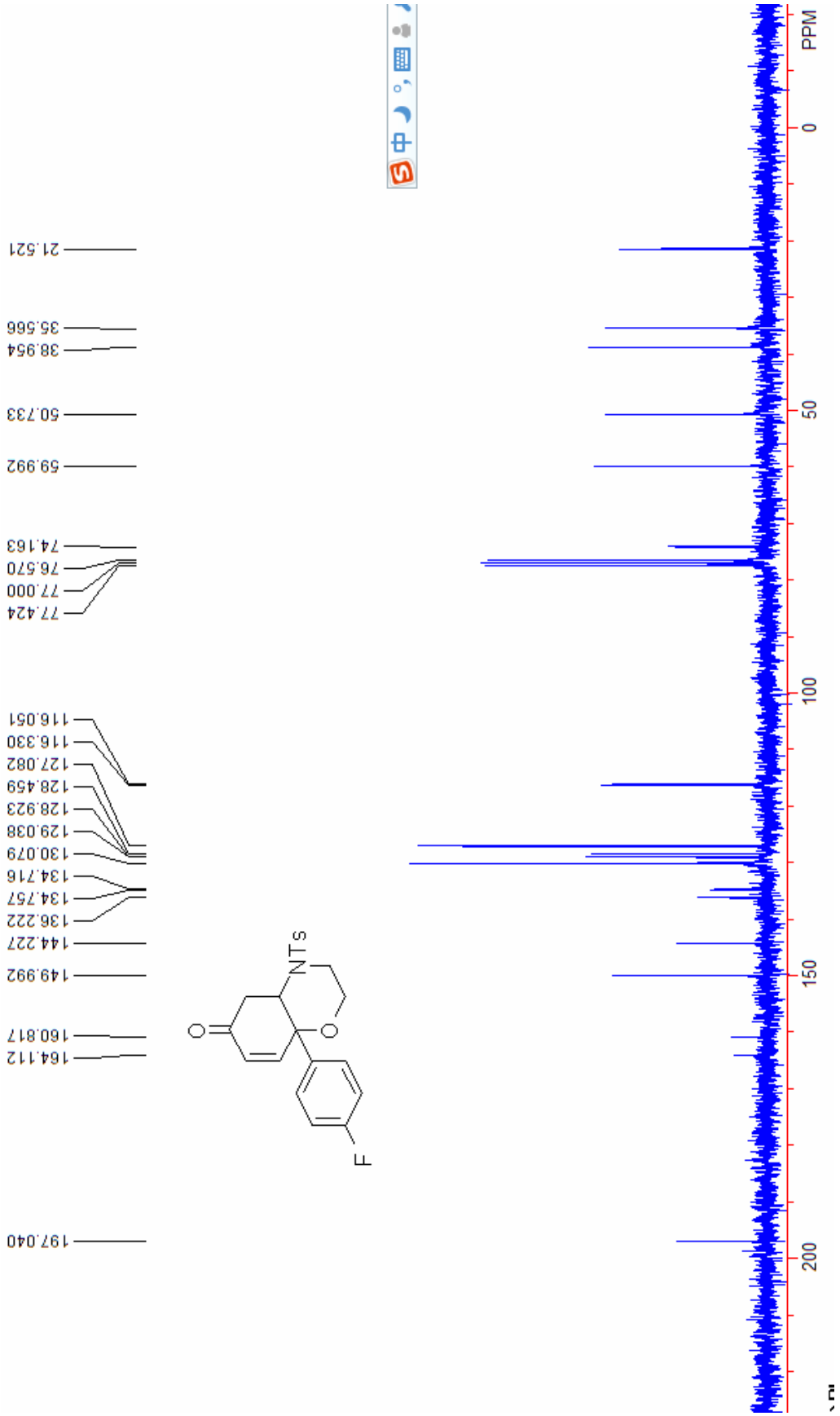

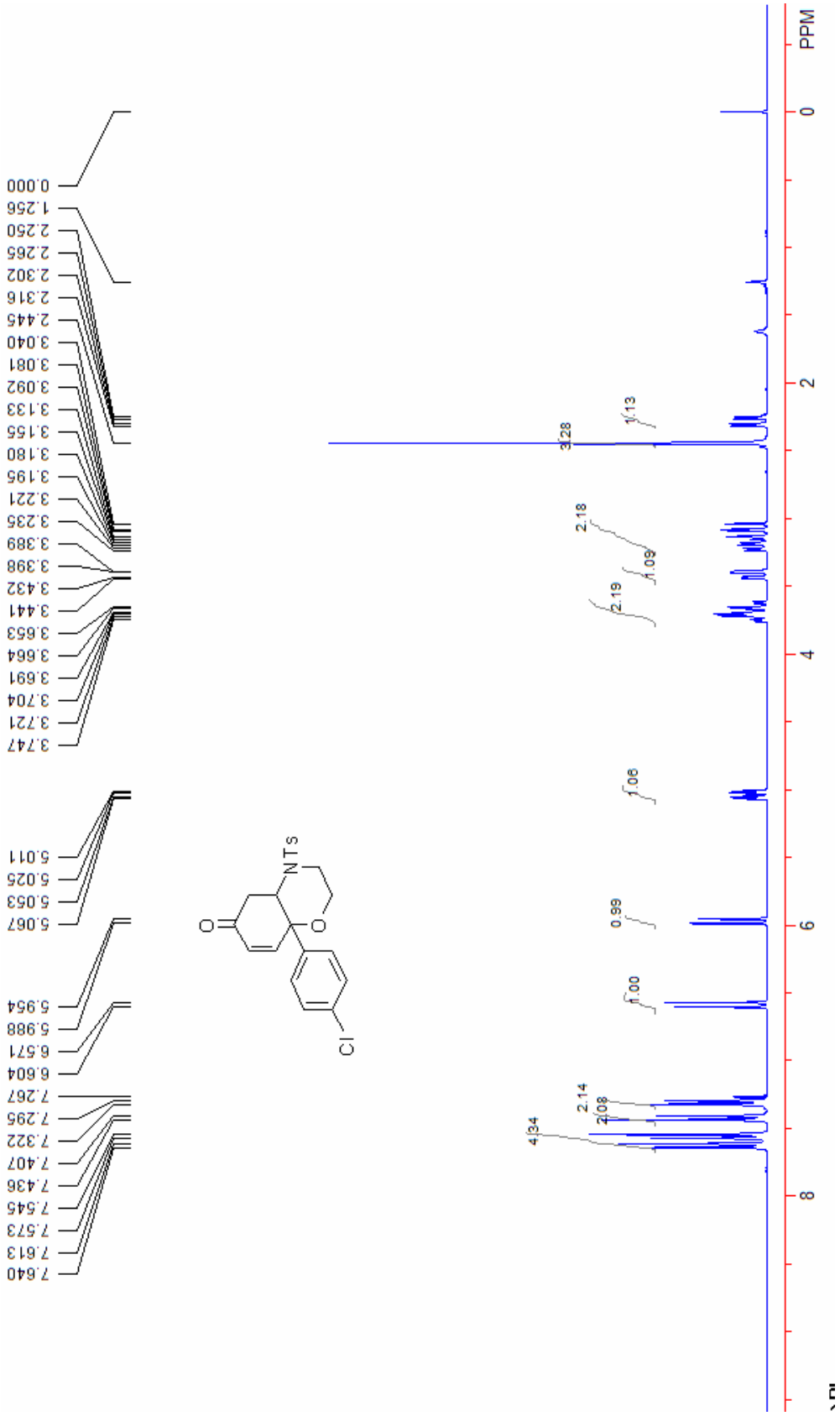

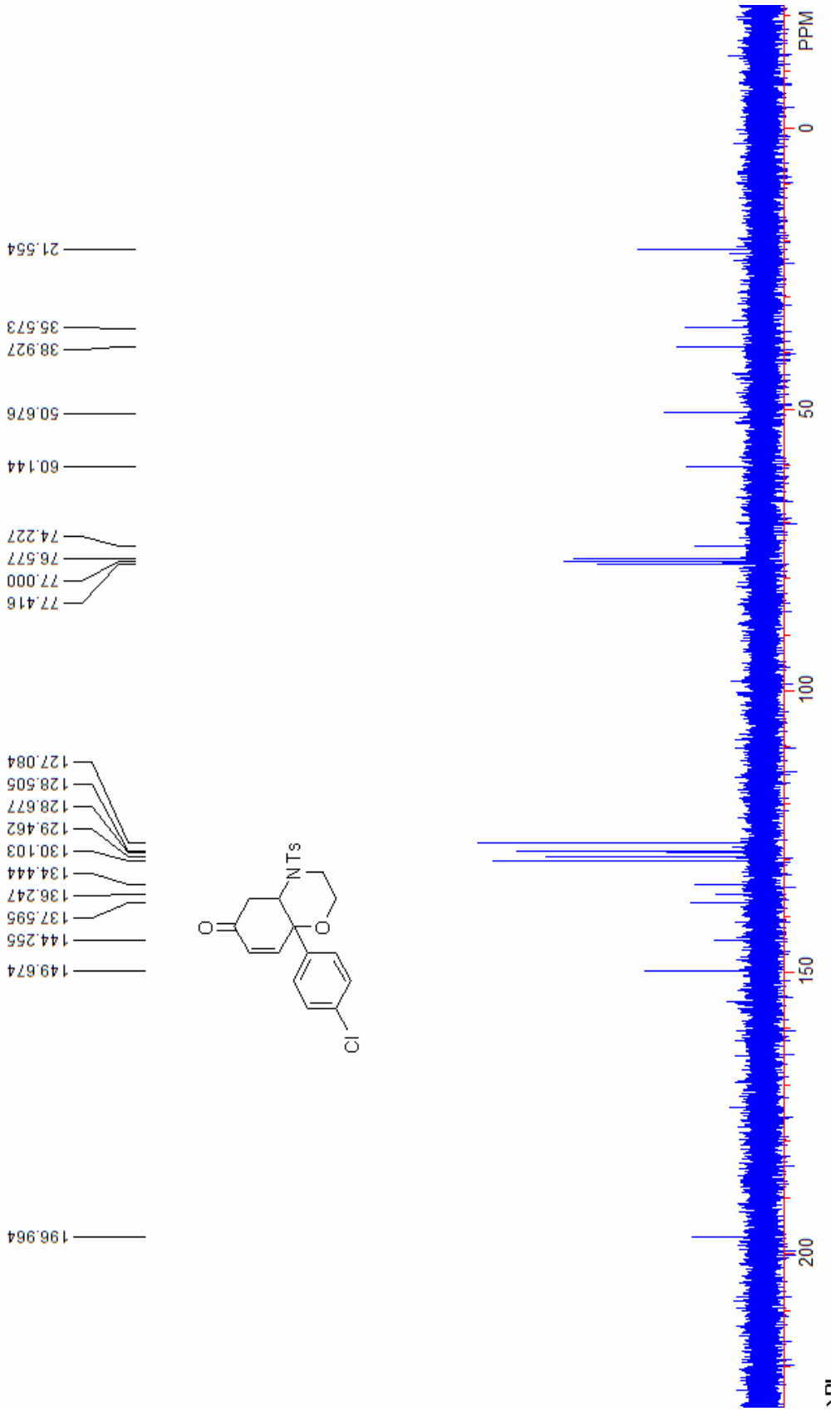
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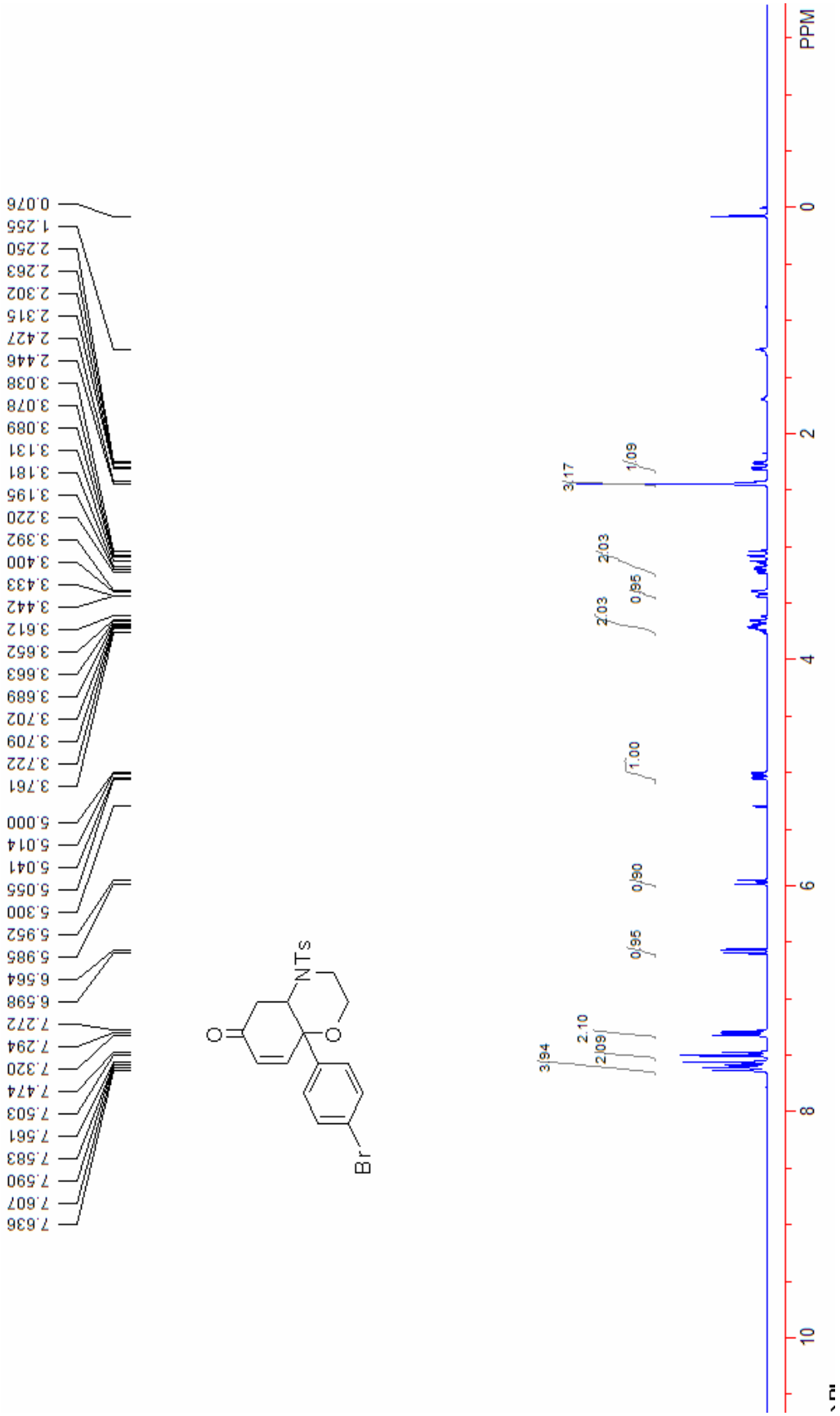
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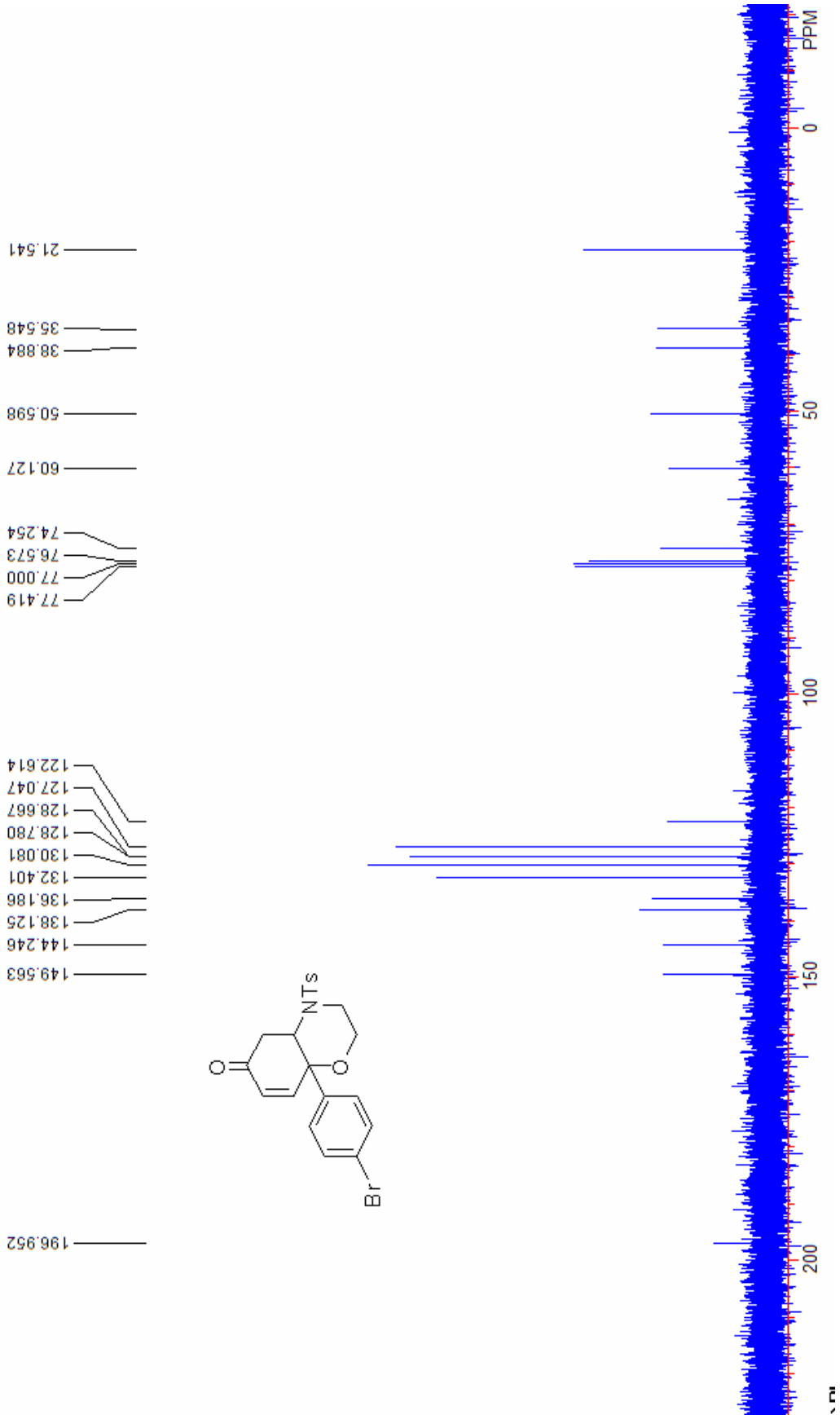
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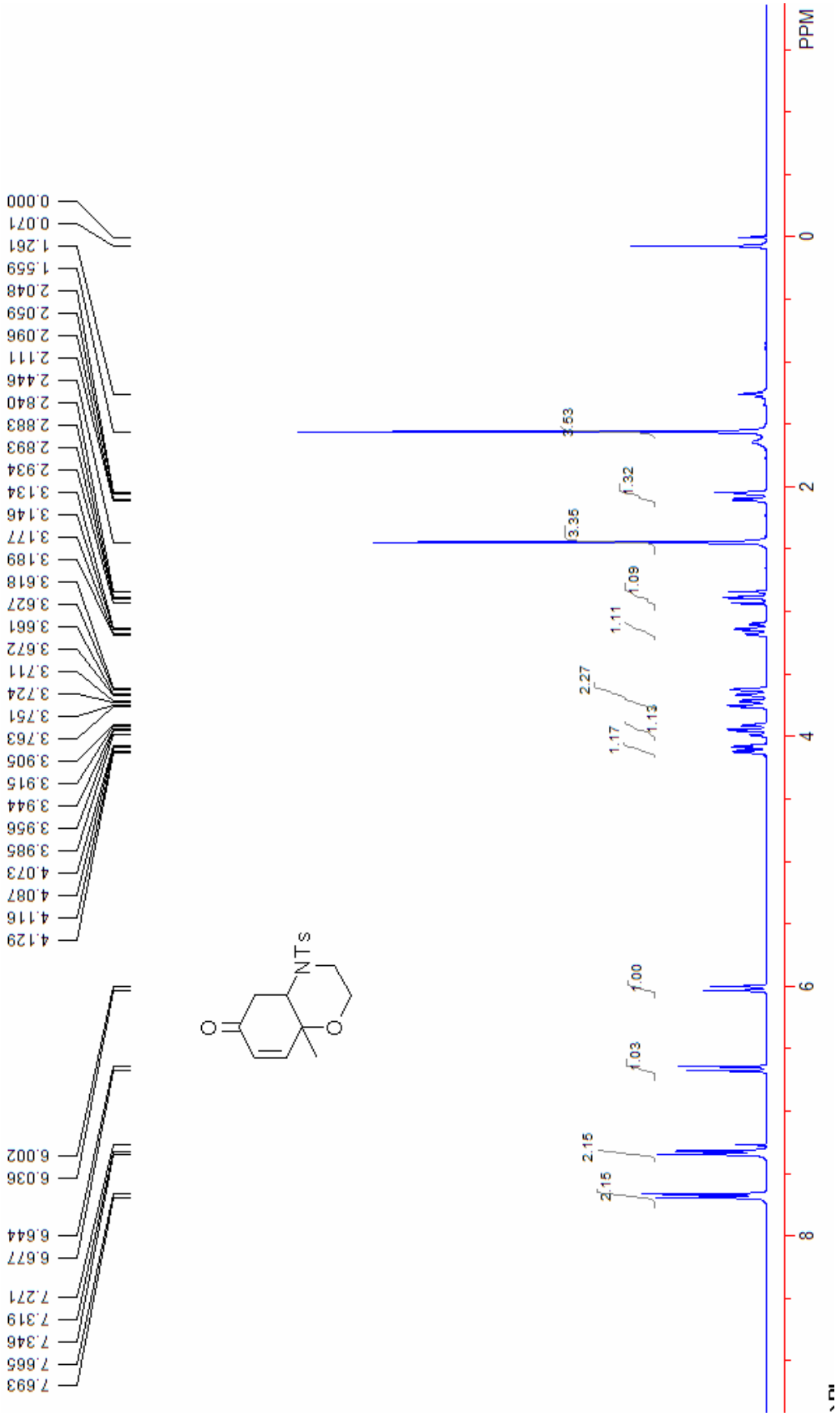
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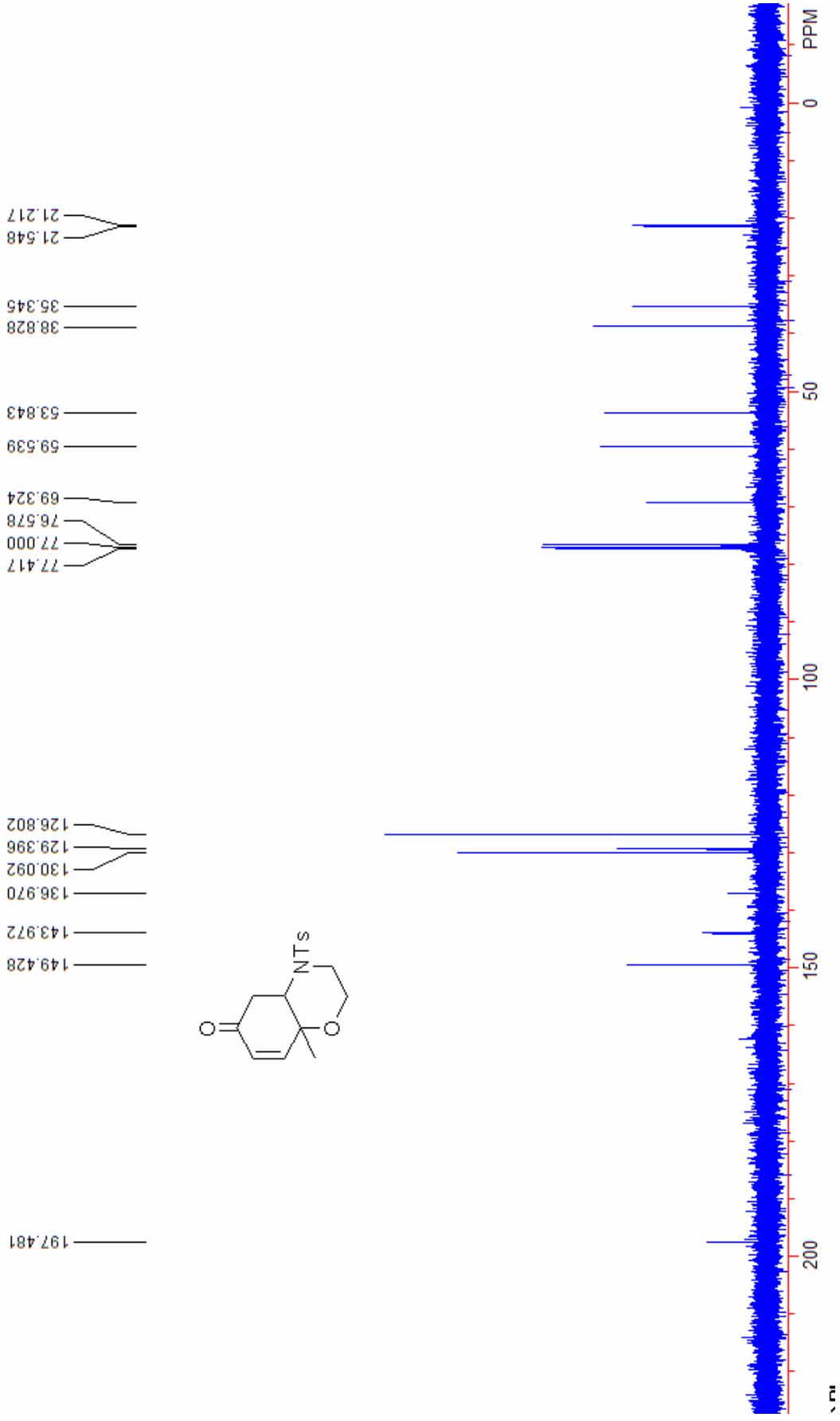
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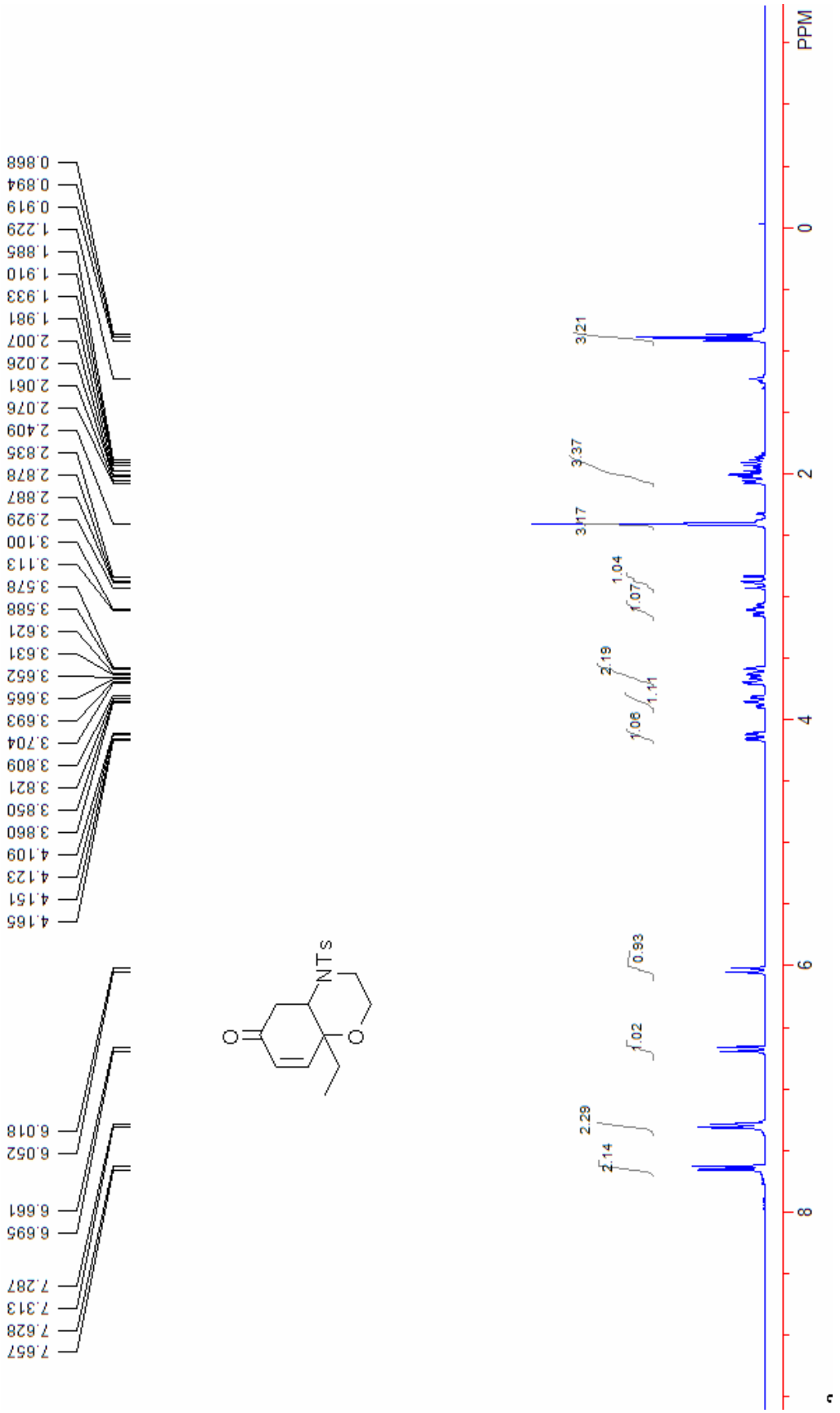
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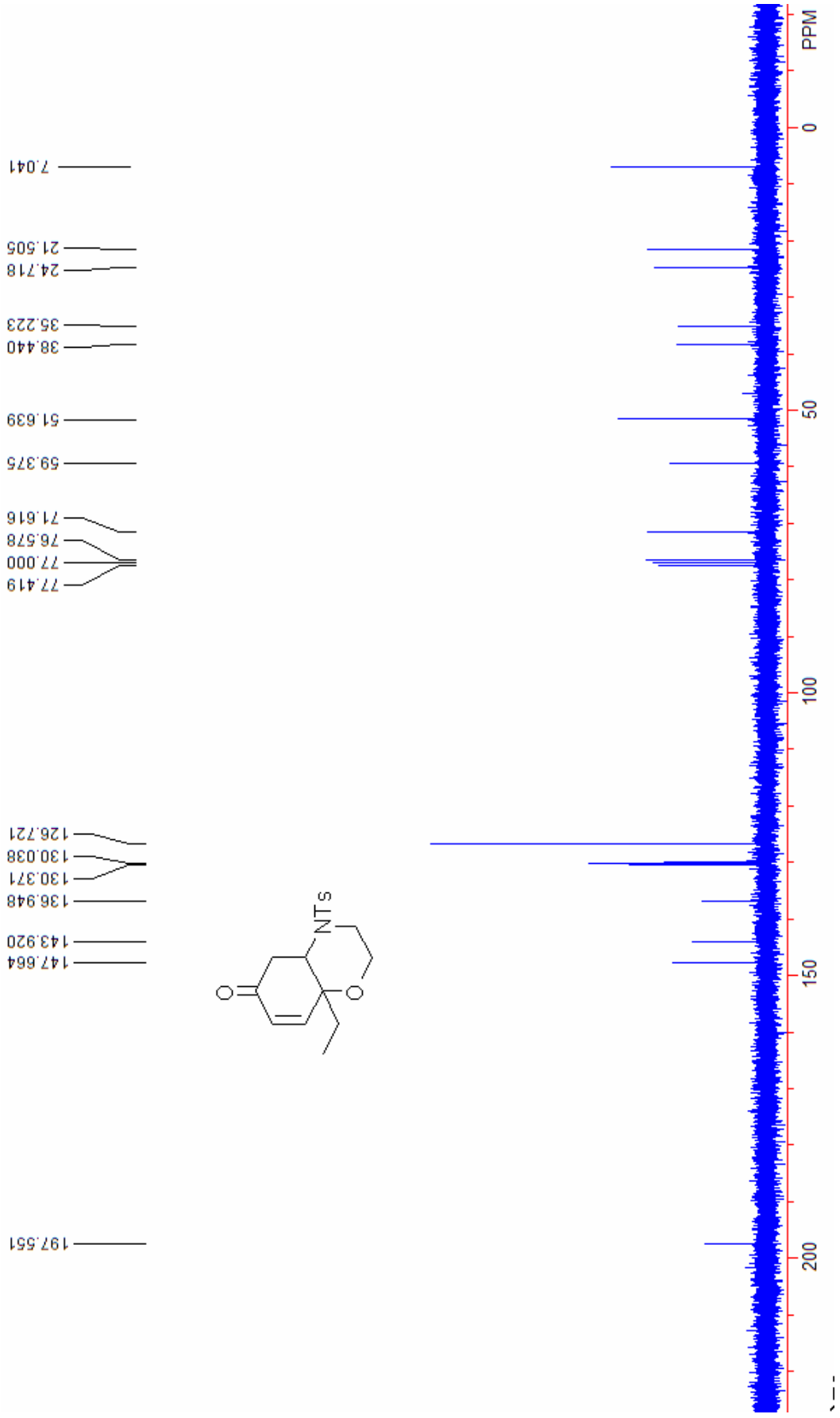
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NTs
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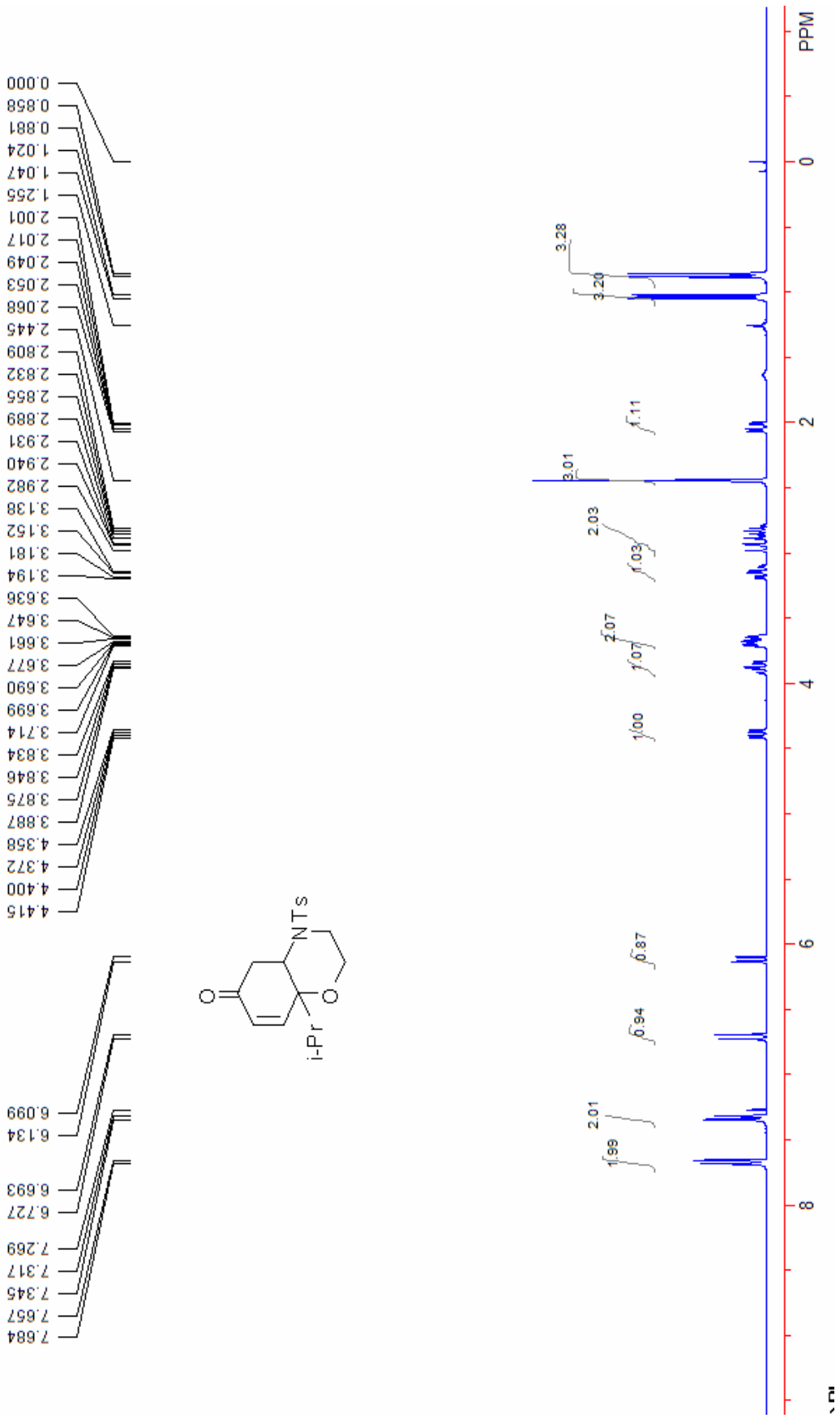
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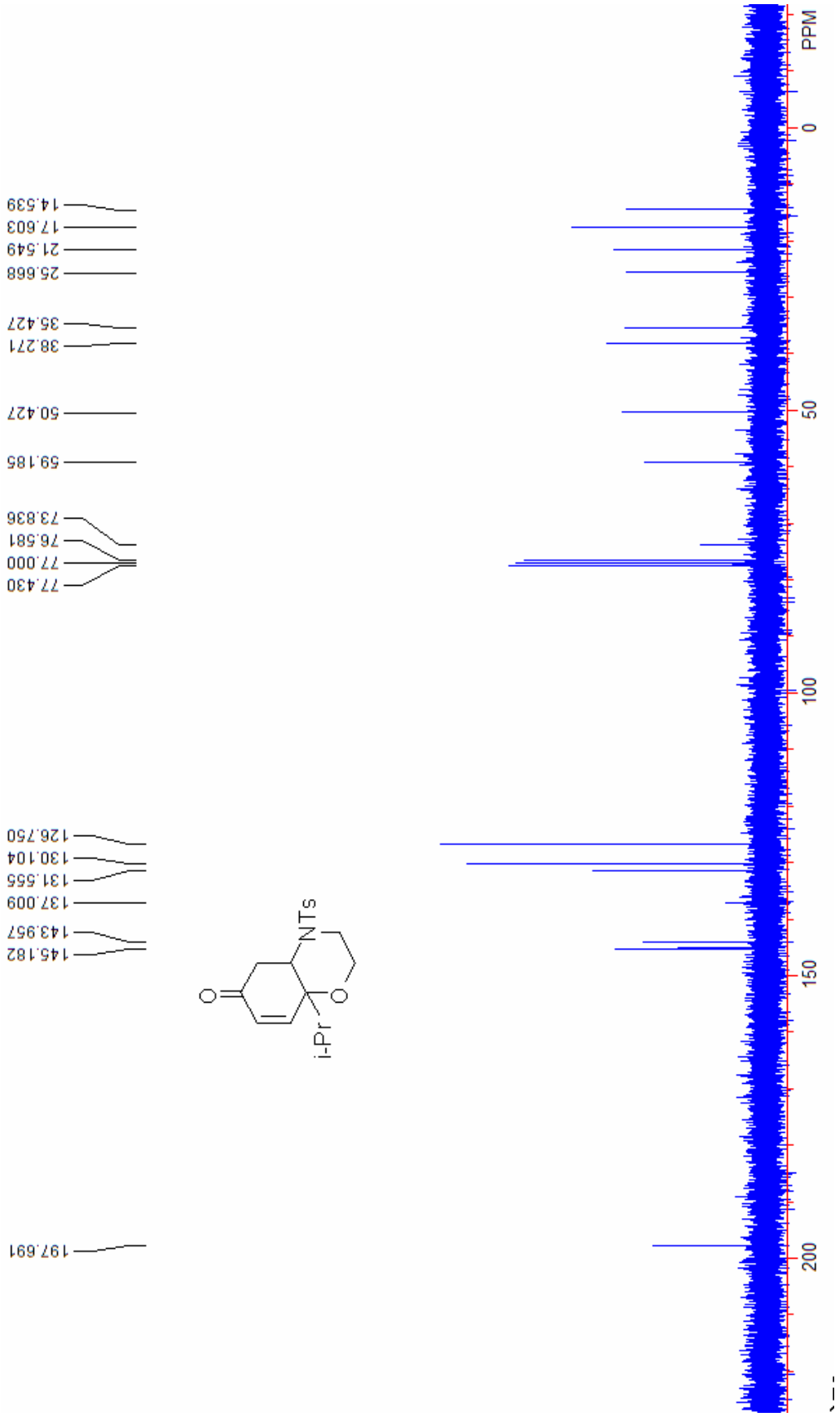

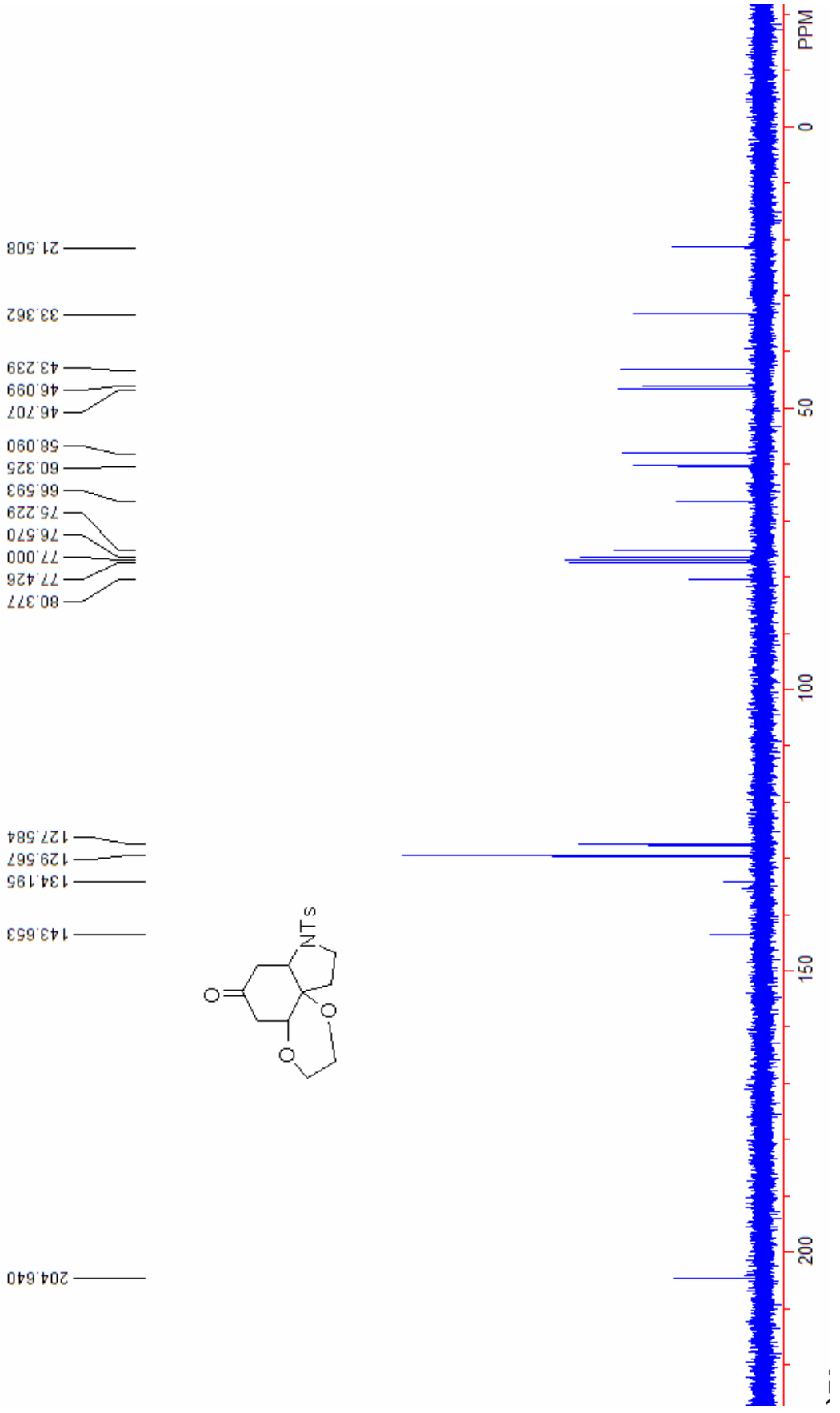
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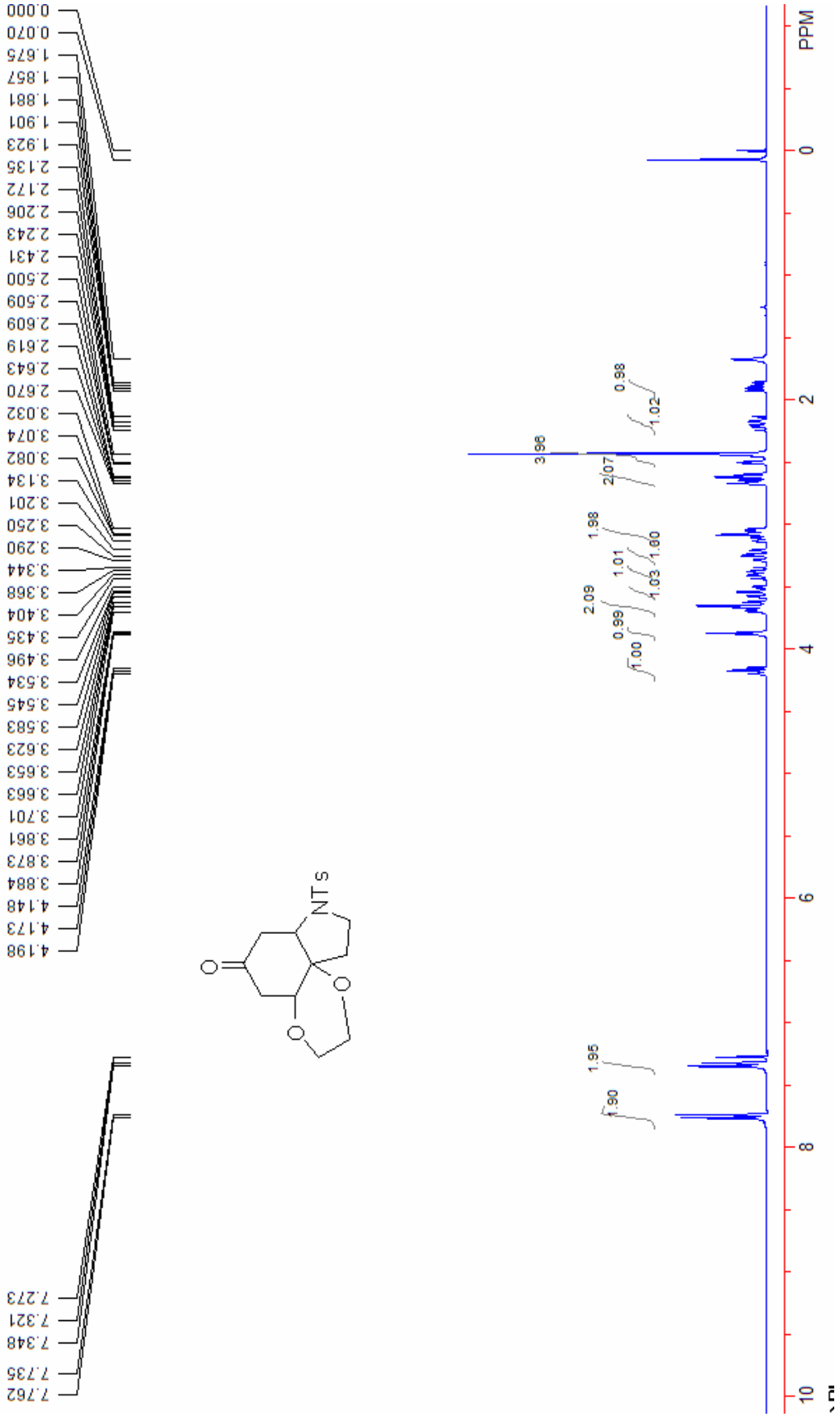
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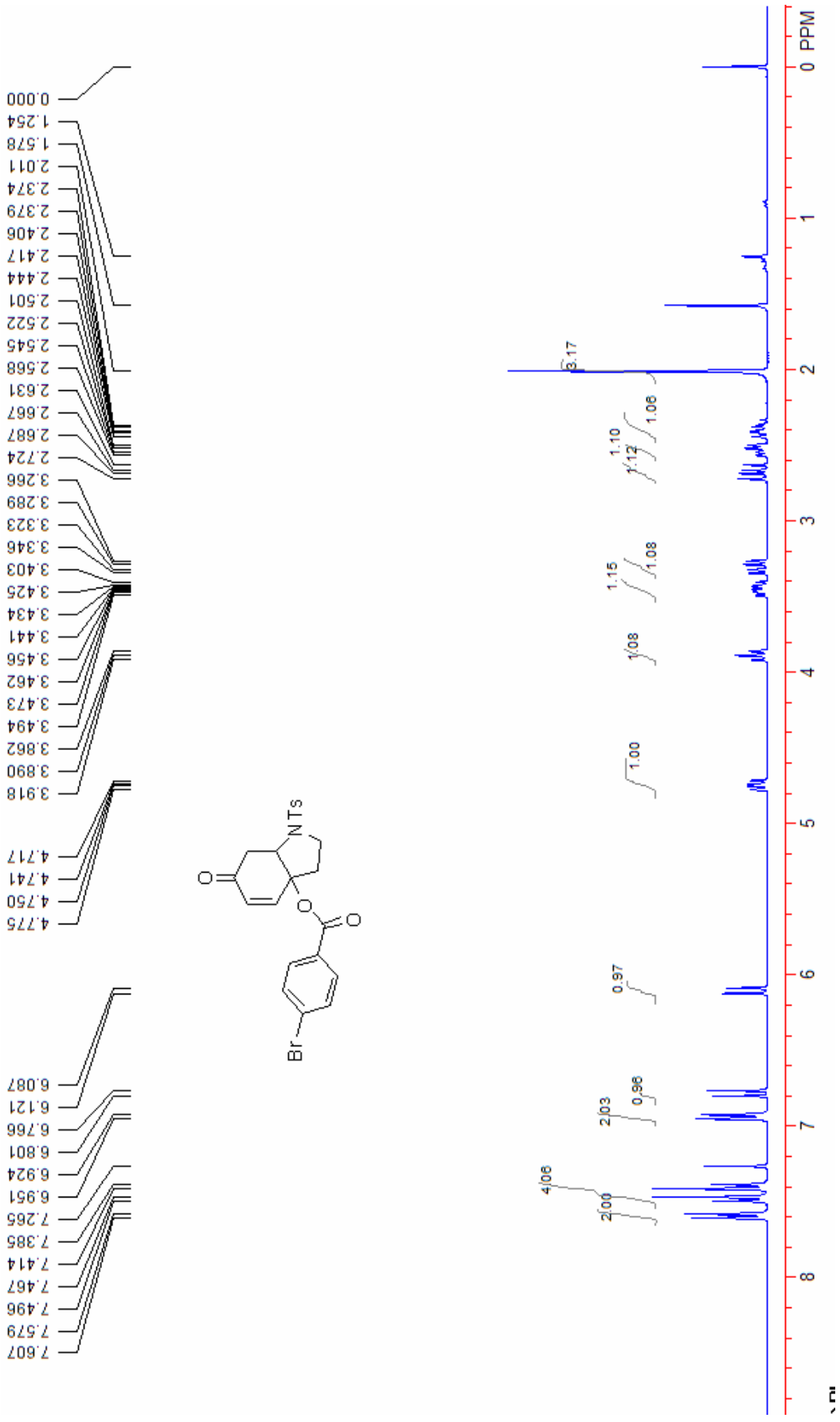
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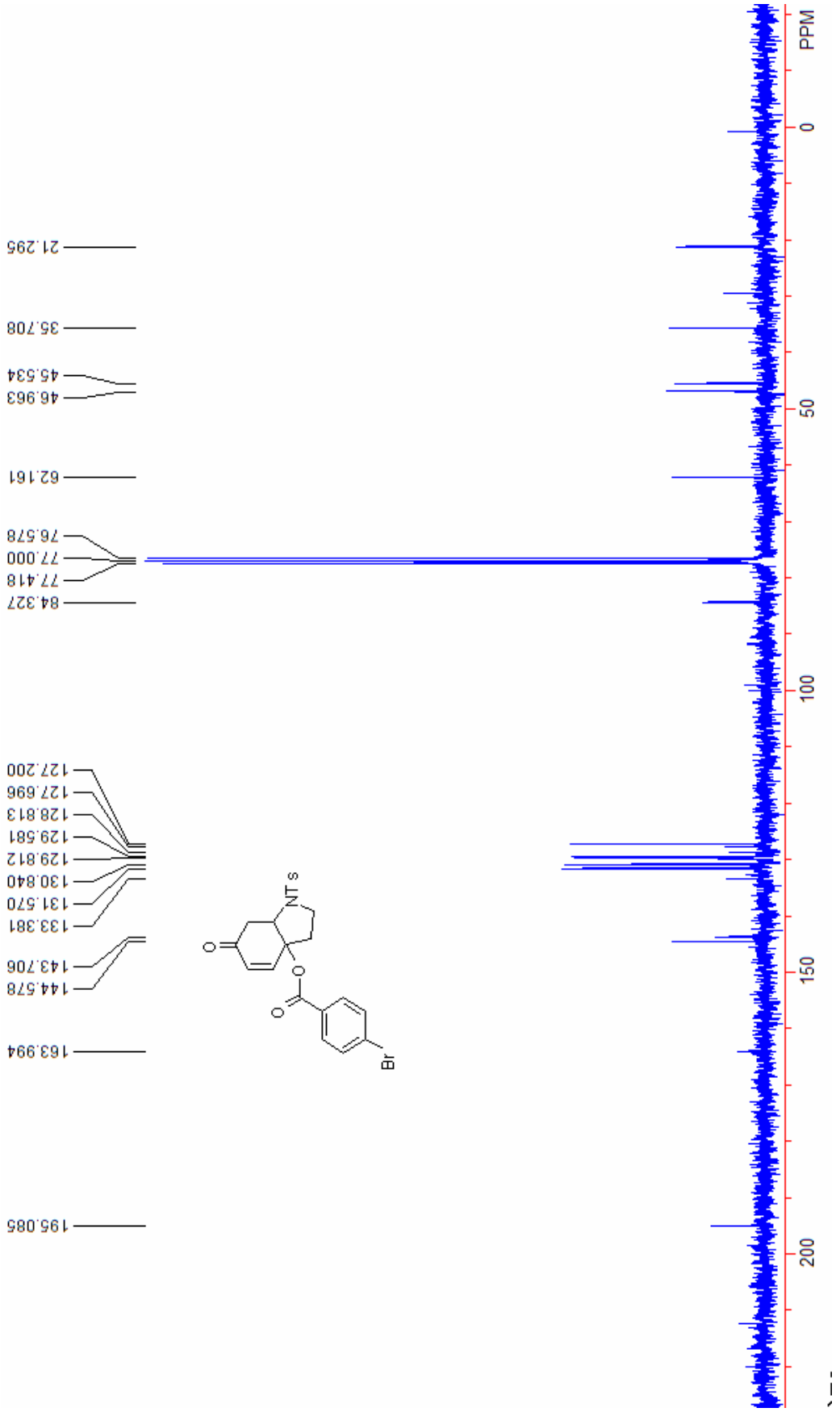

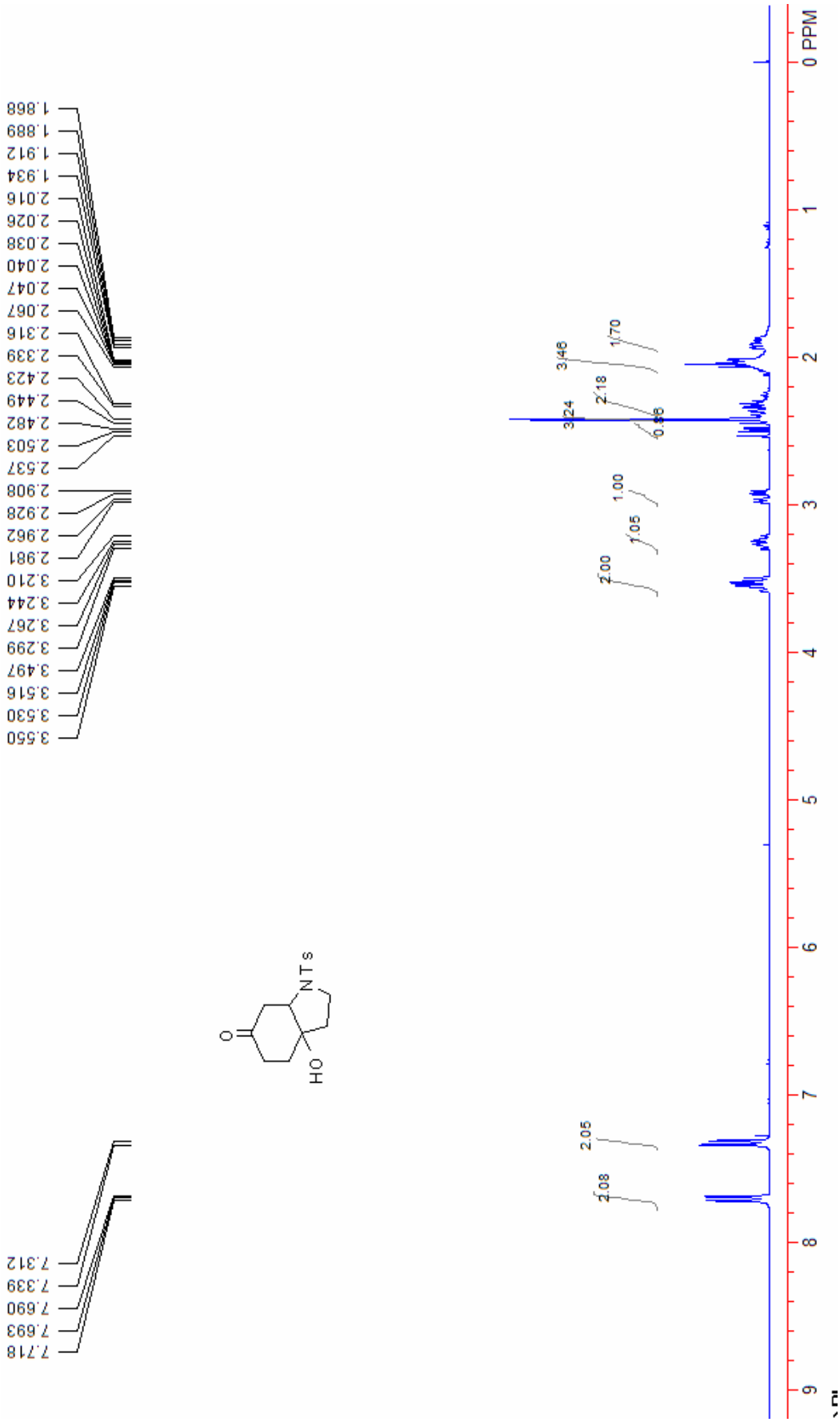
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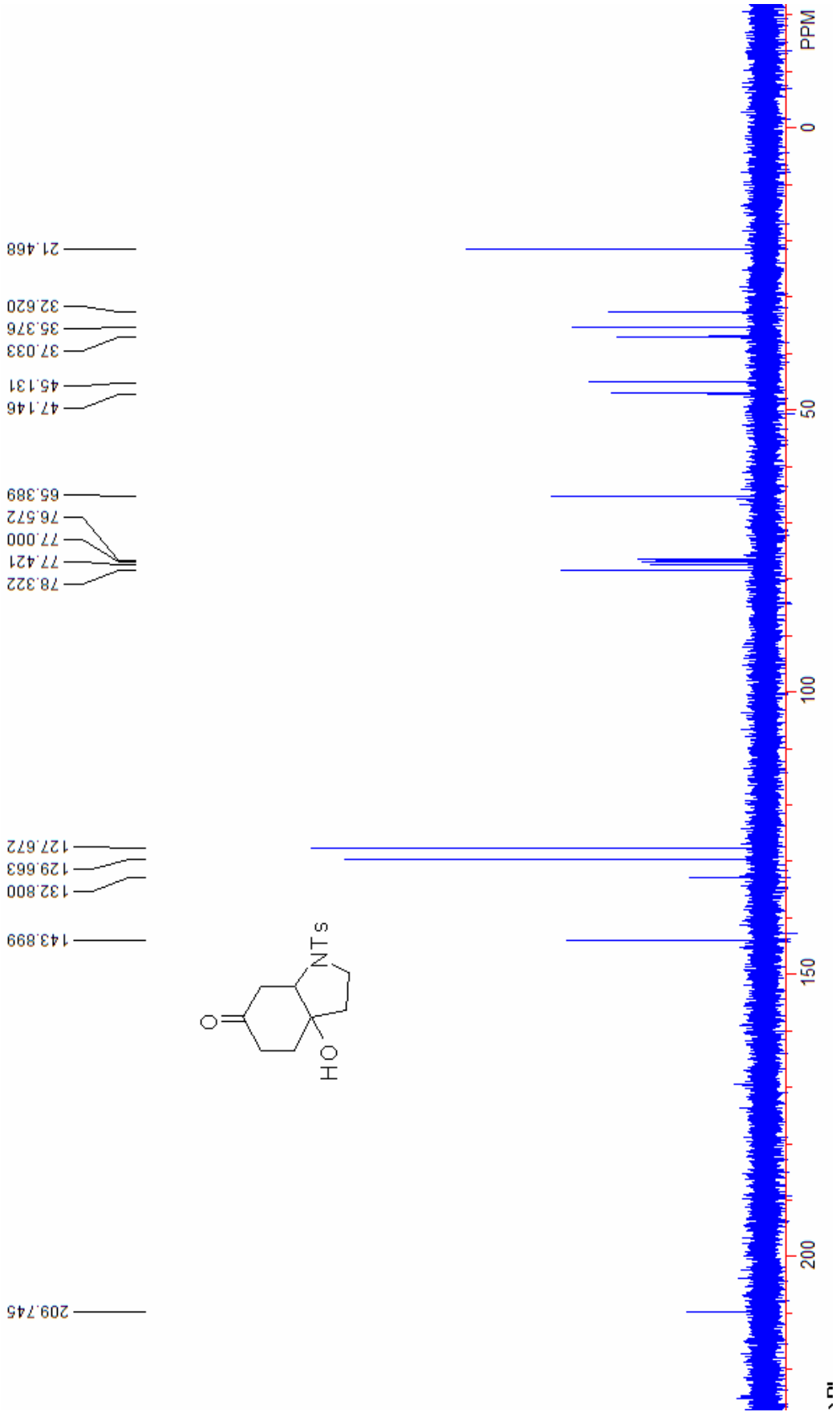
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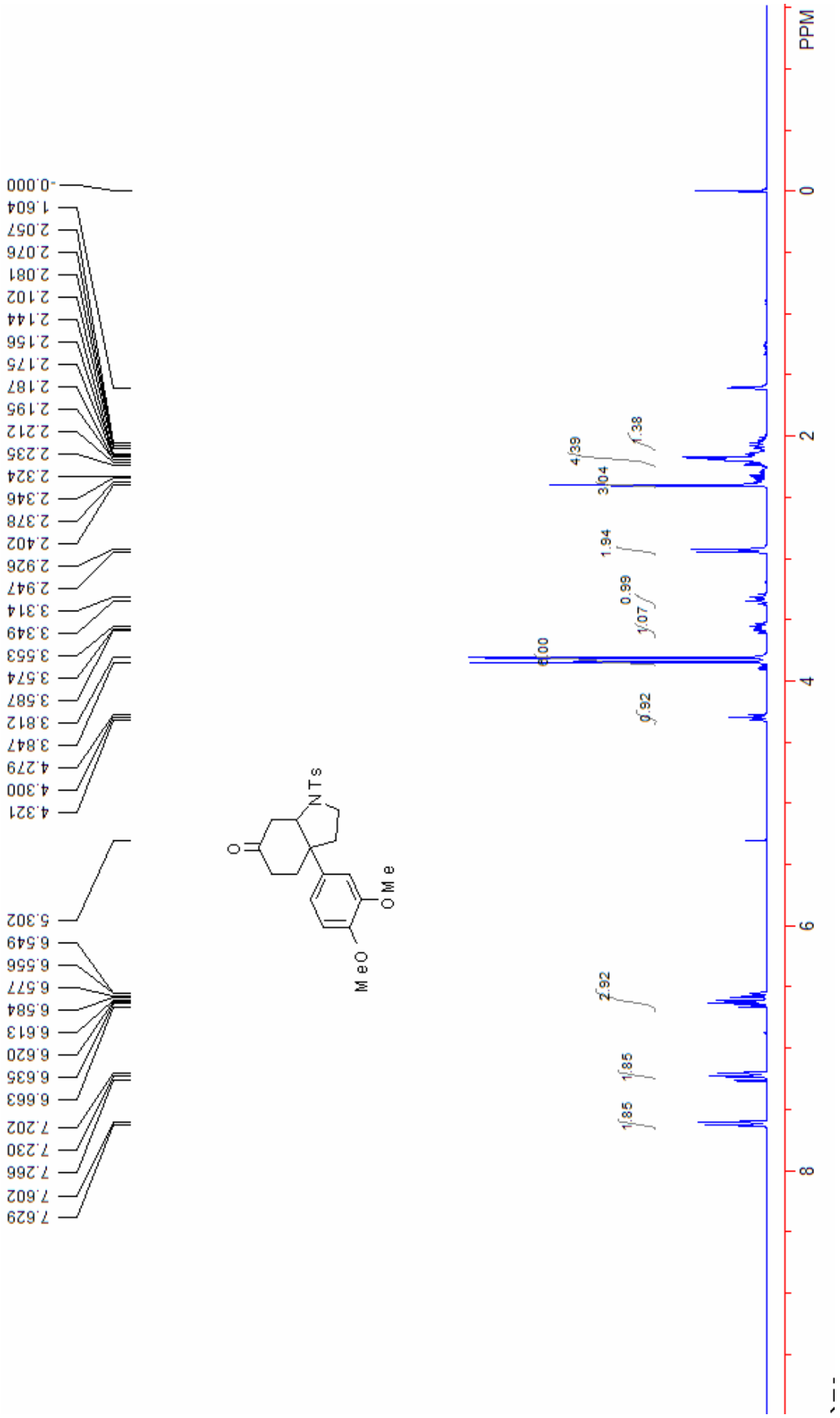
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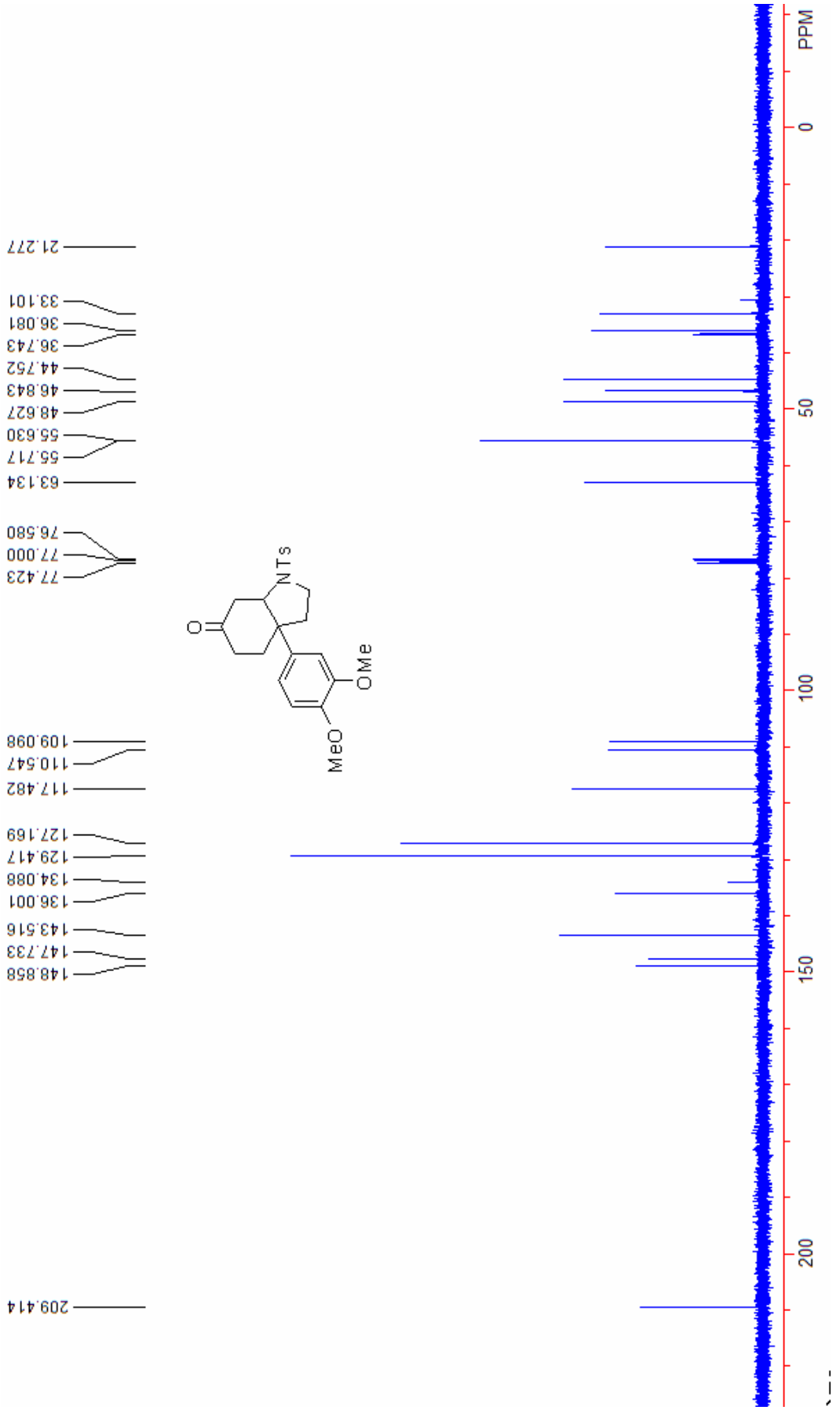
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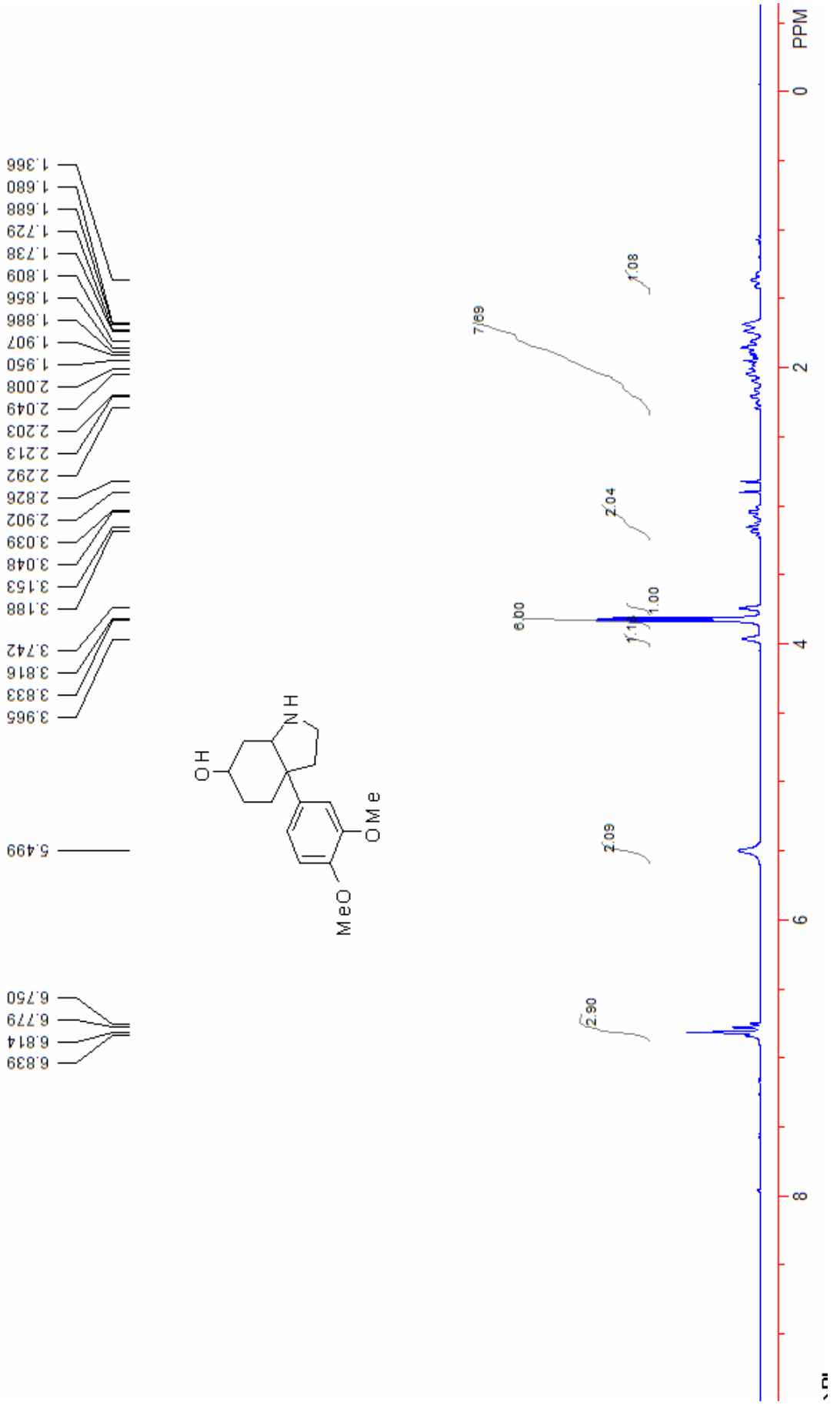
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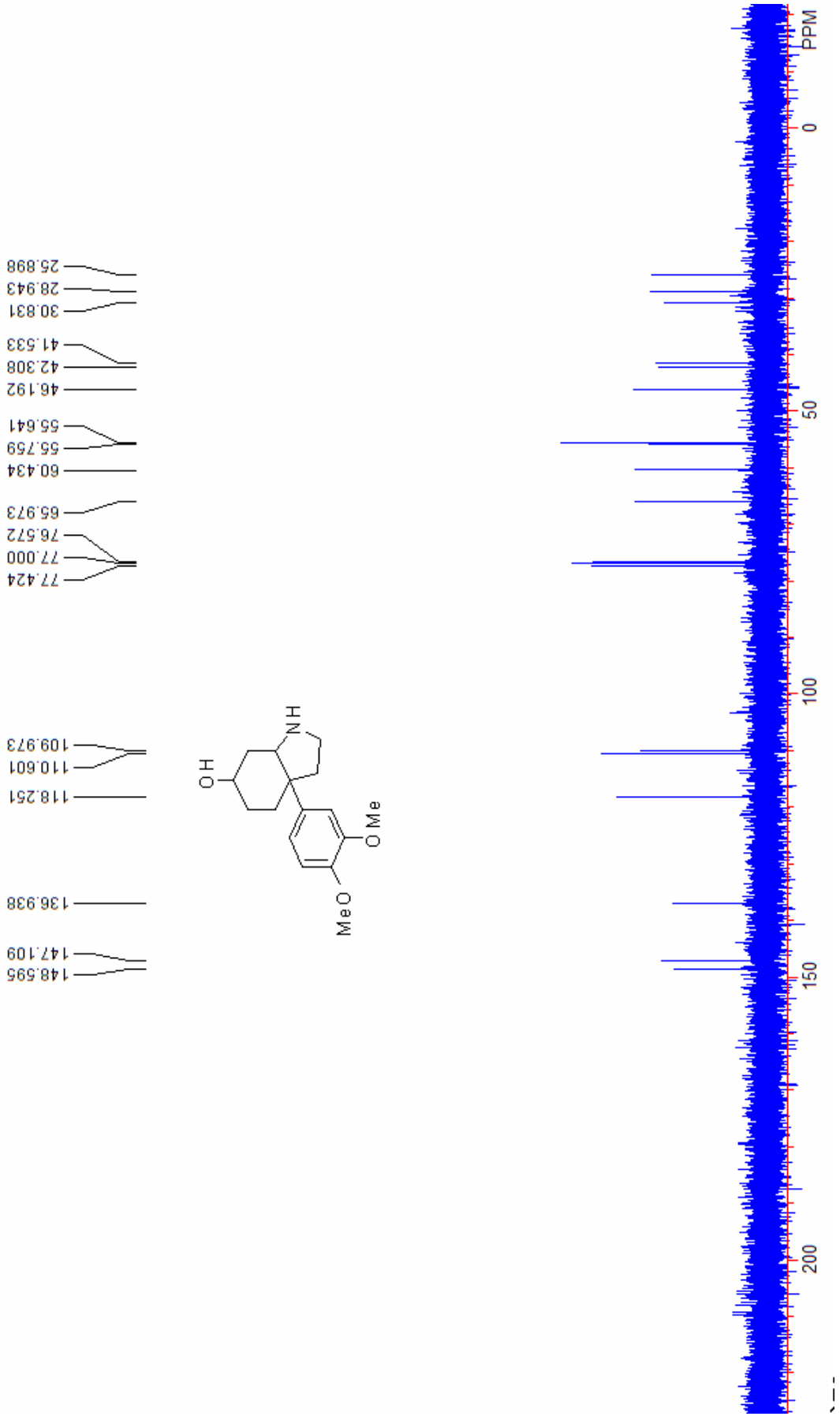
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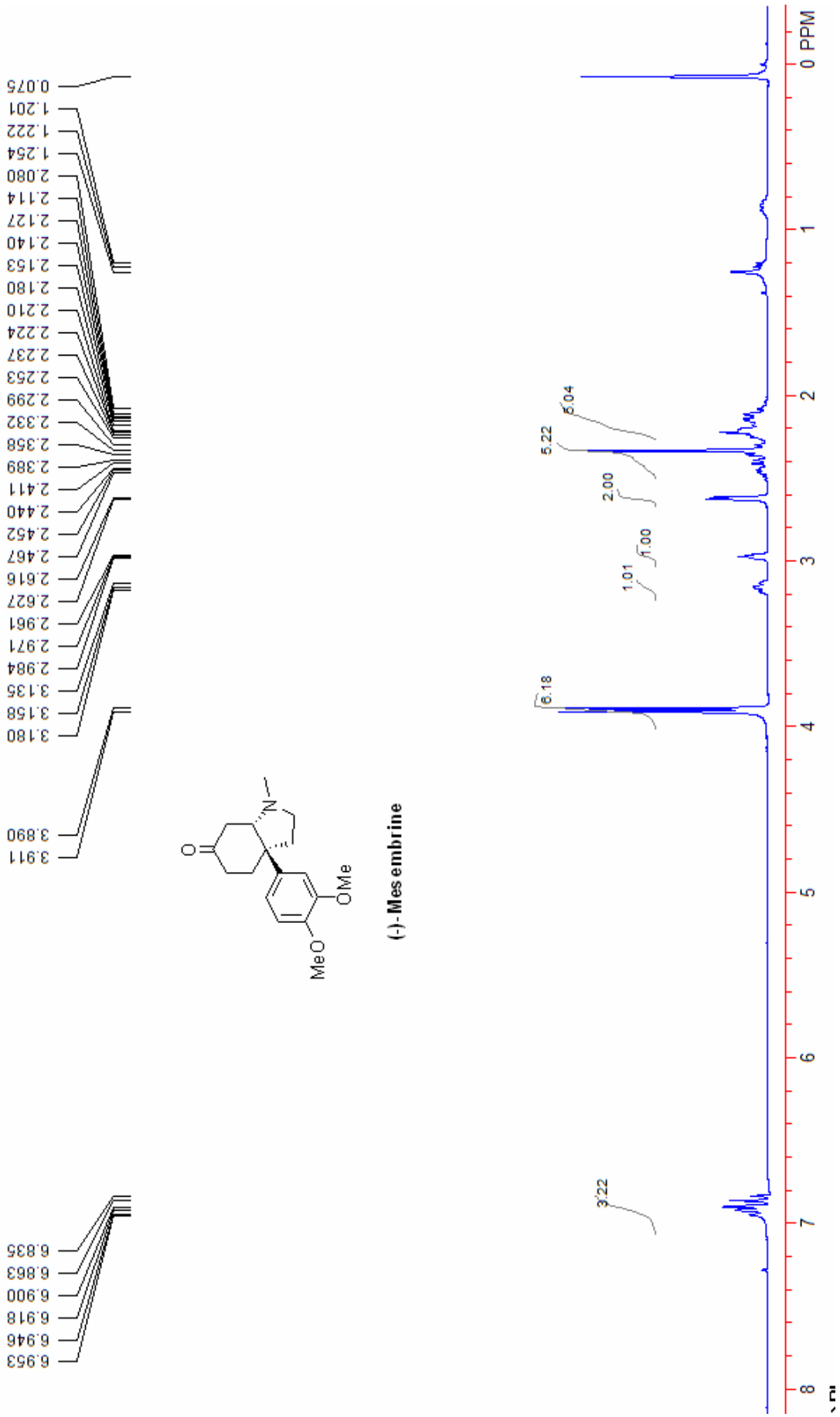
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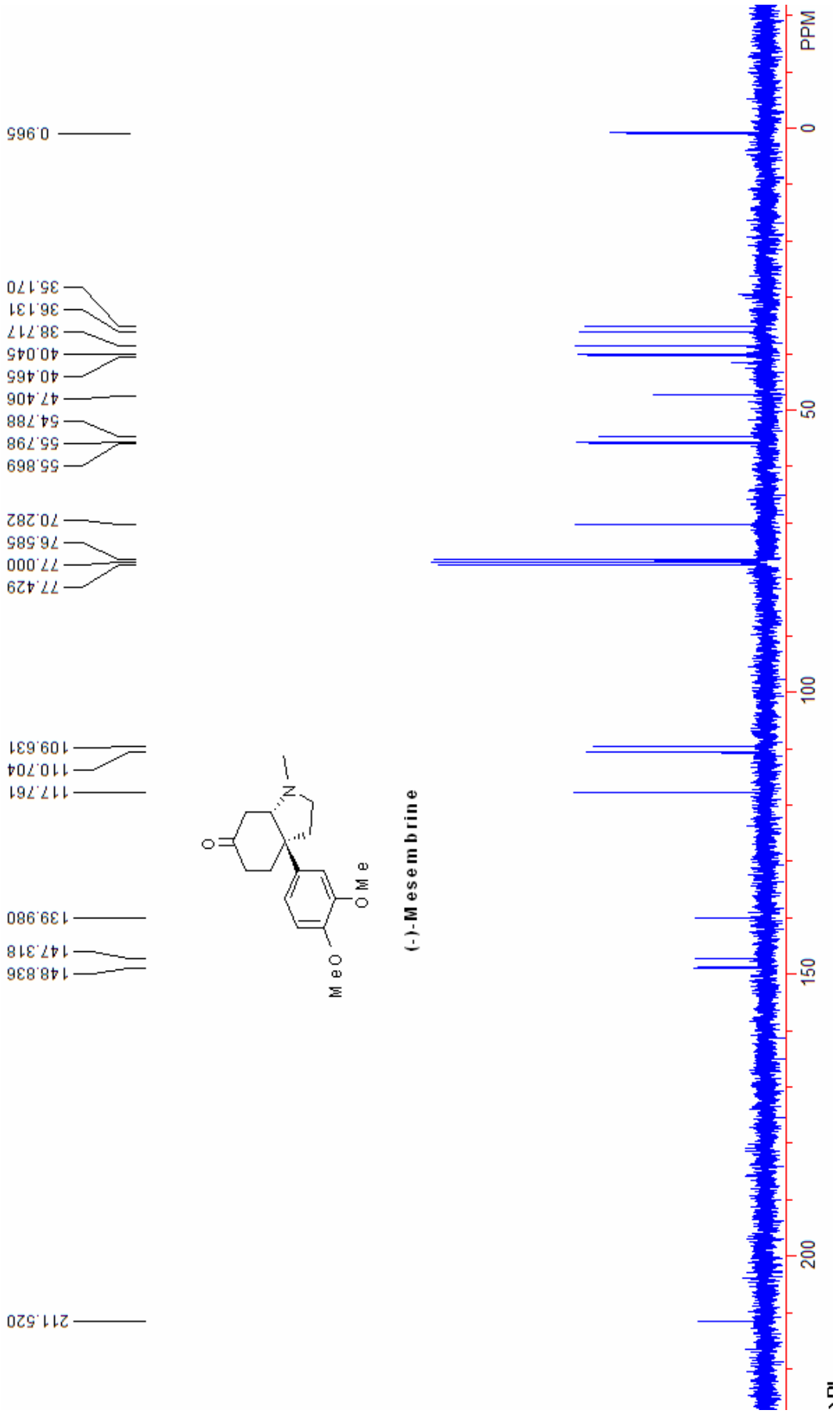

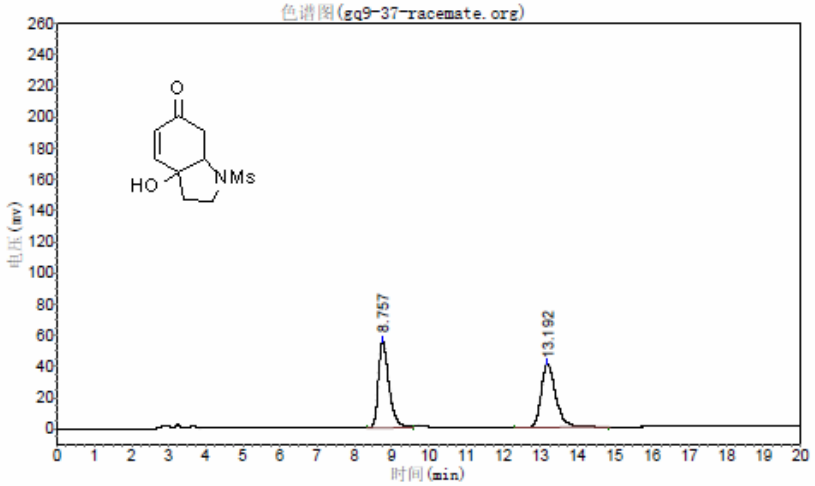

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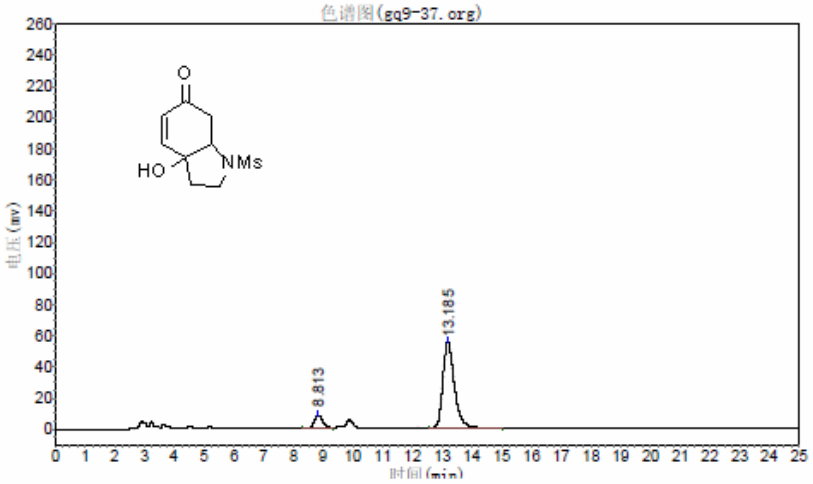

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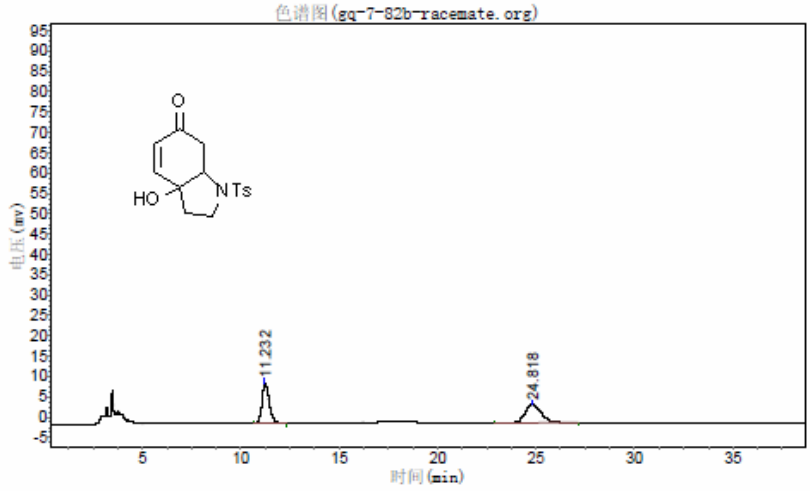

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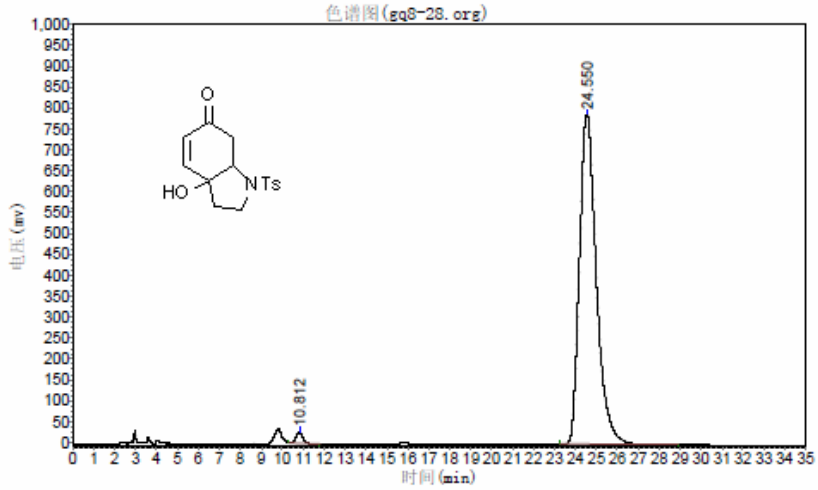

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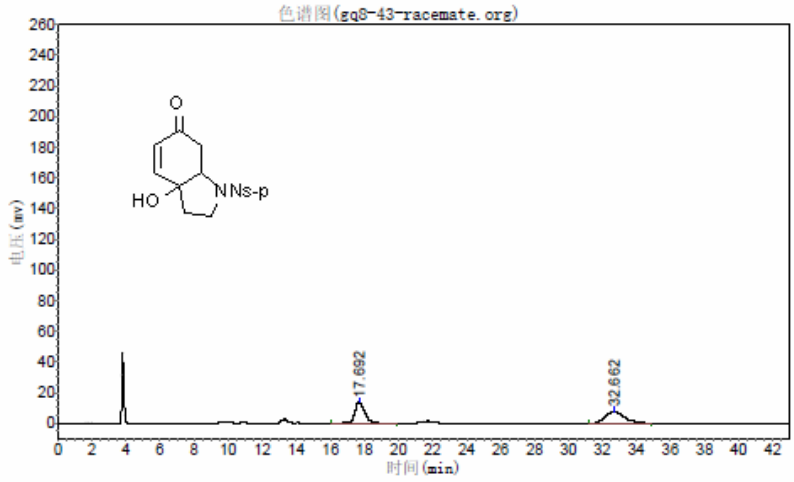

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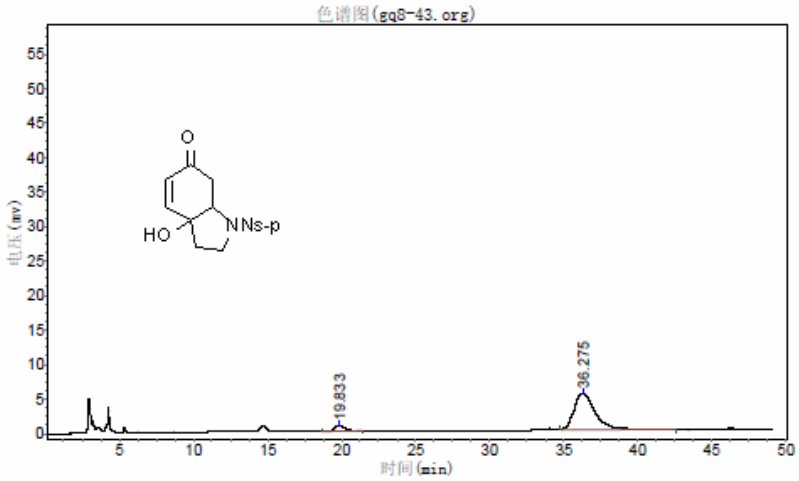

NO.	Time	Height	Area	Percent
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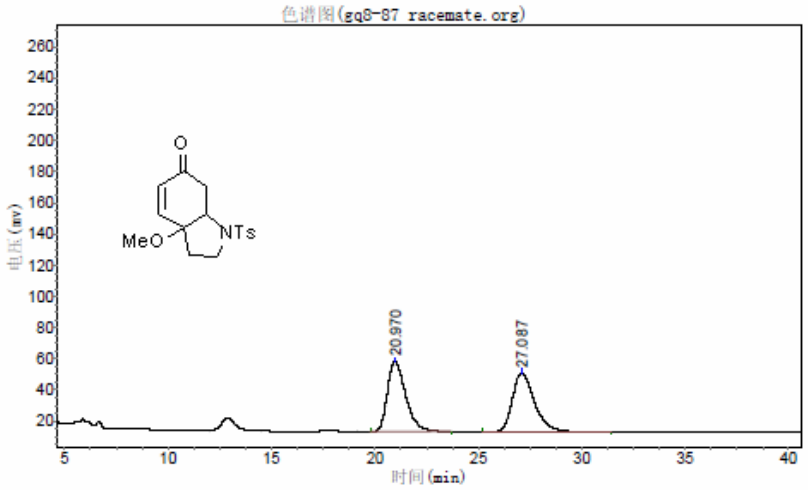

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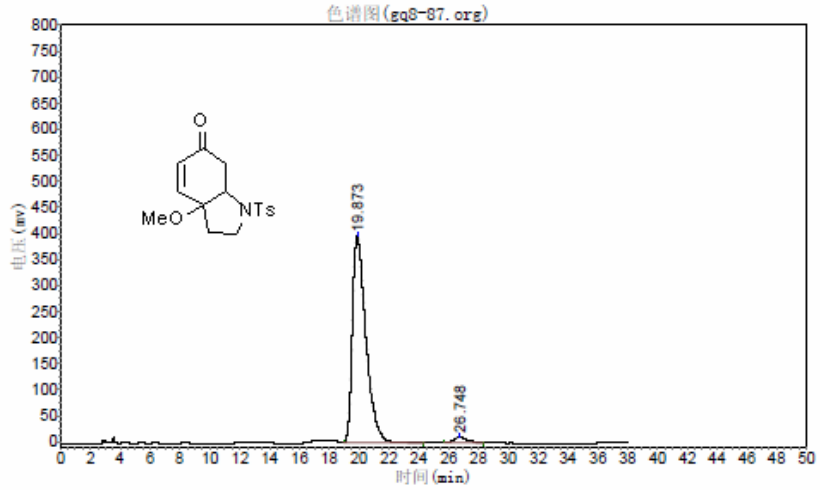

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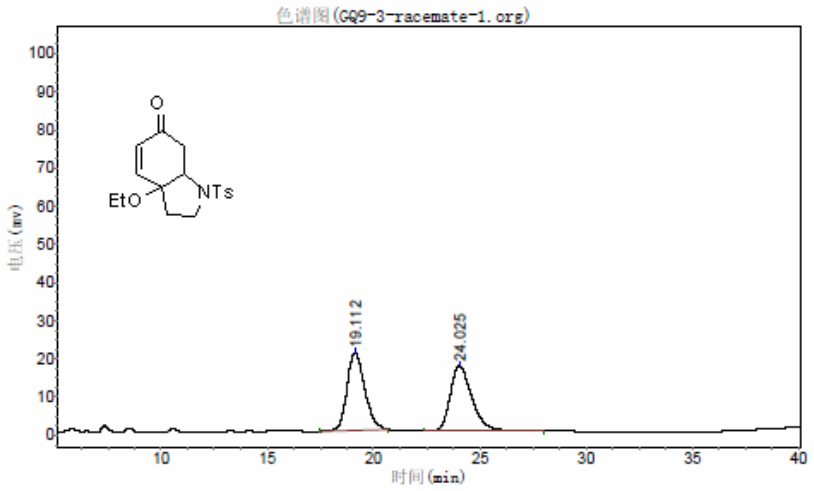

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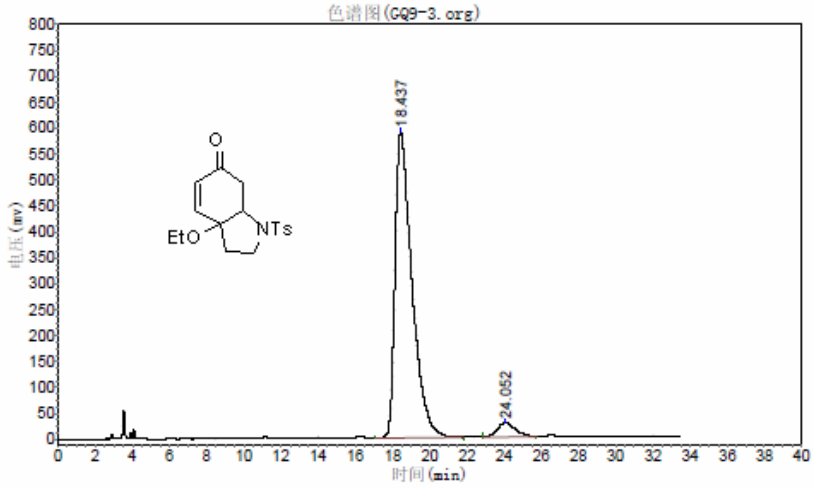

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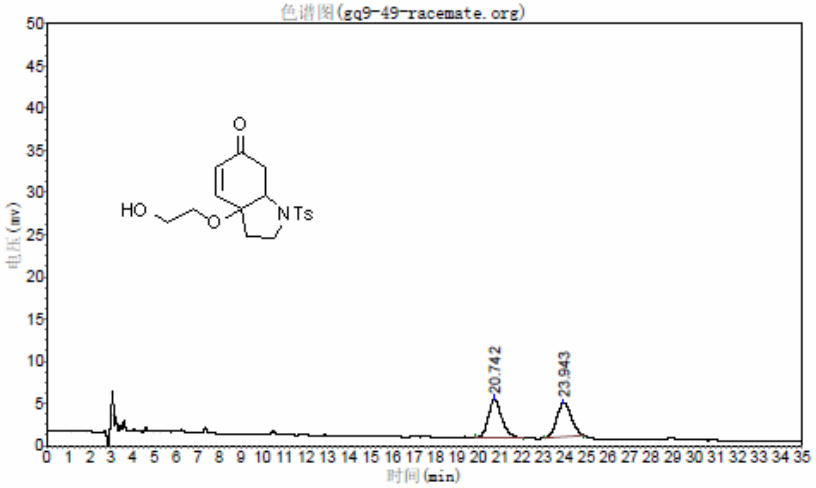

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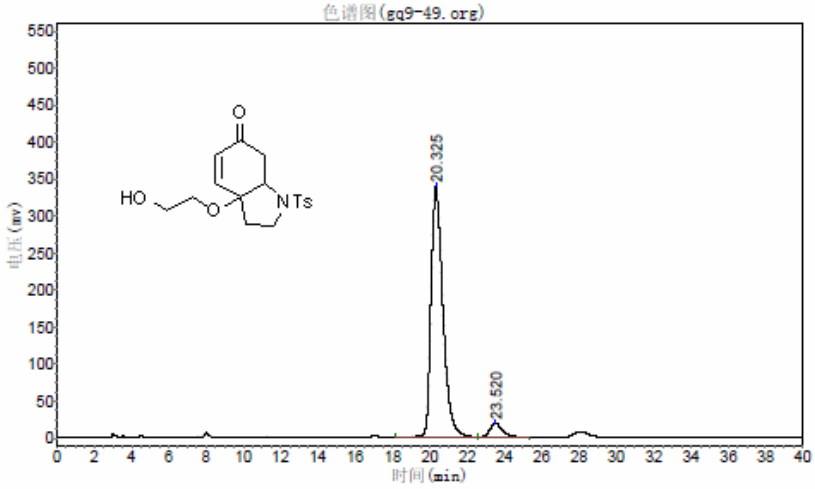

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1	20.325	338488.531	14861093.000	94.5072
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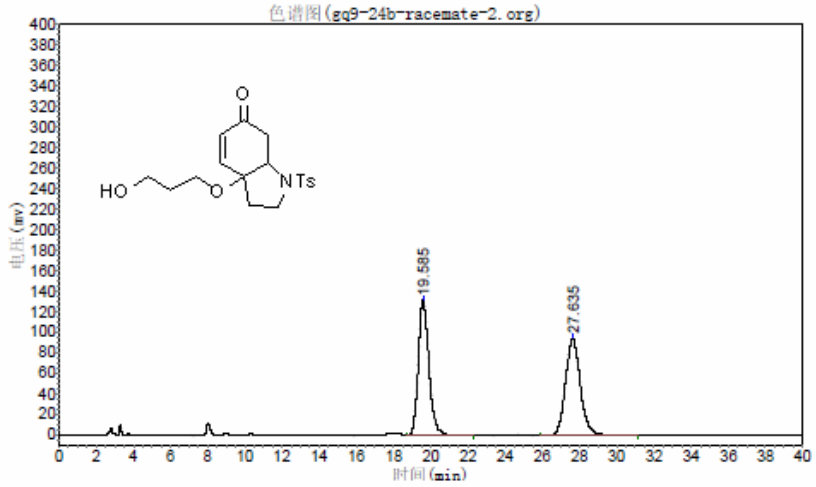

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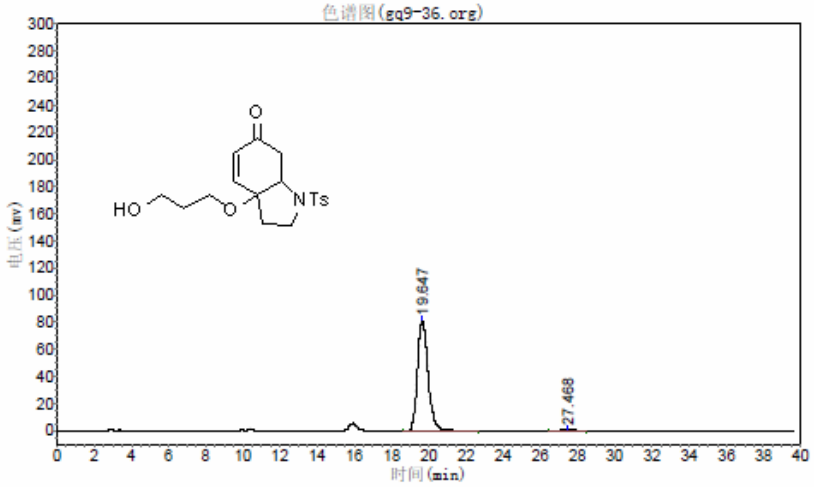

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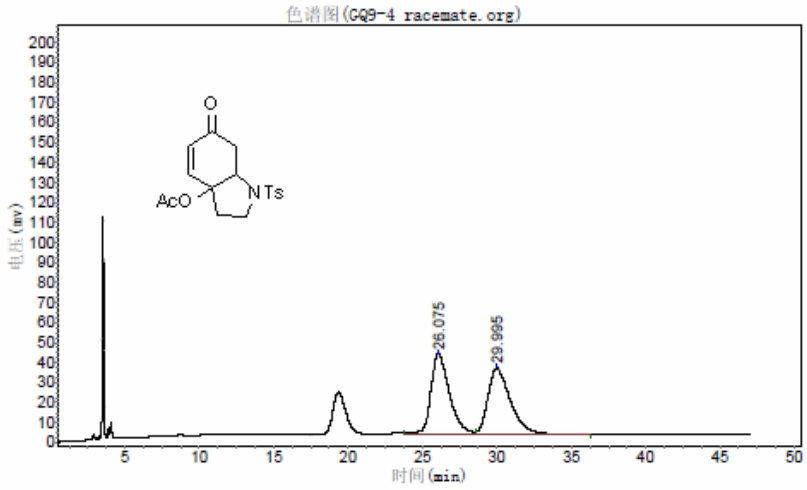

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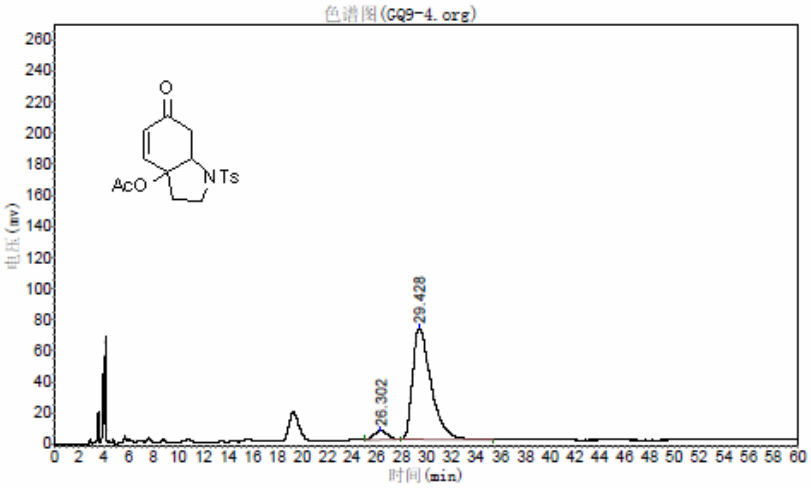

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1	26.302	5527.781	454487.563	5.7657
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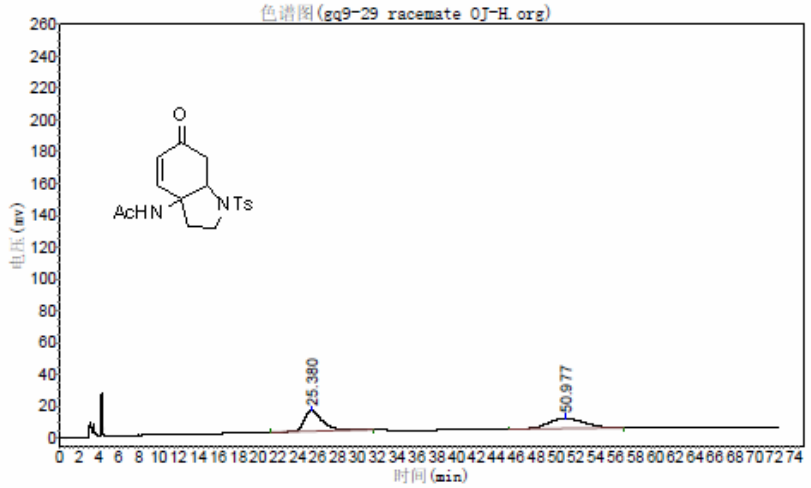

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1	25.380	12900.809	1604752.000	50.0812
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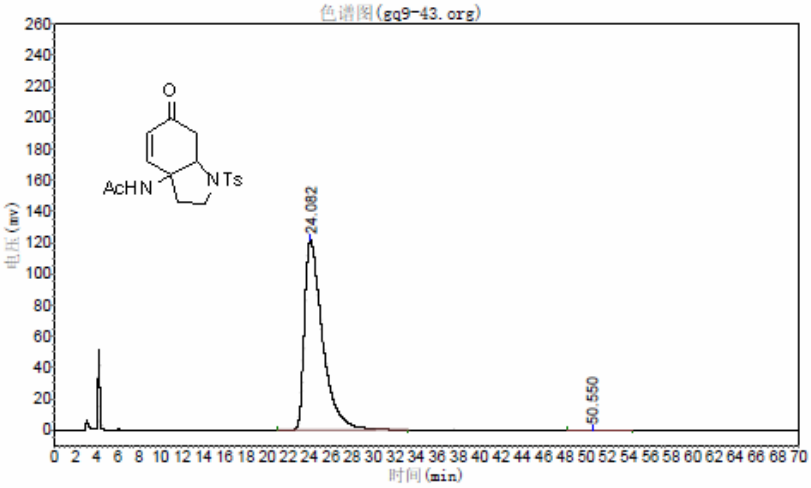
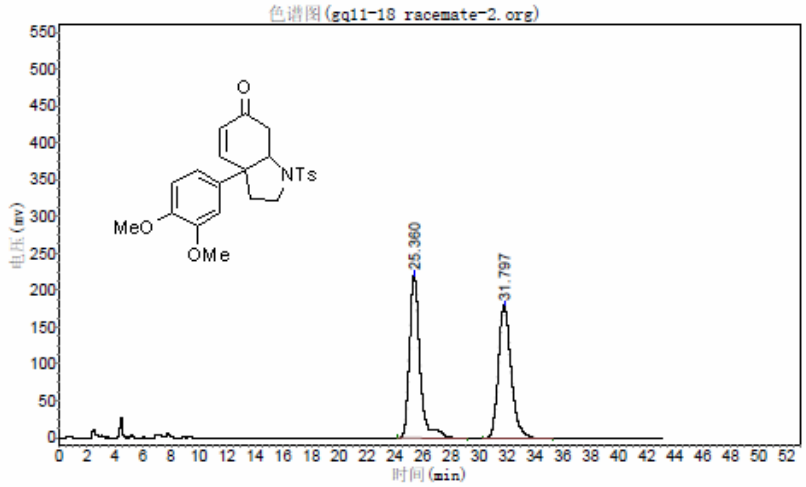
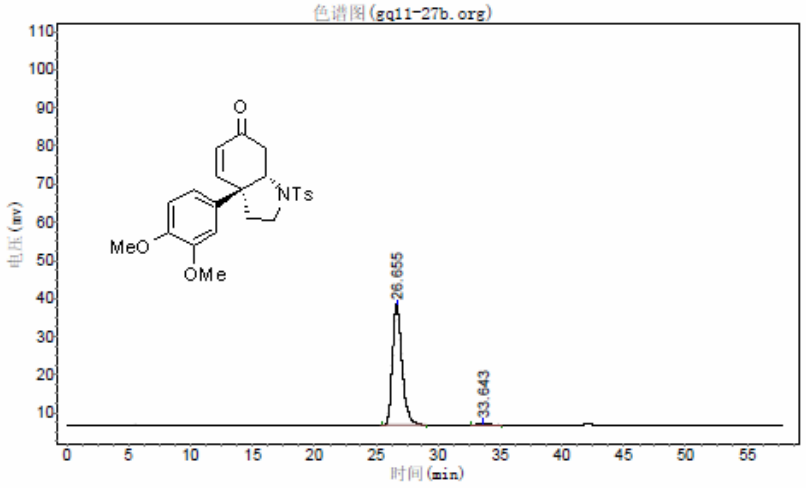


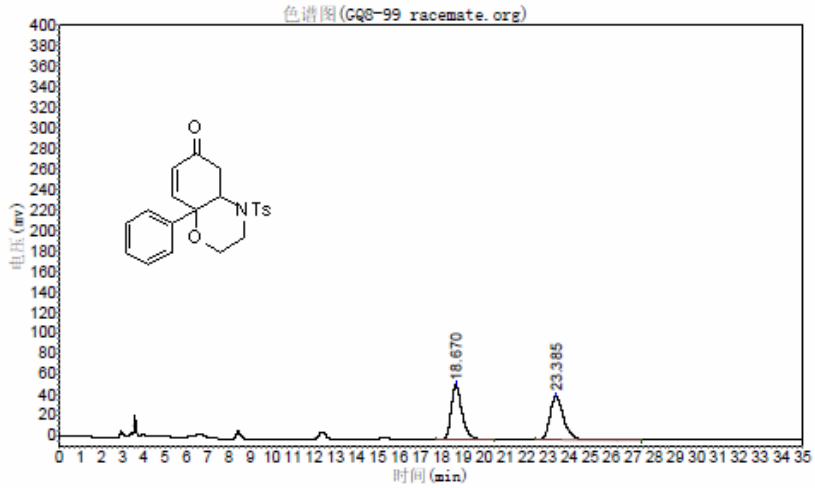
No.	Time	Height	Area	Percent
1	24.082	122336.672	14435500.000	99.4850
2	50.550	395.596	74728.594	0.5150
		122732.267	14510228.594	100.0000



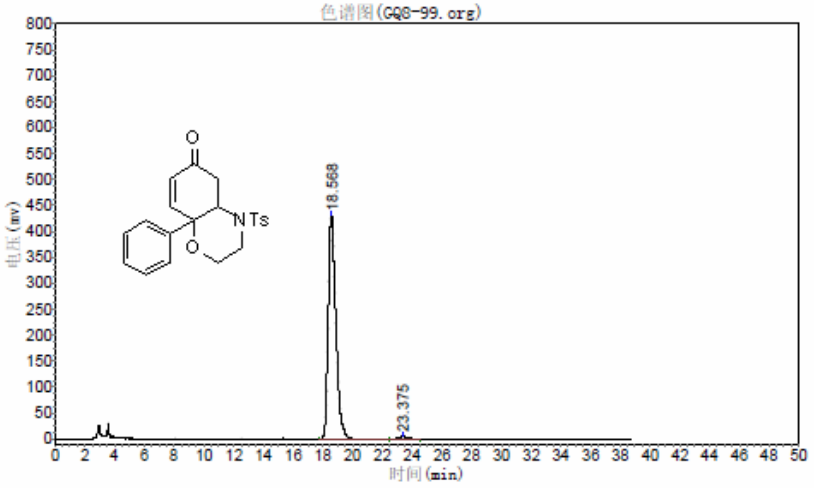
NO.	Time	Height	Area	Percent
1	25.360	221489.875	11685019.000	50.4527
2	31.797	180416.906	11475333.000	49.5473
		401906.781	23160352.000	100.0000



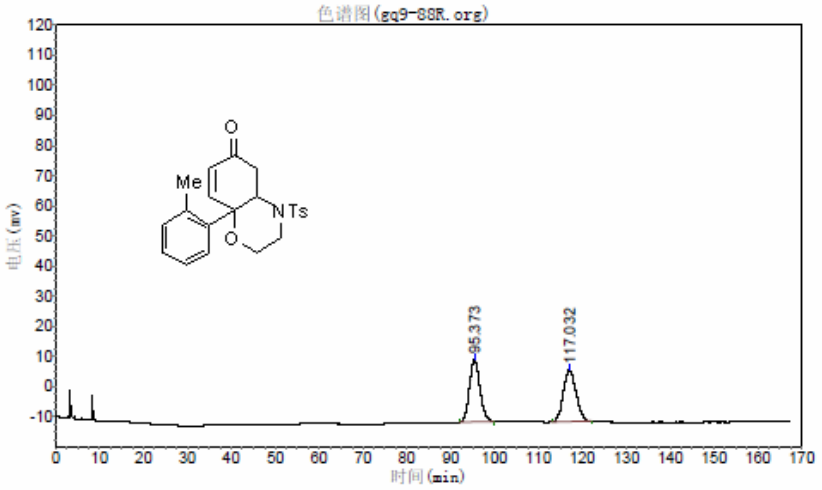
NO.	Time	Height	Area	Percent
1	26.655	31607.791	1706573.000	98.5149
2	33.643	403.034	25725.898	1.4851
		32010.825	1732298.898	100.0000



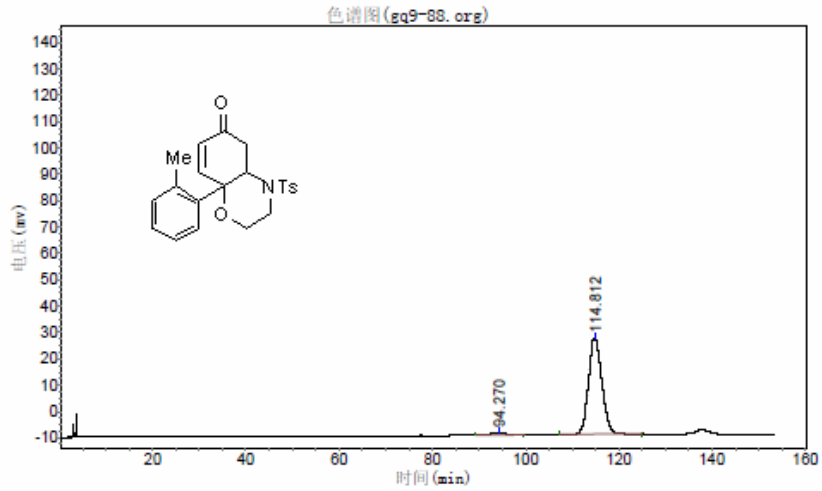
No.	Time	Height	Area	Percent
1	18.670	52749.480	1878455.875	49.9218
2	23.385	42439.355	1884340.250	50.0782
		95188.836	3762796.125	100.0000



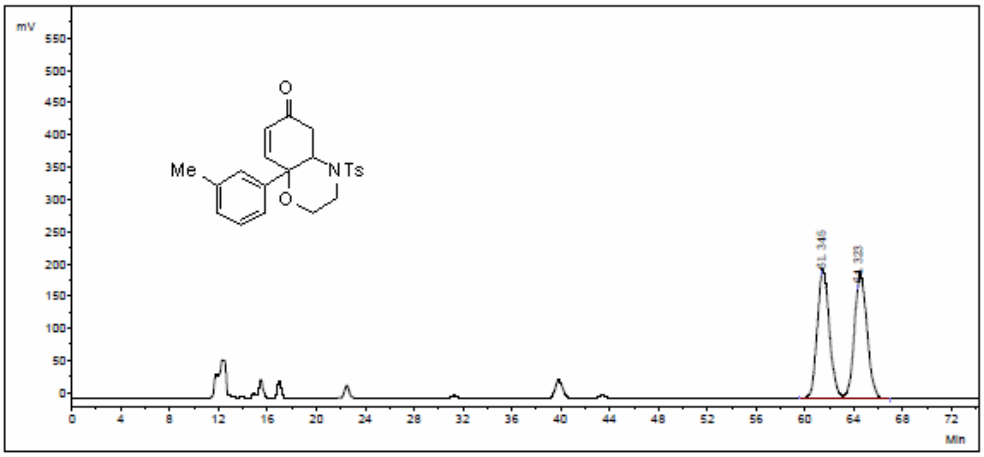
No.	Time	Height	Area	Percent
1	18.568	430840.281	15333988.000	98.4438
2	23.375	5667.840	242399.797	1.5562
		436508.121	15576387.797	100.0000



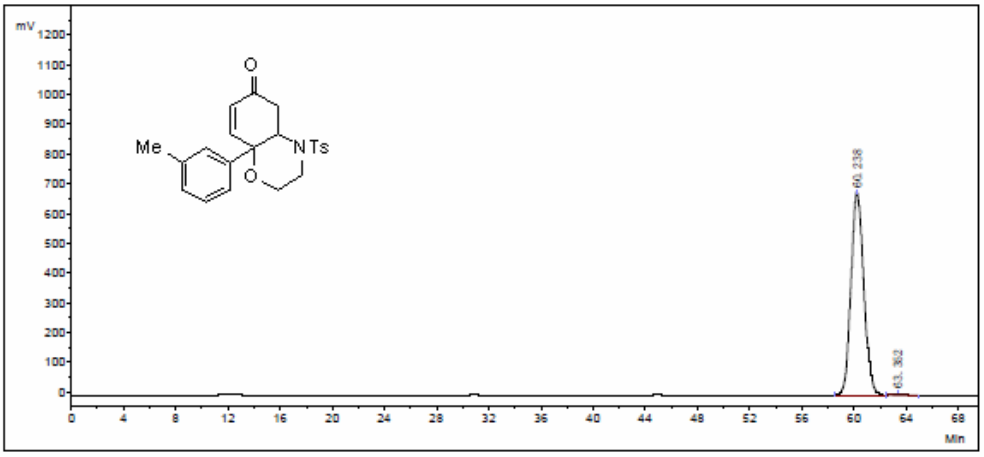
No.	Time	Height	Area	Percent
1	95.373	20871.604	3474488.000	50.0205
2	117.032	17344.973	3471636.500	49.9795
		38216.576	6946124.500	100.0000



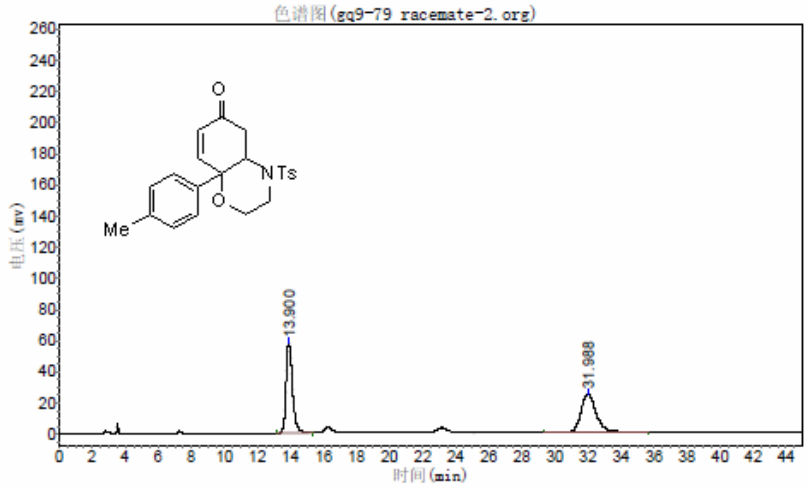
No.	Time	Height	Area	Percent
1	94.270	1005.809	174054.719	2.3617
2	114.812	36631.918	7195735.500	97.6383
		37637.727	7369790.219	100.0000



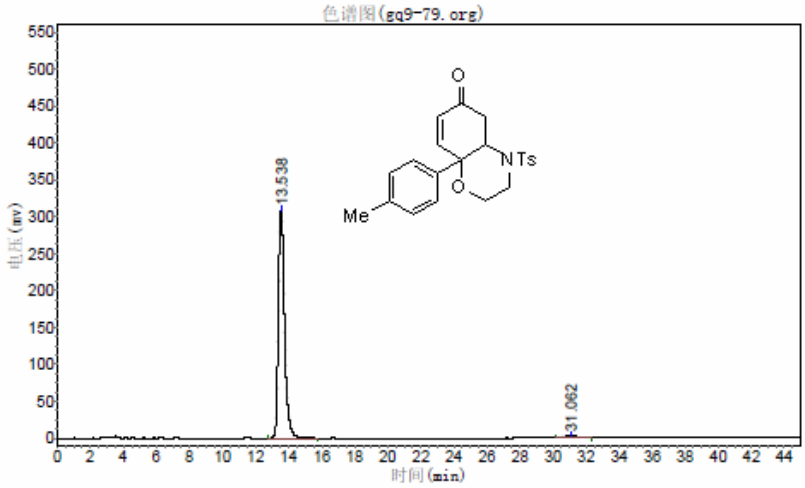
No.	PeakNo	R.Time	PeakHeight	PeakArea	PerCent
1	1	61.345	199712.7	13936421.8	49.7168
2	2	64.323	194160.6	14095202.1	50.2832
Total			393873.3	28031623.9	100.0000



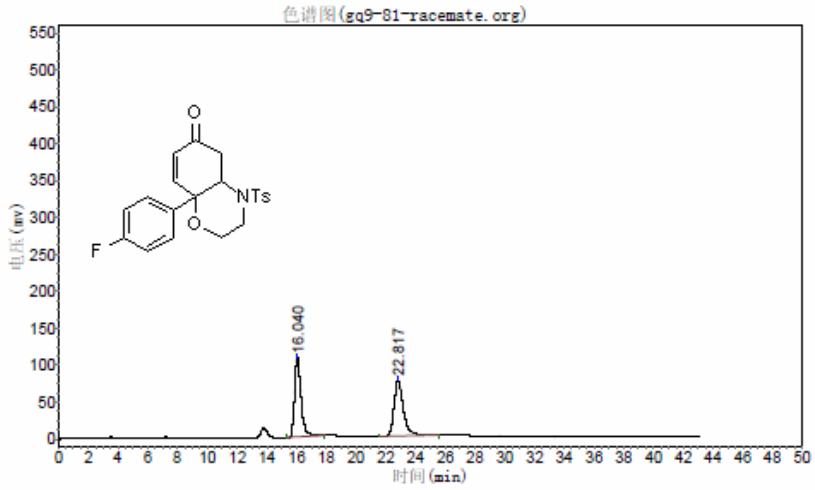
No.	PeakNo	R.Time	PeakHeight	PeakArea	PerCent
1	1	60.238	682952.5	46618411.2	99.0992
2	2	63.352	6849.8	423776.1	0.9008
Total			689802.3	47042187.3	100.0000



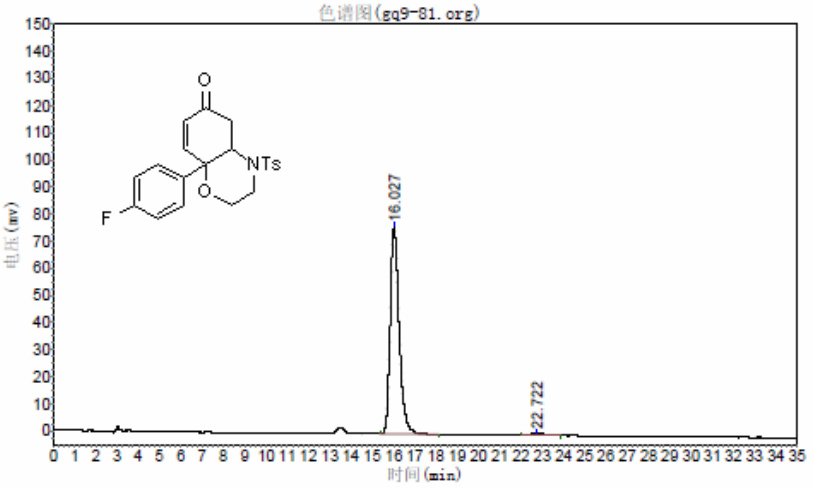
No.	Time	Height	Area	Percent
1	13.900	57981.488	1537729.250	50.2636
2	31.988	24641.467	1521603.000	49.7364
		82622.955	3059332.250	100.0000



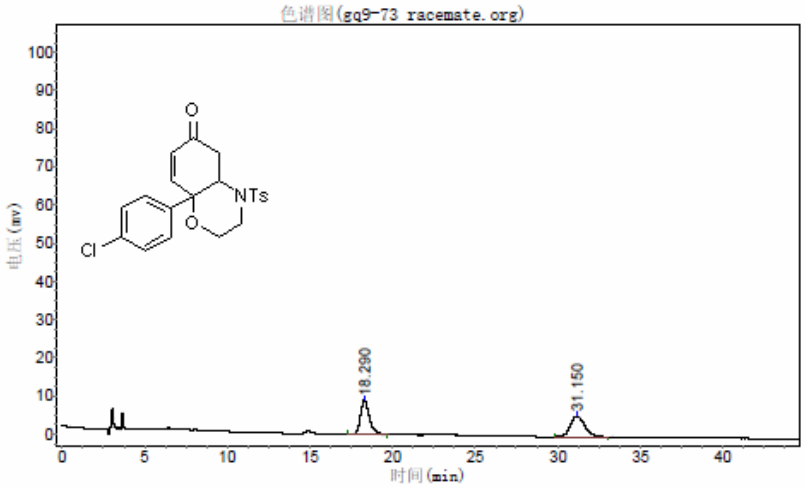
No.	Time	Height	Area	Percent
1	13.538	308182.813	7968218.000	98.2066
2	31.062	2626.800	145510.297	1.7934
		310809.612	8113728.297	100.0000



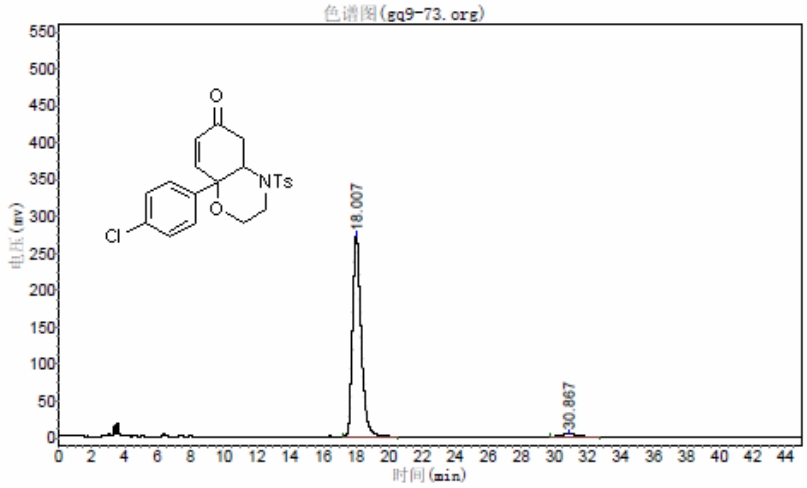
No.	Time	Height	Area	Percent
1	16.040	106726.461	3276415.750	49.6323
2	22.817	75457.977	3324961.000	50.3677
		182184.438	6601376.750	100.0000



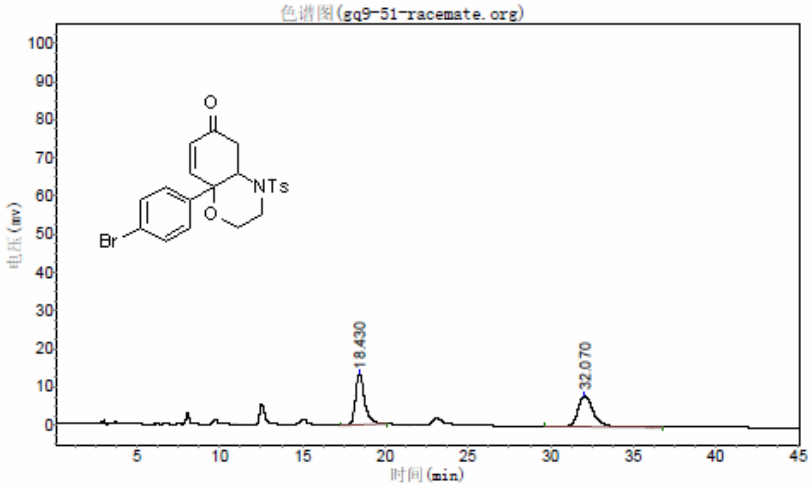
No.	Time	Height	Area	Percent
1	16.027	76470.711	2257515.500	98.7592
2	22.722	686.356	28364.084	1.2408
		77157.067	2285879.584	100.0000



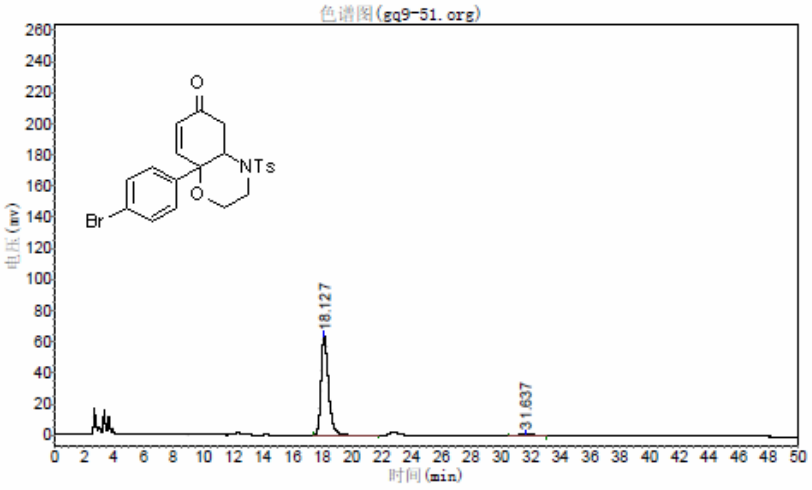
No.	Time	Height	Area	Percent
1	18.290	8884.388	329489.500	49.7216
2	31.150	5493.803	333178.656	50.2784
		14378.191	662668.156	100.0000



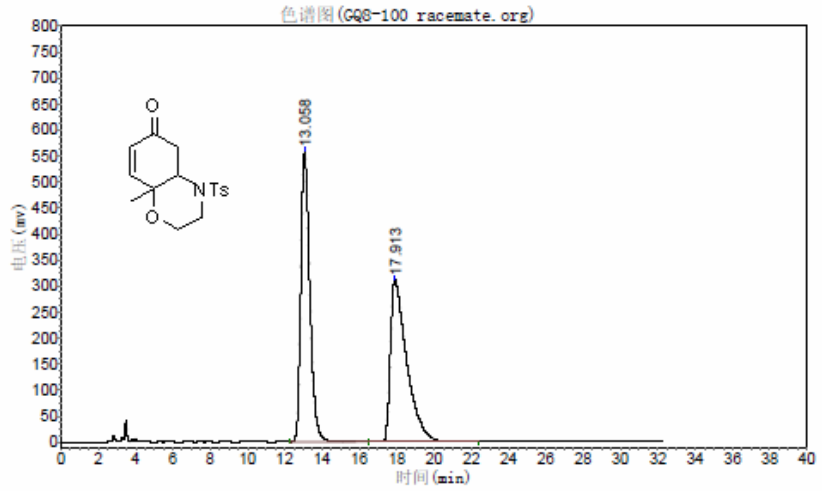
No.	Time	Height	Area	Percent
1	18.007	271893.156	9809407.000	98.1111
2	30.867	3225.387	188853.016	1.8889
		275118.543	9998260.016	100.0000



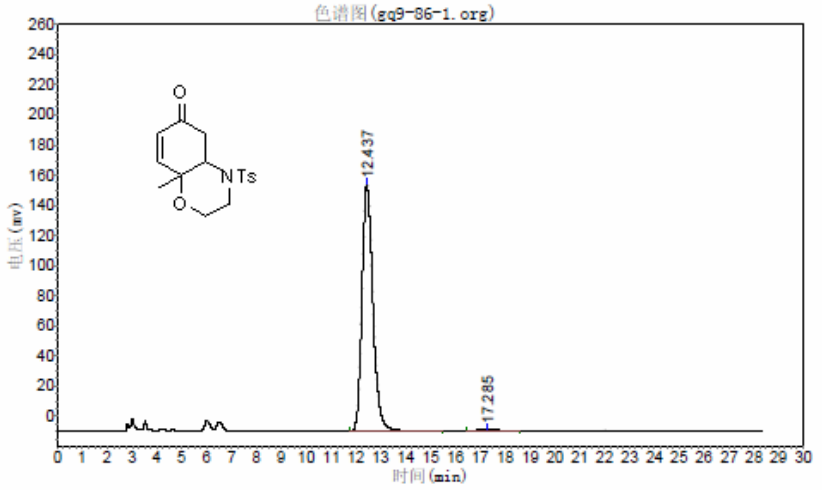
No.	Time	Height	Area	Percent
1	18.430	13481.796	515875.125	50.2878
2	32.070	8157.506	509970.906	49.7122
		21639.302	1025846.031	100.0000



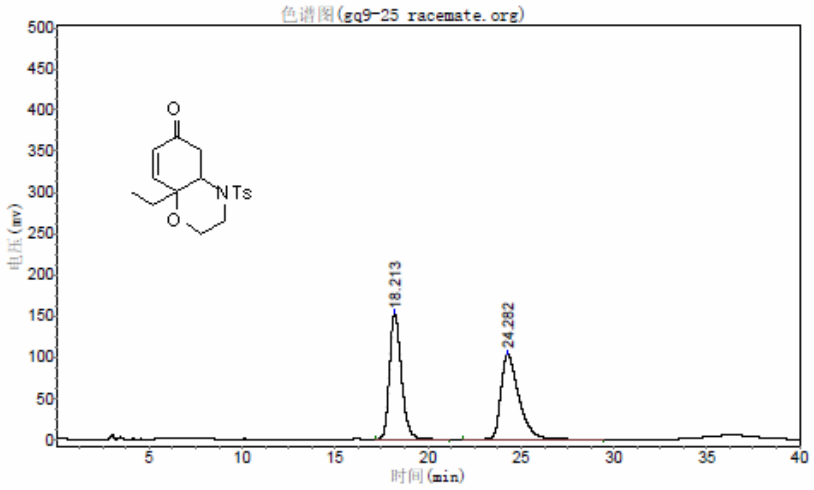
No.	Time	Height	Area	Percent
1	18.127	63607.859	2260186.250	96.6981
2	31.637	1361.288	77178.445	3.3019
		64969.148	2337364.695	100.0000



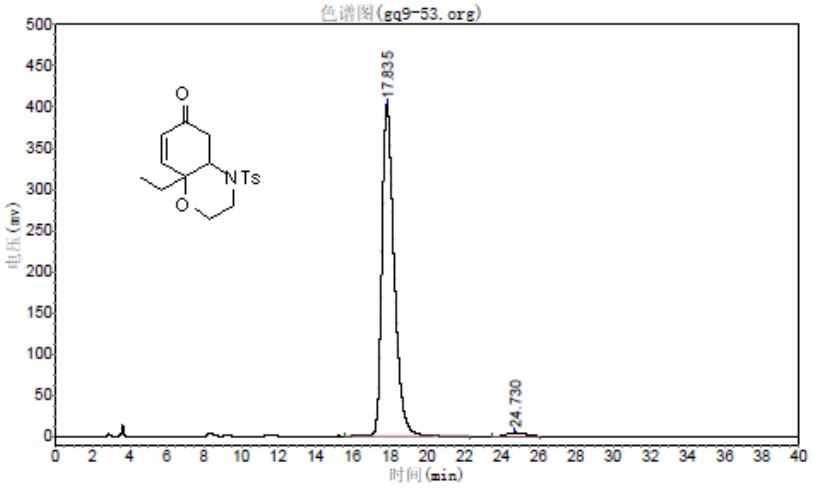
No.	Time	Height	Area	Percent
1	13.058	559144.125	18789026.000	49.7507
2	17.913	311678.906	18977306.000	50.2493
		870823.031	37766332.000	100.0000



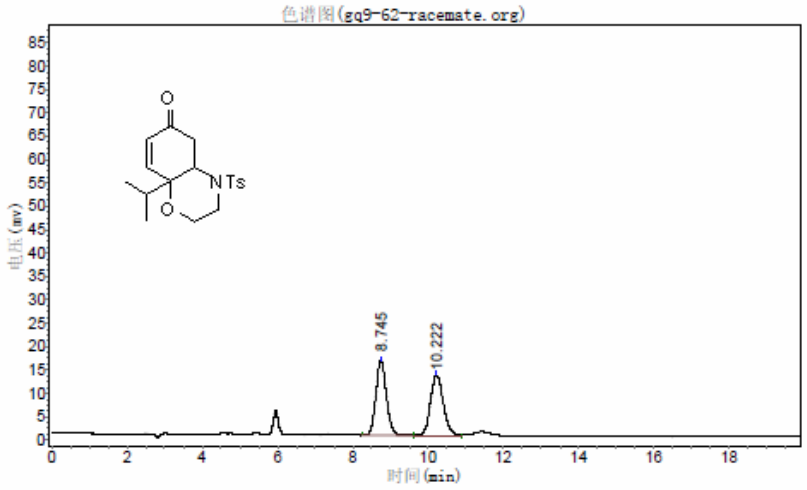
No.	Time	Height	Area	Percent
1	12.437	164617.031	5032752.500	98.6837
2	17.285	1467.293	67129.734	1.3163
		166084.324	5099882.234	100.0000



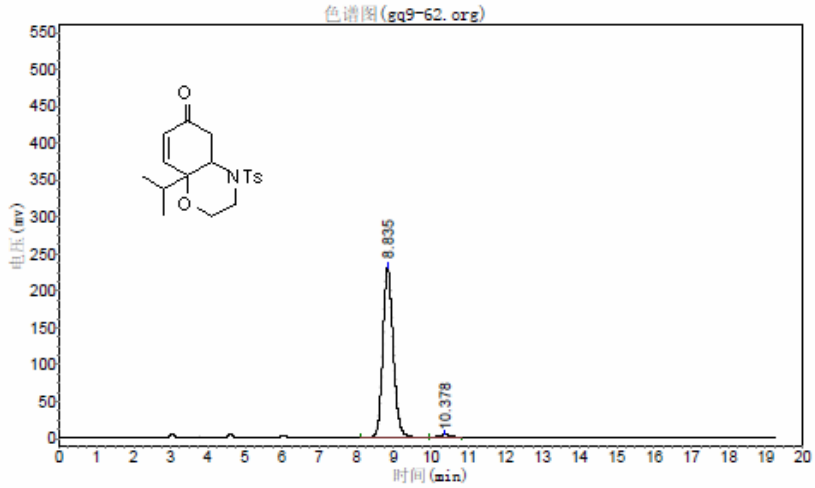
No.	Time	Height	Area	Percent
1	18.213	152700.031	6748003.500	49.6315
2	24.282	103208.094	6848213.000	50.3685
		255908.125	13596216.500	100.0000



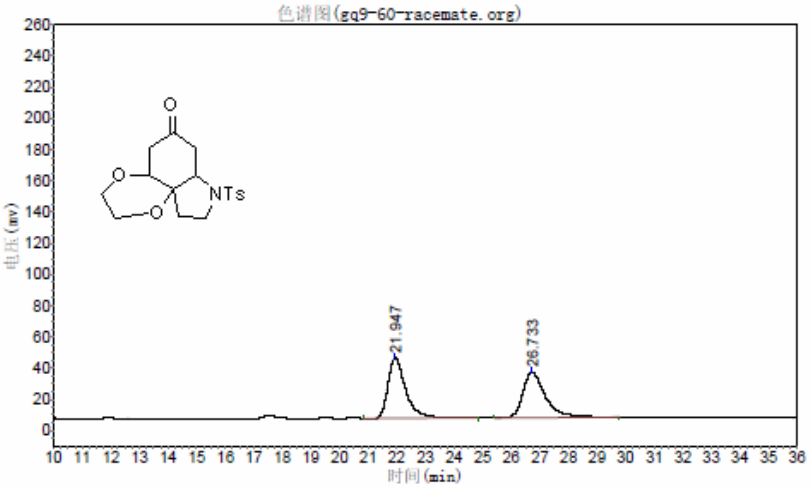
No.	Time	Height	Area	Percent
1	17.835	402813.219	18578656.000	98.4832
2	24.730	4613.542	286131.813	1.5168
		407426.760	18864787.813	100.0000



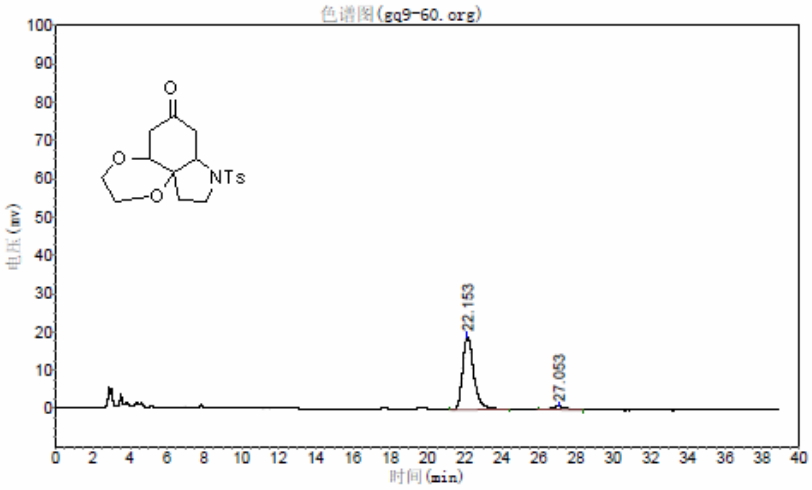
No.	Time	Height	Area	Percent
1	8.745	16084.759	312271.844	50.1330
2	10.222	13081.658	310614.844	49.8670
		29166.417	622886.688	100.0000



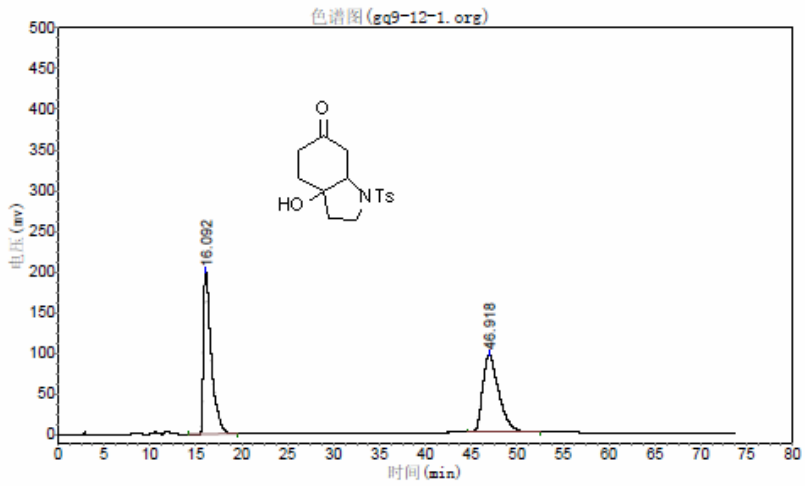
No.	Time	Height	Area	Percent
1	8.835	230509.750	4490715.500	97.8976
2	10.378	3753.893	96440.977	2.1024
		234263.643	4587156.477	100.0000



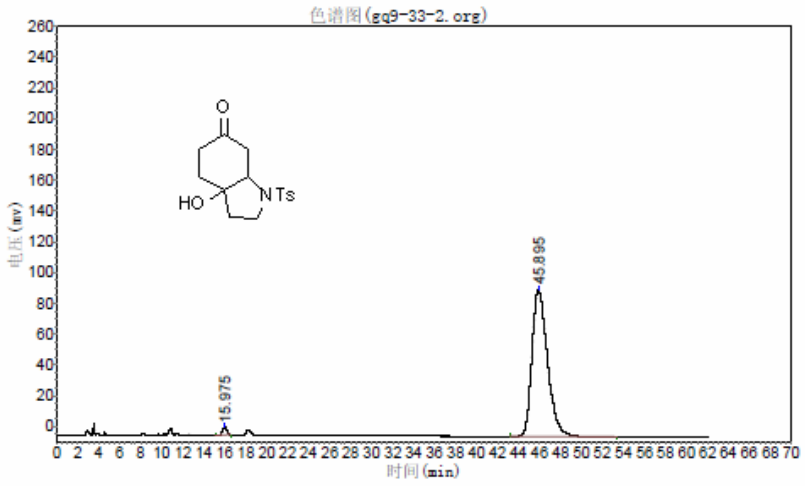
No.	Time	Height	Area	Percent
1	21.947	38781.219	1672596.375	51.5169
2	26.733	29124.273	1574097.375	48.4831
		67905.492	3246693.750	100.0000



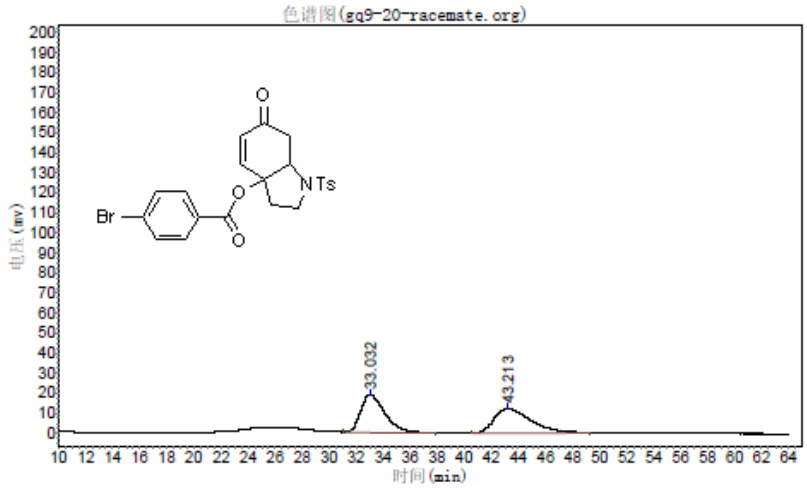
No.	Time	Height	Area	Percent
1	22.153	19101.490	797448.375	94.6805
2	27.053	890.676	44803.398	5.3195
		19992.166	842251.773	100.0000



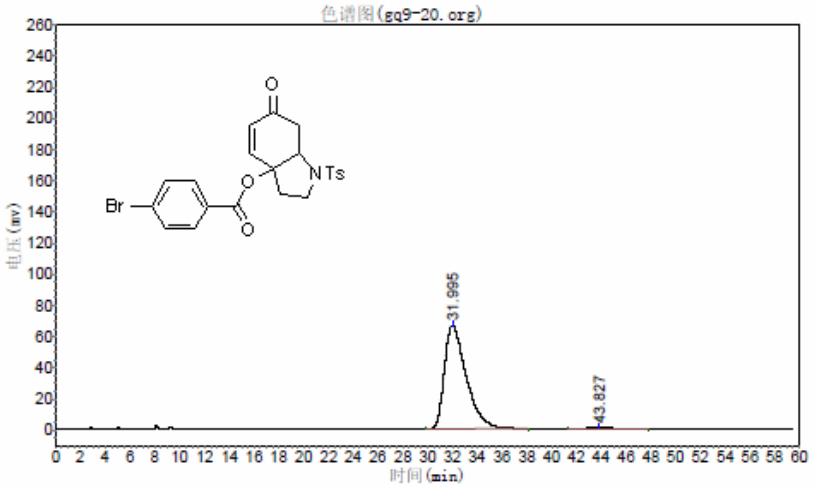
No.	Time	Height	Area	Percent
1	16.092	199566.906	11819450.000	50.1906
2	46.918	95688.086	11729691.000	49.8094
		295254.992	23549141.000	100.0000



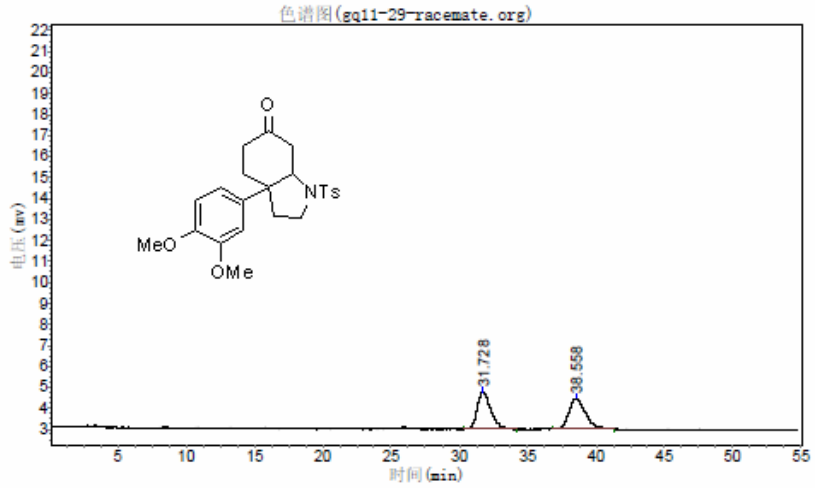
No.	Time	Height	Area	Percent
1	15.975	4854.993	139818.344	1.4110
2	45.895	95482.391	9769042.000	98.5890
		100337.383	9908860.344	100.0000



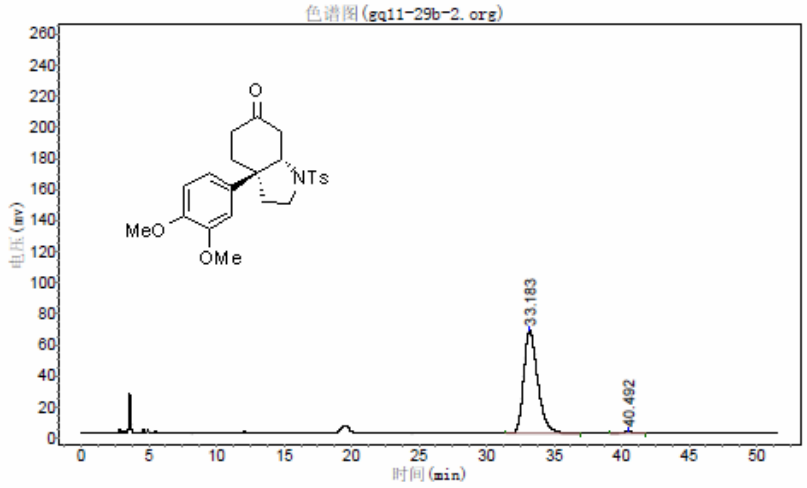
No.	Time	Height	Area	Percent
1	33.032	18908.582	2323277.250	50.4425
2	43.213	12270.780	2282519.750	49.5575
		31179.362	4605797.000	100.0000



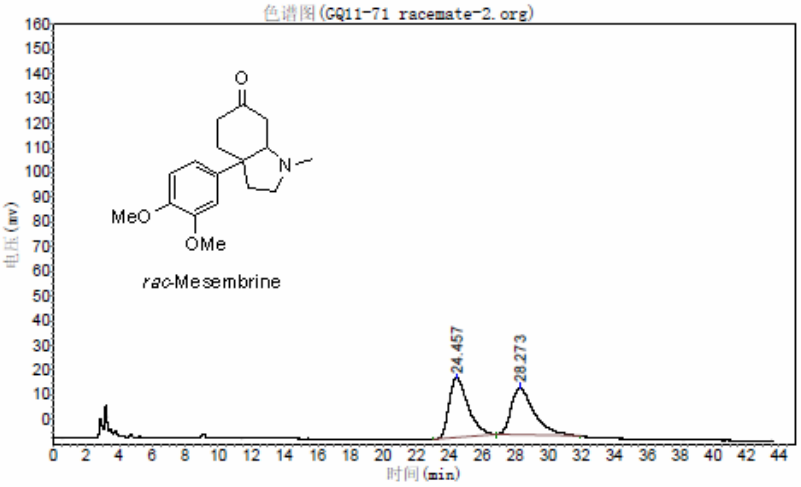
No.	Time	Height	Area	Percent
1	31.995	66638.797	8167239.000	98.7022
2	43.827	600.852	107390.813	1.2978
		67239.649	8274629.813	100.0000



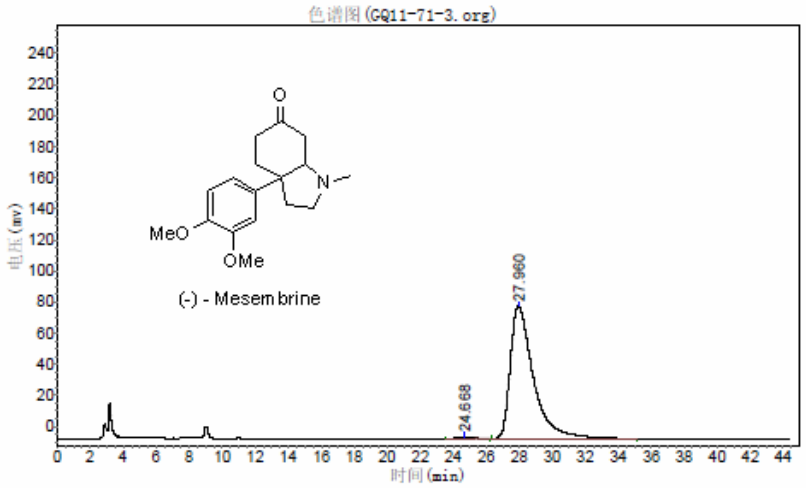
NO.	Time	Height	Area	Percent
1	31.728	1753.169	121570.555	49.8839
2	38.558	1472.000	122136.648	50.1161
		3225.169	243707.203	100.0000



NO.	Time	Height	Area	Percent
1	33.183	66337.938	4822055.500	98.2889
2	40.492	1134.987	83948.930	1.7111
		67472.924	4906004.430	100.0000



NO.	Time	Height	Area	Percent
1	24.457	24165.344	1944133.750	51.0044
2	28.273	19083.162	1867566.000	48.9956
		43248.506	3811699.750	100.0000



NO.	Time	Height	Area	Percent
1	24.668	1268.888	98431.188	1.1708
2	27.960	85340.367	8308398.500	98.8292
		86609.255	8406829.688	100.0000