

A Unified Synthesis of Quinone Sesquiterpenes Based on a Radical Decarboxylation and Quinone Addition Reaction

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Supporting Information

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Experimental Section

General techniques. All reagents were commercially obtained (Aldrich, Acros) at highest commercial quality and used without further purification except where noted. Air- and moisture-sensitive liquids and solutions were transferred via syringe or stainless steel cannula. Organic solutions were concentrated by rotary evaporation below 45 °C at about 20 mmHg. All nonaqueous reactions were carried out using flame-dried glassware, under an argon atmosphere in dry, freshly distilled solvents under anhydrous conditions, unless otherwise noted. Tetrahydrofuran (THF), diethyl ether (Et₂O), dichloromethane (CH₂Cl₂), toluene and benzene were purified by passage through a bed of activated alumina.¹ *N,N*-diisopropylethylamine, diisopropylamine, pyridine, triethylamine and boron trifluoride etherate were distilled from calcium hydride prior to use.² Dimethyl sulfoxide and dimethylformamide were distilled from calcium hydride under reduced pressure (20 mmHg) and stored over 4Å molecular sieves. Quinones **19**, **21**, **33**, and **36** were commercially available and used without any additional purification. Quinones **23**, **25**, **29**, **30**, and **37** were prepared from the corresponding commercially available hydroquinones via oxidation with excess manganese dioxide in diethyl ether. Quinones **27**,³ **40**,⁴ **43**⁵ and **46**⁶ were prepared based on the literature procedures. Compounds **18a**, **18b** and **18c** were prepared by coupling of the corresponding carboxylic acids with *N*-hydroxy-2-thiopyridone in the presence of DCC.⁷ Yields refer to chromatographically and spectroscopically (¹H NMR) homogeneous materials, unless otherwise stated. Reactions were monitored by thin-layer chromatography carried out on 0.25 mm E. Merck silica gel plates (60F-254) using UV light as visualizing agent and 7% ethanolic phosphomolybdic acid, or *p*-anisaldehyde solution and heat as developing agents. E. Merck silica gel (60, particle size 0.040-0.063 mm) was used for flash chromatography. Preparative thin-layer chromatography separations were carried out on 0.25 or 0.50 mm E. Merck silica gel plates (60F-254). NMR spectra were recorded on Varian Mercury 300, 400 and/or Unity 500 MHz instruments and calibrated using residual undeuterated solvent as an internal reference. The following abbreviations were used to explain the multiplicities: s = singlet; d = doublet, t = triplet, q = quartet, m = multiplet, b = broad. IR spectra were recorded on a Nicolet 320 Avatar FT-IR spectrometer and values are reported in cm⁻¹ units. Optical rotations

¹. Pangborn, A. B.; Giardello, M. A.; Grubbs, R. H.; Rosen, R. K.; Timmers, F. J. *Organometallics* **1996**, *15*, 1518-1520.

². Perrin, D. D.; Armarego, W. L. *Purification of Laboratory Chemicals*; 3rd Ed.; Pergamon Press, Oxford, **1988**.

³. Mehta, G, Krishna, R. S. H. *Tetrahedron* **1991**, *47*, 7821-7836. Vaughan, W. R.; Yoshima, M. *J. Org. Chem.* **1959**, *26*, 7.

⁴. Bansal, V.; Kanodia, S.; Thapliyal, P. C.; Khanna, R. N. *Synth. Commun.* **1996**, *26*, 887-892. Rao, A. V. R.; Gurjar, M. K.; Reddy, A. B.; Khare, V. B. *Tetrahedron Lett.* **1993**, *34*, 1657-1660.

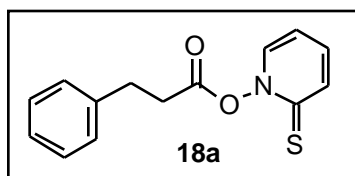
⁵. Lau, P. T. S.; Gompf, T. E. *J. Org. Chem.* **1970**, *35*, 4103-4108.

⁶. Gould, S. J.; Ben, S.; Whittle, Y. G. *J. Am. Chem. Soc.* **1989**, *111*, 7932-7938.

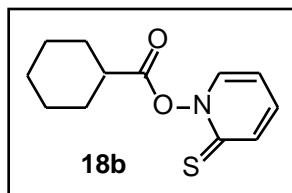
⁷. Barton, D. H. R.; Osbalik, N.; Vacher, B. *Tetrahedron* **1988**, *44*, 7385-7392.

were recorded on a Jasco P-1010 polarimeter and values are reported as follows: $[\alpha]_D^{25}$ (c: g/100ml, solvent). High resolution mass spectra (HRMS) were recorded on a VG 7070 HS mass spectrometer under chemical ionization (CI) conditions or on a VG ZAB-ZSE mass spectrometer under fast atom bombardment (FAB) conditions. X-ray data were recorded on a Bruker SMART APEX 3kW Sealed Tube X-ray diffraction system.

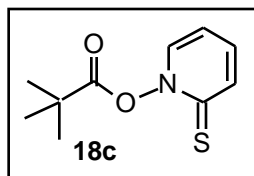
General procedure for the preparation of thiohydroxamic esters 18a-c: In a flask protected from the light with aluminum foil at 0 °C was added the corresponding carboxylic acid (6.66 mmol) and 2-mercaptopyridine N-oxide (**57**) (846 mg, 6.66 mmol) in 5 ml of dry CH₂Cl₂. DCC (1.37 g, 6.66 mmol) was then added and the mixture was stirred for 10 h at 25 °C. After completion of the reaction the solid DCU was removed with gravity filtration and the organic layer was washed with aqueous saturated NaHCO₃ (2 x 10 ml) and then with brine (1 x 10 ml). While minimizing exposure to light, the combined aqueous layers were extracted with CH₂Cl₂ (2 x 10 ml) and the organic layers were dried (MgSO₄), filtered and concentrated under reduced pressure at 25 °C. The residue was filtered through a short pad of silica gel (CH₂Cl₂:Et₂O:hexanes= 1:2:7), concentrated under vacuum at 25 °C and crystallized from CH₂Cl₂/hexane.



Compound 18a: (89%); Pale green solid; $R_f = 0.5$ (75% ether in hexanes); IR (film) ν_{\max} 3022, 1806, 1601, 1529 cm⁻¹; ¹H NMR (400MHz, CDCl₃) 7.67 (d, 1H), 7.46 (s, 1H), 7.25-7.38 (m, 5H), 7.20 (t, 1H), 6.62 (t, 1H), 3.14 (Cpx, 2H), 3.07 (Cpx, 2H); ¹³C NMR (400MHz, CDCl₃) 175.4, 168.1, 139.2, 137.6, 133.8, 128.6, 128.3, 126.6, 112.8, 33.3, 30.5.

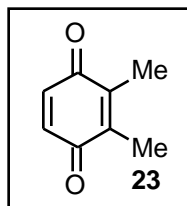


Compound 18b: (87%); Pale green solid; $R_f = 0.8$ (75% ether in hexanes); IR (film) ν_{\max} 2991, 2927, 1780, 1527 cm⁻¹; ¹H NMR (400MHz, CDCl₃) 7.67 (d, 1H), 7.53 (s, 1H), 7.16 (t, 1H), 6.61(t, 1H), 2.70 (t, 1H), 1.2-2.2 (m, 10H); ¹³C NMR (400MHz, CDCl₃) 175.7, 171.1, 137.9, 137.3, 133.7, 112.9, 41.3, 29.1, 25.7, 25.4.

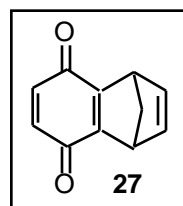


Compound 18c: (78%); Pale green solid; $R_f = 0.5$ (50% ether in hexanes); IR (film) ν_{\max} 2991, 2927, 2857, 1779, 1607 cm⁻¹; ¹H NMR (400MHz, CDCl₃) 7.67 (d, 1H), 7.53 (s, 1H), 7.14 (t, 1H), 6.6(t, 1H), 2.3-2.0 (m, 9H), 1.9-1.6 (m, 6H); ¹³C NMR (400MHz, CDCl₃) 175.4, 171.1, 137.8, 137.6, 133.3, 112.5, 38.6, 36.2, 27.7.

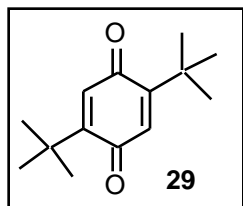
Preparation of quinones: Quinones **19**, **21**, **33**, and **36** were commercially available and used without any additional purification. Quinones **23**, **25**, **29**, **30**, and **37** were prepared from the corresponding commercially available hydroquinones via oxidation with excess manganese dioxide in diethyl ether. Quinones **27**,³ **40**,⁴ **43**⁵ and **46**⁶ were prepared based on the literature procedures.



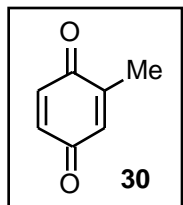
Compound 23: (85%); Yellow solid; $R_f = 0.80$ (75% ether in hexanes); IR (film) ν_{\max} 2949, 1650 cm^{-1} ; $^1\text{H NMR}$ (400MHz, CDCl_3) 6.55 (s, 2H), 1.85 (s, 6H); $^{13}\text{C NMR}$ (400MHz, CDCl_3) 188.1, 141.8, 137.2, 13.4.



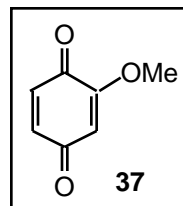
Compound 27: (88%); Yellow solid; $R_f = 0.80$ (75% ether in hexane); IR (film) ν_{\max} 1643 cm^{-1} ; $^1\text{H NMR}$ (400MHz, CDCl_3) 6.82 (s, 2H), 6.53 (s, 2H), 4.06 (s, 2H), 2.29 (d, 1H), 2.14 (d, 1H); $^{13}\text{C NMR}$ (400MHz, CDCl_3) 183.6, 160.3, 142.2, 135.5, 73.7, 48.3.



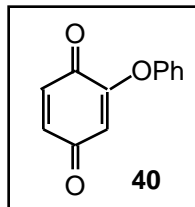
Compound 29: (82%); Yellow solid; $R_f = 0.80$ (75% ether in hexanes); IR (film) ν_{\max} 3424, 2956, 1641 cm^{-1} ; $^1\text{H NMR}$ (400MHz, CDCl_3) 6.45 (s, 1H), 1.23 (s, 9H); $^{13}\text{C NMR}$ (400MHz, CDCl_3) 188.1, 154.0, 133.4, 34.7, 29.1.



Compound 30: (78%); Yellow solid; $R_f = 0.75$ (75% ether in hexanes); IR (film) ν_{\max} 3051, 1655 cm^{-1} ; $^1\text{H NMR}$ (400MHz, CDCl_3) 6.73 (dd, 2H), 6.60 (s, 1H), 2.04 (s, 3H); $^{13}\text{C NMR}$ (400MHz, CDCl_3) 187.4, 187.3, 145.6, 136.4, 136.3, 133.2, 15.93.

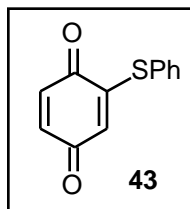


Compound 37: (78%); Yellow solid; $R_f = 0.55$ (75% ether in hexanes); IR (film) ν_{\max} 3061, 1676, 1641, 1586 cm^{-1} ; $^1\text{H NMR}$ (400 MHz, CDCl_3) 6.65 (s, 2H), 5.89 (s, 1H), 3.77 (s, 3H); $^{13}\text{C NMR}$ (400MHz, CDCl_3) 187.0, 181.3, 158.2, 136.9, 134.1, 107.4, 56.1.

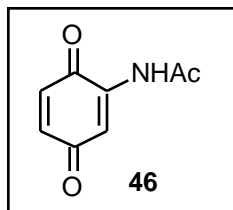


Compound 40: (67%); Orange solid; IR (film) ν_{\max} 1680, 1652, 1582, 1596, 1488, 1213 cm^{-1} ; $^1\text{H NMR}$ (400MHz, CDCl_3) 7.46-7.42 (m, 2H), 7.31 (d, 1H, $J = 7.2$ Hz), 7.08 (d, 2H, $J = 8.4$ Hz), 6.81 (d, 1H, $J = 8.4$ Hz), 6.70 (dd, 1H, $J = 2.4, 10$ Hz), 5.72 (d, 1H, $J = 2$ Hz); $^{13}\text{C NMR}$ (400MHz, CDCl_3) 187.2, 181.2, 158.3, 152.1, 136.8, 134.4, 130.2, 126.5, 120.8,

110.9; HRMS calc for $\text{C}_{12}\text{H}_8\text{O}_3$ (M^+) 200.0473, found 200.0481.



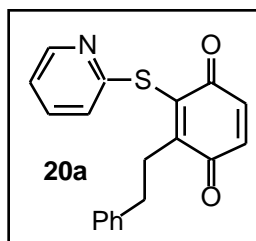
Compound 43: (78%); Orange solid; $R_f = 0.65$ (75% ether in hexanes); IR ν_{\max} 1659, 1688 cm^{-1} ; $^1\text{H NMR}$ (400MHz, CDCl_3) 7.45 (s, 5H), 6.79 (d, 1H), 6.64 (dd, 1H), 5.84 (d, 1H, $J = 2.5$ Hz); $^{13}\text{C NMR}$ (400 MHz, CDCl_3) 184.0, 183.4, 154.0, 137.1, 135.5, 135.3, 130.3, 130.1, 126.6, 125.5; HRMS calc for $\text{C}_{17}\text{H}_{17}\text{NO}_2\text{S}$ ($\text{M}+\text{Cs}^+$) 216.2050, found 216.2010.



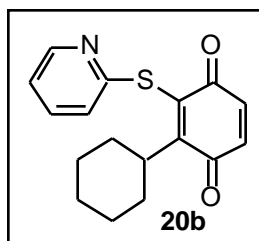
Quinone **46:** $^1\text{H NMR}$ (400MHz, CDCl_3) 8.05 (bs, 1H), 7.59 (s, 1H), 6.78 (s, 2H), 2.25 (s, 3H).

General procedure for the radical decarboxylation and quinone addition reaction:

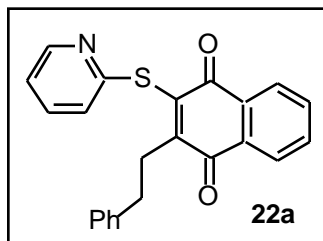
In a flask protected from the light with aluminum foil under argon atmosphere was added ester **18a** (13.2 mmol) and the appropriate quinone (39.6 mmol, 3.0 equiv) in 40 ml of dry CH_2Cl_2 at 0°C . The reaction mixture was subsequently exposed to light using two 500 W halogen lamps from a distance of 30 cm, while maintaining the temperature at $0\text{-}5^\circ\text{C}$. After the end of the reaction (approximately 3 h, monitoring by tlc), the crude reaction mixture was concentrated and the residue purified with flash chromatography (10% CH_2Cl_2 , 1-30% Et_2O in hexanes). The isolated yields for each quinone are shown in Tables 1,2.



Compound 20a: Orange-red solid; $R_f = 0.20$ (50% ether in hexanes); IR (film) ν_{\max} 3029, 2923, 1655, 1564 cm^{-1} ; $^1\text{H NMR}$ (400MHz, CDCl_3) 8.29 (m, 1H), 7.60 (t, 1H, $J = 8$ Hz), 7.4-7.2 (m, 6H), 7.07 (m, 1H), 6.91 (d, 1H, $J = 10$ Hz), 6.89 (d, 1H, $J = 10$ Hz), 3.14 (m, 2H), 2.84 (m, 2H); $^{13}\text{C NMR}$ (400MHz, CDCl_3) 184.5, 181.6, 156.8, 151.0, 149.6, 141.3, 140.4, 137.3, 136.6, 136.4, 128.4, 128.3, 126.2, 122.9, 120.7, 35.3, 31.7; HRMS calc for $\text{C}_{19}\text{H}_{15}\text{NO}_2\text{S}$ ($\text{M}+\text{Cs}^+$) 453.9874, found 453.9891.

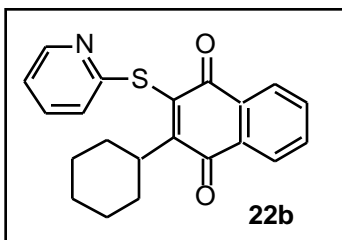


Compound 20b: Orange solid; $R_f = 0.5$ (50% ether in hexanes); IR (film) ν_{\max} 3050, 2927, 1655 cm^{-1} ; $^1\text{H NMR}$ (400MHz, CDCl_3) 8.31 (d, 1H, $J = 4.4$ Hz), 7.55 (t, 1H, $J = 8$ Hz), 7.30 (d, 1H, $J = 8$ Hz), 7.01 (m, 1H), 6.80 (d, 1H, $J = 10$ Hz), 6.72 (d, 1H, $J = 10$ Hz), 3.25 (m, 1H), 2.1-1.95 (m, 2H), 1.8-1.6 (m, 4H), 1.4-1.2 (m, 4H); $^{13}\text{C NMR}$ (400MHz, CDCl_3) 185.1, 182.1, 157.3, 155.2, 149.6, 137.3, 136.6, 136.4, 122.7, 120.4, 42.8, 30.1, 26.8, 25.8; HRMS calc for $\text{C}_{17}\text{H}_{17}\text{NO}_2\text{S}$ ($\text{M}+\text{Cs}^+$) 432.0031, found 432.0043.



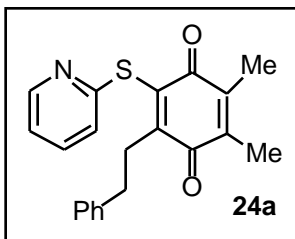
Compound 22a: Orange solid; $R_f = 0.35$ (30% ether in hexanes); IR (film) ν_{\max} 2928, 2850, 1666, 1594 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.31 (m, 1H), 8.20 (m, 1H), 8.07 (m, 1H), 7.79 (m, 2H), 7.65 (m, 1H), 7.44 (d, 1H), 7.35 (m, 5H), 7.07 (t, 1H), 3.33 (t, 2H, $J = 8$ Hz), 2.93 (t, 2H, $J = 8$ Hz); ^{13}C NMR (400MHz, CDCl_3) 182.40, 179.99, 157.18, 153.16, 149.64,

143.74, 140.69, 136.65, 133.52, 132.75, 132.06, 128.45, 128.34, 126.97, 126.60, 126.14, 122.99, 120.69, 35.42, 32.50; HRMS calc for $\text{C}_{23}\text{H}_{17}\text{NO}_2\text{S}$ ($\text{M}+\text{H}^+$) 372.1058, found 372.1081.



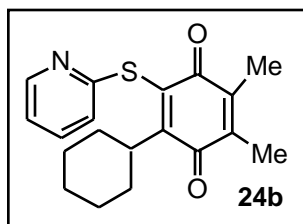
Compound 22b: Pale orange solid; $R_f = 0.75$ (50% ether in hexane); IR (film) ν_{\max} 2927, 2845, 1664, 1567, 1281 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.26 (d, 1H, $J = 5.2$ Hz), 8.06 (d, 1H), 7.94 (d, 1H), 7.63 (t, 1H), 7.62 (t, 1H), 7.52 (t, 1H), 7.00 (t, 1H), 3.40 (t, 1H), 1.2-2.2 (m, 10H); ^{13}C NMR (400MHz, CDCl_3) 182.6, 180.3, 157.6, 157.3, 149.5, 143.0, 136.4, 133.3, 133.1,

132.3, 126.5, 126.4, 122.6, 120.3, 41.2, 30.1, 26.8, 25.8; HRMS calc for $\text{C}_{21}\text{H}_{19}\text{NO}_2\text{S}$ ($\text{M}+\text{H}^+$) 350.1214, found 350.1201.



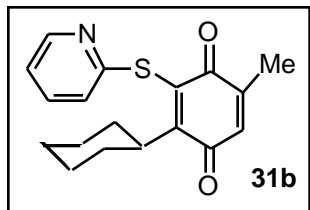
Compound 24a: Orange-red solid; $R_f = 0.8$ (50% ether in hexanes); IR (film) ν_{\max} 3145, 3089, 1678 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.30 (d, 1H, $J = 4.8$ Hz), 7.55 (t, 1H, $J = 7.6$ Hz), 7.31-7.19 (m, 6H), 7.04 (t, 1H, $J = 6.8$ Hz), 3.08 (t, 2H, $J = 8.8$ Hz), 2.77 (t, 2H, $J = 8.8$ Hz), 2.06 (s, 3H), 2.02 (s, 3H); ^{13}C NMR (400MHz, CDCl_3) 184.6, 182.0, 157.3, 150.8, 149.6, 142.2, 140.9, 136.6, 128.4,

128.3, 126.1, 122.8, 120.5, 35.5, 32.0, 13.2, 12.7; HRMS calc for $\text{C}_{21}\text{H}_{19}\text{NO}_2\text{S}$ ($\text{M}+\text{H}^+$) 350.1214, found 350.1229.



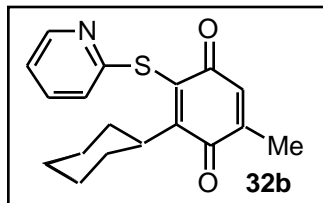
Compound 24b: Orange solid; $R_f = 0.65$ (50% ether in hexane); IR (film) ν_{\max} 2925, 2825, 1651 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.30 (d, 1H, $J = 5.2$ Hz), 7.54 (t, 1H, $J = 7.6$ Hz), 7.31 (d, 1H, $J = 8.4$ Hz), 7.02 (t, 1H, $J = 5.2$ Hz), 3.23 (m, 1H), 2.01-1.92 (m, 2H), 2.02 (s, 3H), 1.98 (s, 3H), 1.8-1.5 (m, 4H), 1.4-1.2 (m, 4H); ^{13}C

NMR (400MHz, CDCl_3) 185.2, 182.5, 158.9, 154.9, 149.5, 141.4, 141.3, 136.5, 122.6, 120.3, 42.8, 30.3, 26.8, 25.8, 13.1, 12.7; HRMS calc for $\text{C}_{19}\text{H}_{21}\text{NO}_2\text{S}$ ($\text{M}+\text{H}^+$) 328.1371, found 328.1392.



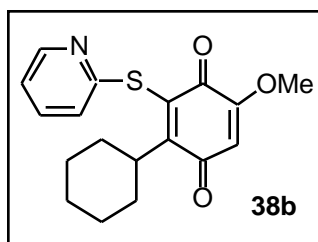
Compound 31b: Yellow solid; $R_f = 0.65$ (50% ether in hexane); IR (film) ν_{\max} 3432, 2915, 1652 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.33 (d, 1H, $J = 5.6$ Hz), 7.57 (t, 1H, $J = 7.6$ Hz), 7.31 (d, 1H, $J = 8$ Hz), 7.05 (t, 1H, $J = 6$ Hz), 6.56 (s, 1H), 3.23 (t, 1H), 2.02 (s, 3H), 1.2-2.2 (m, 10H); ^{13}C NMR (400MHz, CDCl_3) 185.2,

183.6, 155.2, 149.2, 146.0, 136.9, 134.2, 122.8, 120.5, 42.7, 30.1, 26.8, 25.8, 16.3, 1.2; HRMS calc for $\text{C}_{18}\text{H}_{19}\text{NO}_2\text{S}$ ($\text{M}+\text{H}^+$) 314.1214, found 314.1232.



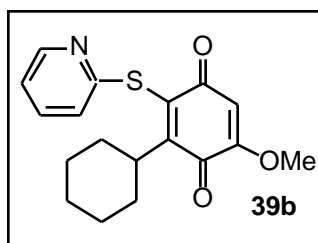
Compound 32b: Yellow solid; $R_f = 0.60$ (50% ether in hexane); IR (film) ν_{\max} 3422, 2925, 1652 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.32 (d, 1H, $J = 5.6$ Hz), 7.55 (t, 1H, $J = 7.6$ Hz), 7.32 (d, 1H, $J = 8$ Hz), 7.03 (t, 1H, $J = 6$ Hz), 6.65 (s, 1H), 3.25 (t, 1H), 1.2-2.2 (m, 10H); ^{13}C NMR (400MHz, CDCl_3) 185.6, 182.0, 155.4,

149.3, 146.4, 146.0, 136.8, 134.2, 133.4, 122.8, 120.5, 42.9, 30.2, 26.8, 16.3, 1.19; HRMS calc for $\text{C}_{18}\text{H}_{19}\text{NO}_2\text{S}$ ($\text{M}+\text{H}^+$) 314.1214, found 314.1232.



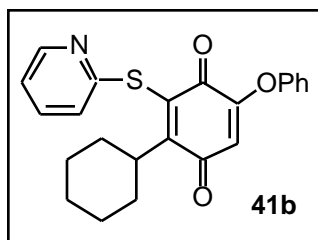
Compound 38b: Red liquid; $R_f = 0.5$ (70% ether in CH_2Cl_2); IR (film) ν_{\max} 1680, 1621 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.31 (d, 1H), 7.54 (t, 1H), 7.31 (d, 1H), 7.02 (t, 1H), 5.92 (s, 1H), 3.08 (s, 3H), 3.27 (t, 1H), 2.1-1.2 (m, 10H); ^{13}C NMR (400MHz, CDCl_3) 182.0, 180.0, 158.6, 153.2, 149.8, 136.6, 122.8, 120.5, 107., 56.3, 42.6, 29.9, 26.7, 25.7; HRMS calc for $\text{C}_{18}\text{H}_{19}\text{NO}_3\text{S}$

($\text{M}+\text{Cs}^+$) 330.4207, found 330.1178.



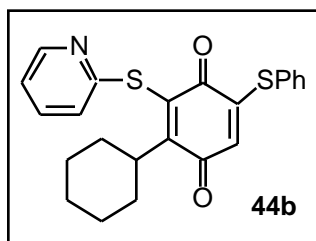
Compound 39b: Red solid; $R_f = 0.6$ (50% ether in hexane); IR (film) ν_{\max} 2155, 1645 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.30 (d, 1H), 7.75 (t, 1H), 7.31 (d, 1H), 7.02 (d, 1H), 5.92 (s, 1H), 3.79 (s, 3H), 3.27 (t, 1H), 1.2-2.0 (m, 10H); ^{13}C NMR (400MHz, CDCl_3) 185.5, 177.9, 158.9, 157.5, 156.3, 149.8, 136.7, 122.8, 120.55, 108.7, 56.2, 41.2, 30.1, 26.6, 26.6, 25.6; HRMS calc for

$\text{C}_{18}\text{H}_{19}\text{NO}_3\text{S}$ ($\text{M}+\text{H}^+$) 329.4253, found 329.0121.

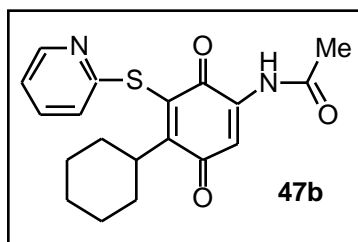


Compound 41b: Red liquid; $R_f = 0.5$ (75% ether in hexanes); IR (film) ν_{\max} 2921, 1686 cm^{-1} ; ^1H NMR (400MHz, CDCl_3) 8.35 (d, 1H), 7.60 (t, 1H), 7.5-7.3 (m, 6H), 7.68 (t, 1H), 6.80 (dd, 1H), 5.74 (s, 1H) 3.32 (t, 1H), 2.1-1.2 (m, 10H); ^{13}C NMR (400MHz, CDCl_3) 186.0, 179.3, 154.7, 149.3, 137.1, 129.9, 129.6, 124.75,

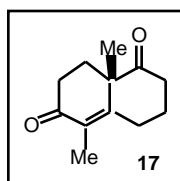
123.4, 120.6, 120.5, 119.8, 118.1, 102.4, 101.5, 42.4, 29.6, 27.0, 26.0; HRMS calc for $C_{23}H_{20}NO_3S$ ($M+Cs^+$) 391.4988, found 391.0443.



Compound 44b: Red oil; $R_f = 0.6$ (75% ether in hexane); IR (film) ν_{max} 2923, 2852, 1615 cm^{-1} ; 1H NMR (400MHz, $CDCl_3$) 8.31 (d, 1H), 7.6-7.4 (m, 6H), 7.30 (d, 1H), 7.02 (t, 1H), 5.90 (s, 1H), 3.27 (t, 1H), 1.2-2.1 (m, 10H); ^{13}C NMR (400MHz, $CDCl_3$) 181.9, 179.1, 157.4, 154.9, 150.9, 149.4, 136.7, 135.6, 130.6, 130.1, 127.1, 126.1, 125.4, 122.9, 120.5, 42.9, 30.1, 29.8, 26.80, 25.8; HRMS calc for $C_{23}H_{21}NO_2S_2(M+H^+)$ 408.1086, found 408.1088.

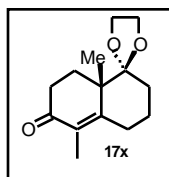


Compound 47b: Red liquid; $R_f = 0.5$ (70% ether in CH_2Cl_2); IR (film) ν_{max} 1650, 1636 cm^{-1} ; 1H NMR (400MHz, $CDCl_3$) 8.32 (d, 1H), 7.99 (s, 1H), 7.53 (s, 1H), 7.68 (t, 1H), 7.32 (d, 1H), 3.28 (t, 1H), 2.23 (s, 3H), 2.1-1.2 (m, 10H); ^{13}C NMR (400MHz, $CDCl_3$) 186.0, 178.92, 169.38, 158.13, 157.50, 149.9, 138.42, 136.8, 122.46, 123.2, 120.65, 116.21, 43.16, 30.5, 25.9, 25.2; HRMS calc for $C_{17}H_{17}NO_2S$ ($M+Cs^+$) 356.0167, found 356.0043.

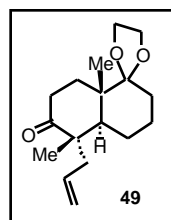


Preparation of enone (+)17: A solution of 2-methyl-1,3-cyclohexadione (0.90 g, 7.17 mmol) in ethyl acetate (50 ml) was treated with triethylamine (1.30 ml, 9.32 mmol) and ethyl vinyl ketone (0.78 ml, 7.89 mmol). The reaction mixture was heated at 70 °C for 10 h and then cooled to 25 °C. The solvent was removed under reduced pressure and the resulting crude material was chromatographed (silica, 10% ether in hexanes) to yield the corresponding triketone (1.45 g, 6.81 mmol, 95%). A solution of the triketone (1.45 g, 6.81 mmol), L-phenylalanine (1.13 g, 6.81 mmol), and D-camphorsulfonic acid (0.79 g, 3.40 mmol) in DMF (100 ml) was stirred at room temperature under a nitrogen atmosphere overnight. Then the mixture was heated at 30 °C for 24 h, and the temperature was raised in 10 °C intervals in every 24 h during 4 days. After the mixture was stirred at 70 °C for 24 h, the oil bath was removed. The resulting solution was poured into cold aqueous $NaHCO_3$, extracted with ether (2 x 50 ml), then dried over $MgSO_4$. Evaporation of ether followed by column chromatography of the residue afforded the crude enone **17** as a viscous oil, which crystallized on standing at -30 °C. Recrystallization from n-hexane in an ice bath gave (+) **17** (1.05g, 5.38 mmol, 79%). **17**: colorless long needles; $R_f = 0.46$ (silica, 35% ether in hexanes); $[\alpha]_D^{25}$: +124.0 (c = 1.0, benzene); IR (film) ν_{max} 2952, 1709, 1665, 1610, 1352,

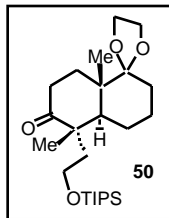
1008; ^1H NMR (400 MHz, CDCl_3) 2.92-2.81 (m, 1H), 2.73-2.64 (m, 1H), 2.55-2.37 (m, 4H), 2.18-2.02 (m, 4H), 1.81 (d, $J = 1.2$ Hz, 3H), 1.42 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) 198.2, 159.9, 129.7, 112.4, 65.1, 64.8, 45.0, 33.4, 29.4, 26.3, 26.2, 21.2, 20.6, 11.2; HRMS, calcd for $\text{C}_{12}\text{H}_{16}\text{O}_2$ ($\text{M} + \text{H}^+$) 193.1228, found 193.1224.



Enone 17x: A solution of enone **17** (1.05 g, 5.38 mmol) and p-toluenesulfonic acid (0.20 g, 1.08 mmol) in benzene (100 ml) was treated with ethylene glycol (0.36 ml, 6.46 mmol), then heated at 80 °C for 24 h under an atmosphere of nitrogen. After cooling in an ice bath, the resulting solution was poured into aqueous NaHCO_3 and the product was extracted with ether (2 x 50 ml). The combined extracts were washed with water (20 ml) and brine (20 ml), and dried over MgSO_4 . Evaporation of the solvent followed by flash column chromatography (silica, 0-10% ether in hexanes) yielded **17x** (1.1 g, 4.84 mmol, 90%). **17x**: colorless liquid; $R_f = 0.57$ (silica, 35% ether in hexanes); $[\alpha]_D^{25}$: +99.5 ($c = 1.0$, benzene); IR (film) max 2952, 1666, 1163, 1093, 1024, 920; ^1H NMR (400 MHz, CDCl_3) 4.00-3.87 (m, 4H), 2.76-2.67 (m, 1H), 2.50-2.32 (m, 2H), 2.25-2.02 (m, 2H), 1.72-1.57 (m, 5H), 1.76 (d, $J = 1.2$ Hz, 3H), 1.31 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) 212.0, 197.5, 158.1, 130.6, 50.6, 37.3, 33.2, 29.5, 27.2, 23.3, 21.4, 11.2; HRMS, calcd for $\text{C}_{14}\text{H}_{20}\text{O}_3$ ($\text{M} + \text{H}^+$) 237.1490, found 237.1495.

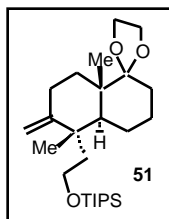


Ketone 49. To a solution of lithium (0.15 g, 21.15 mmol) in liquid ammonia (100 ml) at -78 °C was added dropwise a solution of the enone **17x** (0.98 g, 4.23 mmol) in THF (2 ml). After a 1-h reflux at -30 °C, water (76.2 μl , 4.23 mmol) was added dropwise. The solution was refluxed for another hour, then allyl bromide (1.83 ml, 21.15 mmol) was added as rapidly as possible, and the reaction mixture was refluxed over 2 h. The ammonia was evaporated and the reaction was quenched with saturated ammonium chloride solution (20 ml). The resulting mixture was then extracted with ether (3 x 30 ml) and the organic solutions were combined, dried over MgSO_4 , concentrated and subjected to column chromatography (silica, 0-10% ether in hexanes) to afford ketone **49** (0.91 g, 3.3 mmol, 78%). **49**: colorless liquid; $R_f = 0.63$ (silica, 50% ether in hexanes); $[\alpha]_D^{25}$: -64.4 ($c = 1.0$, CH_2Cl_2); IR (film) max 2946, 2872, 1703, 1441, 1186, 1045, 910; ^1H NMR (500 MHz, CDCl_3) 5.66 (m, 1H), 5.03-4.96 (m, 2H), 3.96-3.83 (m, 4H), 2.57-2.50 (m, 2H), 2.33 (m, 1H), 2.13 (m, 1H), 2.01-1.90 (m, 2H), 1.70-1.31 (m, 7H), 1.20 (s, 3H), 1.03 (s, 3H); ^{13}C NMR (125 MHz, CDCl_3) 135.2, 117.4, 112.8, 65.3, 64.8, 50.8, 44.2, 42.5, 42.3, 34.9, 30.2, 28.8, 22.6, 21.7, 21.3, 16.3; HRMS, calcd for $\text{C}_{17}\text{H}_{26}\text{O}_3$ ($\text{M} + \text{Na}^+$) 301.3814, found 301.3827.



Ketone 50. A solution of ketone **49** (1.02 g, 3.59 mmol) in CH_2Cl_2 (50 ml) was exposed to ozone at $-78\text{ }^\circ\text{C}$ until the starting material was consumed. The resulting mixture was flushed with argon, treated with PPh_3 (2.82 g, 10.77 mmol) and allowed to warm up to $25\text{ }^\circ\text{C}$. After stirring for 2 h, the solution was concentrated, redissolved in Et_2O (20 ml) was added dropwise into a suspension

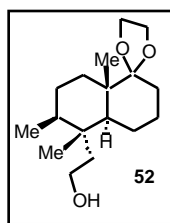
of LiAlH_4 (0.54 g, 14.36 mmol) in Et_2O at $0\text{ }^\circ\text{C}$. The mixture was stirred for 2 h, then quenched with saturated ammonium chloride (100 ml). The organic layer was extracted with ether (3 x 100 ml), combined, dried over MgSO_4 , concentrated and subjected to flash chromatography (silica, 50% ether in hexanes) to afford the corresponding diol (65% from **49**). A solution of the above diol in CH_2Cl_2 (100 ml) was treated with 2,6-lutidine (0.82 ml, 7.04 mmol) and triisopropylsilyl trifluoromethanesulfonate (1.04 ml, 3.87 mmol) at $-78\text{ }^\circ\text{C}$. The reaction mixture was stirred for 1 h and then diluted with water (50 ml) and extracted with ether (3 x 50 ml). The combined organic extracts were dried over MgSO_4 , concentrated, and subjected to flash chromatography (silica, 0-20% ether in hexanes) to afford the corresponding alcohol (98%). A solution of above alcohol in dichloromethane (40 ml) was treated with pyridine (0.55 ml, 6.81 mmol) and Dess-Martin periodinane (1.25 g, 2.95 mmol). The reaction mixture was stirred at $25\text{ }^\circ\text{C}$ for 2 h, diluted with ether (40 ml), quenched with 25% $\text{Na}_2\text{S}_2\text{O}_3$ in aqueous NaHCO_3 (20 ml), and stirred vigorously for 15 min. The aqueous phase was separated and extracted with ether (3 x 20 ml). The combined organic extracts were dried over MgSO_4 , concentrated and subjected to flash chromatography (silica, 0-5% ether in hexanes) to afford ketone **50** (0.59 g, 1.97 mmol, 55% from ketone **49**). **50**: colorless liquid; $R_f = 0.58$ (silica, 25% ether in hexanes); $[\alpha]_D^{25}$: -62.3 ($c = 0.7$, CH_2Cl_2); IR (film) ν_{max} 2939, 2865, 1703, 1461, 1098, 884, 682; $^1\text{H NMR}$ (500 MHz, CDCl_3) 3.96-3.92 (m, 2H), 3.90-3.84 (m, 2H), 3.64 (m, 1H), 3.57 (m, 1H), 2.48 (m, 1H), 2.39 (m, 1H), 2.16 (dd, $J = 12.0, 3.0$ Hz, 1H), 2.07 (m, 1H), 1.99 (m, 1H), 1.71-1.40 (m, 10H), 1.34 (s, 1H), 1.16 (s, 3H), 1.04 (m, 18H), 1.02 (s, 3H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 113.0, 65.3, 65.0, 60.1, 49.7, 44.8, 42.5, 41.2, 34.9, 30.3, 28.9, 22.8, 22.0, 21.8, 18.1, 16.6, 12.1; HRMS, calcd for $\text{C}_{25}\text{H}_{46}\text{O}_4\text{Si}$ ($\text{M} + \text{Na}^+$) 461.3066, found 461.3068.



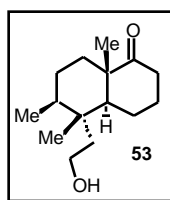
Alkene 51. A solution of methyltriphenylphosphonium bromide (1.22 g, 3.42 mmol) in THF (50 ml) was treated dropwise with sodium bis(trimethylsilyl)amide (2.96 ml of a 1.0 M solution in THF, 2.96 mmol) at $0\text{ }^\circ\text{C}$. The resulting orange solution was treated dropwise with a solution of ketone **50** (1.01 g, 2.28 mmol) in THF (2 ml) at $0\text{ }^\circ\text{C}$. After stirring at $65\text{ }^\circ\text{C}$ for

3 h, the mixture was quenched with acetone (1 ml), diluted with ether (50 ml), washed with brine (3 x 30 ml). The organic solution was dried over MgSO_4 , concentrated, then subjected to flash

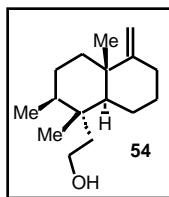
chromatography (silica, 0-5% ether in hexanes) to afford alkene **51** (0.89 g, 2.14 mmol, 89%). **51**: colorless liquid; $R_f = 0.74$ (silica, 25% ether in hexanes); $[\alpha]_D^{25}$: -75.1 ($c = 1.0$, CH_2Cl_2); IR (film) max 2939, 2865, 1461, 1085, 1072, 884; $^1\text{H NMR}$ (500 MHz, CDCl_3) 4.74 (s, 1H), 4.69 (s, 1H), 3.92-3.88 (m, 3H), 3.82 (m, 1H), 3.72 (m, 1H), 3.58 (m, 1H), 2.33 (m, 1H), 2.14 (m, 1H), 1.83-1.71 (m, 2H), 1.67-1.31 (m, 11H), 1.24 (s, 1H), 1.11 (s, 3H), 1.04 (m, 18H), 0.96 (s, 3H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 154.6, 113.6, 106.6, 65.4, 64.9, 59.7, 45.2, 43.5, 42.1, 41.7, 31.6, 30.4, 29.6, 23.9, 23.0, 21.6, 18.2, 18.0, 12.2; HRMS, calcd for $\text{C}_{26}\text{H}_{48}\text{O}_3\text{Si}$ ($\text{M} + \text{Cs}^+$) 569.2429, found 569.2432.



Alcohol 52. A mixture of 10% Pd/C (0.50 g) and alkene **51** (5.05 g, 17.84 mmol) in 50 ml of ethyl acetate was hydrogenated in a Parr apparatus for 3 h at 40 psi. The catalyst was then removed by filtration and the solvent was evaporated to afford the reduced material as an unseparable mixture of diastereomers at the C8 center (ratio 8:1) in 95% total yield. This mixture was redissolved in THF (40 ml) and treated with TBAF (1.0 M in THF, 3.44 ml, 3.44 mmol) at 25 °C for 1h. Then the reaction was quenched with water (10 ml) and extracted with ether (3 x 50 ml). The organic layers were dried (MgSO_4), concentrated and chromatographed (silica, 10% ether in hexanes) to afford alcohol **52** in 84% yield. **52**: colorless liquid; $R_f = 0.35$ (silica, 70% ether in hexanes); $[\alpha]_D^{25}$: -52.1 ($c = 1.0$, CH_2Cl_2); IR (film) max 3382, 2939, 2872, 1710, 1448, 1387, 1139, 1051; $^1\text{H NMR}$ (500 MHz, CDCl_3) 3.93-3.88 (m, 3H), 3.83-3.79 (m, 1H), 3.69-3.58 (m, 2H), 1.68-1.29 (m, 14H), 1.02 (s, 3H), 0.83 (d, $J = 6.5$ Hz, 3H), 0.70 (s, 3H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 113.6, 65.3, 64.8, 58.3, 44.6, 43.6, 40.7, 38.6, 37.3, 30.4, 30.2, 26.9, 22.9, 20.6, 17.8, 17.1, 16.2; HRMS, calcd for $\text{C}_{17}\text{H}_{30}\text{O}_3$ ($\text{M} + \text{H}^+$) 283.2275, found 283.2273.

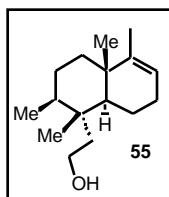


Ketone 53: To a solution of ketal **52** (3.0 g, 10.6 mmol) in THF (20 ml) was added hydrochloric acid (1.0 ml, 0.1 N). The reaction was stirred at room temperature for 3 h, then neutralized with saturated sodium bicarbonate (15 ml). The two layers were separated and the aqueous layer was extracted with ether (3 x 50 ml). The organic solutions were combined, dried over MgSO_4 , concentrated and subjected to flash chromatography to afford hydroxy ketone **53** (2.17 g, 10.0 mmol, 93% yield). **53**: white solid; $R_f = 0.25$ (silica, 50% ethyl ether in hexane); $[\alpha]_D^{25}$: -39.0 ($c = 5.33$, benzene); IR (film) max 3441, 2938, 1702, 1455, 1381, 1257, 1135, 1027, 952; $^1\text{H NMR}$ (500 MHz, CDCl_3) 3.40-3.70 (m, 2H), 2.01-2.60 (m, 3H), 1.05-1.95 (m, 11H), 1.12 (s, 3H), 0.85 (d, 3H, $J = 4.80$ Hz), 0.81 (s, 3H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 215.8, 57.9, 49.3, 48.9, 40.6, 39.6, 37.4, 37.1, 32.9, 26.5, 26.0, 20.8, 19.1, 18.1, 16.1; HRMS, calcd for $\text{C}_{15}\text{H}_{26}\text{O}_2$ ($\text{M} + \text{H}^+$) 239.2011, found 239.2030.



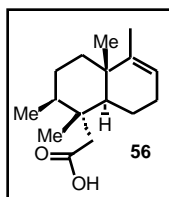
Alcohol 54. To a suspension of methyltriphenylphosphonium bromide (3.40 g, 9.50 mmol) in tetrahydrofuran (10 ml) was added dropwise sodium bis-trimethylsilyl amide (1.0 M in THF, 8.0 ml, 8.0 mmol) and the suspension was stirred at 25 °C for 30 min. Hydroxyketone **53** (0.76 g, 3.20 mmol) in THF (2.0 ml) was then added to the above reaction and the mixture and stirred at 25 °C for

18 hr. The reaction was quenched with aqueous saturated sodium bicarbonate (10 ml) and the mixture extracted with ethyl ether (3 x 5 ml). The organic layers were collected, dried (MgSO₄), concentrated and chromatographed (silica, 10-20 % ethyl ether in hexane) to afford olefin **54** (0.68 g, 2.90 mmol, 91% yield). **54**: white solid; $R_f = 0.30$ (silica, 50 % ethyl ether in hexane); $[\alpha]_D^{25}$: - 31.2 (c = 0.5, benzene); IR (film) \max 3321, 2931, 2859, 1633, 1447, 1379, 1026, 889; NMR (500 MHz, CDCl₃) 4.49 (d, 2 H, J= 1.60 Hz), 3.40- 3.70 (m, 2 H), 1.84- 2.40 (m, 3 H), 1.05- 1.80 (m, 9 H), 1.03 (s, 3 H), 0.86 (d, 3 H, J= 6.40 Hz), 0.74 (s, 3 H); ¹³C NMR (125 MHz, CDCl₃) 160.2, 102.5, 58.7, 49.8, 40.9, 40.2, 39.4, 37.8, 37.3, 33.1, 28.7, 27.6, 22.1, 21.0, 18.0, 16.4; HRMS, calcd for C₁₅H₂₈O (M+ H⁺) 237.2218, found 237.2221.



Alcohol 55. To a solution of olefin **54** (2.40 g, 10.2 mmol) in o-xylene (20 ml) was added iodine (0.13 g, 0.50 mmol) and the mixture was refluxed at 150 °C for 12 hr. The reaction mixture was cooled to 25 °C and treated with saturated aqueous sodium thiosulfate (20 ml). The organic layer was extracted with ethyl ether (3 x 15 ml), dried (MgSO₄), concentrated and chromatographed (silica, 10-

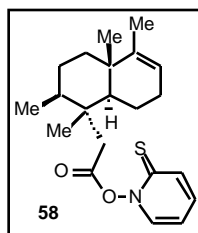
20 % ethyl ether in hexane) to afford alcohol **55** (2.20 g, 9.20 mmol, 89%). **55**: clear oil; $R_f = 0.30$ (silica, 50 % ethyl ether in hexane); $[\alpha]_D^{25}$: +82.3 (c =12.0, benzene); IR (film) \max 3329, 2939, 1743, 1266, 1174, 1134, 1028; NMR (500 MHz, CDCl₃) 5.17 (s, 1 H), 3.60 (m, 2 H), 1.85- 2.20 (m, 2 H), 1.02-1.90 (m, 12 H), 0.985 (s, 3 H), 0.86 (d, 3 h, J= 6.0 Hz), 0.732 (s, 3 H); ¹³C NMR (125 MHz, CDCl₃) 143.9, 120.3, 58.2, 47.4, 40.8, 38.7, 38.2, 37.3, 36.7, 27.5, 26.8, 19.9, 18.6, 18.1, 17.9, 16.2; HRMS, calcd for C₁₅H₂₈O (M+ H⁺) 237.2218, found 237.2229.



Carboxylic acid 56. To a solution of alcohol **55** (0.80 g, 3.40 mmol) in dichloromethane (2 ml) at 25 °C was added Dess-Martin periodinane (1.80 g, 4.20 mmol) in four portions over a period of 1 hr. The reaction was quenched with aqueous saturated sodium bicarbonate and sodium thiosulfate (10 ml), and

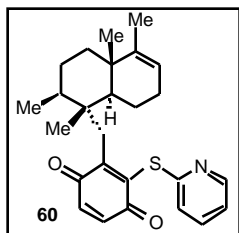
the mixture was extracted with ethyl ether (3 x 5 ml). The organic layers were collected, dried (MgSO₄), concentrated under vacuum and the residue was chromatographed (silica, 10-15 % ethyl ether in hexane) to afford aldehyde (0.72 g, 3.10 mmol, 90%): clear oil; $R_f = 0.40$ (silica, 50 % ethyl ether in hexane); $[\alpha]_D^{25}$: + 13.2 (c = 5.83, benzene); IR (film) \max 2928, 1703, 1449,

1377, 1223, 1101, 1042, 979; ^1H NMR (400 MHz, CDCl_3) 9.83 (m, 1H), 5.18 (m, 1 H), 2.46 (d, 1 H, $J= 15.0$ Hz), 2.33 (d, 1 H, $J= 14.4$ Hz), 1.85- 2.20 (m, 3 H), 1.05- 1.80 (m, 7 H), 1.00 (s, 3 H), 0.95 (d, 3 H, 6.80 Hz), 0.82 (s, 3 H); ^{13}C NMR (100 MHz, CDCl_3) 203.3, 143.3, 120.4, 51.7, 49.3, 41.6, 39.0, 38.4, 36.4, 27.3, 26.6, 19.9, 18.9, 17.9, 17.2, 16.3. To a solution of the above aldehyde (0.72 g, 3.10 mmol), 2-methyl-2-butene (4.90 ml, 9.74 mmol, 2.0 M in THF), NaH_2PO_4 (1.34 g, 9.74 mmol) in tert-butanol and H_2O (5 ml: 2.5 ml) was added sodium chlorite (0.88 g, 9.74 mmol) and the mixture was stirred at 25 °C for 1 hr. Then 10 ml of H_2O were added to the reaction mixture, and the organic residue was extracted with ethyl acetate (3 X 10 ml). The organic layers were collected, dried (MgSO_4), concentrated under vacuum, the residue was chromatographed (silica, 20-30 % ethyl ether in hexane) to afford carboxylic acid **56** (0.62 g, 2.50 mmol, 81% yield from **55**). **56**: white solid; $R_f = 0.2$ (silica, 50% ethyl acetate in hexanes); $[\alpha]_D^{25}$: 48.1 ($c= 0.6$, CH_2Cl_2); IR (film) max 2922, 2686, 1700, 1451, 1406, 1383, 1311, 1229, 1120, 948; ^1H NMR (400 MHz, CDCl_3) 5.20 (s, 1H), 2.46 (d, 1H, $J= 13.6$ Hz), 2.30 (d, 1H, 13.6 Hz), 2.08 (bs, 2H), 1.8-1.2 (m, 12H), 1.0 (s, 3H), 0.91 (d, 3H, $J= 6.8$ Hz), 0.79 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) 178.5, 143.5, 120.8, 48.0, 43.1, 41.2, 38.5, 37.5, 36.4, 27.4, 26.7, 20.0, 19.3, 18.1, 17.5, 16.3; HRMS, calcd for $\text{C}_{16}\text{H}_{26}\text{O}_2$ (M^+ Cs^+) 383.0985, found 383.0979.

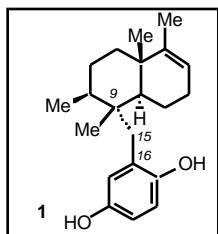


Thiohydroxamic derivative 58. To a solution of acid **56** (0.13 g, 0.52 mmol) and 2-mercaptopyridine-*N*-oxide (**57**) (66 mg, 0.52 mmol) in dichloromethane (3 ml) was added DCC (107 mg, 0.52 mmol) and the mixture was stirred at 25 °C in the dark (flask was covered with aluminum foil) for 12 h. The mixture was diluted with dichloromethane (5 ml), subjected to filtration over cotton to remove the DCU and the filtrate was partitioned with aqueous

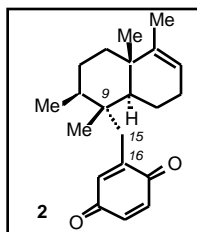
saturated sodium bicarbonate (10 ml) and extracted with dichloromethane (3 x 10 ml). The organic layer was collected, dried (MgSO_4), concentrated and the residue was chromatographed (silica, 10-20% ether and 10% dichloromethane in hexanes) to afford ester **58** (170 mg, 0.47 mmol, 91 %). *Note*: the above procedure needs to be performed in a semi-dark room, since thiohydroxamate esters such as **58** are light-sensitive. **58**: yellow solid; $R_f = 0.7$ (silica, 50% ethyl ether in hexanes); IR (film) max 1780, 1610; ^1H NMR (400 MHz, CDCl_3) 7.66 (m, 1H), 7.48 (m, 1H), 7.18 (m, 1H), 6.60 (m, 1H), 5.17 (s, 1H), 2.86 (d, 1H, $J= 13.2$ Hz), 2.70 (d, 1H, $J= 13.2$ Hz), 2.11 (bs, 2 H), 1.81-1.2 (m, 11 H), 1.01 (s, 3H), 0.96 (d, $J= 6.8$ Hz, 3H), 0.86 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) 175.5, 166.5, 143.5, 137.6, 137.3, 133.2, 120.4, 112.4, 47.7, 41.6, 39.9, 38.4, 37.8, 36.3, 27.3, 26.8, 19.9, 19.3, 18.1, 17.3, 16.4.



Quinone 60. A solution of ester **58** (63.1 mg, 0.17 mmol) and 1,4-benzoquinone (**19**) (56 mg, 0.51 mmol) in dichloromethane (5 ml) was cooled at 0 °C and irradiated with one tungsten lamp (GE, 300W) for 2 h. The reaction mixture was concentrated and subjected to flash chromatography (silica, 10-30% ether in hexanes) to afford thioether **60** (58.5 mg, 0.14 mmol, 81%). **60**: colorless liquid; $R_f = 0.45$ (silica, 50% ether in hexanes); $[\alpha]_D^{25} : +28.6$ ($c = 0.9$, CH_2Cl_2); IR (film) ν_{max} 2926, 2360, 2341, 1654, 1417, 1274; $^1\text{H NMR}$ (400 MHz, CDCl_3) 8.3 (bs, 1H), 7.6 (m, 1H), 7.31 (d, 1H, $J = 8$ Hz), 7.03 (m, 1H), 6.83 (s, 2H), 5.15 (bs, 1H), 3.01 (d, 1H, $J = 12.4$ Hz), 2.84 (d, 1H, $J = 12.4$ Hz), 2.1-1.2 (m, 13H), 1.00 (s, 3H), 0.85 (s, 3H), 0.75 (d, $J = 6.8$ Hz, 3H); $^{13}\text{C NMR}$ (100 MHz, CDCl_3) 185.1, 181.7, 153.3, 149.4, 144.0, 142.1, 137.4, 136.9, 136.7, 122.9, 120.7, 120.4, 51.9, 45.5, 42.2, 39.7, 38.9, 36.1, 28.4, 27.1, 20.9, 20.0, 19.0, 18.2, 16.0. HRMS, calcd for $\text{C}_{26}\text{H}_{31}\text{NO}_2\text{S}$ ($\text{M}+\text{Cs}^+$) 554.1128, found 554.1142.

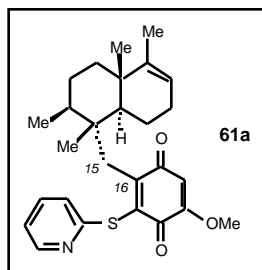


Avarol 1. A solution of quinone **60** (13.0 mg, 31 μmol) in dichloromethane (3 ml) was treated with excess of Raney[®] Nickel for 10 min. The reaction mixture was then filtered, the filtrate concentrated and the residue purified by a preparative thin layer chromatography plate (silica, 40% ether in hexanes) to produce avarol (**1**) (8.1 mg, 26 μmol , 84%). **1**: light yellow liquid; $R_f = 0.5$ (silica, 50% ether in hexanes); $[\alpha]_D^{25} : +10.2$ ($c = 0.8$, CH_2Cl_2); $^1\text{H NMR}$ (500 MHz, CDCl_3) 6.59 (m, 3H), 5.14 (bs, 1H), 2.66 (d, 1H, $J = 14.5$ Hz), 2.57 (d, 1H, $J = 14.5$ Hz), 2.10-2.0 (m, 4H), 1.6-1.2 (m, 11 H), 1.2 (s, 3H), 1.02 (d, 3H, $J = 6.8$ Hz), 0.86 (s, 3H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 146.7, 125.6, 120.5, 119.7, 116.2, 113.9, 110.0, 101.3, 45.8, 37.5, 36.0, 35.7, 30.2, 29.6, 27.6, 26.6, 20.0, 19.7, 18.0, 17.6, 17.4; HRMS, calcd for $\text{C}_{21}\text{H}_{30}\text{O}_2$ ($\text{M}+\text{Cs}^+$) 447.1297, found 447.1289.



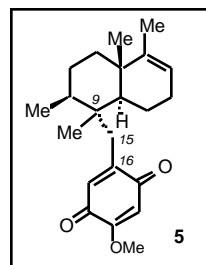
Avarone 2. A solution of avarol (**49**) (5.2 mg, 17 μmol) in ethyl ether (0.5 ml) was treated with manganese (IV) oxide (10 mg, 84 μmol) for 10 min at 25 °C. The reaction mixture was filtered through cotton, the filtrate concentrated and the residue purified by a preparative thin layer chromatography plate (silica, 30% ether in hexanes) to produce avarone (**50**) (5.1 mg, 16.5 μmol , 97%). **50**: purple liquid; $R_f = 0.85$ (silica, 50% ether in hexanes); $[\alpha]_D^{25} : +13.1$ ($c = 0.5$, CH_2Cl_2); $^1\text{H NMR}$ (500 MHz, CDCl_3) 6.71 (m, 2H), 6.5 (s, 1H), 5.13 (bs, 1H), 2.64 (d, 1H, $J = 13.5$ Hz), 2.43 (d, 1H, $J = 13.5$ Hz), 2.10-2.0 (m, 2H), 1.82-1.78 (m, 2H), 1.6-1.2 (m, 9H), 1.0 (s, 3H), 0.93 (d, 3H, $J = 6.5$ Hz), 0.84 (s, 3H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 187.5, 187.4, 147.5, 144.1, 137.2, 136.2, 136.0, 120.7, 47.0, 42.6, 38.4, 36.9, 36.0, 35.3, 27.3,

26.3, 19.9, 19.2, 17.9, 17.7, 16.6; HRMS, calcd for C₂₁H₂₈O₂ (M+Cs⁺) 445.1140, found 445.1162.



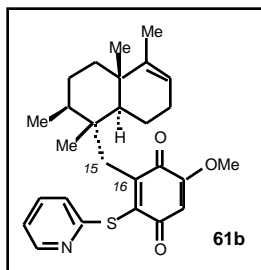
Adduct 61a. A solution of ester **58** (0.16 g, 0.43 mmol) and 2-methoxy benzoquinone (**37**) (0.18 g, 1.30 mmol) in dichloromethane (2 ml) was cooled at 0 °C and irradiated with two halogen lamps (500 W) for 2 hr. The reaction mixture was concentrated and chromatographed (silica, 10-30 % ethyl ether in hexane) to afford quinone **61a** (0.141 g, 0.34 mmol, 78%). **61a**: Red solid; $R_f = 0.30$ (silica, 50 % ethyl ether

in hexane); $[\alpha]_D^{25} : + 20.6$ ($c = 0.5$, CH₂Cl₂); IR (film) ν_{\max} 2925, 1683, 1632, 1574, 1453, 1417, 1196; ¹H NMR (500 MHz, CDCl₃) 8.30 (m, 1 H), 7.59 (m, 1 H), 7.35 (m, 1 H), 7.06 (m, 1 H), 6.00 (s, 1 H), 5.15 (s, 1 H), 3.82 (s, 3 H), 3.00 (d, 1 H, $J = 12.0$ Hz), 2.84 (d, 1 H, $J = 12.0$ Hz), 1.05-2.10 (m, 10 H), 0.99 (s, 3 H), 0.84 (s, 3 H), 0.72 (d, 3 H, $J = 6.5$ Hz); ¹³C NMR (125 MHz, CDCl₃) 185.2, 177.2, 159.5, 157.9, 153.8, 149.0, 144.2, 143.9, 137.6, 123.4, 120.9, 120.5, 107.9, 105.3, 65.8, 56.3, 51.9, 45.8, 42.4, 38.8, 35.9, 28.2, 26.9, 20.8, 19.8, 18.9, 18.0; HRMS, calcd for C₂₇H₃₃NO₃S (M+Cs⁺) 584.1232, found 584.1241.

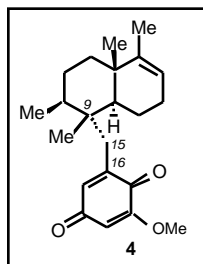


C-19 methoxy avarone (5). A solution of quinone **61a** (6.0 mg, 13.0 μmol) in tetrahydrofuran (2 ml) was treated with excess of Raney nickel at 70 °C for 10 min. The reaction mixture was filtered and the filtrate was concentrated, redissolved in dichloromethane (1 ml) and treated with excess manganese (IV) oxide for 20 min at 25 °C. The reaction mixture was filtered through cotton, the filtrate was concentrated and subjected to chromatography

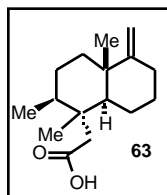
(silica, 10-20 % ethyl ether in hexane) to afford C19- methoxy avarone (**5**) (3.5 mg, 10.2 μmol, 79 %). **5**: red solid; $R_f = 0.56$ (silica, 50 % ethyl ether in hexane); $[\alpha]_D^{25} : + 11.5$ ($c = 0.25$, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) 6.45 (s, 1 H), 5.91 (s, 1 H), 5.14 (s, 1 H), 3.81 (s, 3 H), 2.67 (d, 1 H, $J = 13.5$ Hz), 2.42 (d, 1 H, $J = 13.5$ Hz), 1.05- 2.10 (m, 10 H), 0.99 (s, 3 H), 0.92 (d, 3 H, $J = 6.5$ Hz), 0.84 (s, 3 H); ¹³C NMR (125 MHz, CDCl₃) 187.4, 182.2, 158.3, 148.4, 144.1, 134.1, 120.7, 107.9, 56.1, 47.1, 42.9, 38.4, 36.9, 36.0, 35.2, 29.6, 27.4, 26.4, 19.9, 19.3, 17.9, 17.7, 16.6; HRMS, calcd for C₂₂H₂₉O₃ (M+Cs⁺) 474.1168, found 474.1189.



Adduct 61b. To a solution of quinone **60** (15 mg, 0.04 mmol) in anhydrous tetrahydrofuran (1 ml) was added dropwise sodium methoxide (0.5 M in methanol, 400 μ l, 0.20 mmol) at -20 $^{\circ}$ C and the mixture was stirred for 1 hr. The reaction mixture was treated with aqueous saturated ammonium chloride (5 ml) and extracted with ethyl acetate (3 x 5 ml). The organic layer was collected, dried (MgSO_4), concentrated under vacuum, and the residue was chromatographed (silica, 10-20 % ethyl ether in hexane) to afford quinone **61b** (11 mg, 24.5 μ mol, 61%) together with the C-19 isomer (14%). **61b**: red solid; $R_f = 0.26$ (silica, 50 % ethyl ether in hexane); $[\alpha]_D^{25} : +26.0$ ($c = 0.8$, CH_2Cl_2); $^1\text{H NMR}$ (500 MHz, CDCl_3) 8.30 (m, 1 H), 7.55 (m, 1 H), 7.31 (m, 1 H), 7.02 (m, 1 H), 5.98 (s, 1 H), 5.15 (s, 1 H), 3.83 (s, 3 H), 3.04 (d, 1 H, $J = 12.8$ Hz), 2.87 (d, 1 H, $J = 12.8$ Hz), 1.05- 2.10 (m, 10 H), 0.99 (s, 3 H), 0.84 (s, 3 H), 0.76 (d, 3 H, $J = 6.10$ Hz); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 181.9, 180.5, 159.1, 157.9, 151.1, 149.8, 144.1, 136.7, 123.0, 120.7, 120.6, 108.3, 56.3, 51.7, 45.0, 41.7, 39.4, 38.7, 35.9, 30.2, 29.6, 28.2, 26.9, 20.6, 19.8, 18.8, 18.0, 15.8; HRMS, calcd for $\text{C}_{27}\text{H}_{33}\text{NO}_3\text{S}$ ($\text{M}+\text{Cs}^+$) 584.1232, found 584.1251.

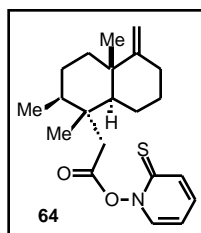


C-18 methoxy avarone (4). A solution of quinone **61b** (5.0 mg, 10.0 μ mol) in tetrahydrofuran (2 ml) was treated with excess of Raney nickel at 70 $^{\circ}$ C for 10 min. The reaction mixture was filtered and the filtrate was concentrated, redissolved in dichloromethane (1 ml) and treated with excess manganese (IV) oxide for 20 min at 25 $^{\circ}$ C. The reaction mixture was filtered through cotton, the filtrate was concentrated and chromatographed (silica, 10-20% ether in hexane) to afford C18-methoxy avarone (**4**) (2.6 mg, 7.7 μ mol, 77 %). **4**: red solid; $R_f = 0.60$ (silica, 50 % ethyl ether in hexane); $[\alpha]_D^{25} : -9.5$ ($c = 0.2$, CH_2Cl_2); IR (film) ν_{max} 2923, 2843, 1735, 1671, 1645, 1598, 1460, 1381, 1228; $^1\text{H NMR}$ (500 MHz, CDCl_3) 6.42 (d, 1 H, $J = 2.40$ Hz), 5.87 (d, 1 H, $J = 2.40$ Hz), 5.14 (s, 1 H), 3.80 (s, 3 H), 2.65 (d, 1 H, $J = 13.6$ Hz), 2.47 (d, 1 H, $J = 13.6$ Hz), 1.05- 2.10 (m, 10 H), 0.99 (s, 3 H), 0.93 (d, 3 H, $J = 6.40$ Hz), 0.84 (s, 3 H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 186.9, 181.8, 158.7, 144.8, 143.7, 136.6, 120.6, 106.8, 56.4, 46.9, 42.5, 38.5, 36.9, 36.1, 35.1, 29.8, 27.5, 26.5, 20.1, 19.4, 18.2, 17.9, 16.8; HRMS, calcd for $\text{C}_{22}\text{H}_{29}\text{O}_3$ ($\text{M}+\text{Cs}^+$) 474.1168, found 474.1171.



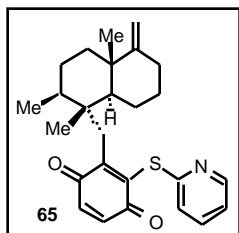
Carboxylic acid 63. To a solution of alcohol **54** (0.90 g, 3.80 mmol) in dichloromethane (2 ml) at 25 $^{\circ}$ C was added Dess- Martin periodinane (1.80 g, 4.20 mmol) in portions over a period of 30 min. Aqueous saturated sodium bicarbonate and sodium thiosulfate (10 ml) was then added and the organic layer was extracted with ethyl ether (3 x 5 ml). The organic layer was collected, dried

(MgSO₄), concentrated under vacuum, and the residue was chromatographed (silica, 10- 15 % ethyl ether in hexane) to afford the corresponding aldehyde (0.76 g, 3.24 mmol, 85 % yield). To a solution of this aldehyde (0.76 g, 3.24 mmol), 2-methyl- 2-butene (4.90 ml, 9.74 mmol, 2.0 M in tetrahydrofuran), NaH₂PO₄ (1.34 g, 9.74 mmol) in tert-butanol and H₂O (5 ml: 2.5 ml), was added sodium chlorite (0.88 g, 9.74 mmol), and the mixture was stirred at 25 °C for 1 hr. The mixture was then treated with 10 ml of H₂O and the reaction was extracted with ethyl acetate (3 X 10 ml). The organic layer was collected, dried (MgSO₄), concentrated under vacuum and the residue was chromatographed (silica, 20-30 % ethyl ether in hexane) to afford carboxylic acid **63** (0.60 g, 2.40 mmol, 74 % yield). **63**: white solid; [α]_D²⁵: - 46.0 (c = 0.6, CH₂Cl₂); R_f = 0.50 (silica, 50 % ethyl ether in hexane); IR (film) ν_{max} 3086, 2924, 2861, 1697, 1449, 1313, 1233; ¹H NMR (500 MHz, CDCl₃) 4.50 (s, 2 H), 2.37 (d, 1 H, J= 10.4 Hz), 2.27 (d, 1 H, J= 10.4 Hz), 1.10- 2.20 (m, 12 H), 1.03 (s, 3 H), 0.89- 0.90 (d, 3 H, J= 5.20 Hz), 0.78 (m, 3 H); ¹³C NMR (125 MHz, CDCl₃) 178.6, 160.1, 102.9, 49.8, 42.9, 41.4, 40.1, 37.8, 36.8, 32.9, 28.1, 27.3, 22.4, 20.6, 17.1, 16.2; HRMS, calcd for C₁₆H₂₆O₂ (M+H⁺) 251.2005, found 251.2008.

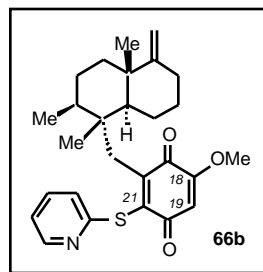


Thiohydroxamic acid derivative 64. To a solution of carboxylic acid **63** (0.20 g, 0.80 mmol) and 2-mercaptopyridine N-oxide (0.10 g, 0.80 mmol) in dichloromethane (1 ml) was added N, N'-dicyclohexylcarbodiimide (DCC, 0.17 g, 0.80 mmol) and the mixture was stirred at 25 °C in the dark (flask was covered with aluminum foil) for 16 hr. The mixture was diluted with

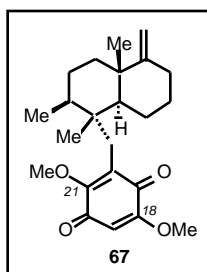
dichloromethane (5 ml), subjected to filtration over cotton to remove DCU and the filtrate was partitioned with aqueous saturated sodium bicarbonate (10 ml) and extracted with dichloromethane (3 X 10 ml). The organic layer was collected, dried (MgSO₄), concentrated under vacuum, and the residue was chromatographed (silica, 10-20 % ethyl ether in hexane) to afford ester **64** (0.27 g, 0.75 mmol, 94 % yield). **64**: yellow solid; R_f = 0.25 (silica, 50 % ethyl ether in hexane); ¹H NMR (500 MHz, CDCl₃) 7.62 (d, 1 H), 7.44 (m, 1 H), 7.16 (m, 1 H), 6.59 (m, 1 H), 4.48 (s, 2 H), 2.79 (d, 1 H, J= 16.0 Hz), 2.66 (d, 1 H, J= 16.0 Hz), 1.05-2.40 (m, 12 H), 1.03 (s, 3 H), 0.92- 0.93 (d, 3 H, J= 6.0 Hz), 0.84 (m, 3 H); ¹³C NMR (125 MHz, CDCl₃) 159.4, 137.7, 137.3, 133.4, 112.5, 103.1, 49.4, 41.6, 40.0, 39.6, 37.8, 36.6, 32.7, 28.2, 27.1, 22.4, 20.4, 16.9, 16.2.



Addition product 65. A solution of ester **64** (0.27 g, 0.75 mmol) and 1,4- benzoquinone (**19**) (0.24 g, 2.25 mmol) in dichloromethane (2 ml) was cooled at 0 °C and irradiated with two halogen lamps (500 W) for 2 hr. The reaction mixture was concentrated and subjected to flash chromatography (silica, 10-30 % ethyl ether in hexane) to afford quinone **65** (0.24 g, 0.56 mmol, 75 %). **65**: red solid; $R_f = 0.60$ (silica, 50 % ethyl ether in hexane); $[\alpha]_D^{25} : -139.0$ ($c = 0.6$, CH_2Cl_2); IR (film) ν_{max} 2924, 1659, 1575, 1451, 1417, 1275, 1118; $^1\text{H NMR}$ (500 MHz, CDCl_3) 8.28 (m, 1 H), 7.55 (m, 1 H), 7.32 (m, 1 H), 7.03 (m, 1 H), 6.82-6.85 (m, 2 H), 4.52 (m, 2 H), 2.95 (d, 1 H, $J = 12.5$ Hz), 2.80 (d, 1 H, $J = 12.5$ Hz), 2.00- 2.40 (m, 2 H), 1.05-1.85 (m, 10 H), 1.03 (s, 3 H), 0.84 (s, 3 H), 0.75 (s, 3 H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 185.4, 181.9, 159.7, 157.5, 153.4, 149.7, 142.8, 137.6, 137.3, 137.0, 136.9, 123.0, 120.8, 103.2, 53.9, 45.7, 42.1, 40.6, 39.9, 36.5, 32.8, 28.4, 28.2, 23.9, 20.2, 18.9, 15.8; HRMS, calcd for $\text{C}_{26}\text{H}_{31}\text{NO}_2\text{S}$ ($\text{M}+\text{H}^+$) 422.2148, found 422.2155.

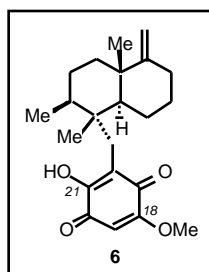


Quinone 66b. To a solution of quinone **65** (15 mg, 0.04 mmol) in anhydrous THF (1 ml) was added dropwise sodium methoxide (0.5 M in methanol, 400 μl , 0.20 mmol) at -20 °C and the mixture was stirred for 1 hr. The reaction was treated with aqueous NH_4Cl (5 ml) and the organic layer was extracted with ethyl acetate (3 x 5 ml). The organic layers were combined, dried concentrated and the residue was chromatographed (silica, 10-20 % ether in hexane) to afford quinone **66b** (11.7 mg, 26.0 μmol , 65 % yield). **66b**: red solid; $R_f = 0.21$ (silica, 50 % ether in hexane); IR (film) ν_{max} 2920, 2851, 1673, 1574, 1223; $^1\text{H NMR}$ (500 MHz, CDCl_3) 8.28 (m, 1 H), 7.52 (m, 1 H), 7.32 (m, 1 H), 7.00 (m, 1 H), 5.99 (s, 1 H), 4.50 (s, 2 H), 3.82 (s, 3 H), 2.97 (d, 1 H, $J = 12.4$ Hz), 2.82 (d, 1 H, $J = 12.4$ Hz), 2.00-2.40 (m, 4 H), 1.05- 2.00 (m, 8 H), 1.03 (s, 3 H), 0.84 s, 3 H), 0.75 (d, 3 H, $J = 6.80$ Hz); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) 184.8, 159.5, 159.1, 149.5, 136.6, 122.8, 120.5, 107.8, 104.5, 103.1, 96.9, 56.4, 54.2, 46.1, 42.4, 40.8, 40.1, 36.7, 32.9, 29.8, 28.5, 28.4, 24.2, 20.4, 19.3, 15.9; HRMS, calcd for $\text{C}_{27}\text{H}_{33}\text{NO}_3\text{S}$ ($\text{M}+\text{H}^+$) 452.2254, found 452.2258.

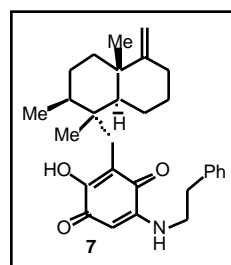


Quinone 67. To a solution of compound **66b** (20 mg, 0.04 mmol) in anhydrous methanol (1 ml) was added dropwise sodium methoxide (0.5 M in methanol, 90 μl , 0.05 mmol) at -20 °C. The reaction mixture was slowly warmed up to 50 °C and stirred at this temperature for 1 hr. The reaction mixture was quenched with aqueous NH_4Cl (5 ml), and extracted with ethyl acetate (3 x 5 ml). The organic layer was collected, dried (MgSO_4), concentrated and the residue was chromatographed (silica, 10-20% ether in hexane) to afford

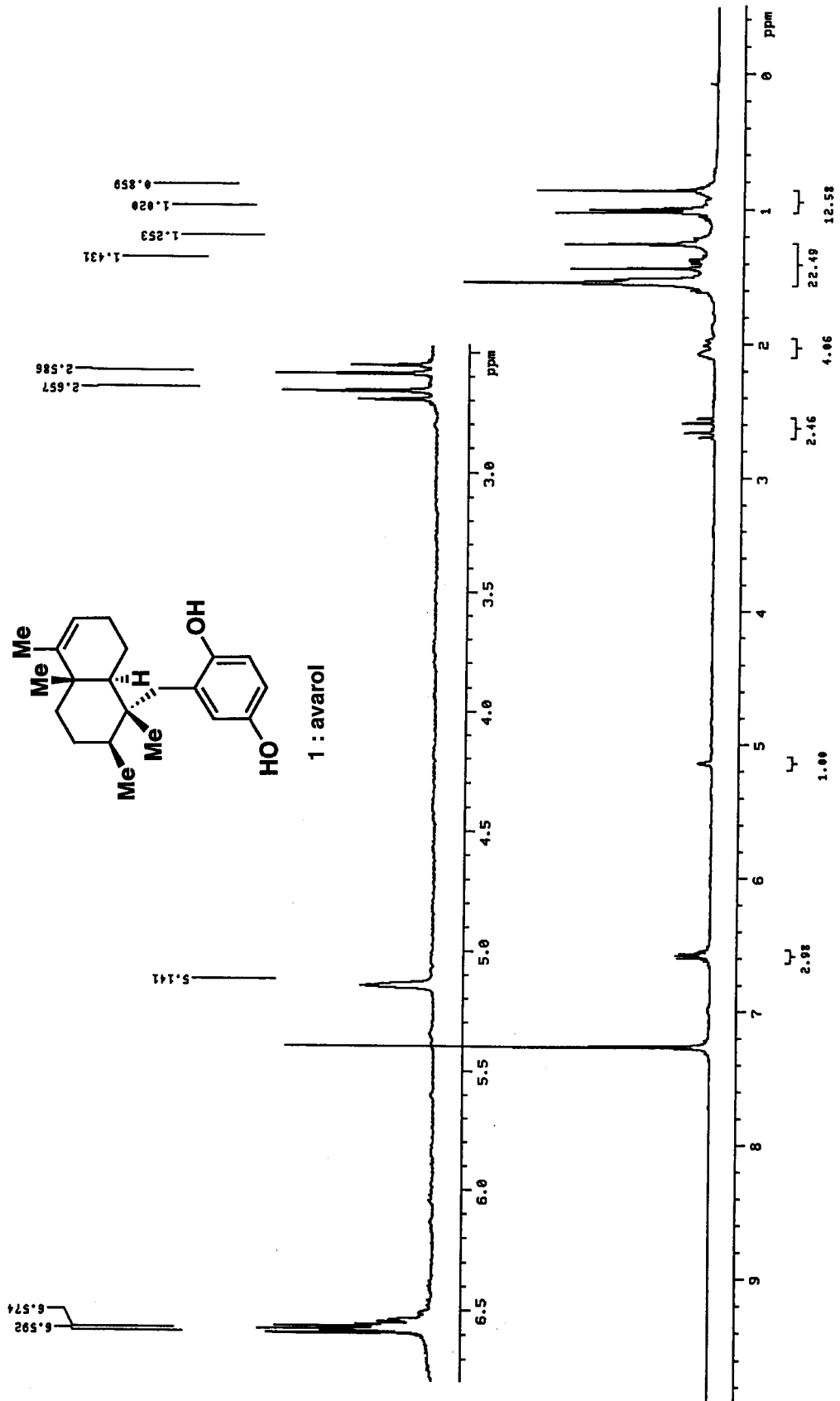
quinone **67** (12.2 mg, 0.033 mmol, 82%). **67**: red solid; $R_f = 0.32$ (silica, 50% ether in hexane); IR (film) ν_{\max} 2937, 1651, 1592, 1453, 1379, 1325, 1215, 1150, 1044; ^1H NMR (500 MHz, CDCl_3) 7.36 (s, 1 H), 5.72 (s, 1 H), 4.44 (d, 2 H, $J = 6.40$ Hz), 4.00 (s, 3 H), 3.80 (s, 3 H), 2.54 (d, 1 H, $J = 13.2$ Hz), 2.46 (d, 1 H, $J = 13.2$ Hz), 1.94- 2.40 (m, 3 H), 1.05- 1.90 (m, 9 H), 1.03 (s, 3 H), 0.92 (d, 3 H, $J = 6.40$ Hz), 0.82 (s, 3 H); ^{13}C NMR (125 MHz, CDCl_3) 183.1, 182.3, 160.1, 159.0, 157.3, 128.8, 128.2, 111.2, 105.1, 102.6, 60.9, 56.5, 50.6, 43.7, 40.6, 38.3, 36.7, 33.0, 32.9, 29.8, 28.6, 28.1, 23.5, 20.7, 18.1, 17.3; HRMS, calcd for $\text{C}_{23}\text{H}_{32}\text{O}_4$ ($\text{M}+\text{H}^+$) 373.2378, found 373.2392.

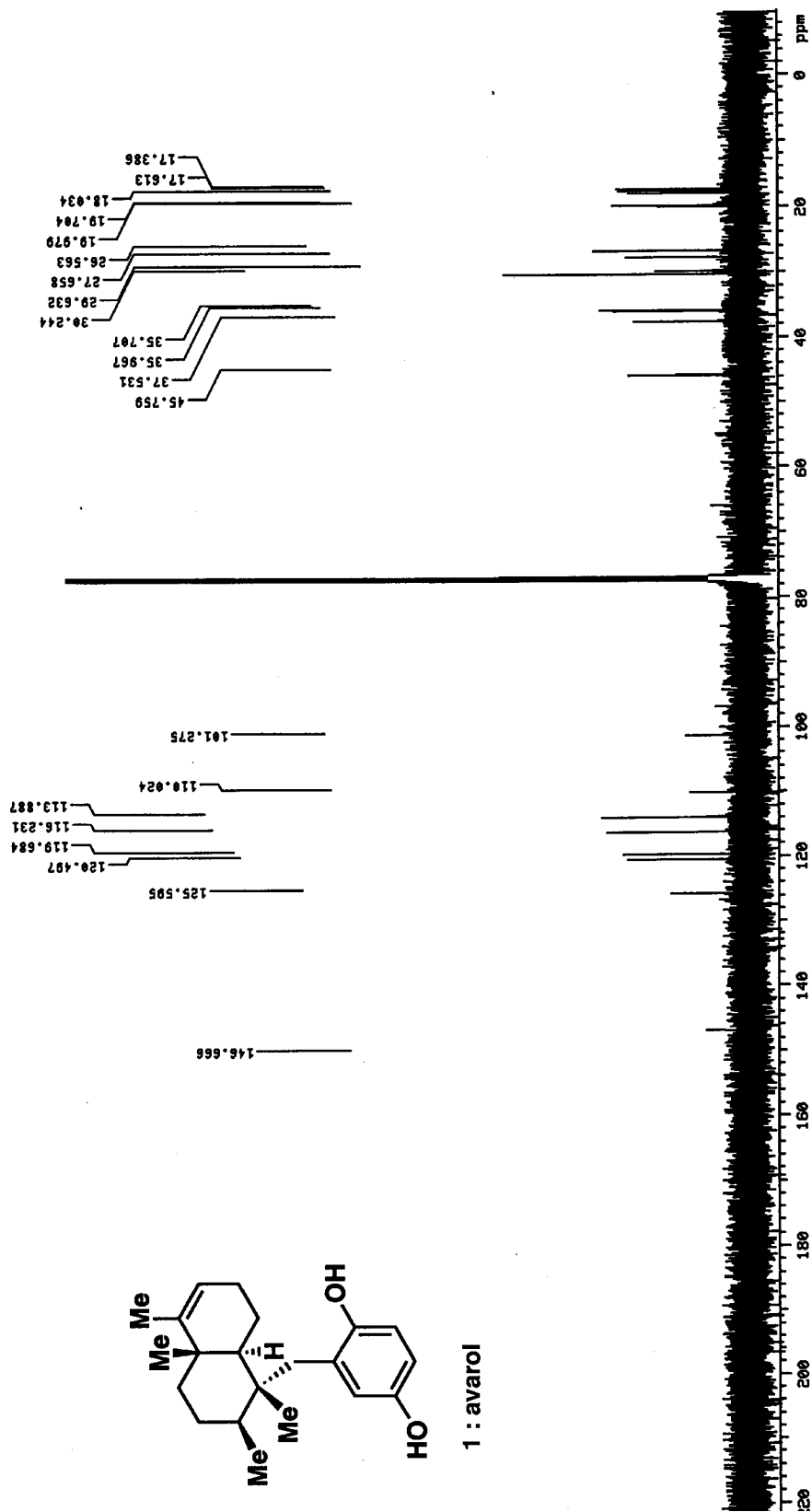


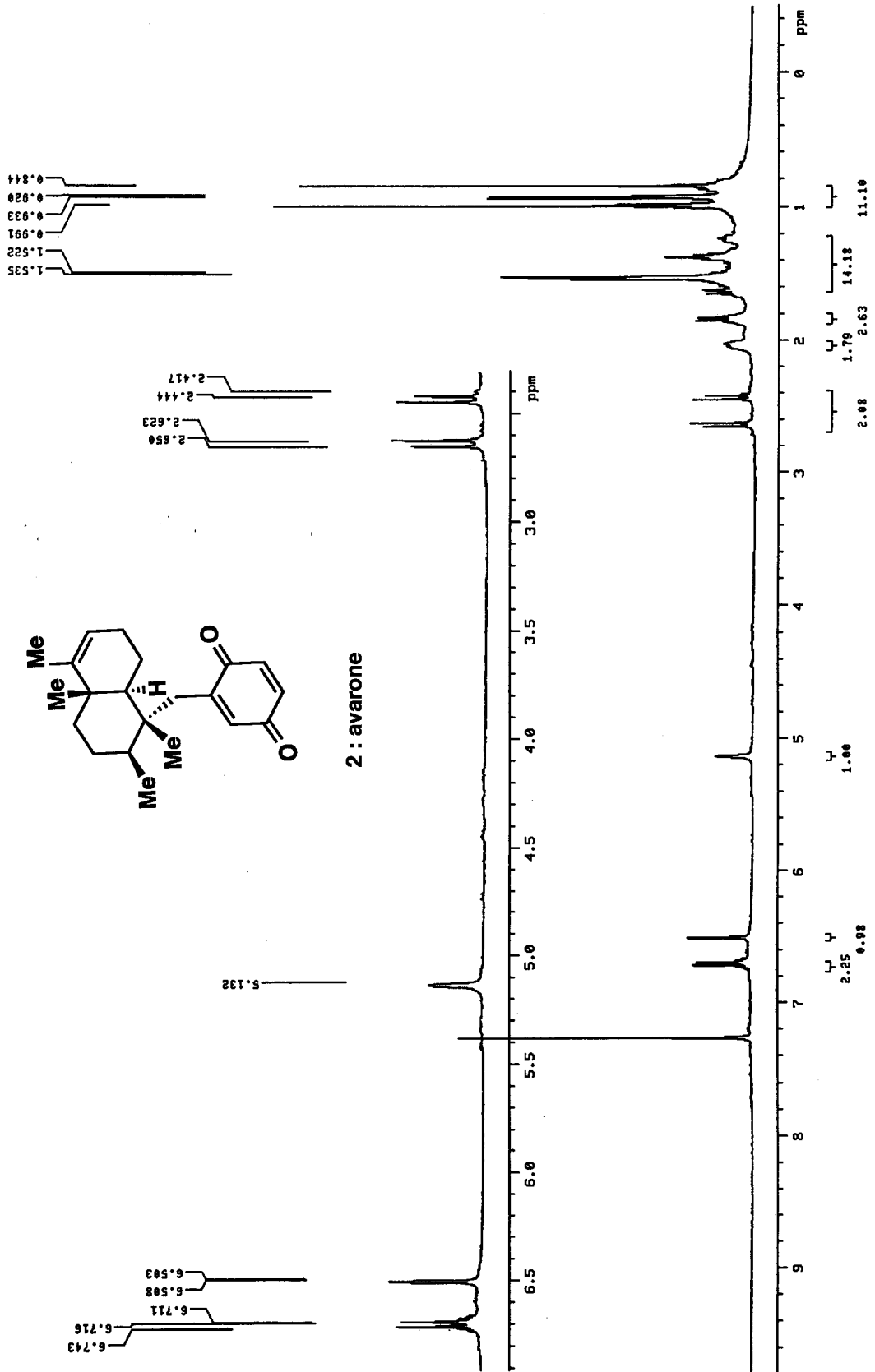
Ilimaquinone (6). A solution of quinone **67** (12.2 mg, 0.033 mmol) in MeOH (0.5 ml) was treated with aqueous potassium hydroxide (0.5 N, 0.07 ml, 0.035 mmol) at 25 °C over a period of 1 hr. The reaction was quenched with aqueous NH_4Cl and the residue extracted with ethyl acetate (3 x 3 ml). The organic layers were dried (MgSO_4), concentrated and the residue was chromatographed (10 to 50 % ether in hexane) to afford ilimaquinone (**6**) (5.7 mg, 0.016 mmol, 48%). **6**: red solid; $R_f = 0.18$ (silica, 50 % ethyl ether in hexane); ^1H NMR (500 MHz, CDCl_3) 7.47 (s, 1 H), 5.85 (s, 1 H), 4.42-4.44 (d, 2H, $J = 7.60$ Hz), 3.86 (s, 3 H), 2.52 (d, 1 H, $J = 14.0$ Hz), 2.47 (d, 1 H, $J = 14.0$ Hz), 1.80- 2.40 (m, 5 H), 1.05- 1.60 (m, 7 H), 1.04 (s, 3 H), 0.97 (d, 3 H, $J = 6.0$ Hz), 0.84 (s, 3 H); ^{13}C NMR (125 MHz, CDCl_3) 182.1, 161.5, 160.4, 153.2, 117.2, 102.4, 101.9, 56.9, 50.1, 43.4, 40.5, 38.1, 36.7, 33.0, 32.4, 28.7, 28.0, 23.3, 20.7, 17.9, 17.5; HRMS, calcd for $\text{C}_{22}\text{H}_{30}\text{O}_4$ ($\text{M}+\text{Na}^+$) 381.2036, found 381.2046.

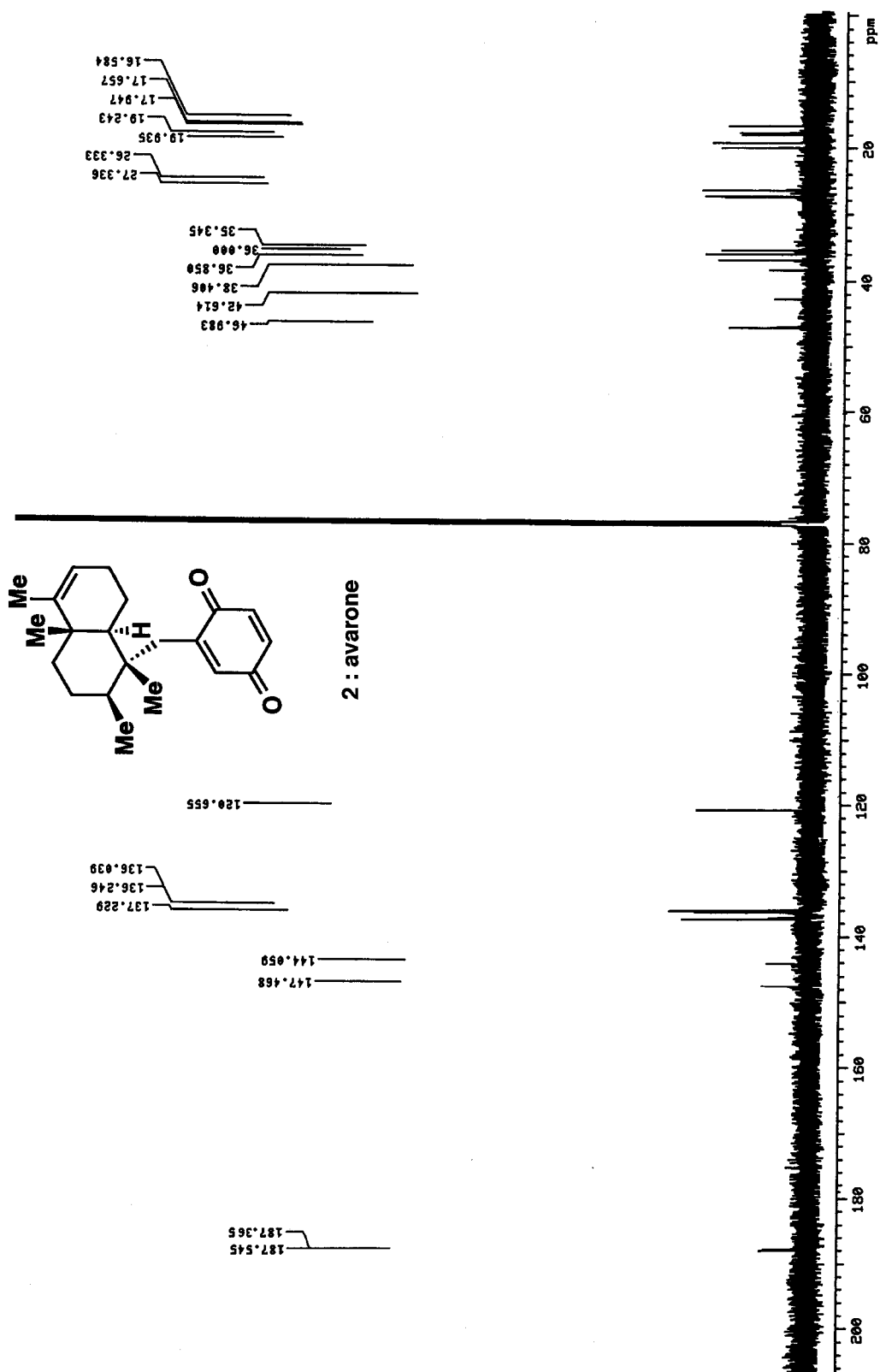


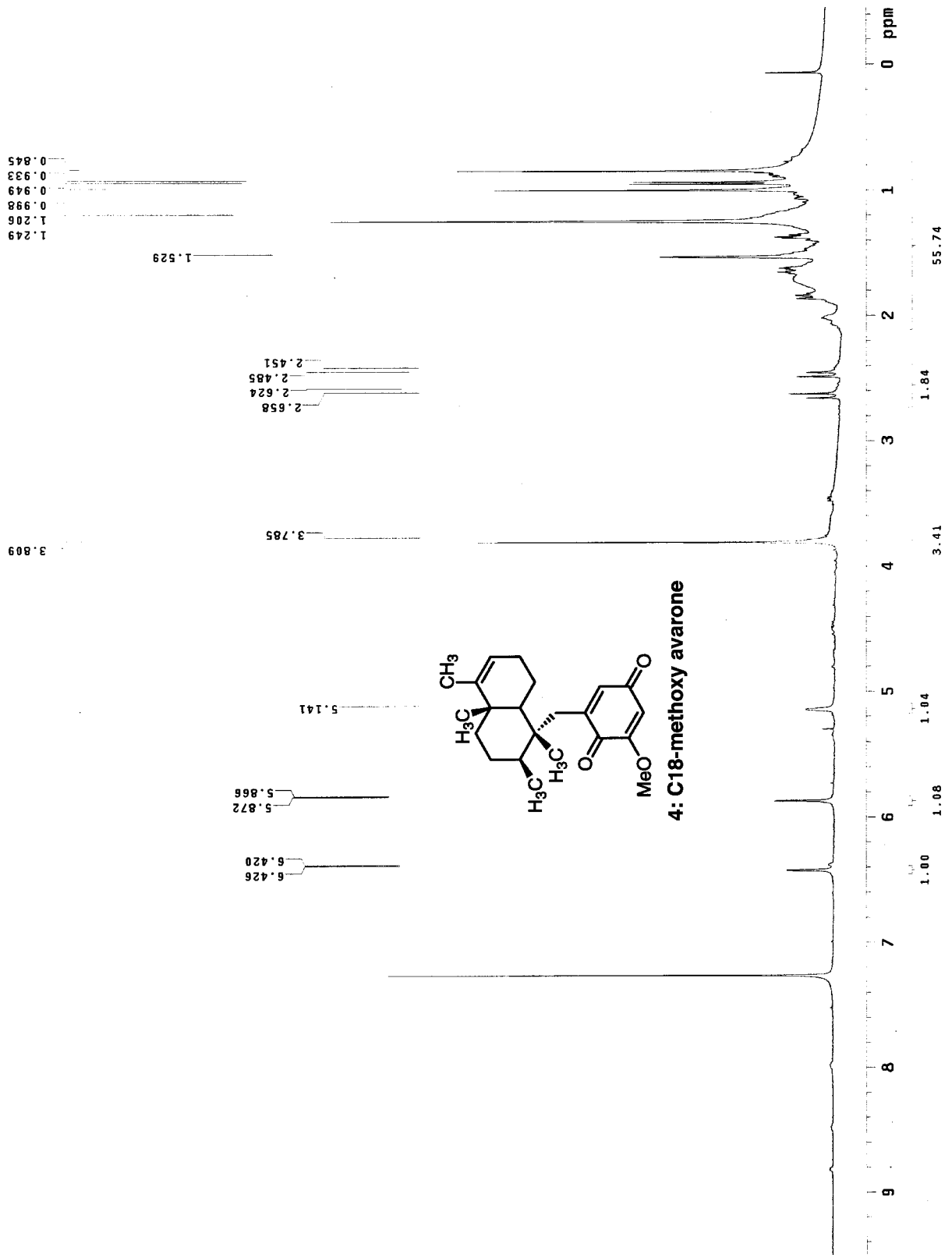
Smenospongidine (7). To a solution of synthetic ilimaquinone (**6**) (1.0 mg, 2.70 μmol) in methanol (0.50 ml) was added phenethylamine (0.50 mg, 4.0 μmol) in methanol (0.10 ml) and NaHCO_3 (excess) and the mixture was stirred at 40 °C for 10 hr. The reaction was cooled to 25 °C, concentrated and subjected to prep. TLC plate (70% ether in hexane) to afford smenospongidine (**7**) (1.10 mg, 2.50 μmol , 91 %). **7**: red solid; $R_f = 0.45$ (70% ether in hexanes); IR (film) ν_{\max} 3263, 2922, 2852, 1584, 1510, 1453, 1381; $[\alpha]_D^{25}$:- 56.0 (c=0.1, benzene); ^1H NMR (400 MHz, CDCl_3) 7.10- 7.40 (m, 5 H), 6.47 (s), 5.39 (s, 1 H), 4.44 (d, 2 H, $J = 5.20$ Hz), 3.42 (m, 2 H), 2.94 (m, 2 H), 2.51 (d, 1 H, $J = 14.0$ Hz), 2.38 (d, 1 H, $J = 14.0$ Hz), 1.04 (s, 3 H), 0.95 (d, 3 H, $J = 6.8$ Hz), 0.82 (s, 3 H); ^{13}C NMR (100 MHz, CDCl_3) 167.7, 161.5, 130.0, 129.7, 128.2, 103.7, 93.0, 69.0, 65.9, 51.1, 45.3, 44.2, 39.1, 37.9, 35.6, 34.3, 33.7, 32.1, 31.0, 29.9, 29.3, 24.5, 21.9, 19.3, 18.7; HRMS calcd for $\text{C}_{29}\text{H}_{37}\text{NO}_3$ ($\text{M}+\text{Na}^+$) 470.2665, found 470.2672.

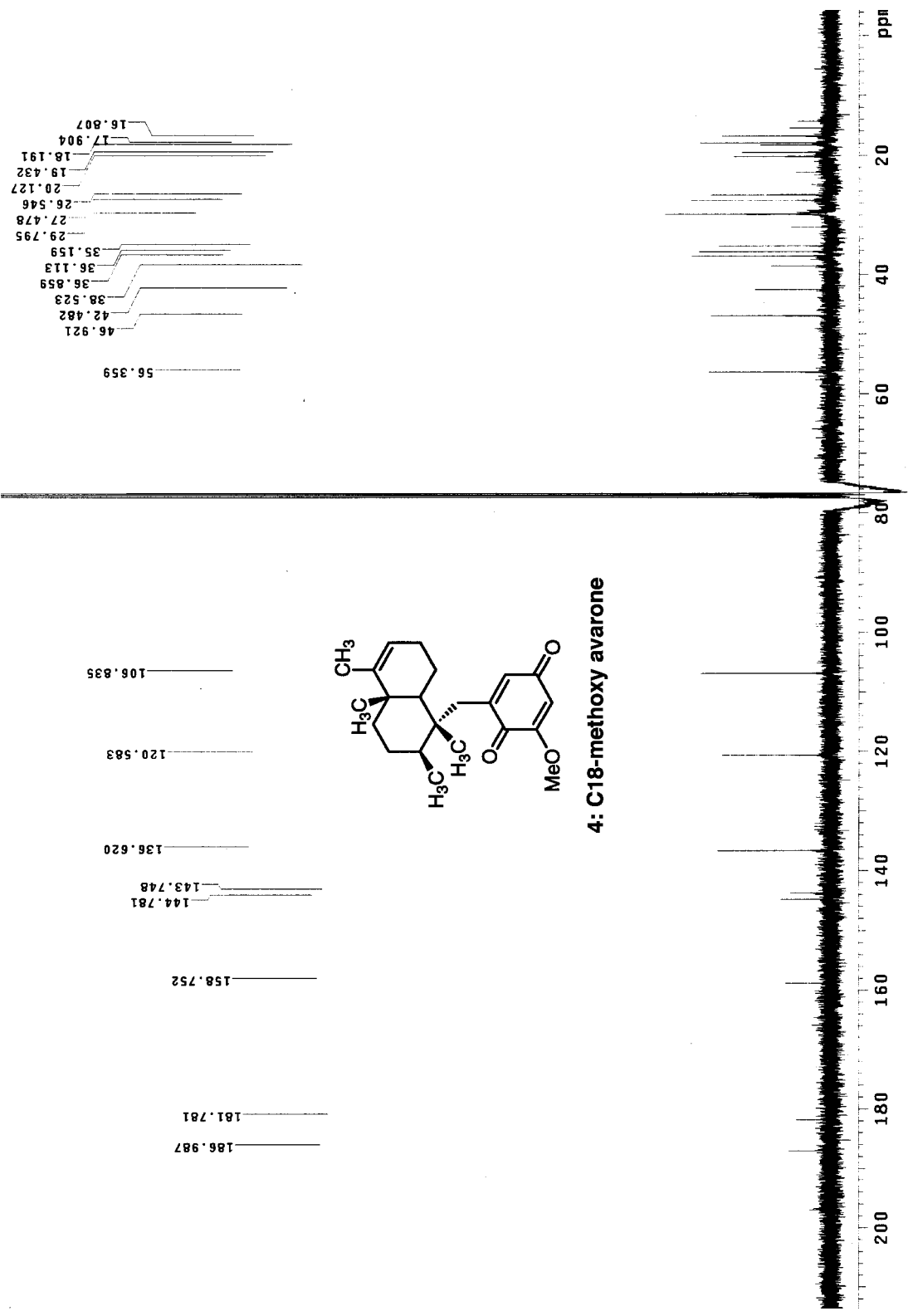


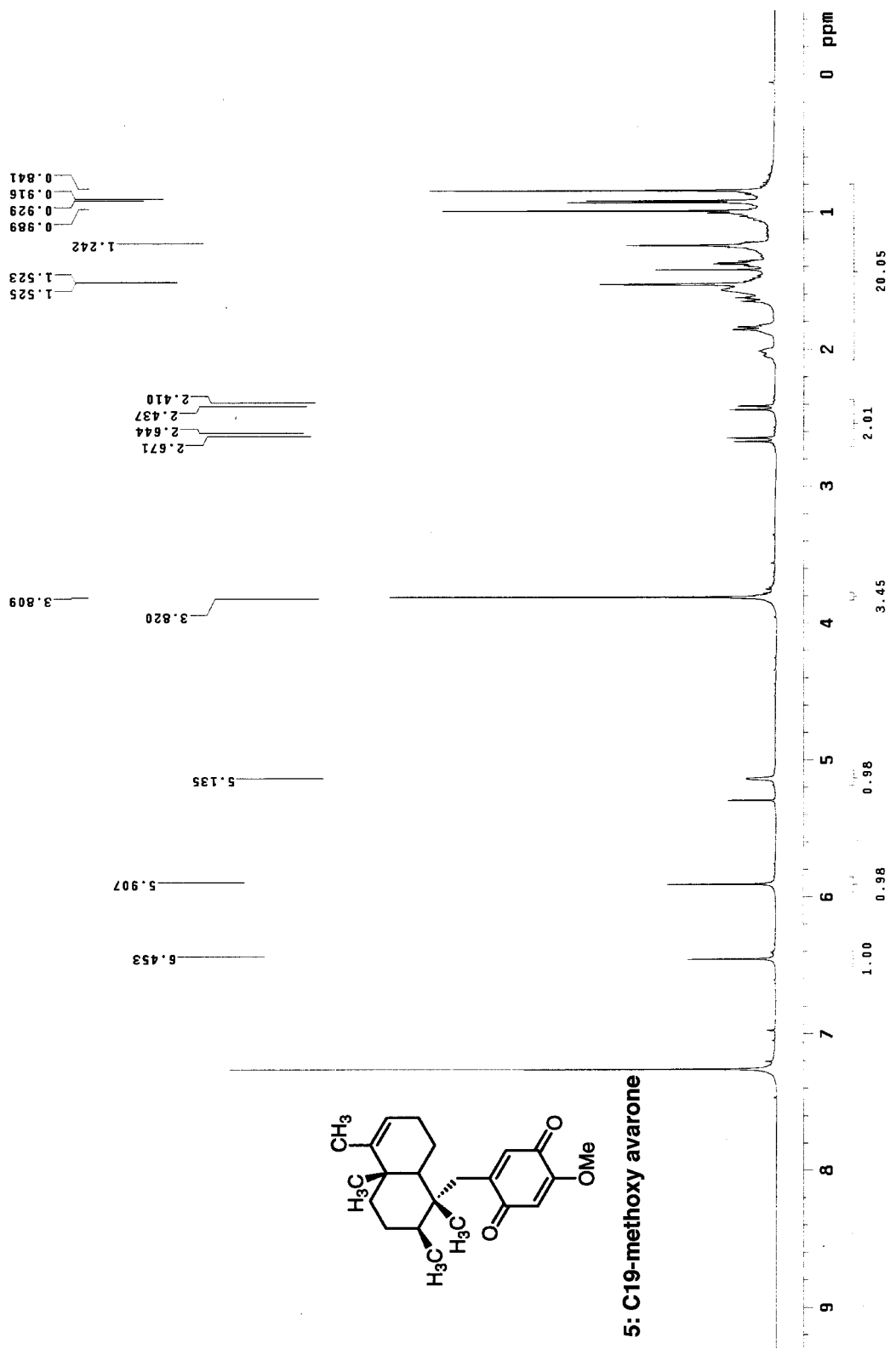


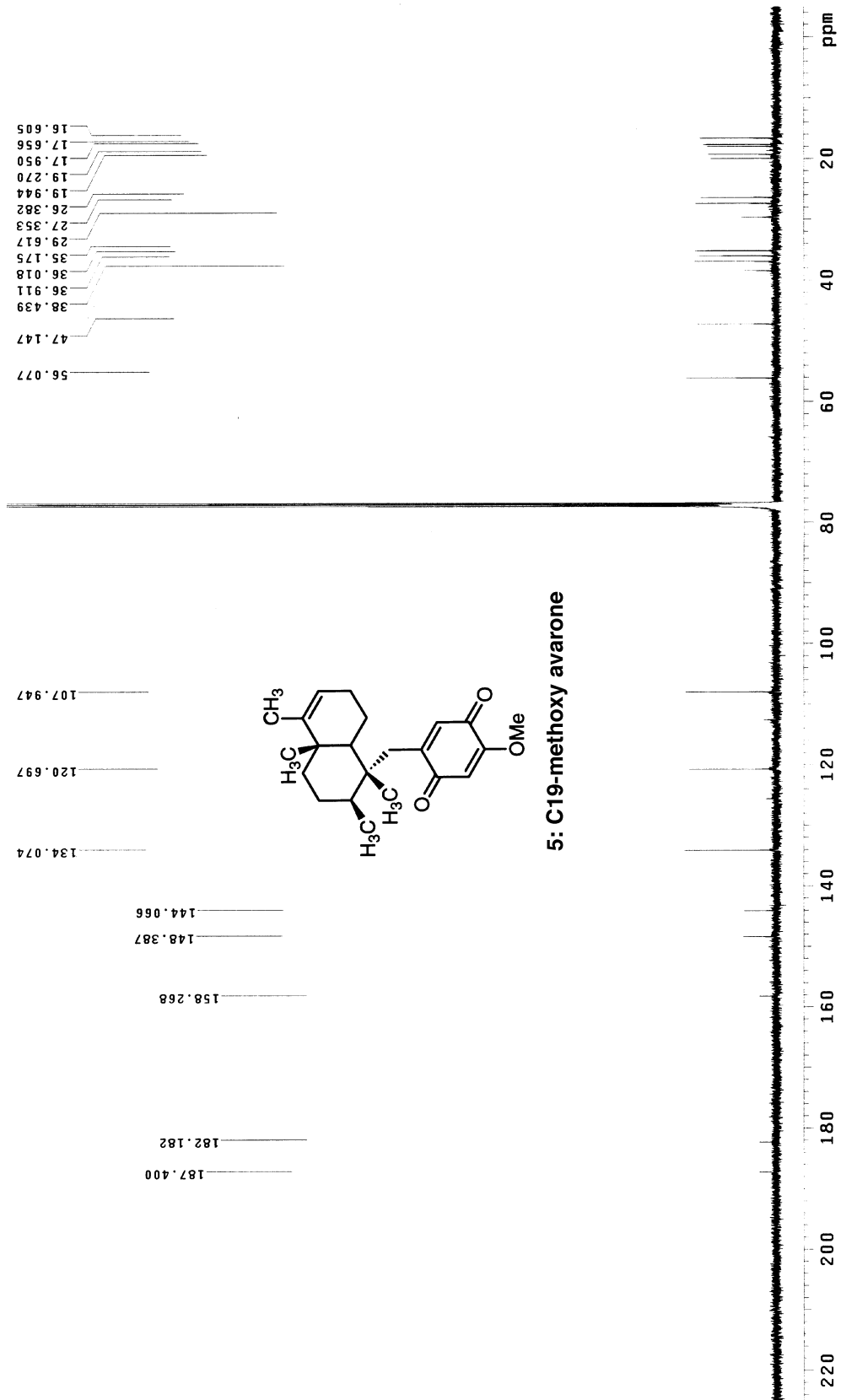


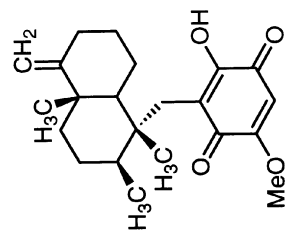




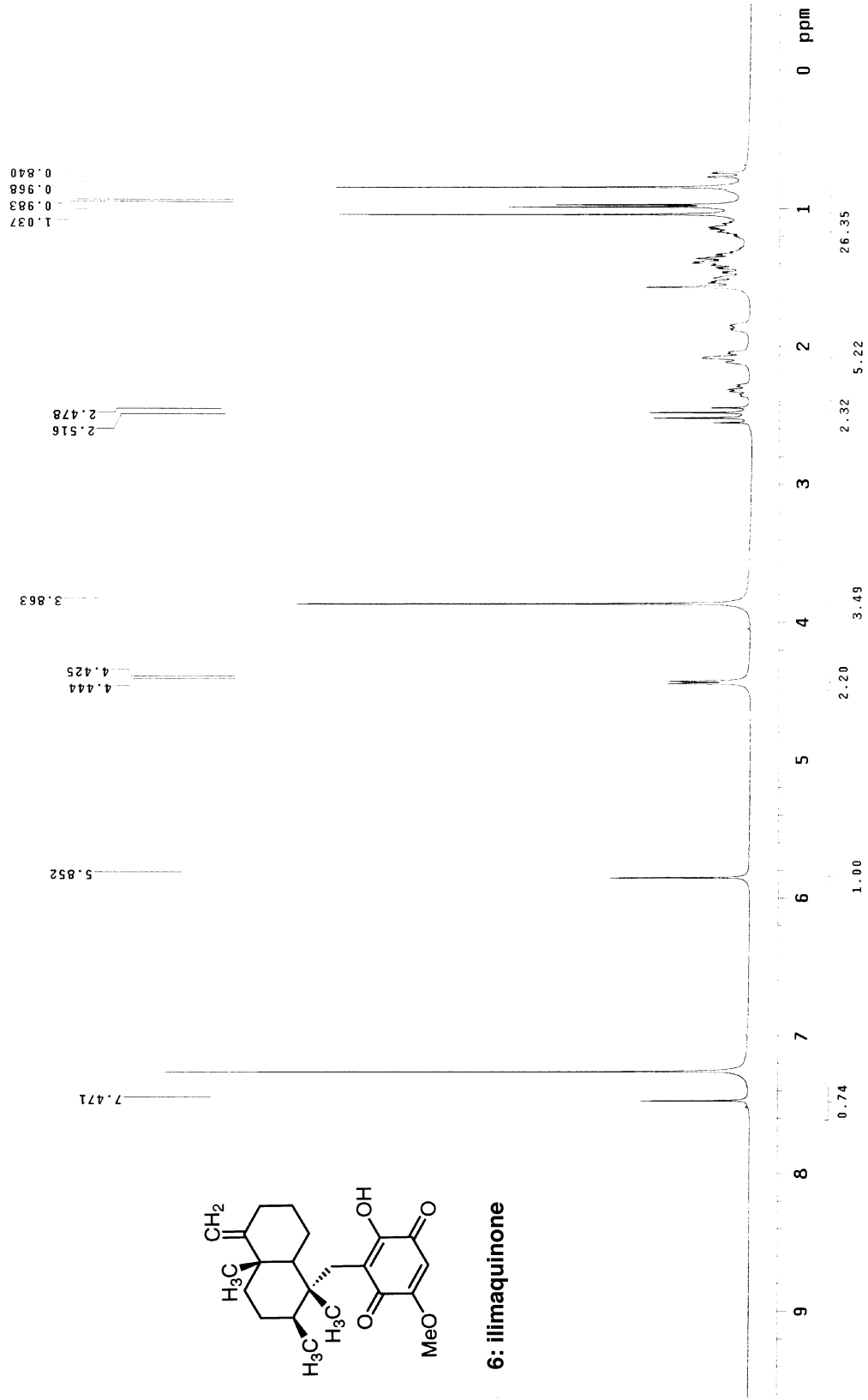


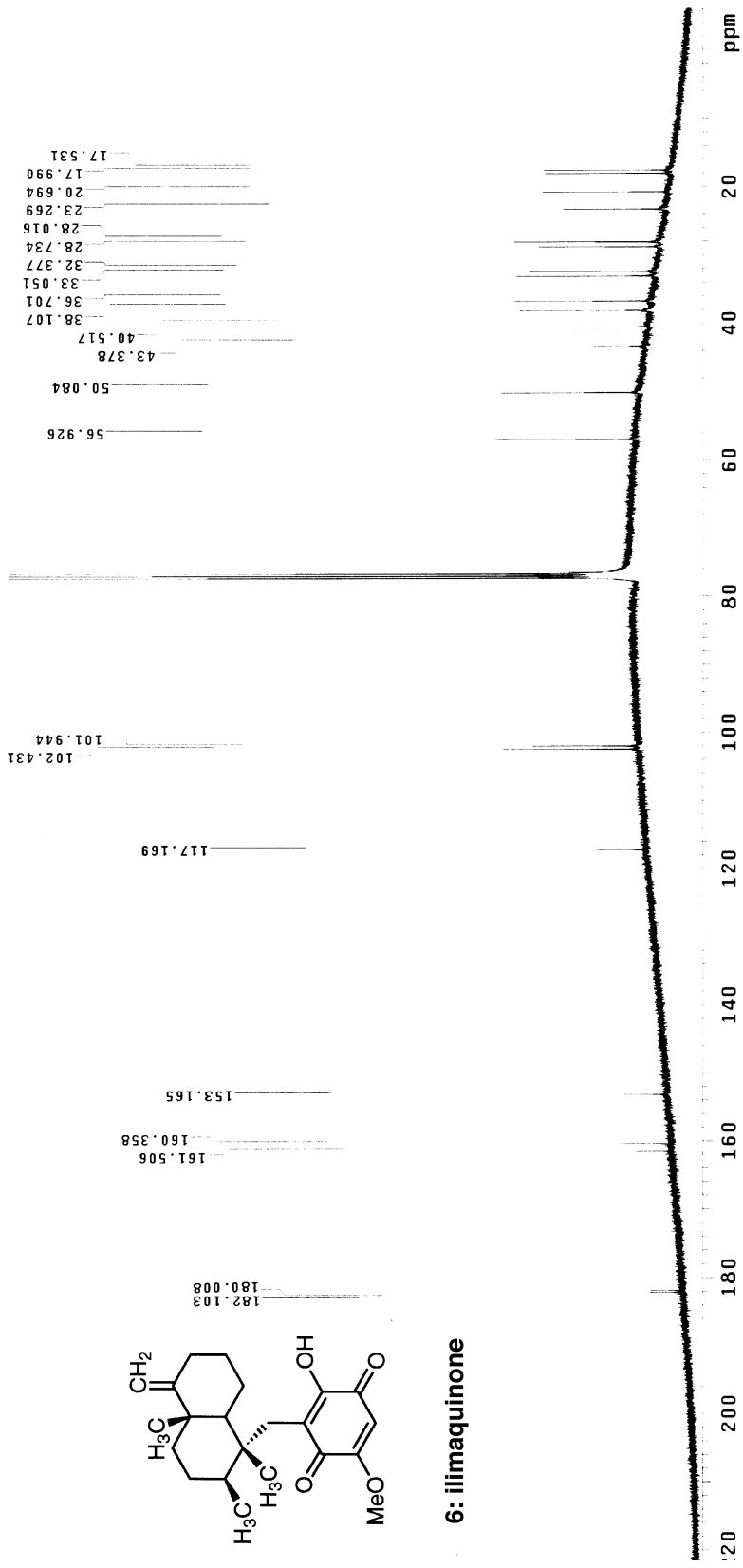




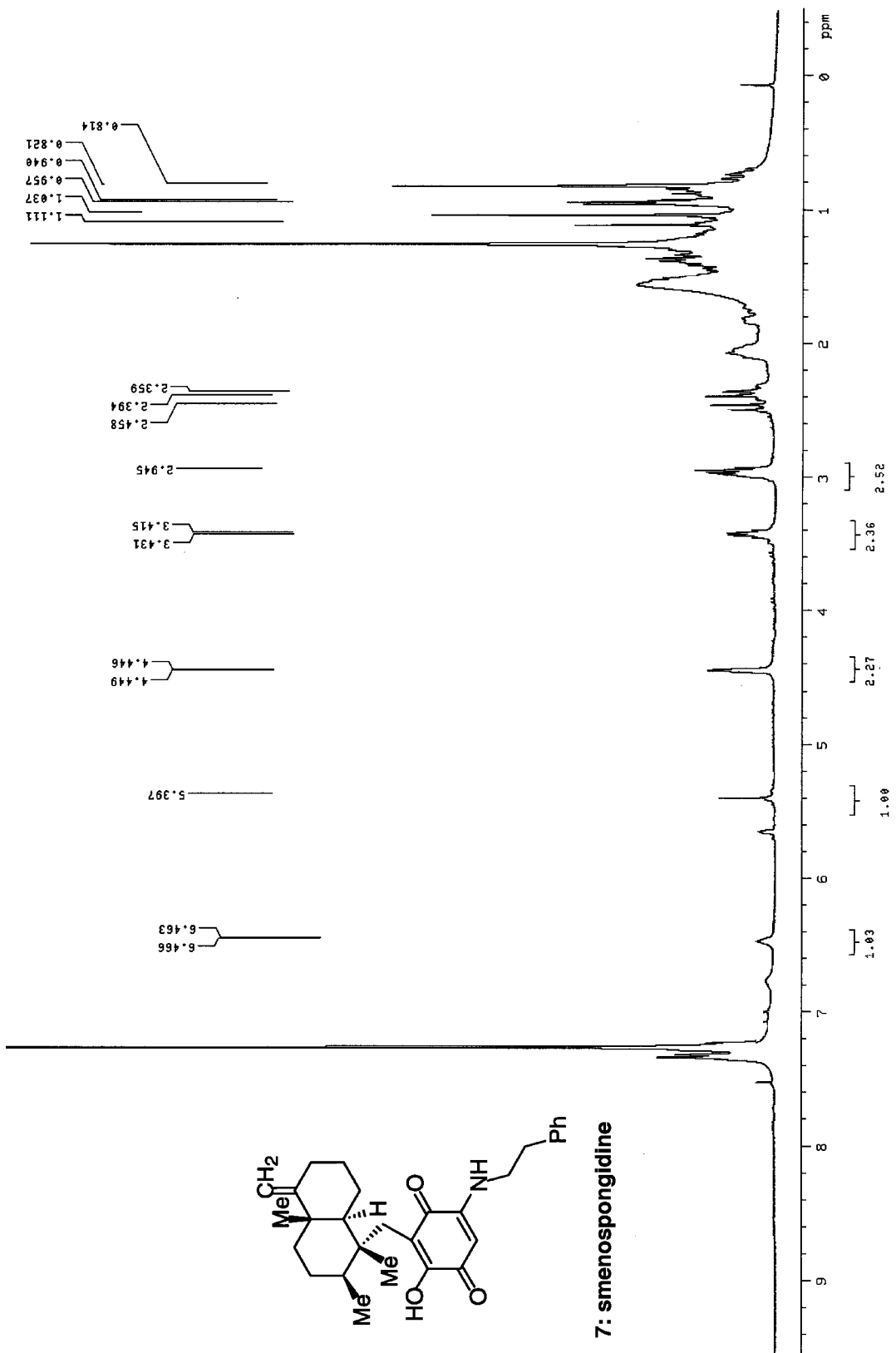


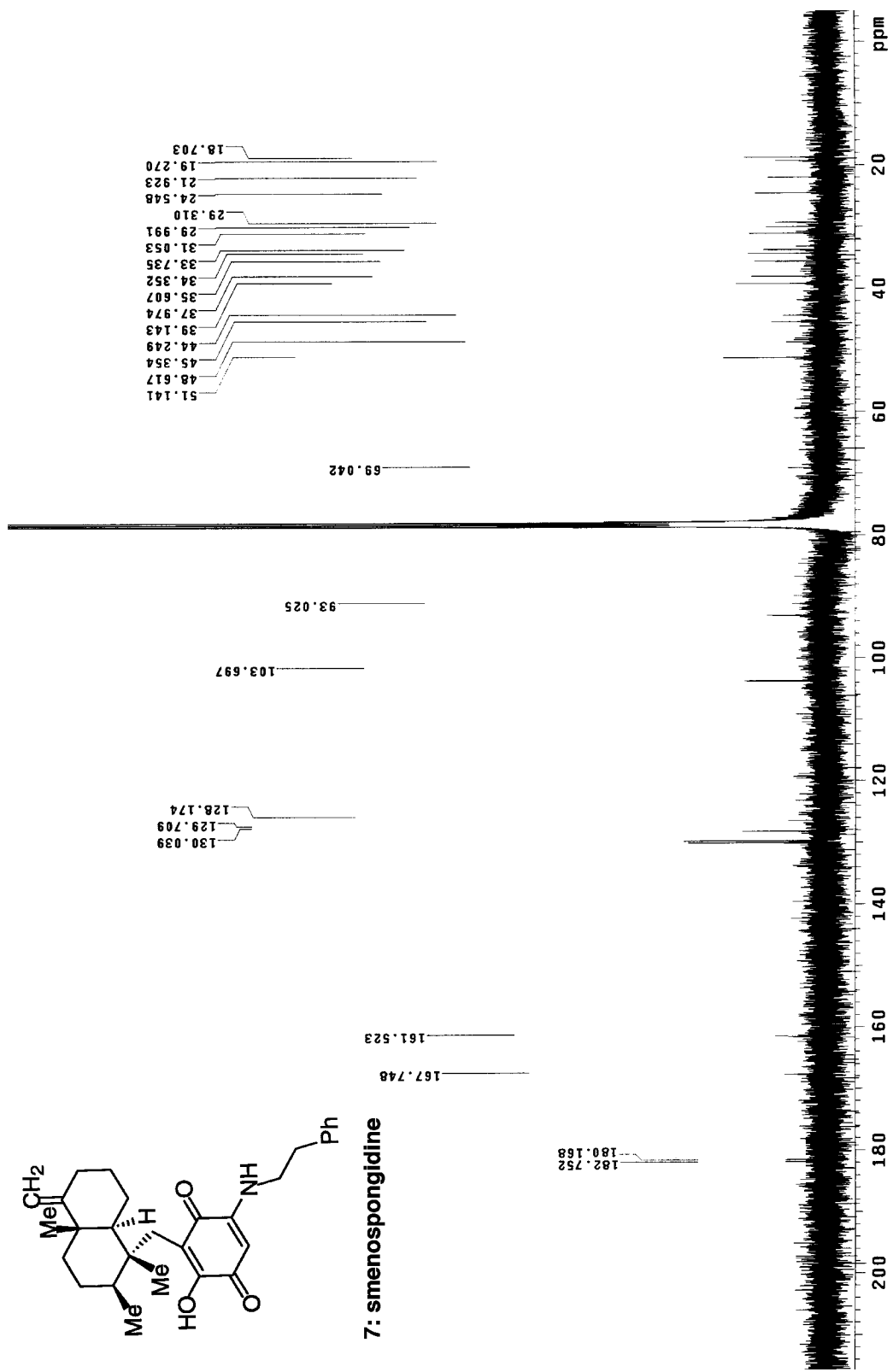
6: ilimaquinone

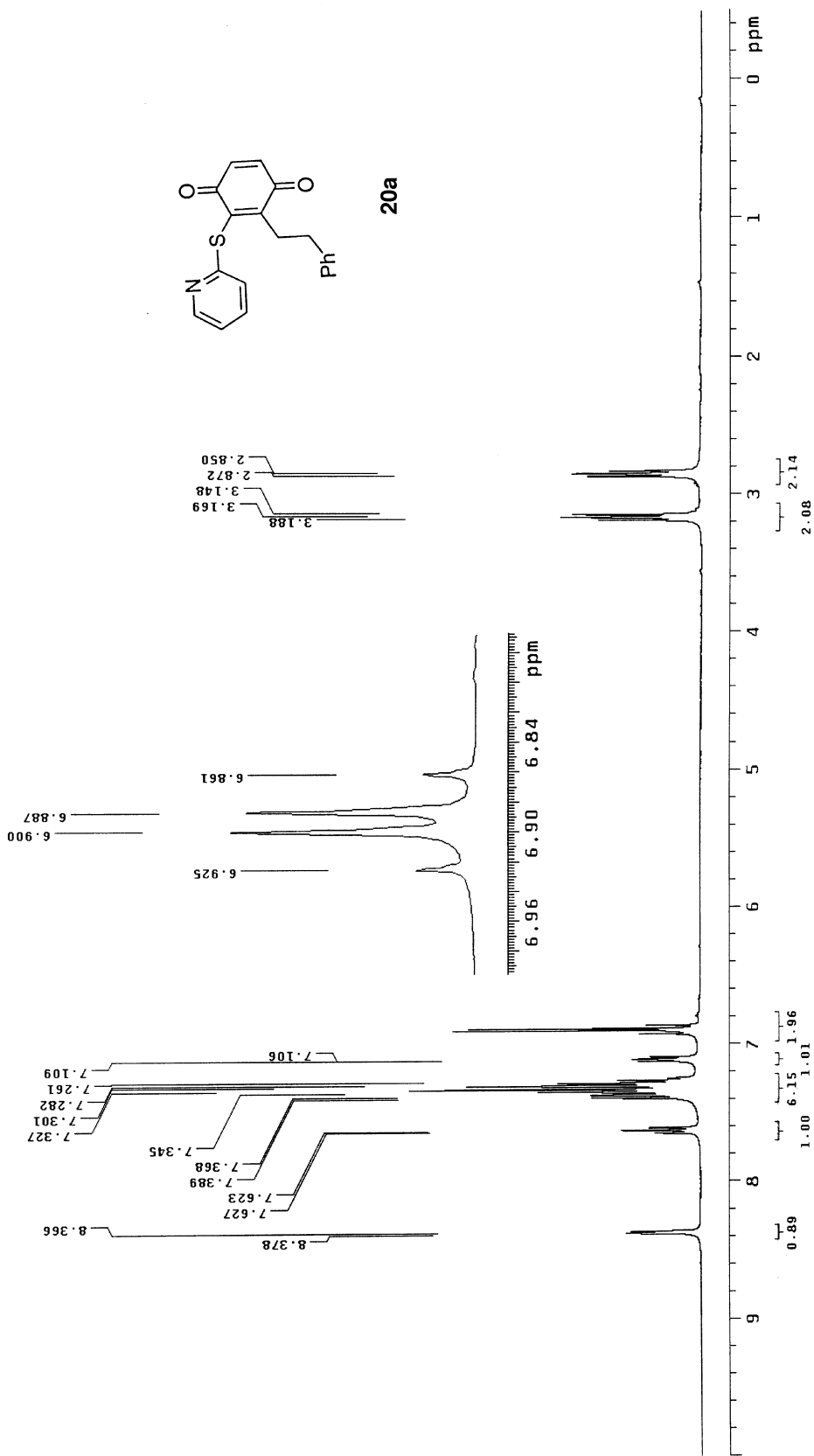


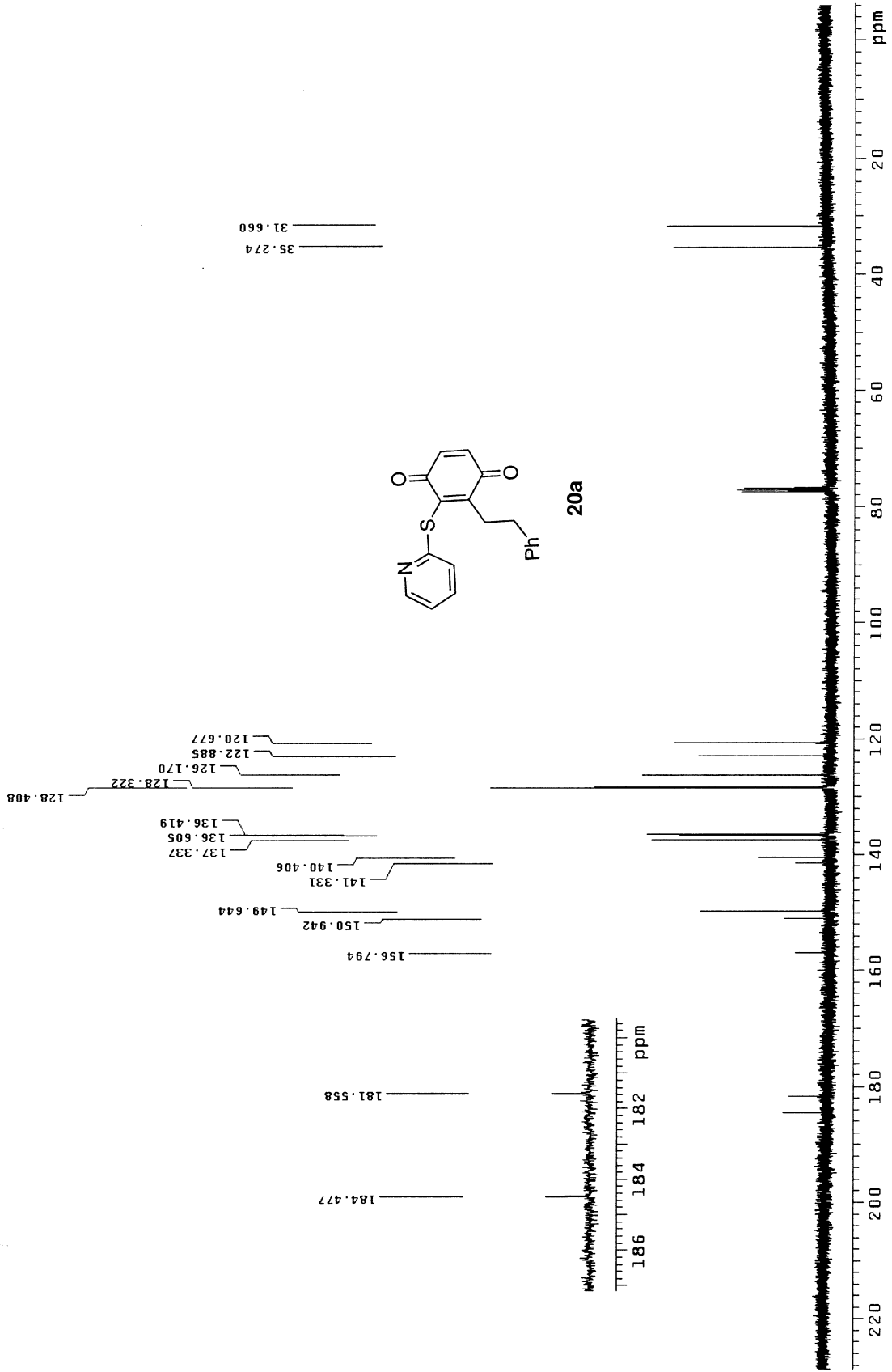


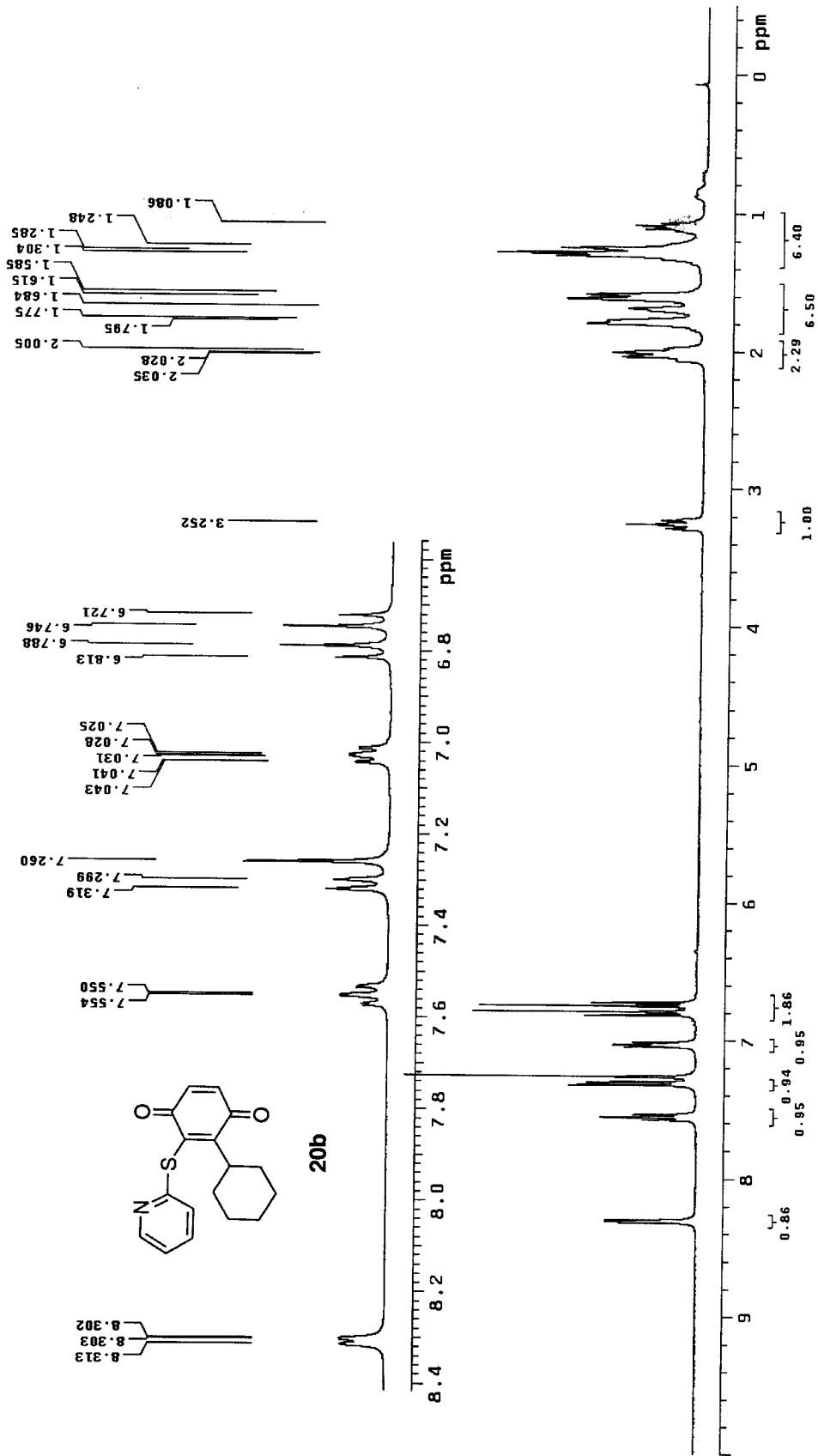
6: ilimaquinone

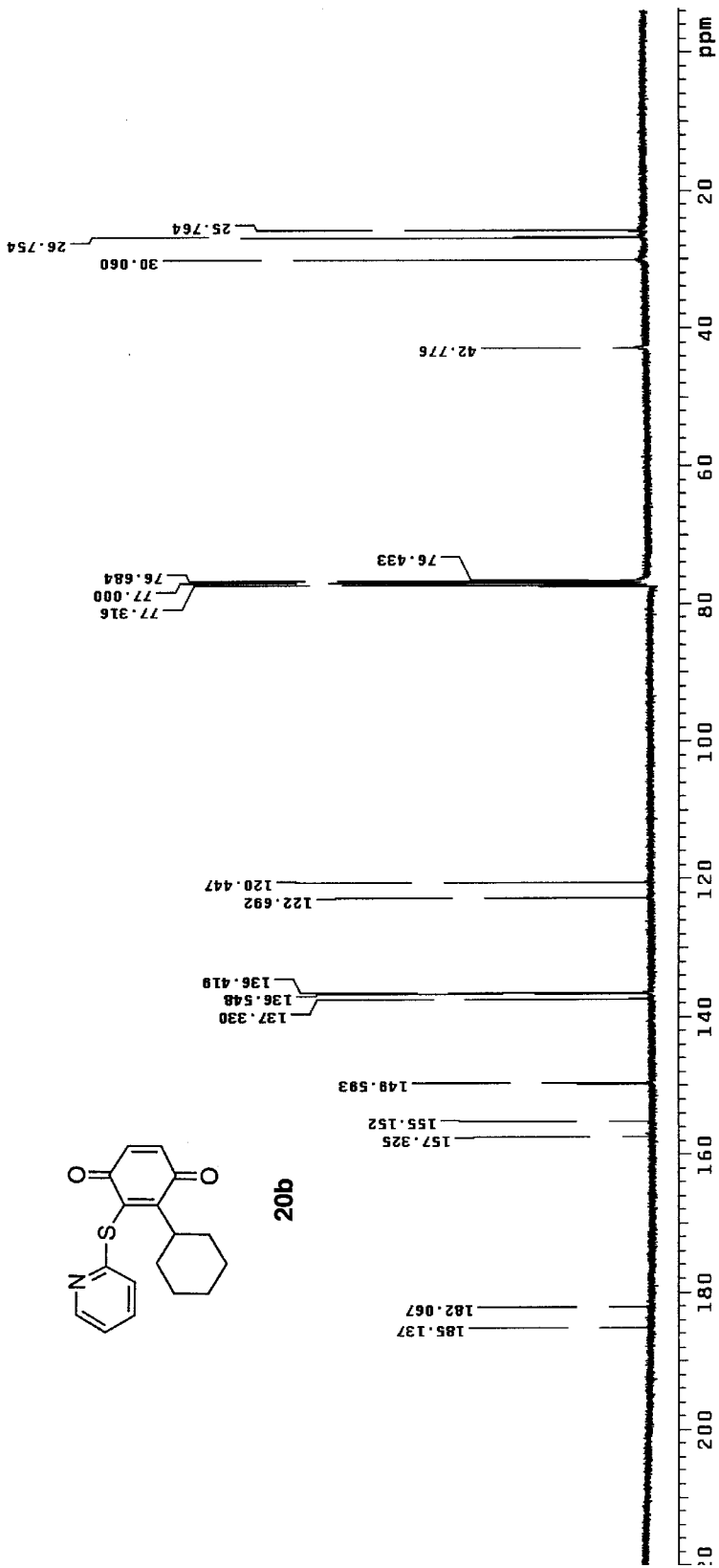


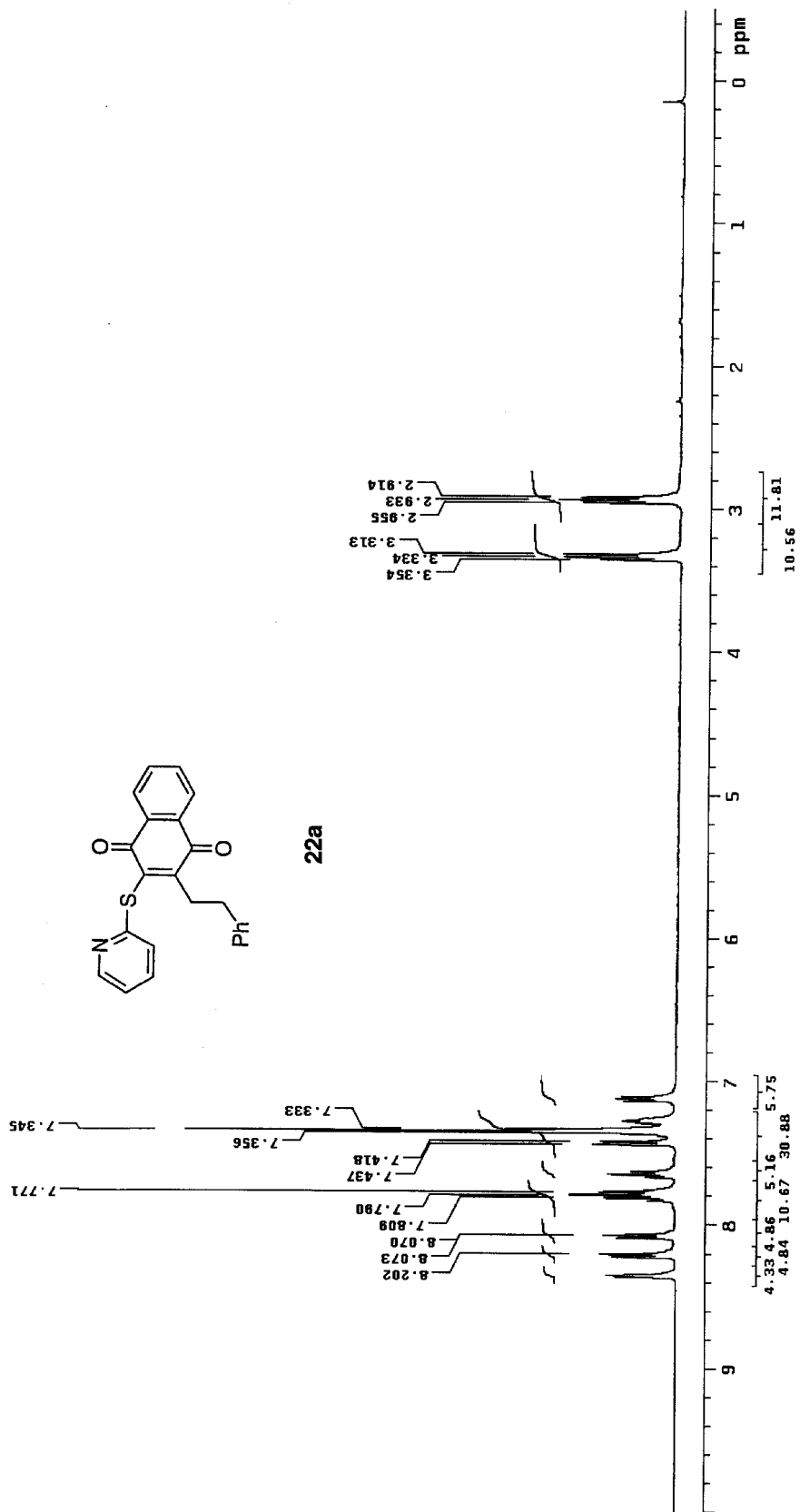


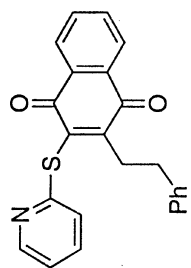




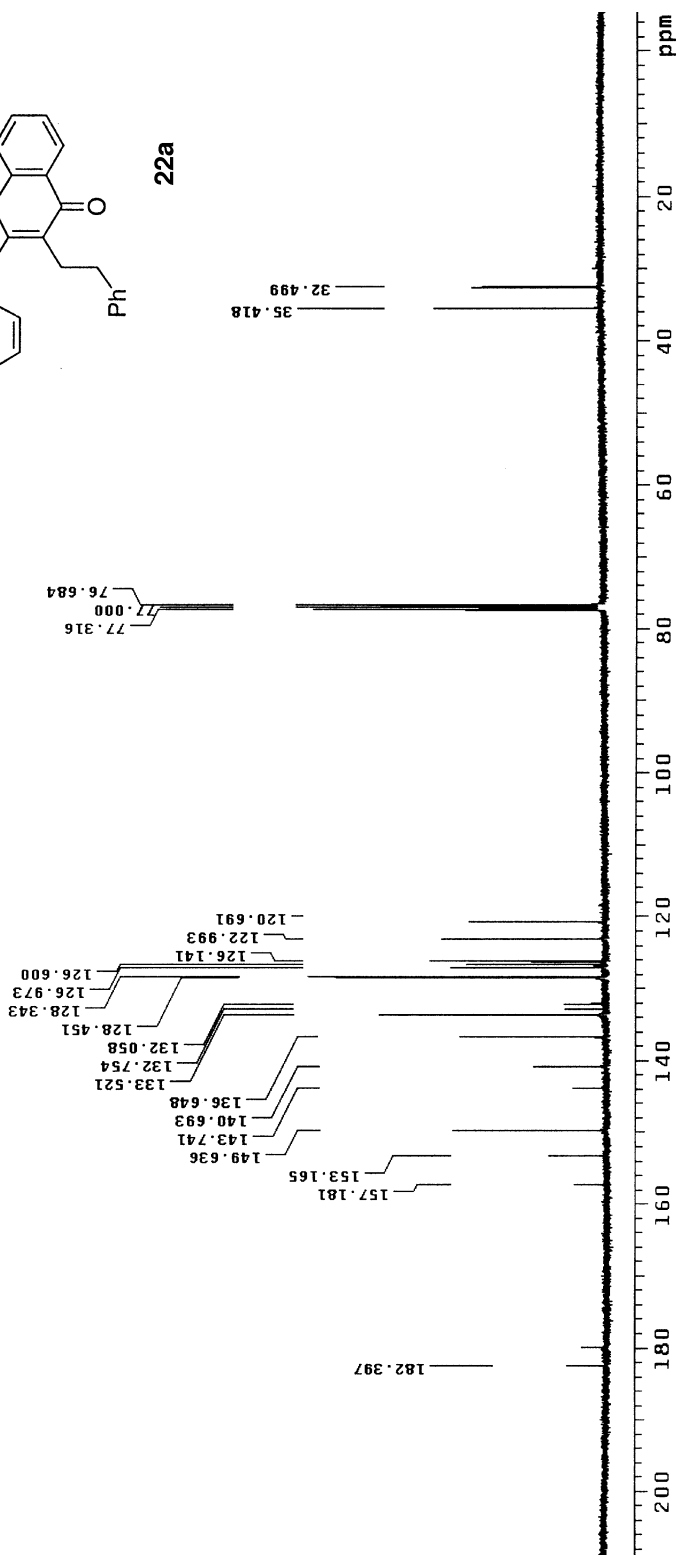


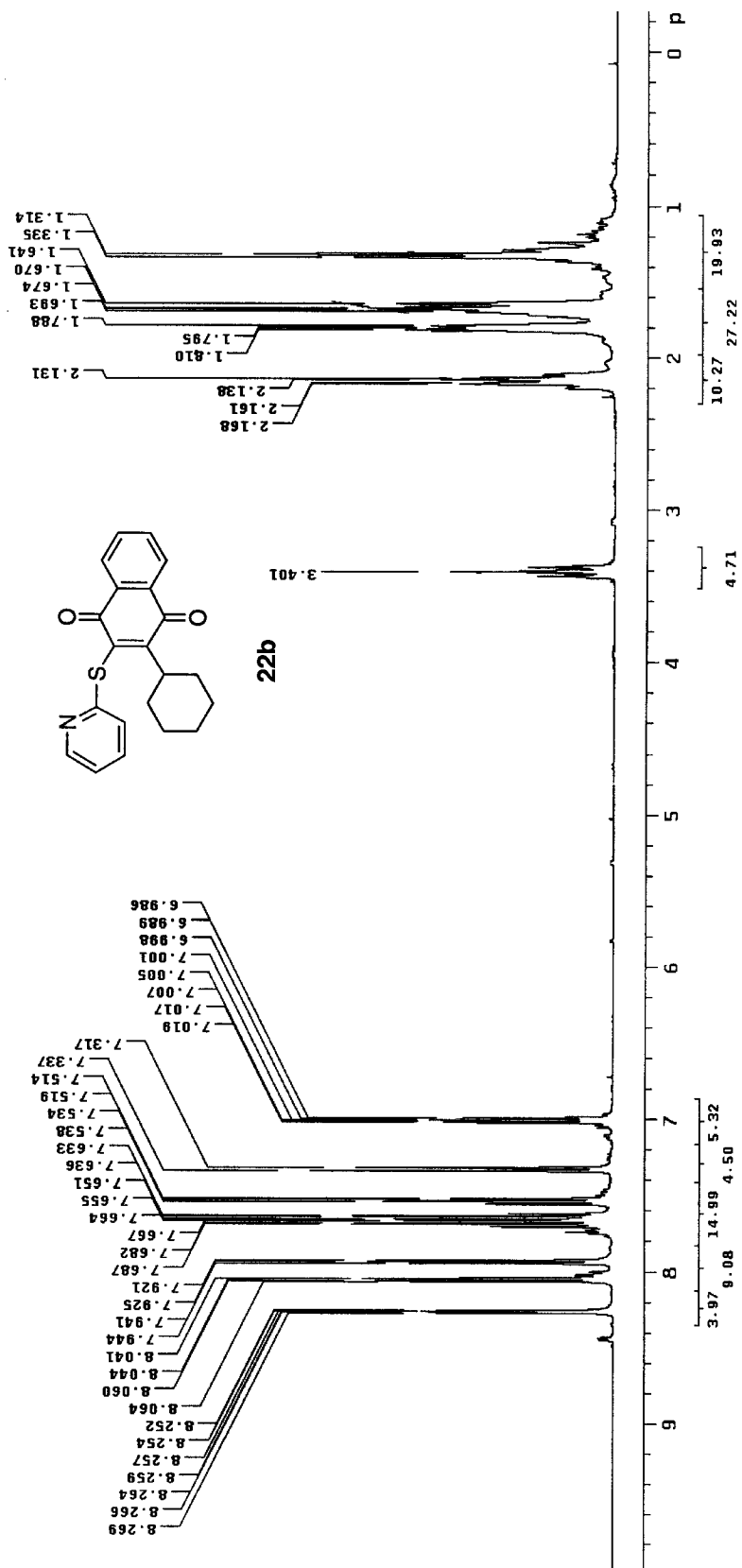


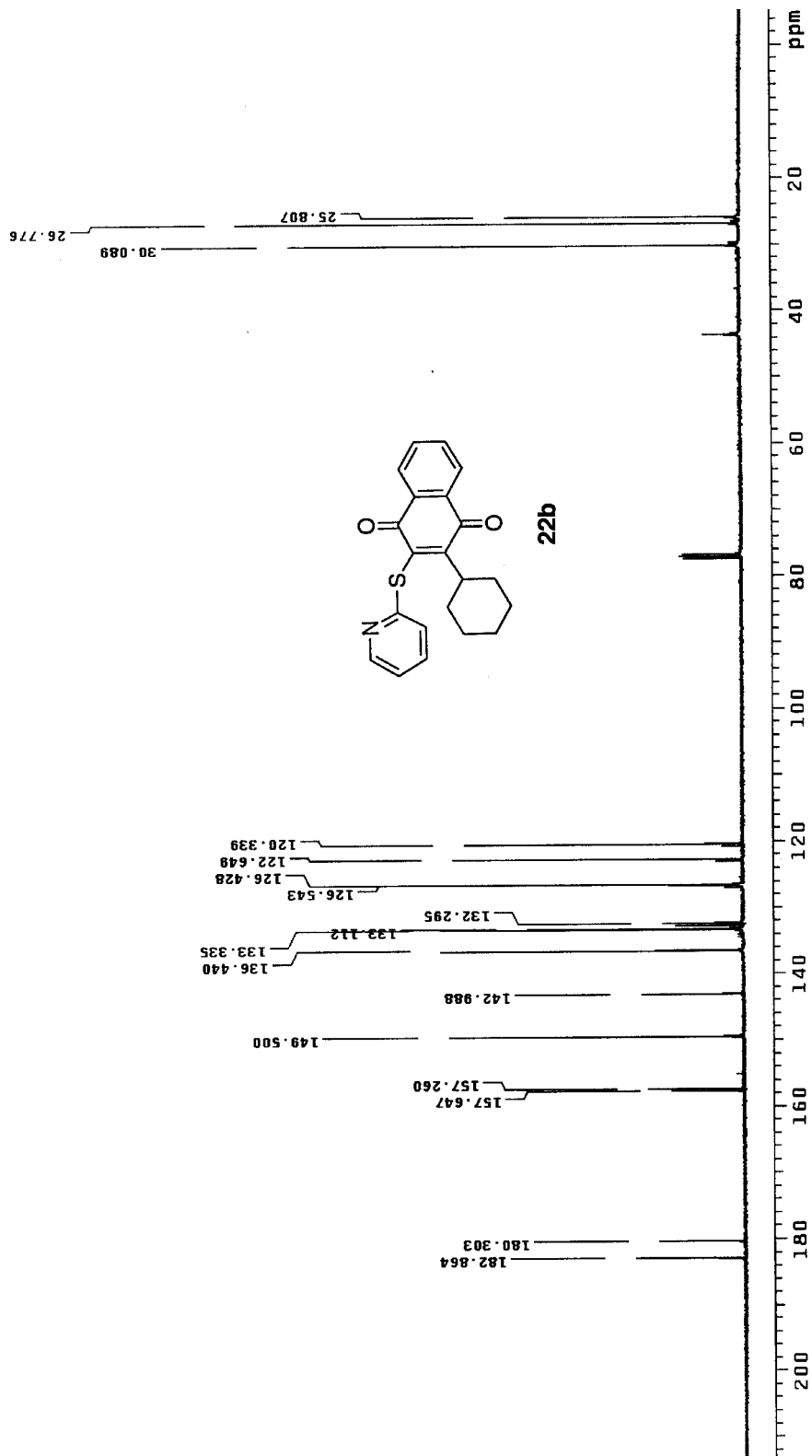


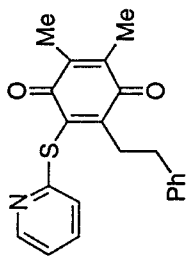


22a

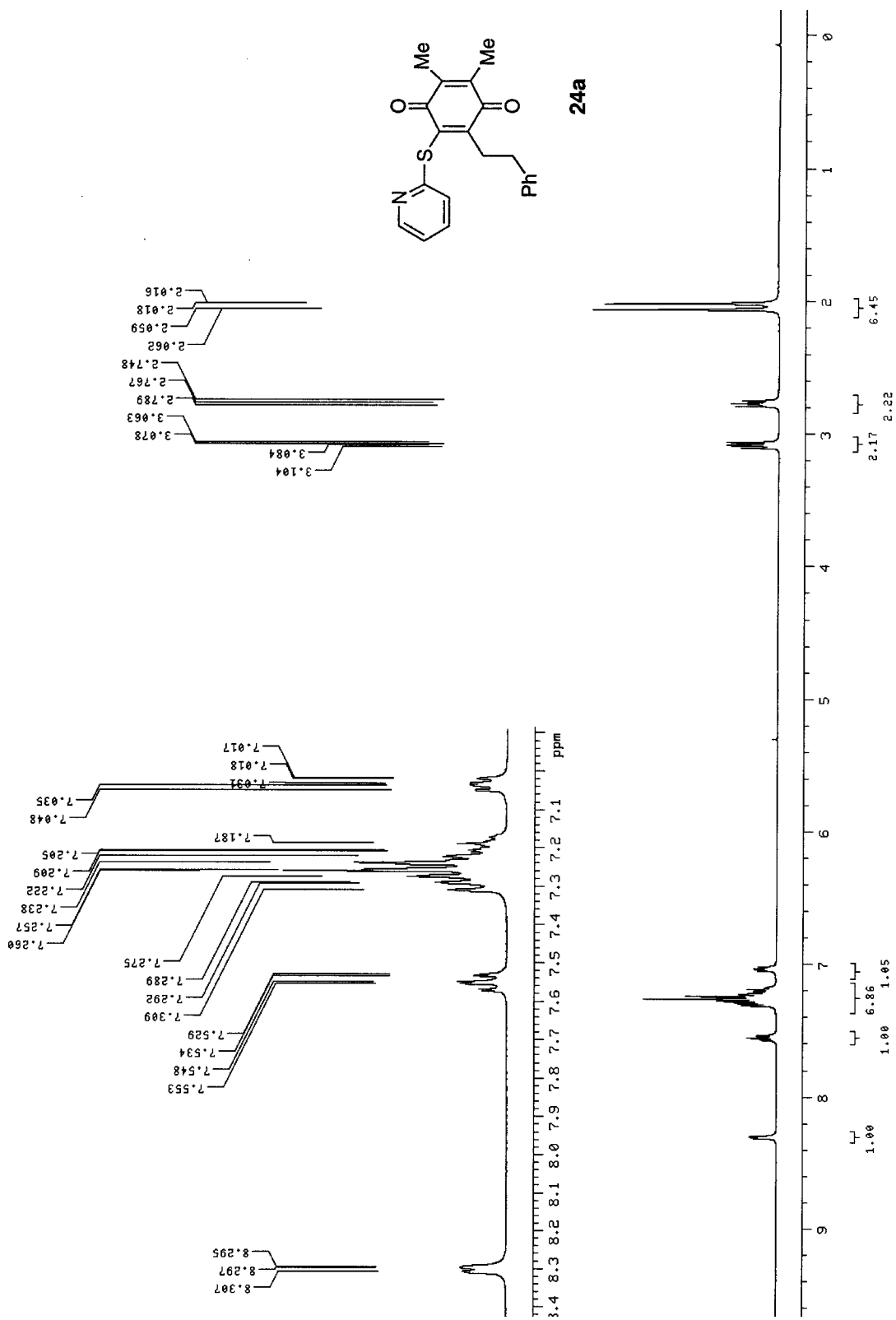


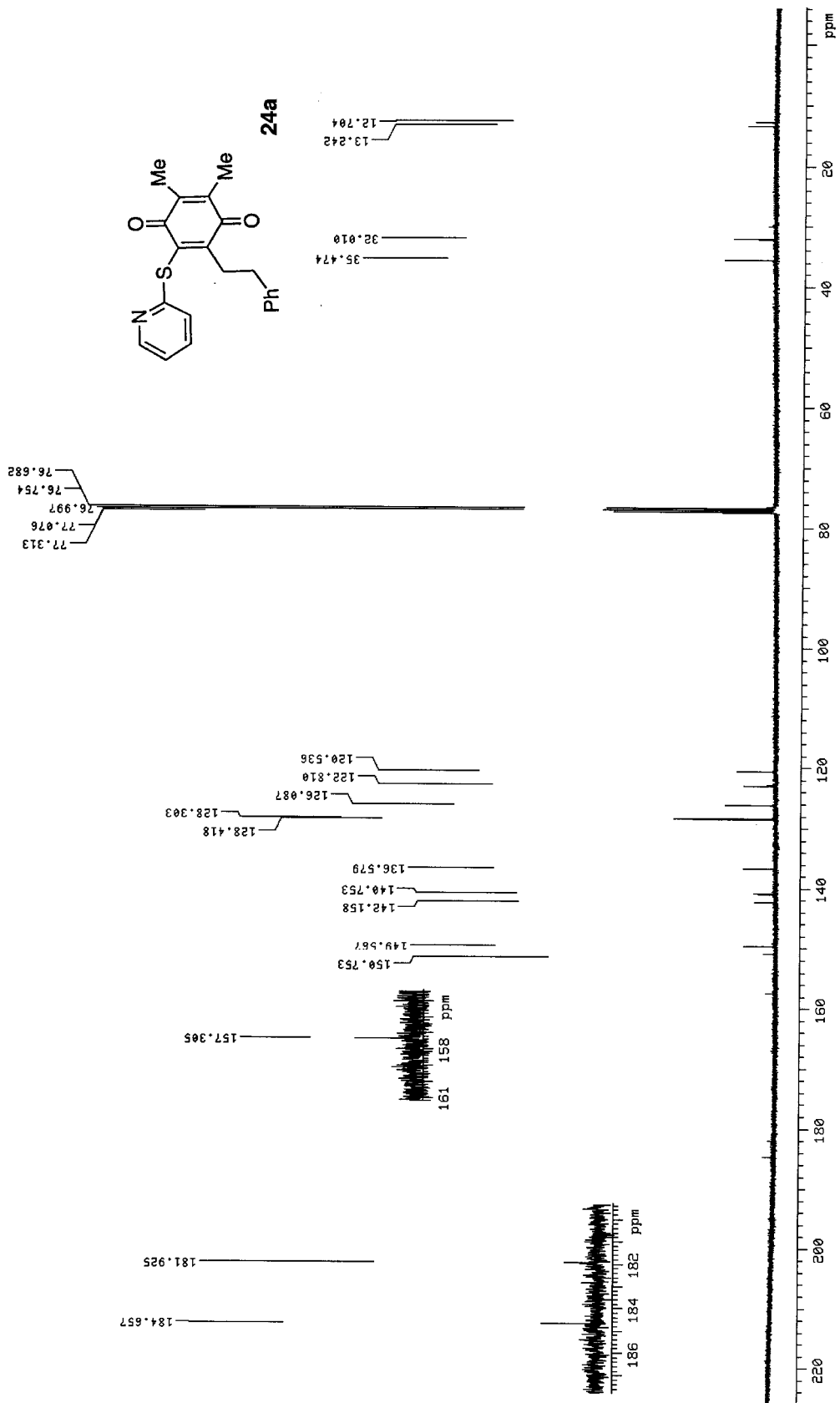


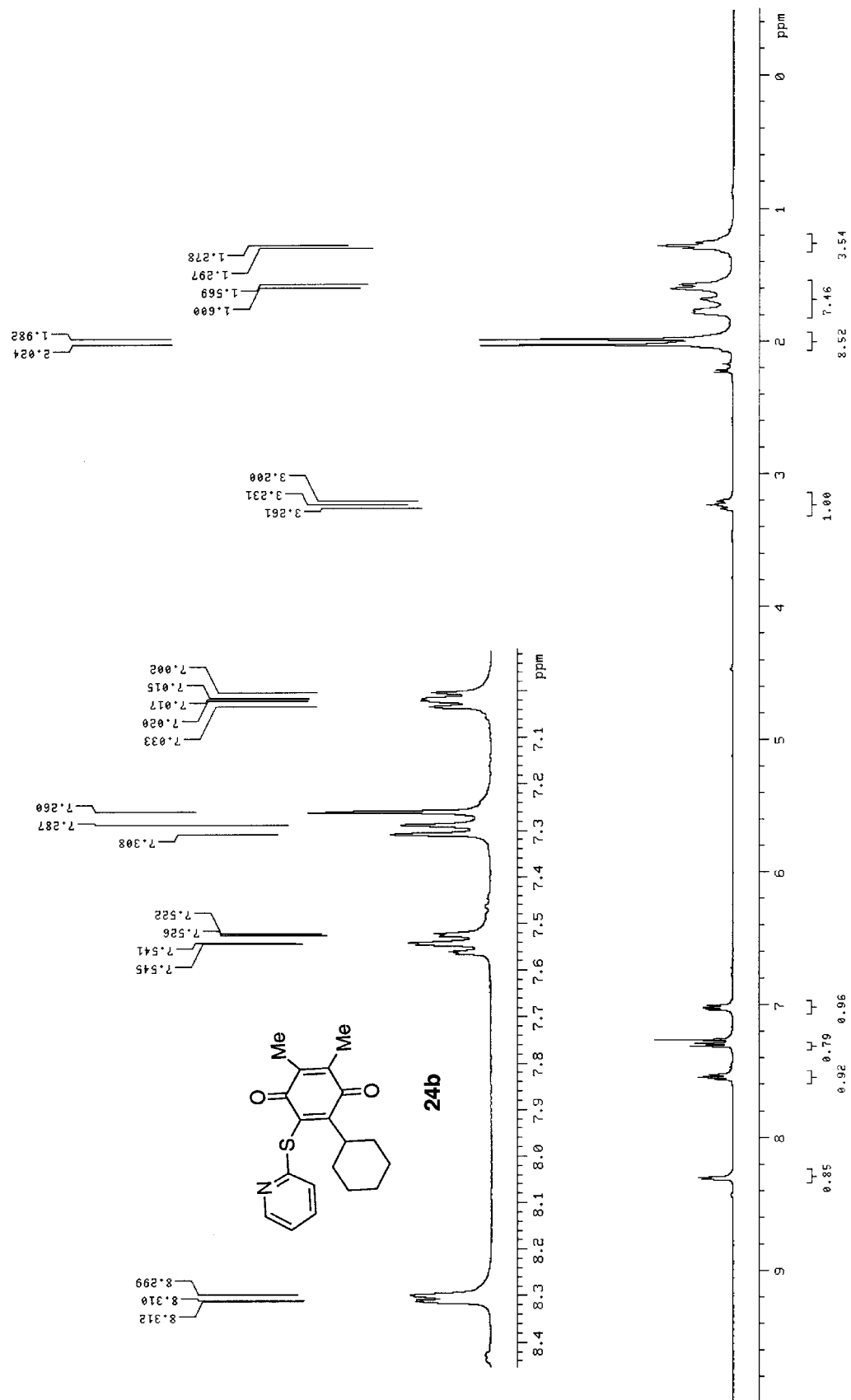


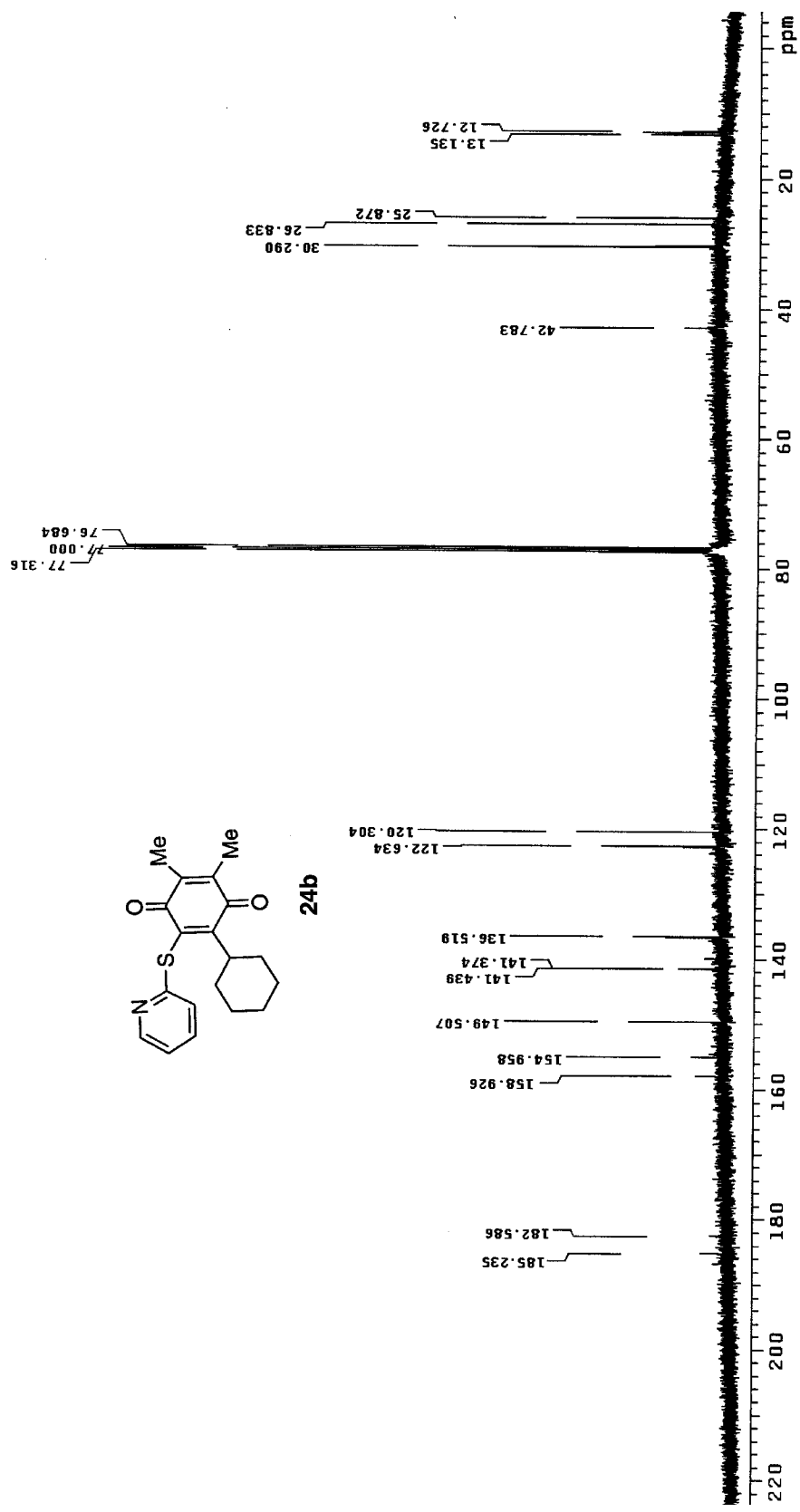


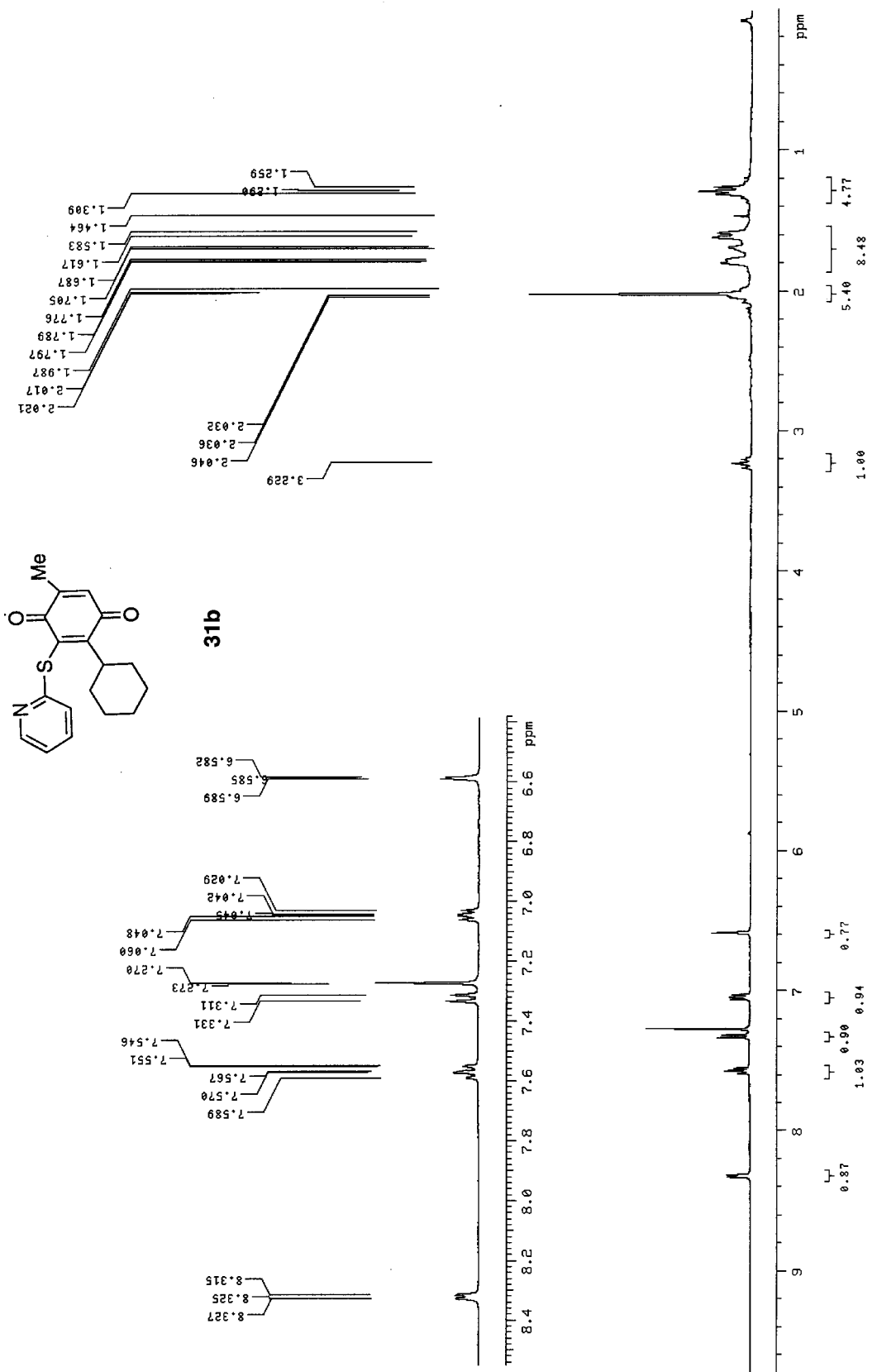
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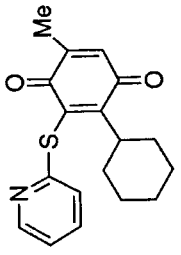
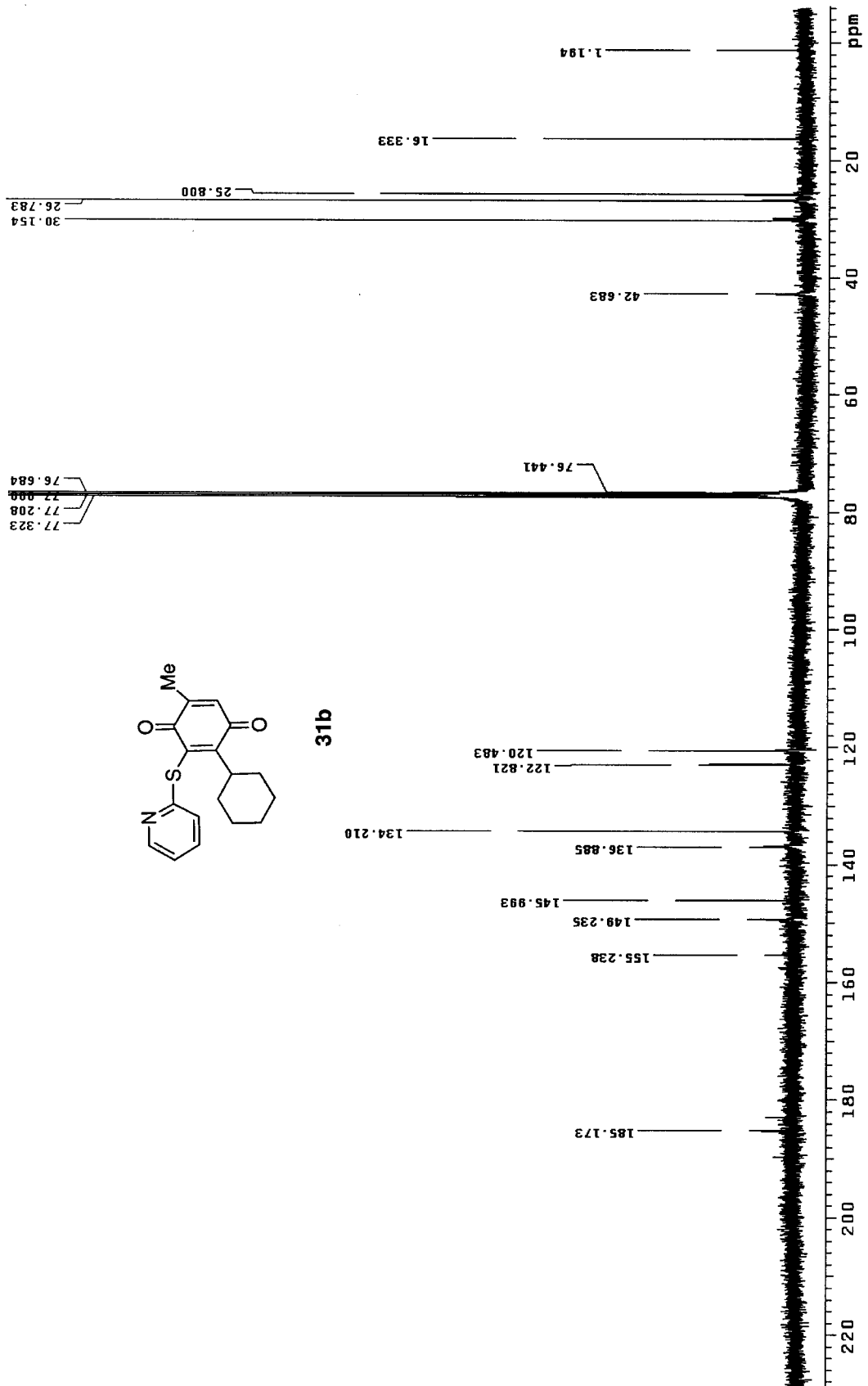




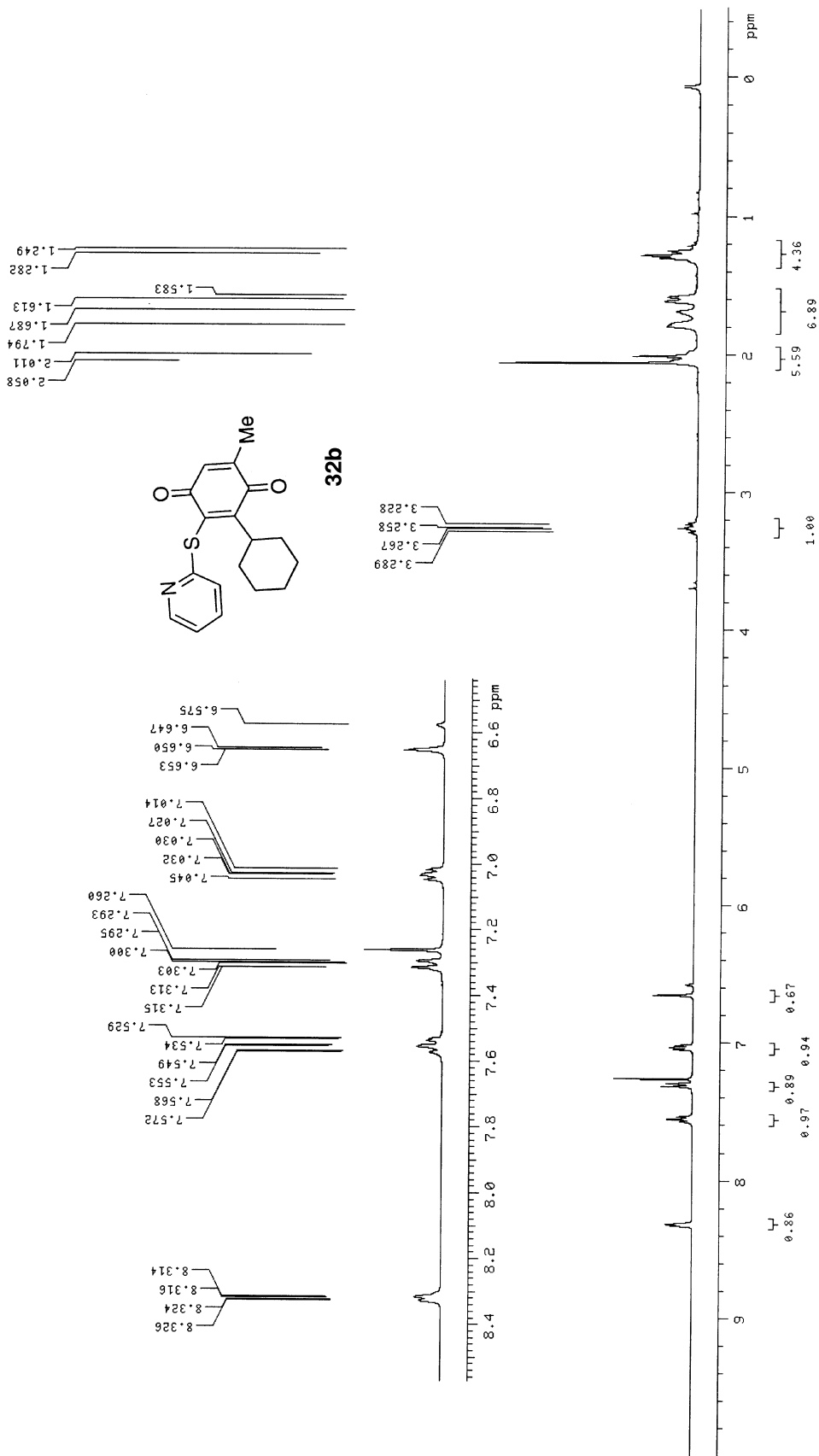


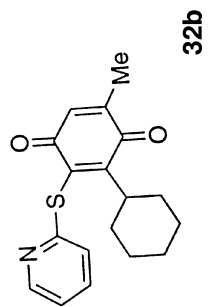
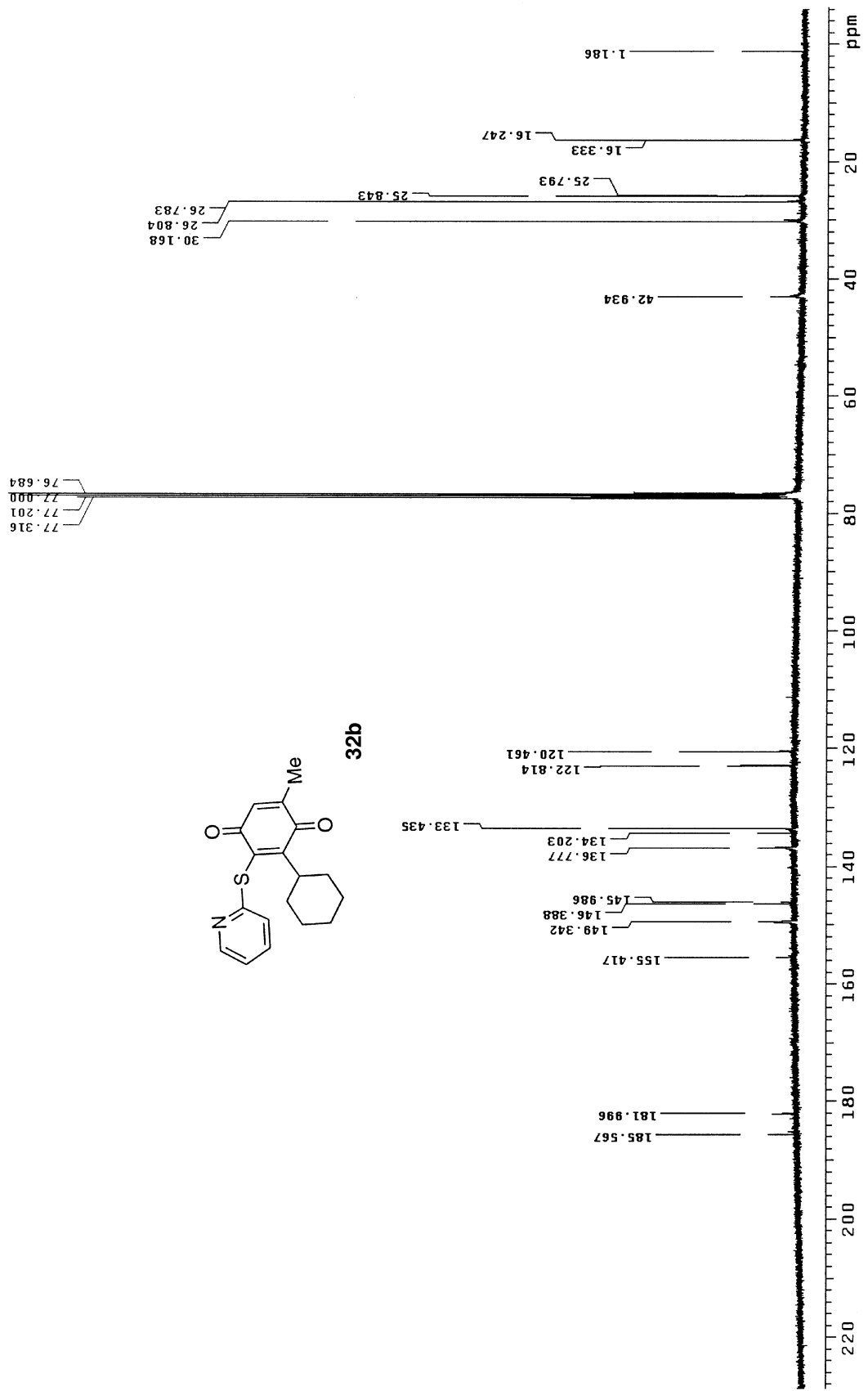


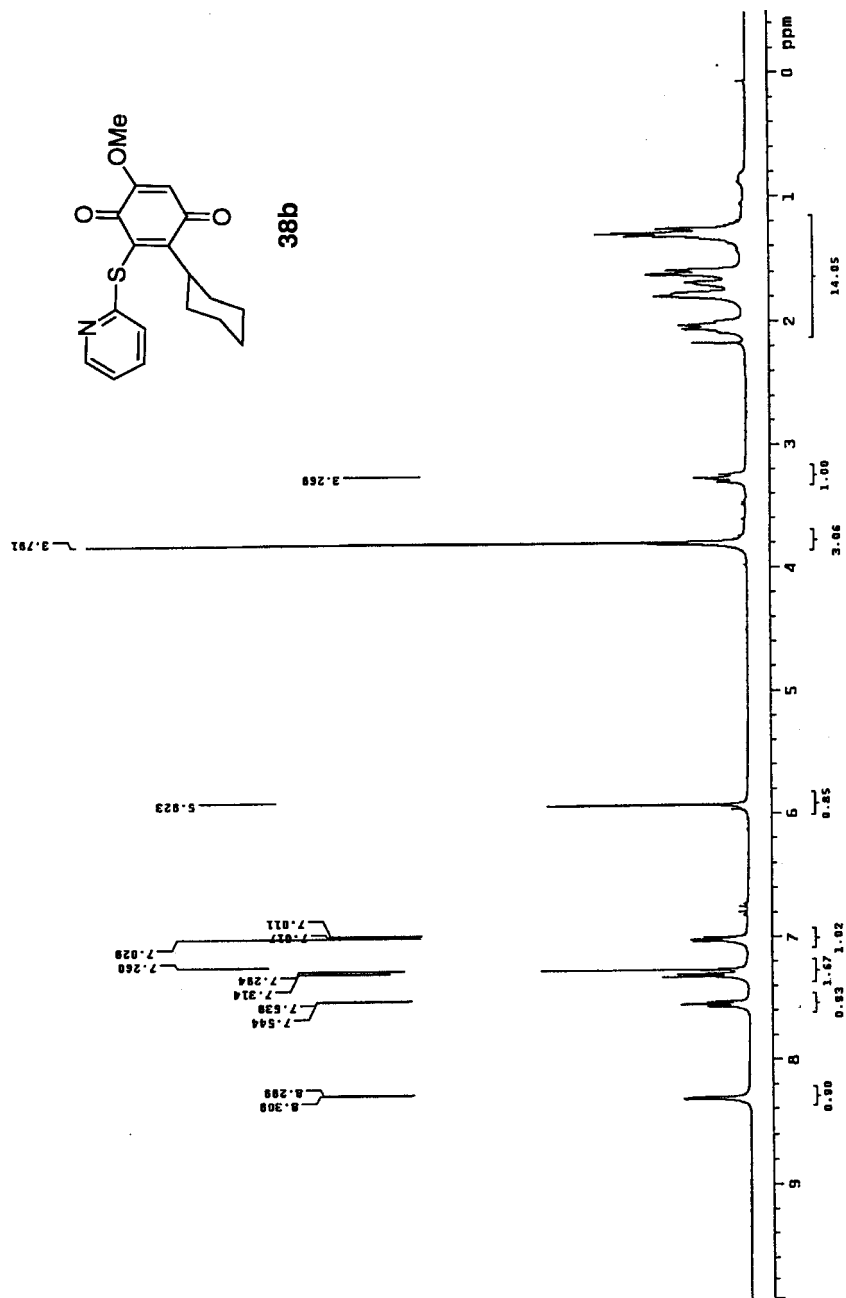


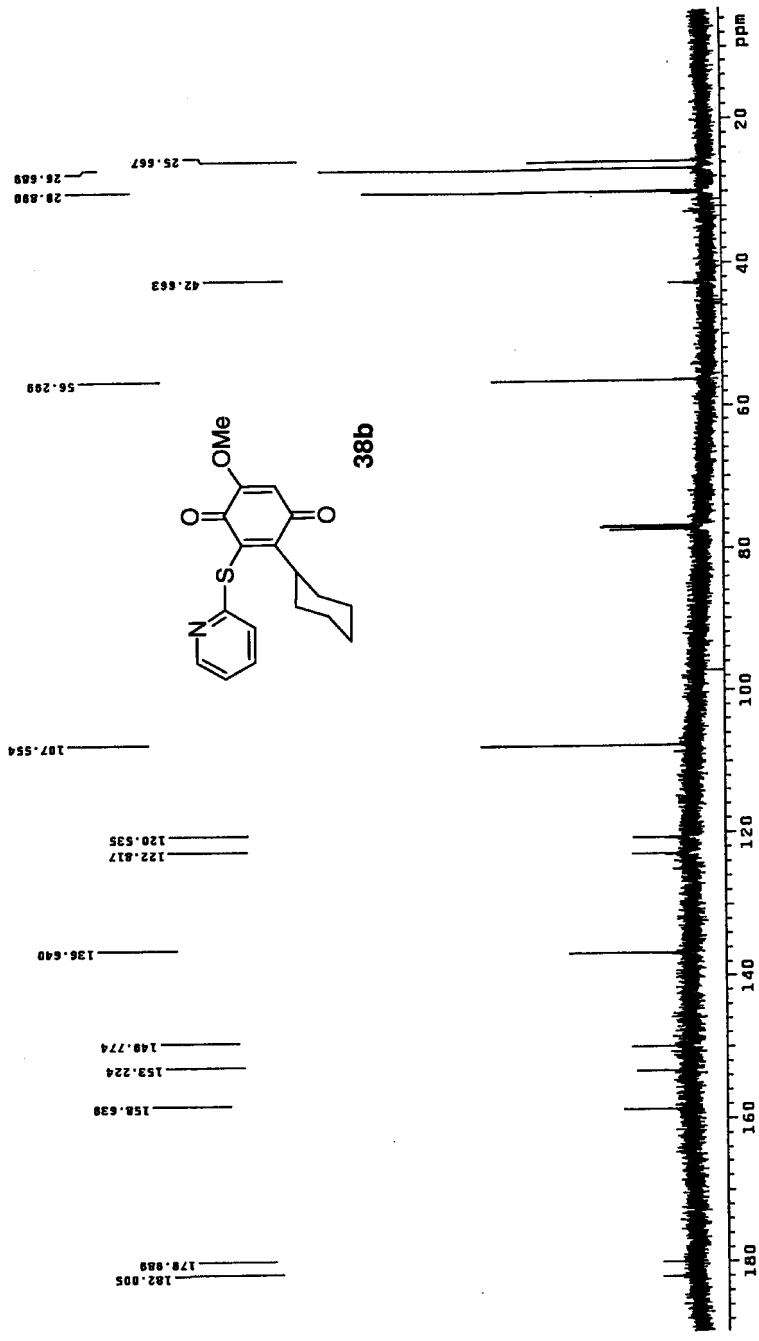


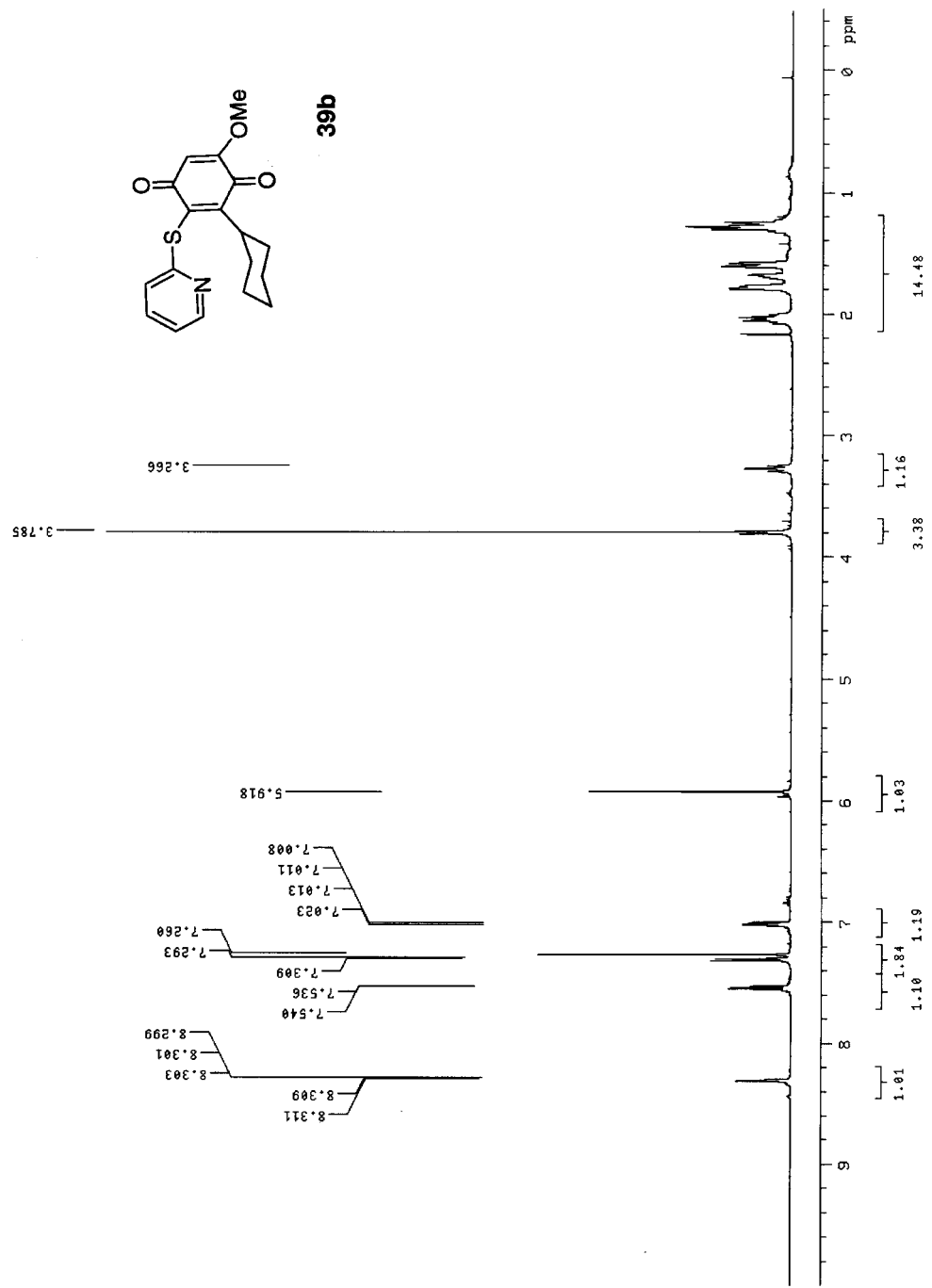
31b

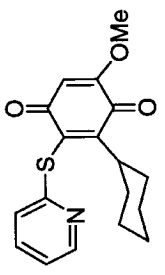
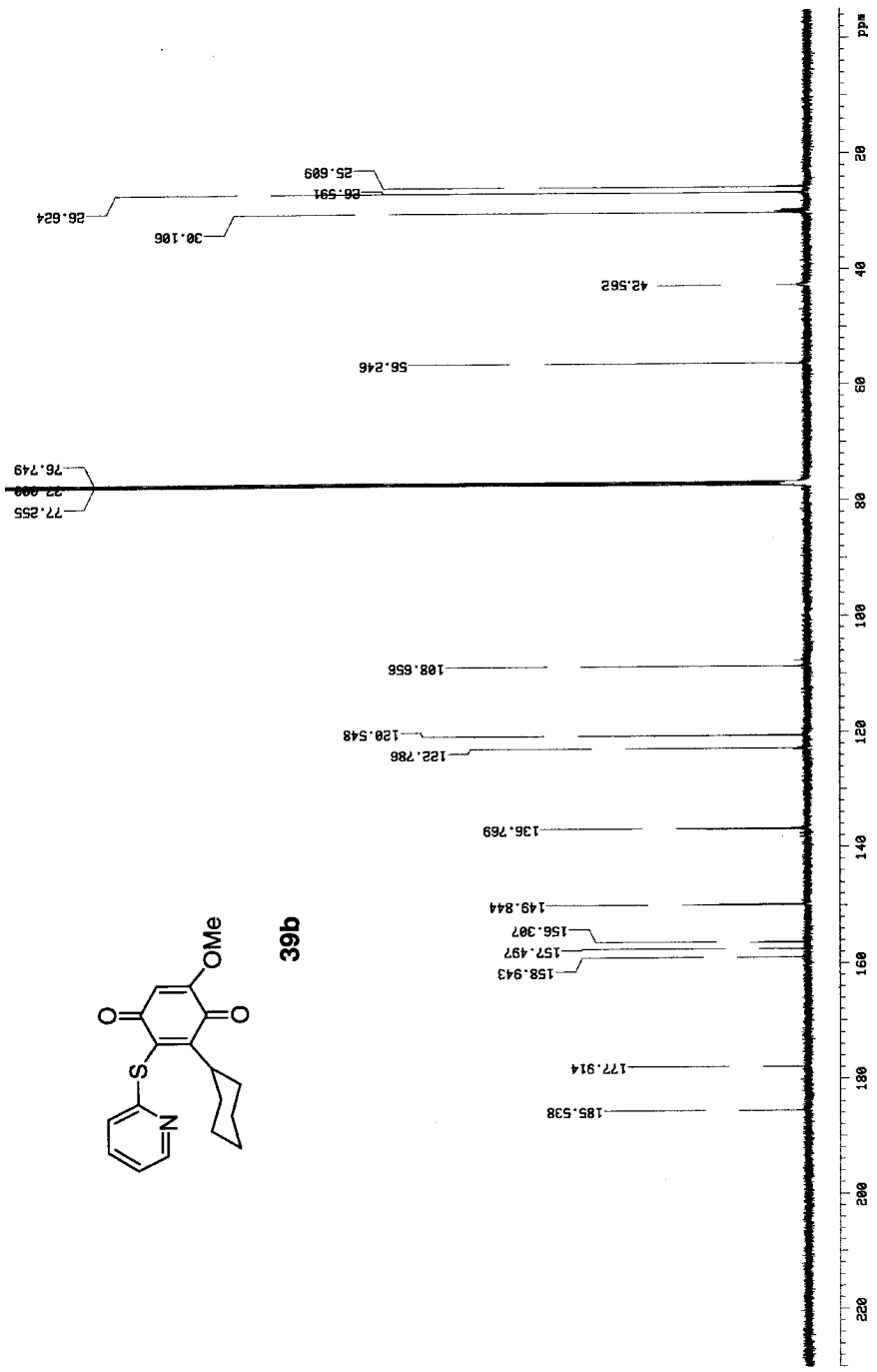




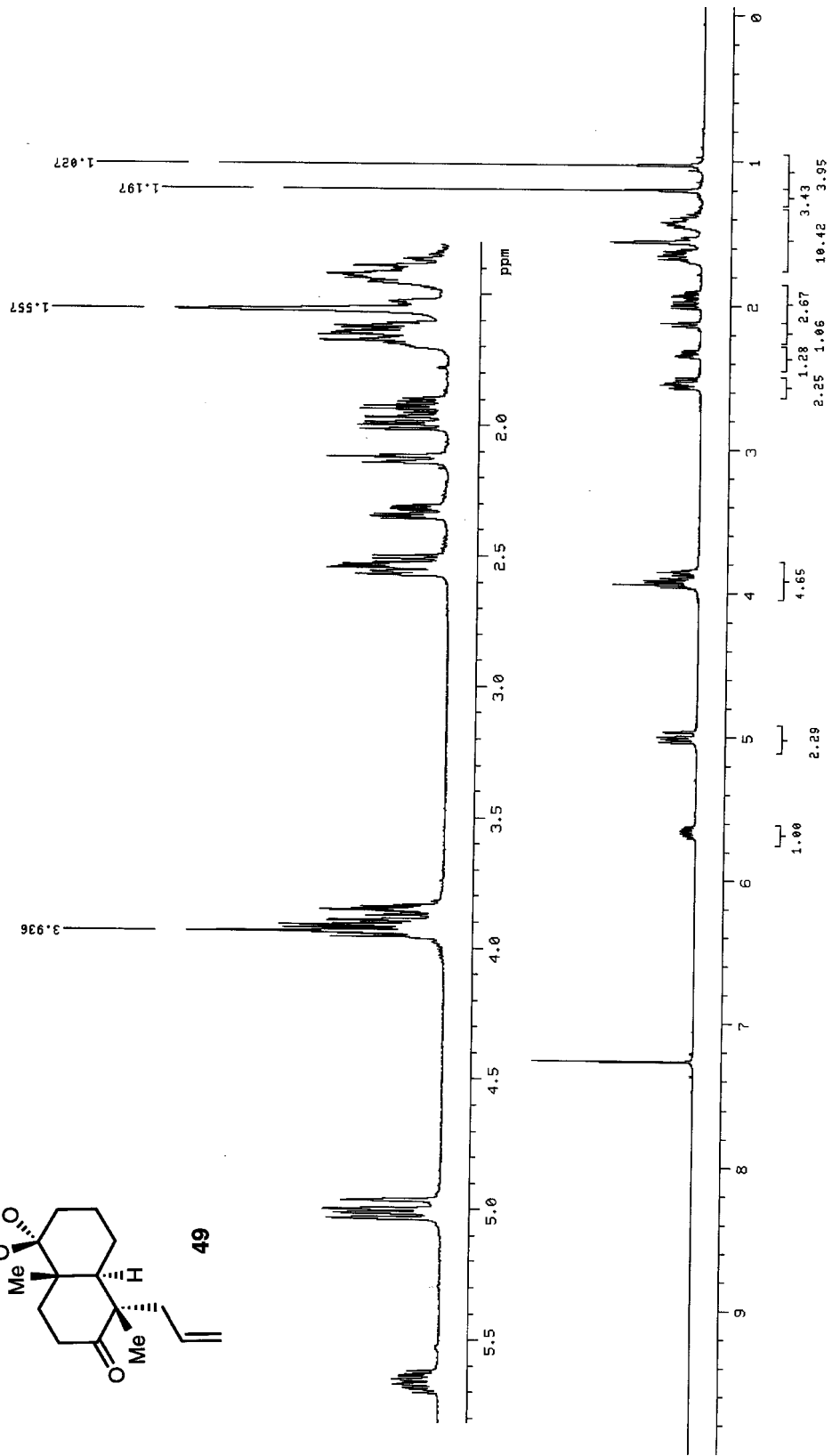
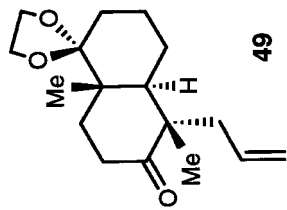


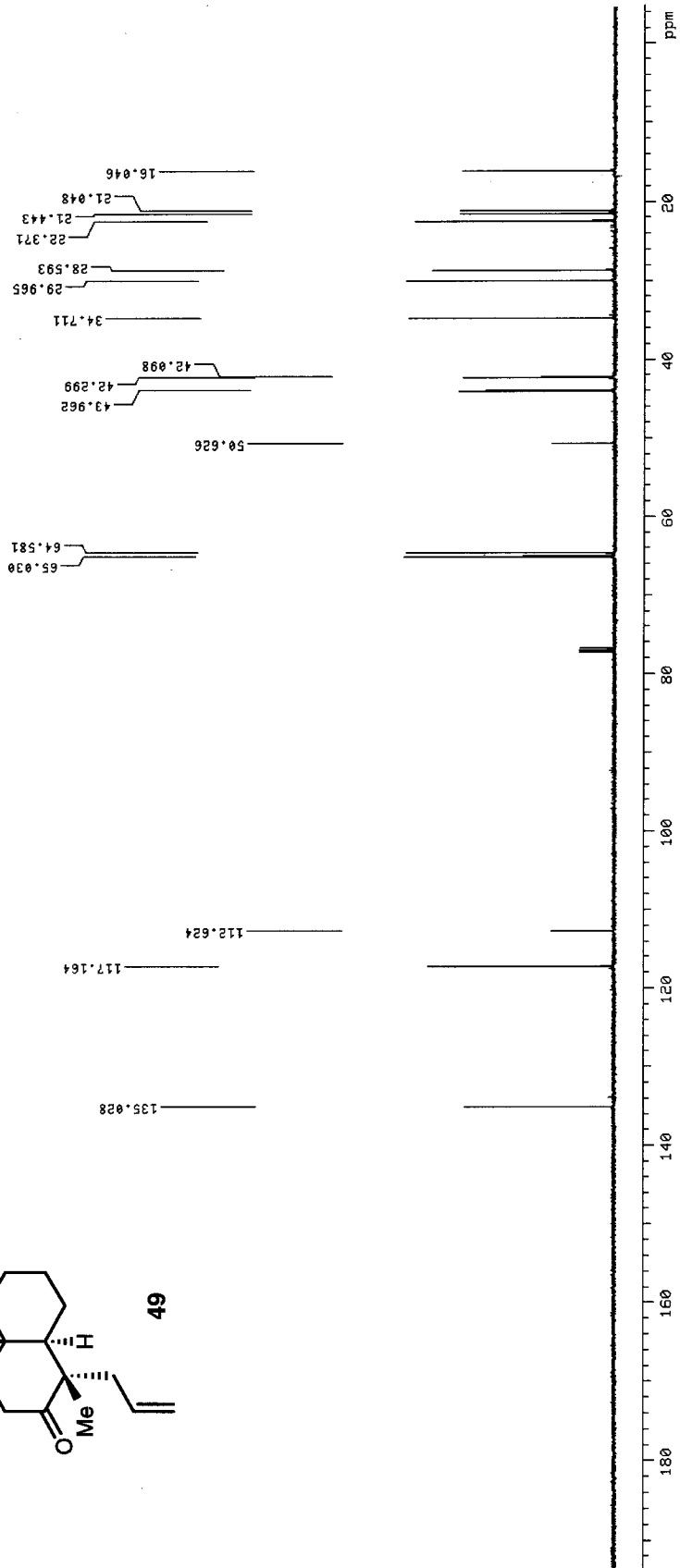
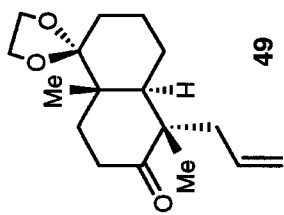


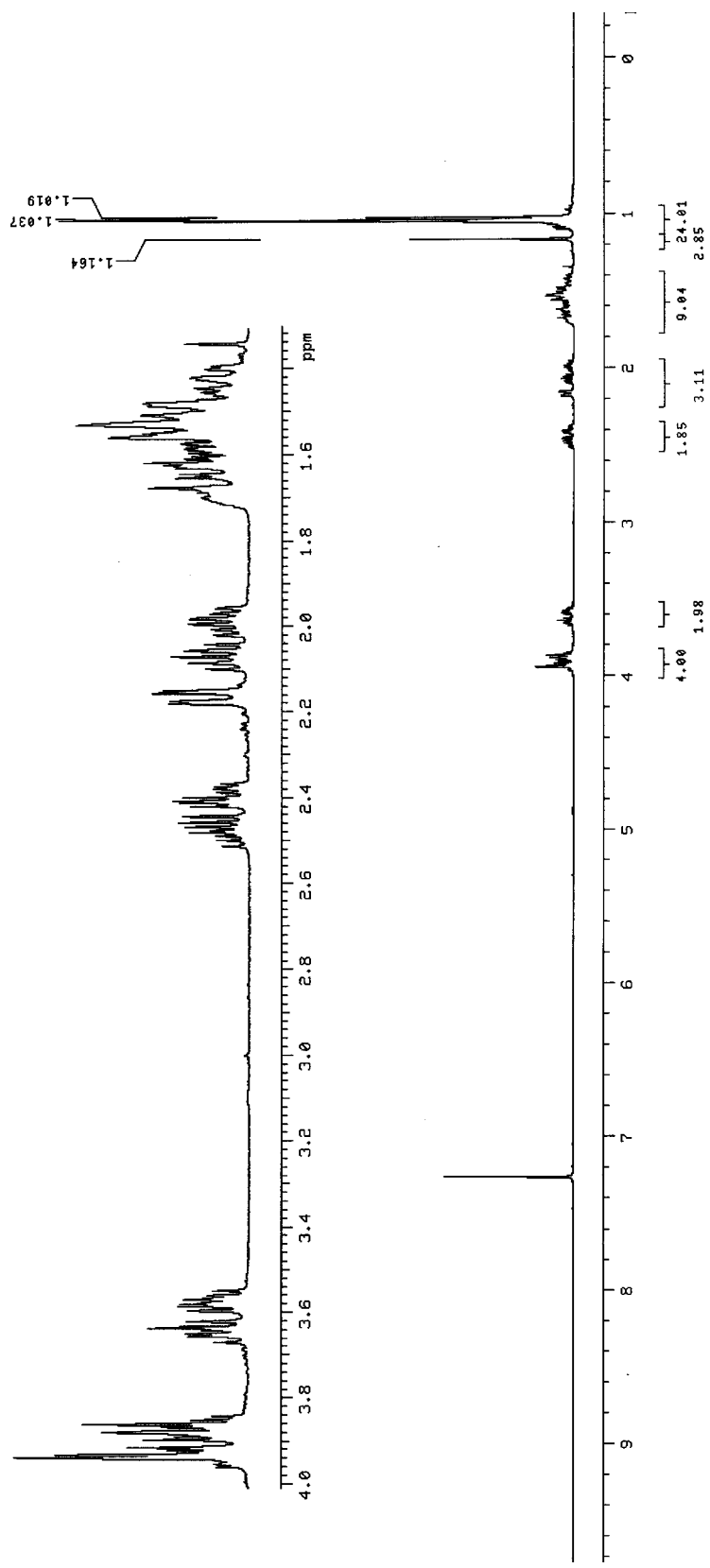
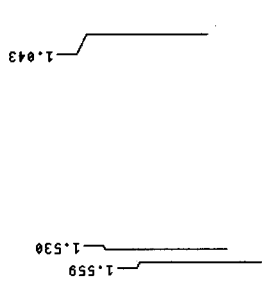
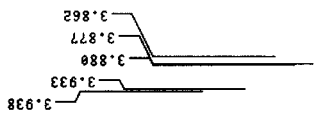
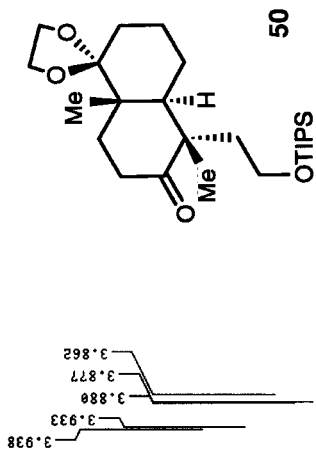


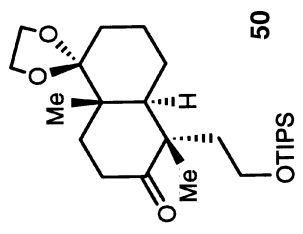
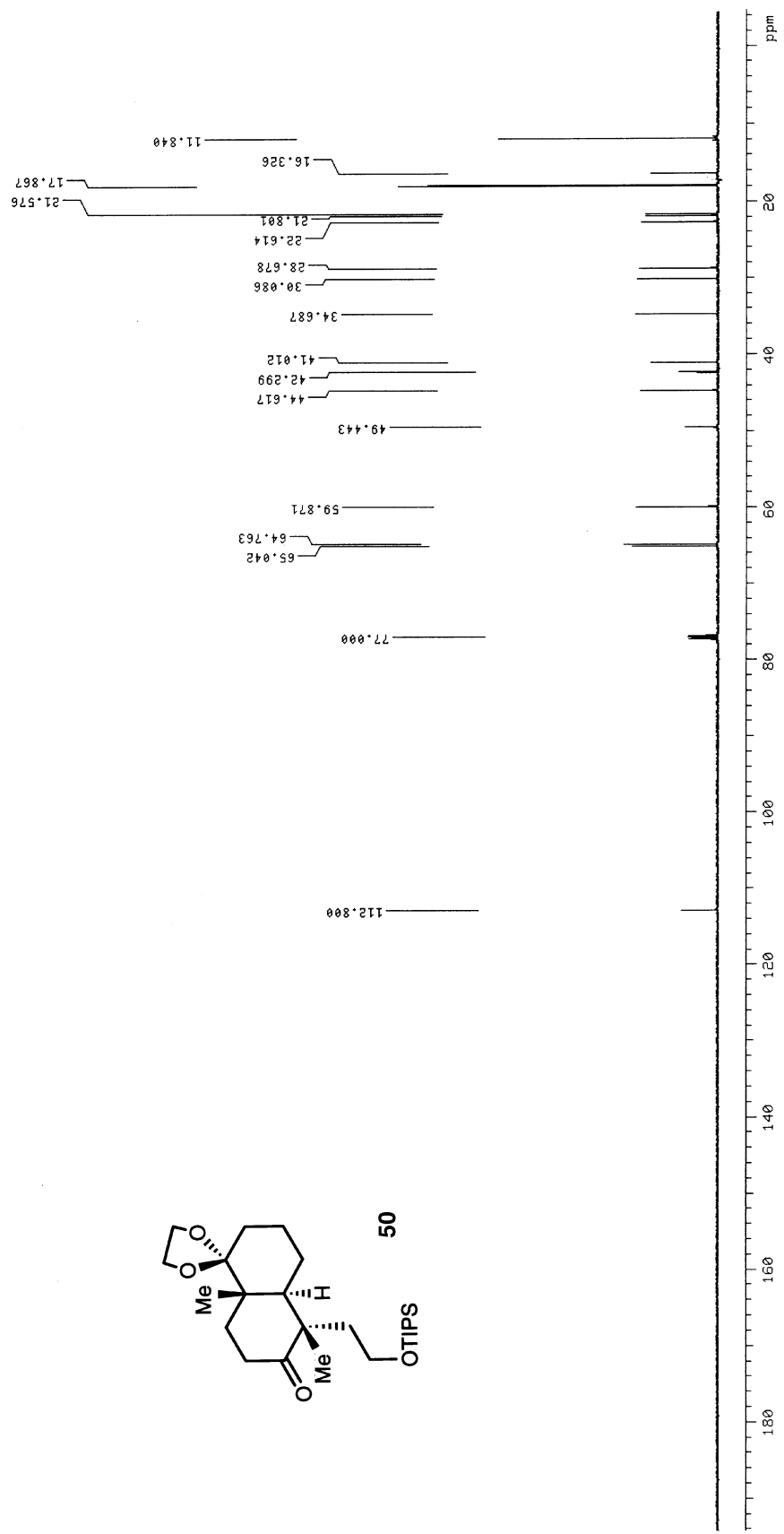


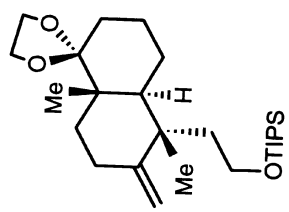
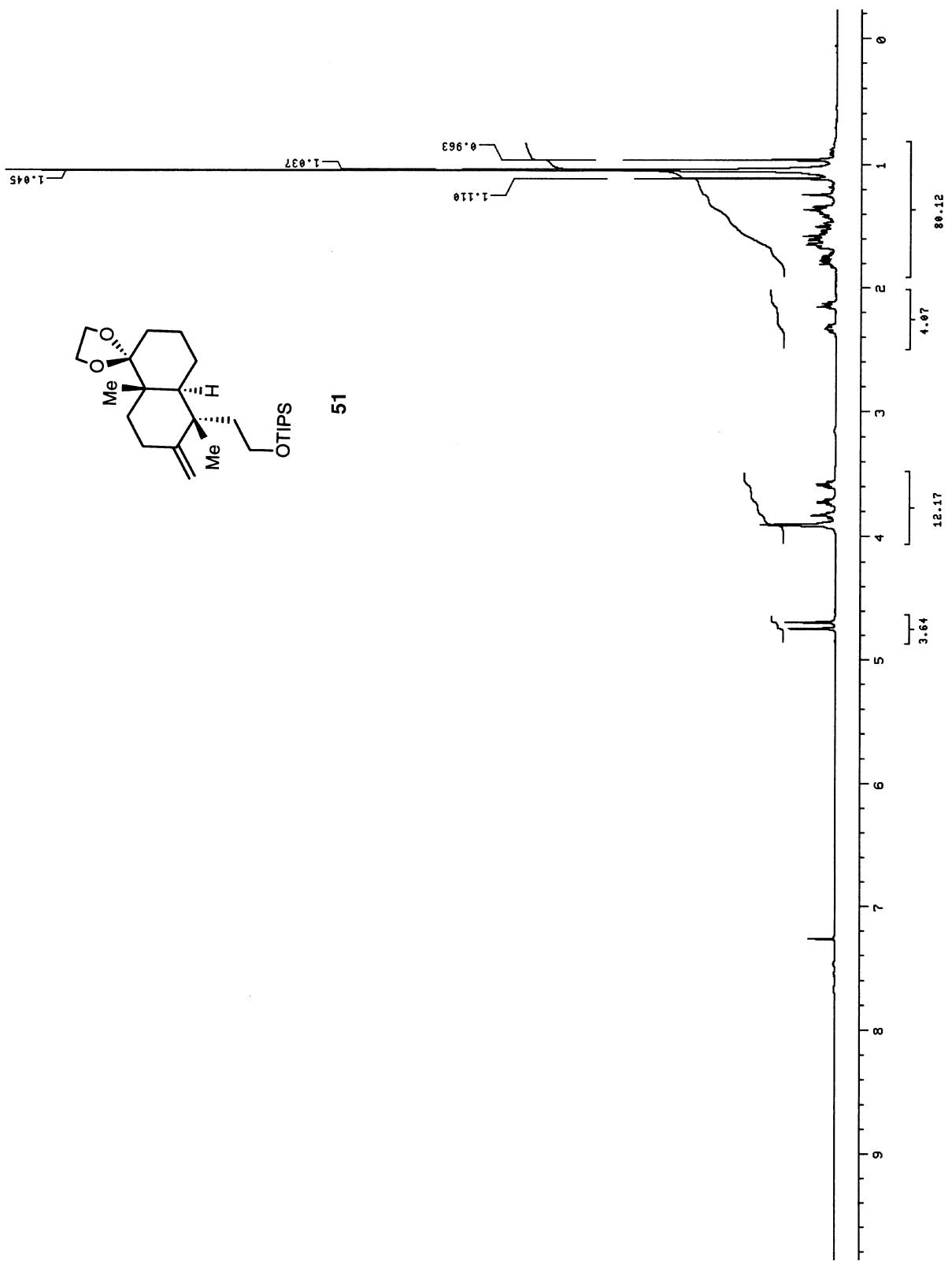
39b



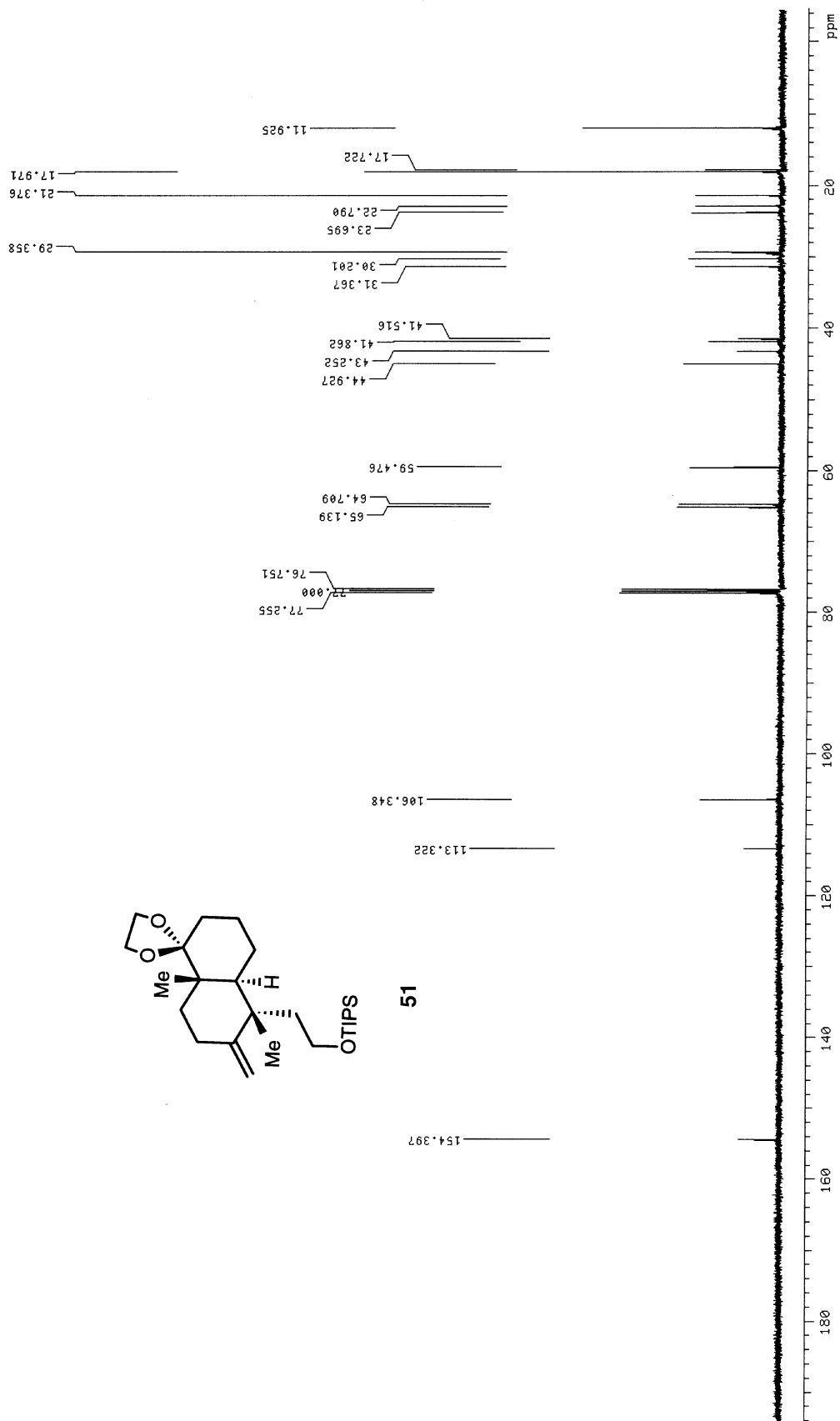


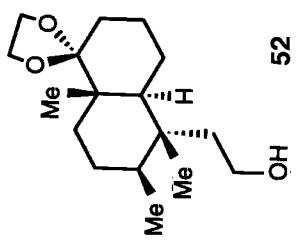
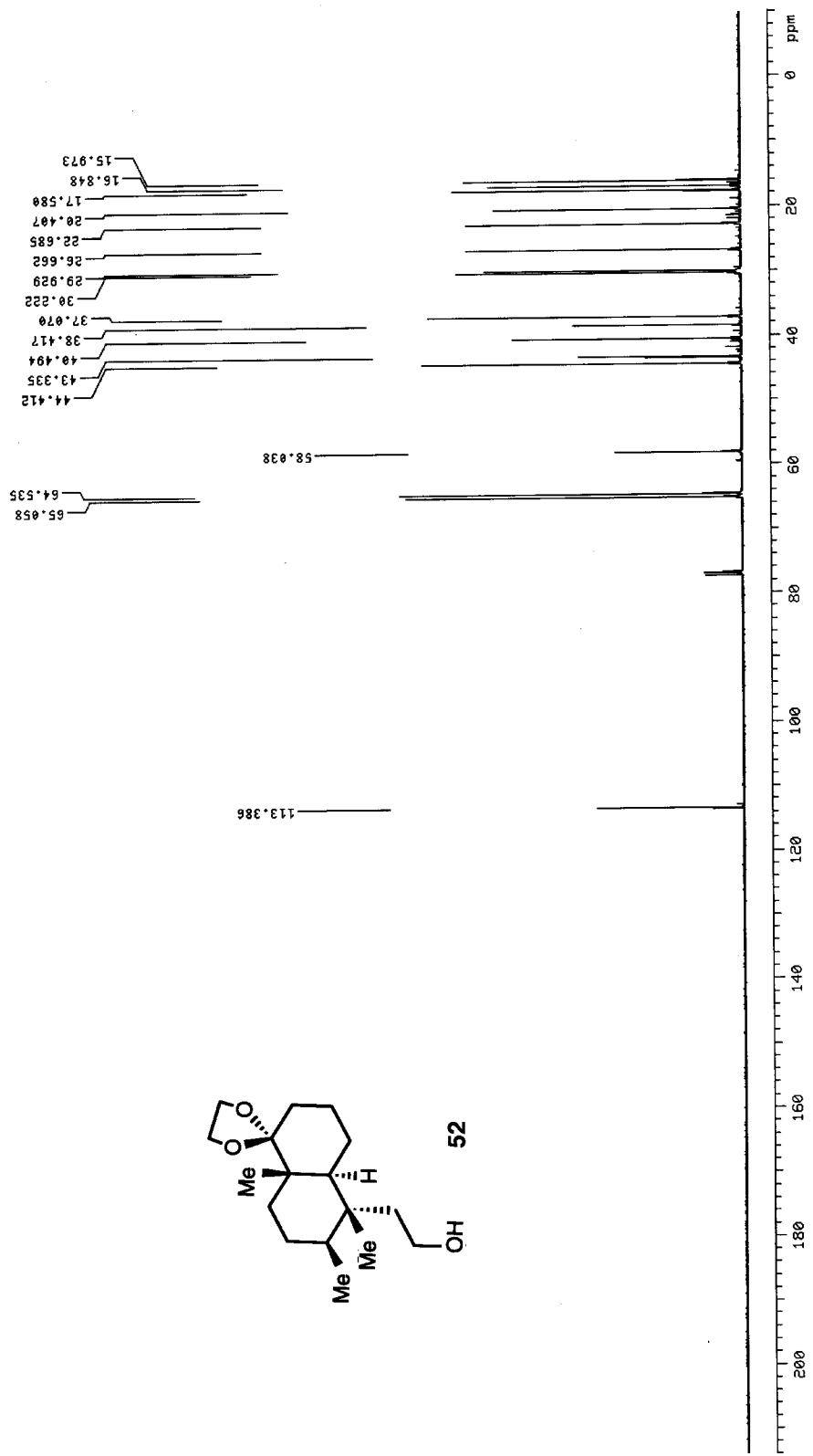


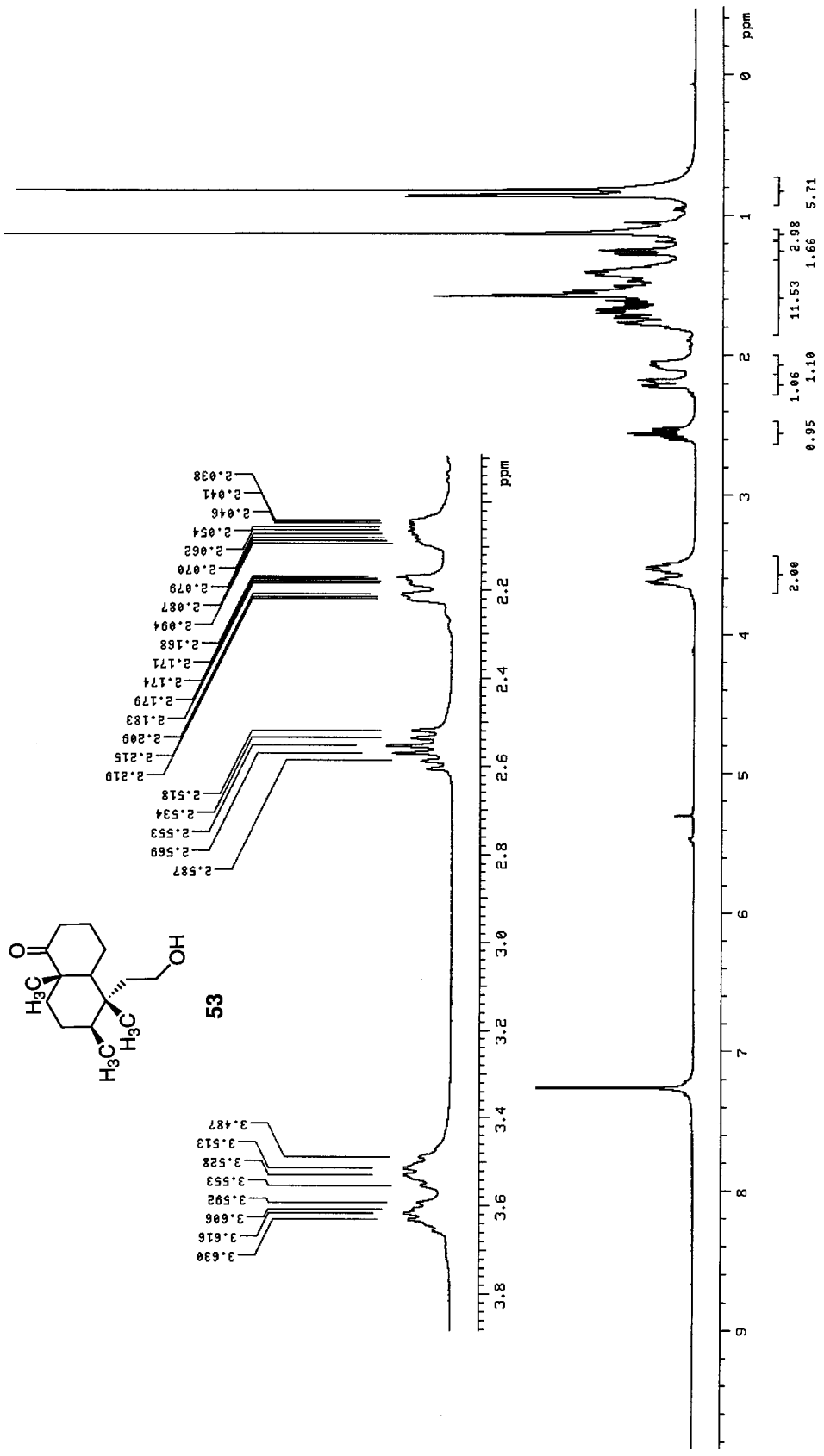


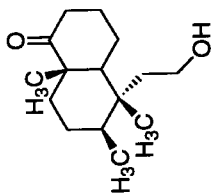


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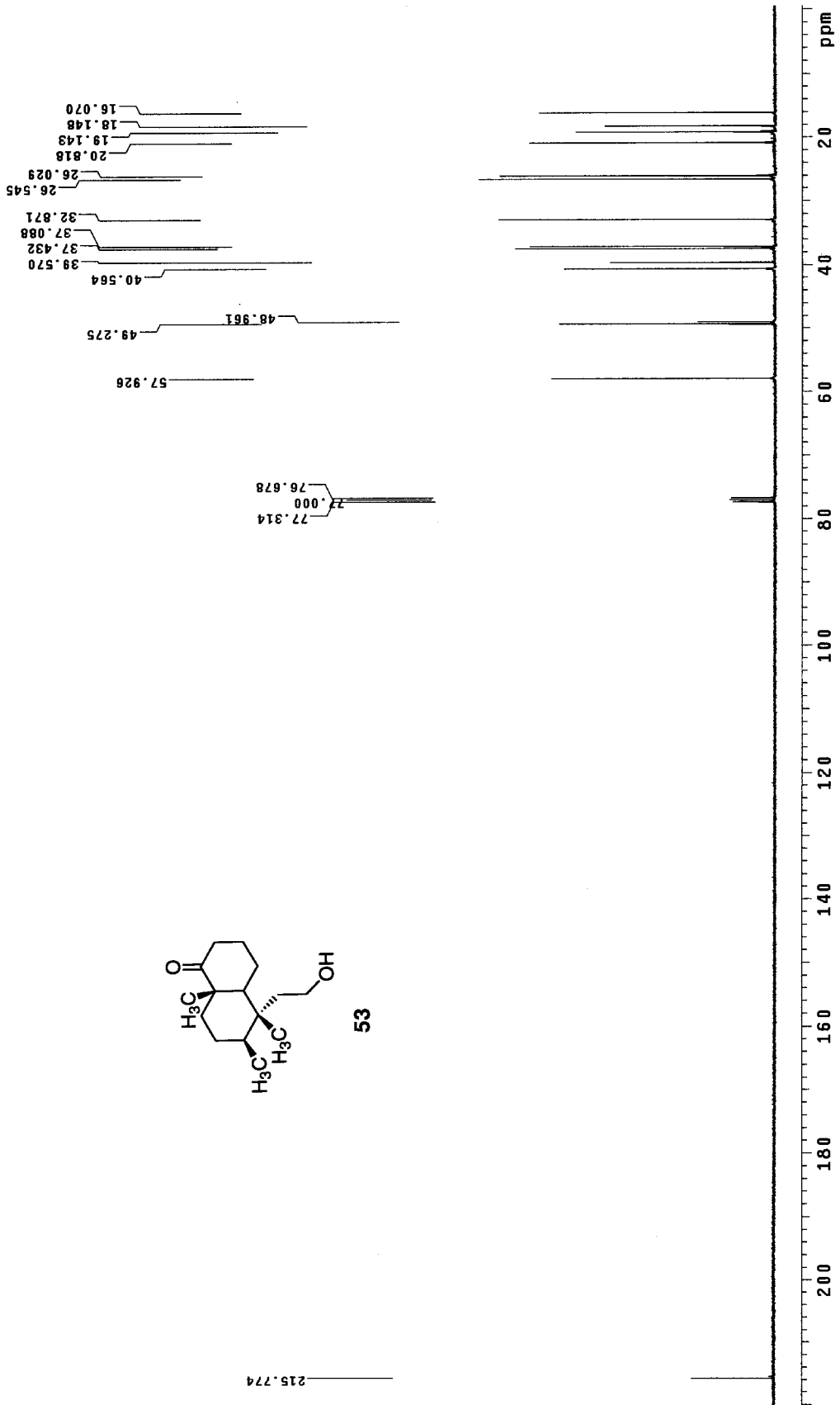


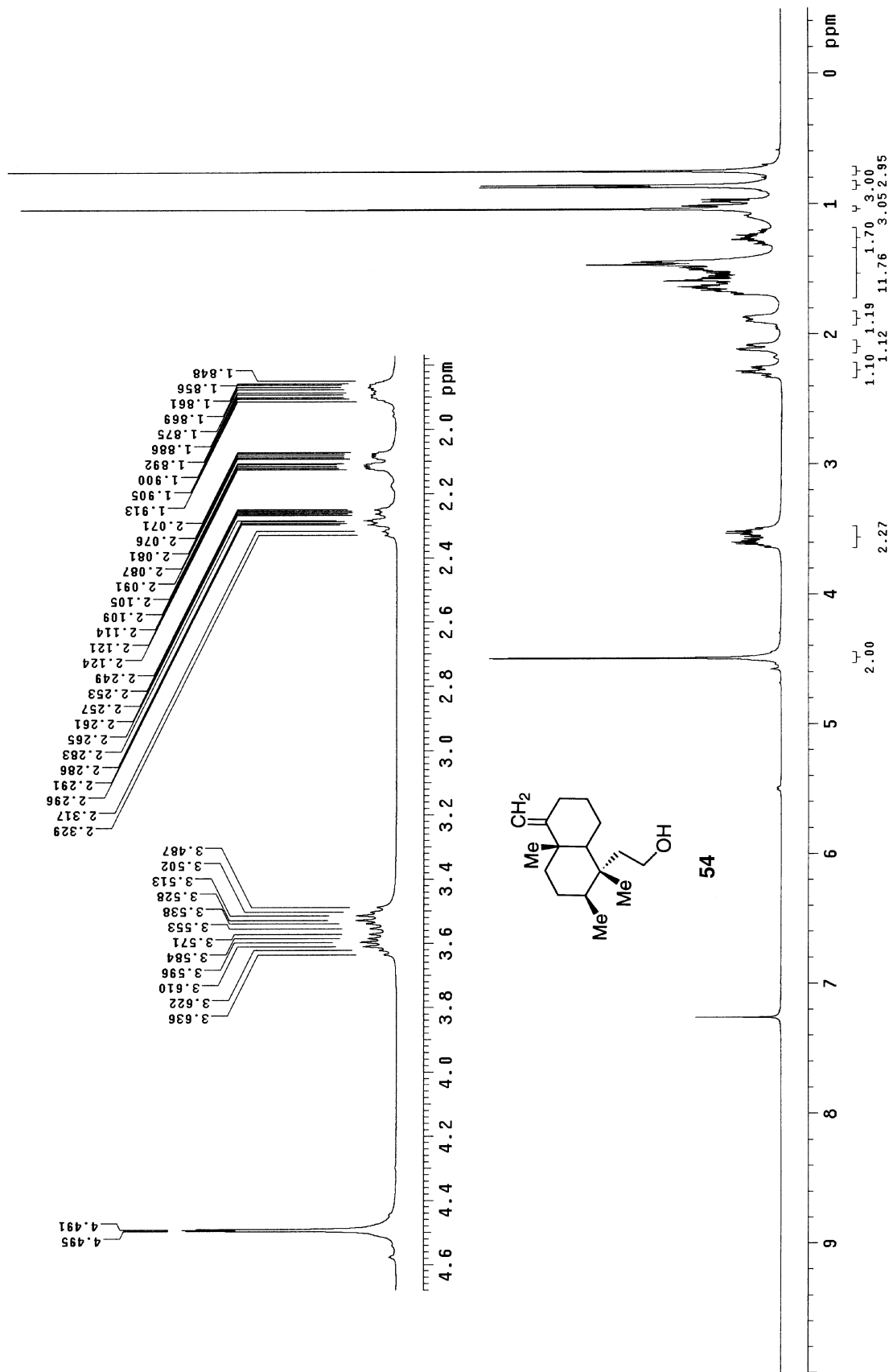


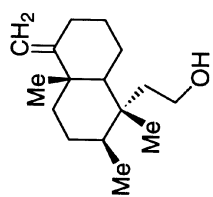




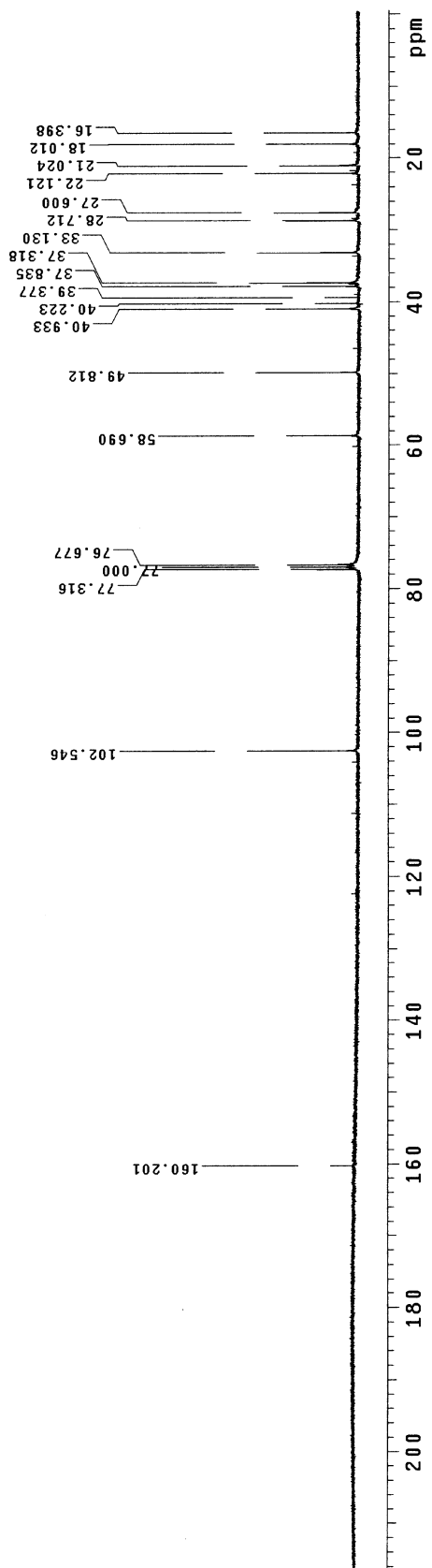
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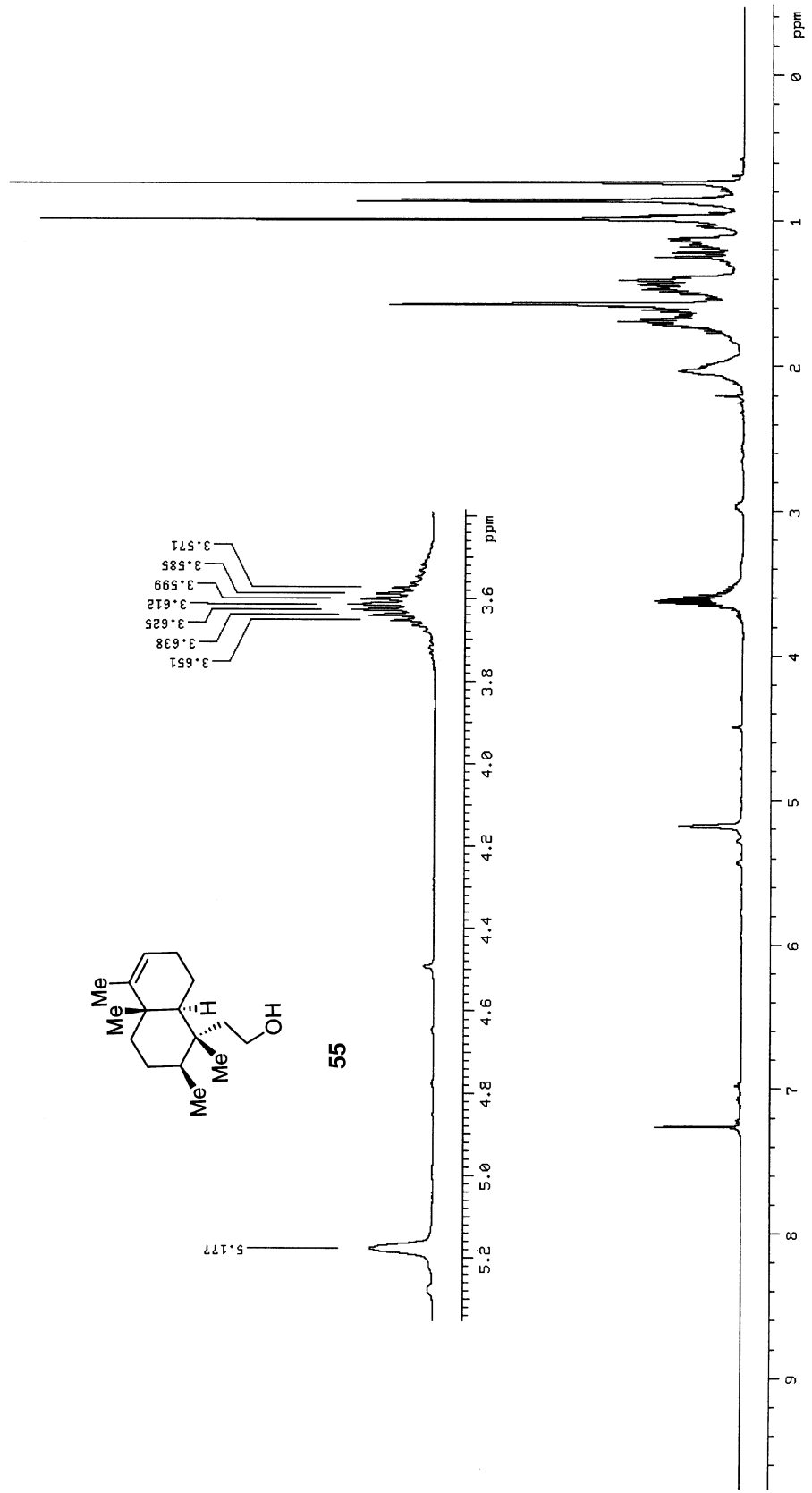


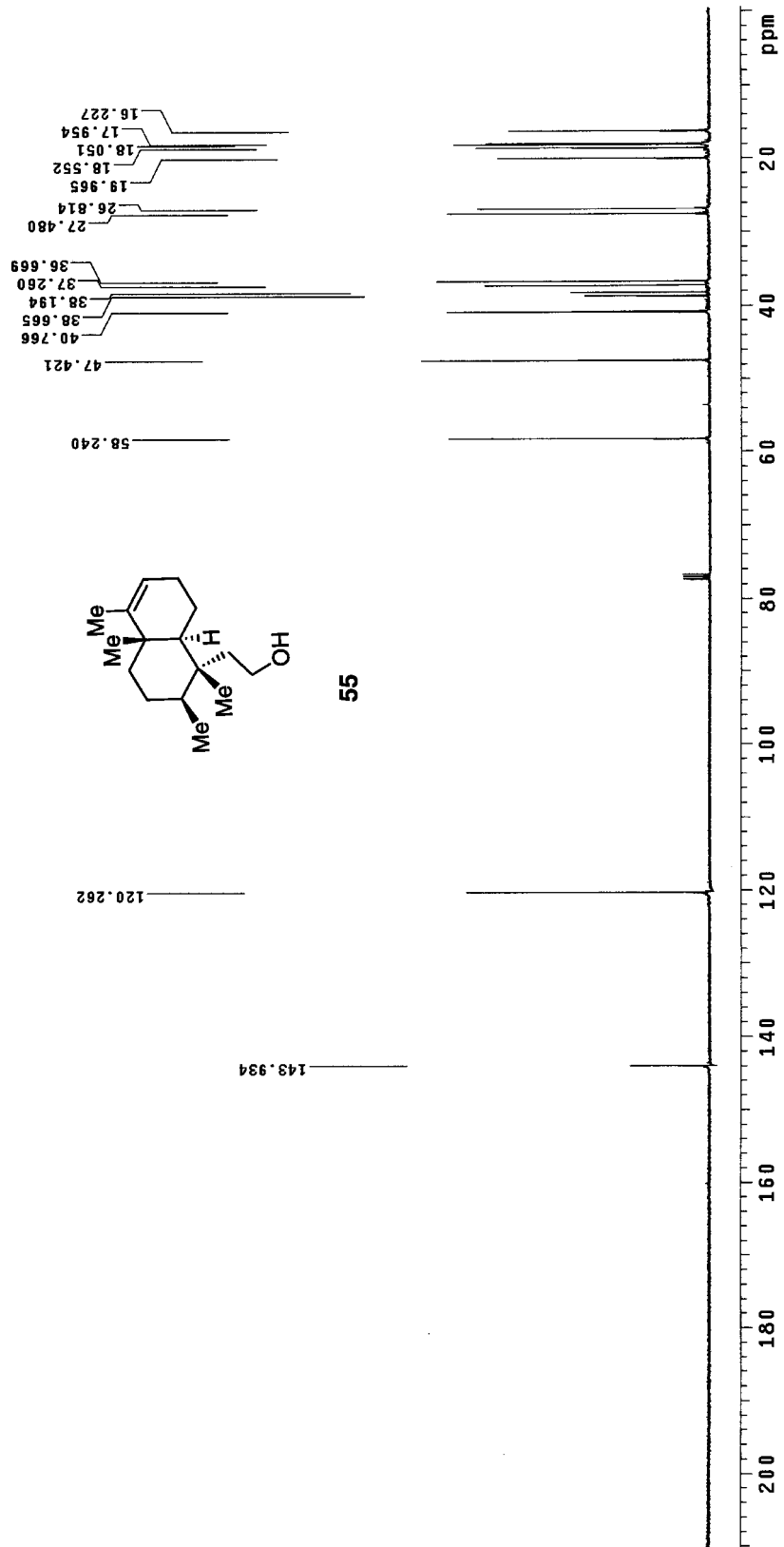


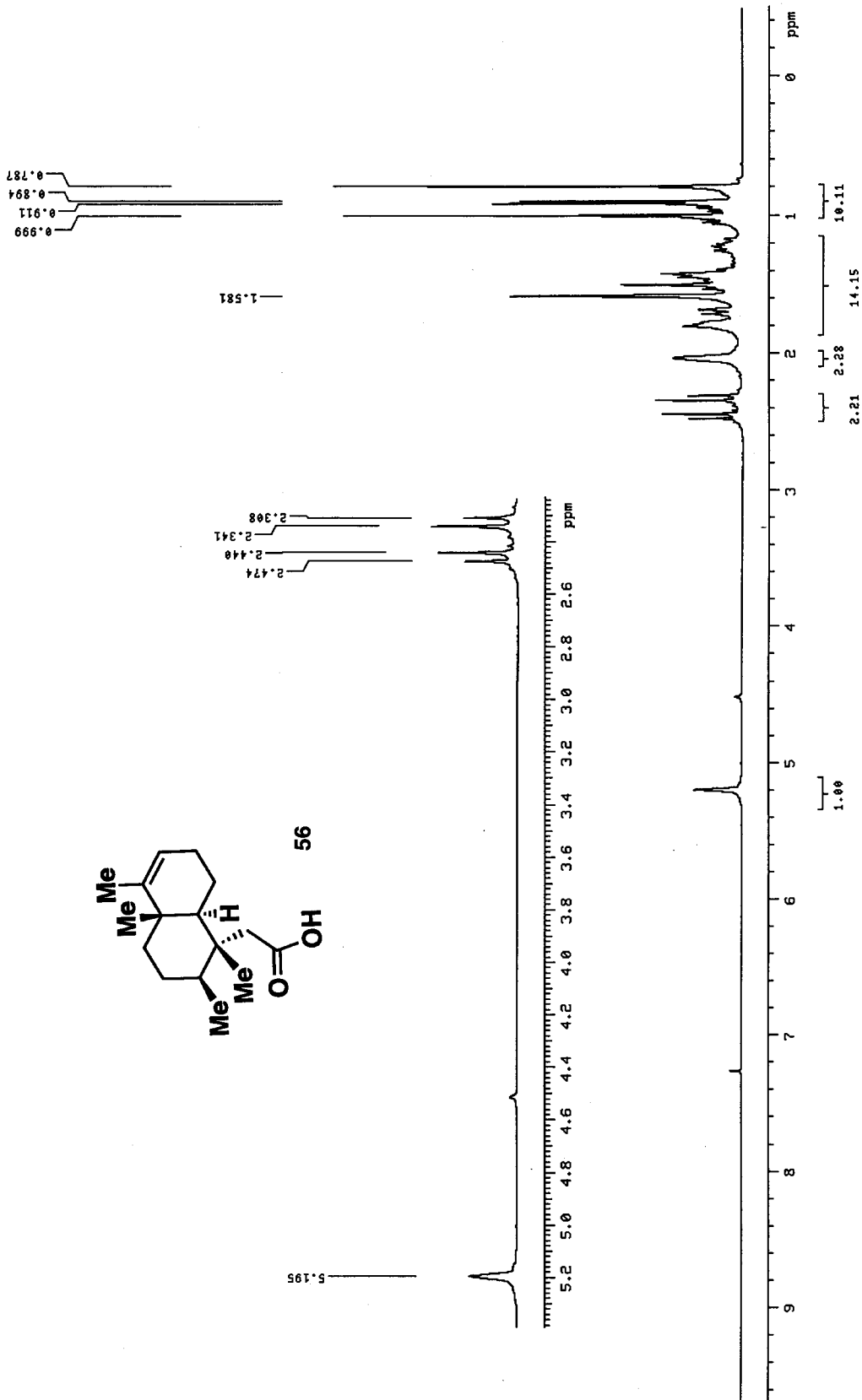


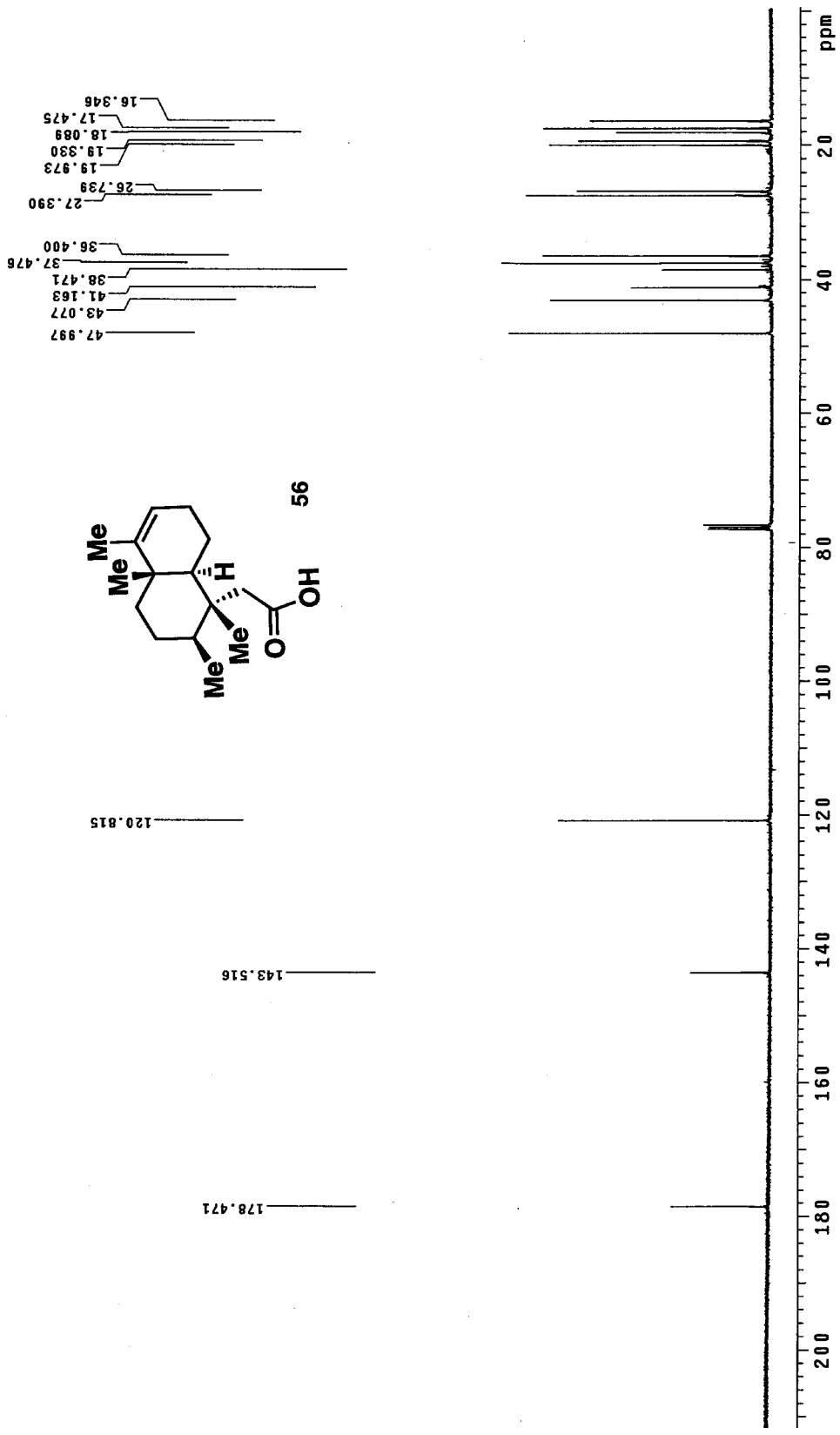
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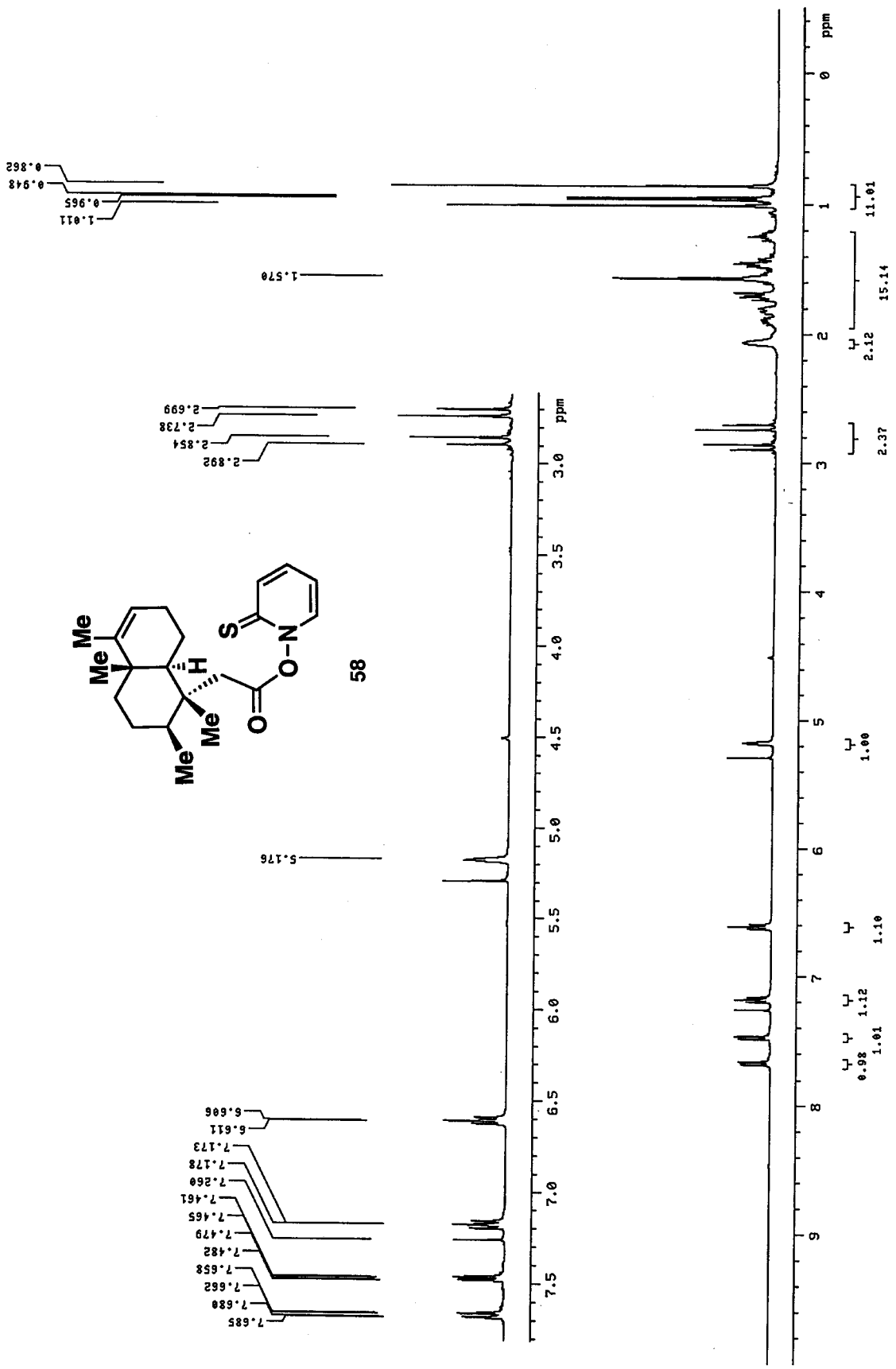


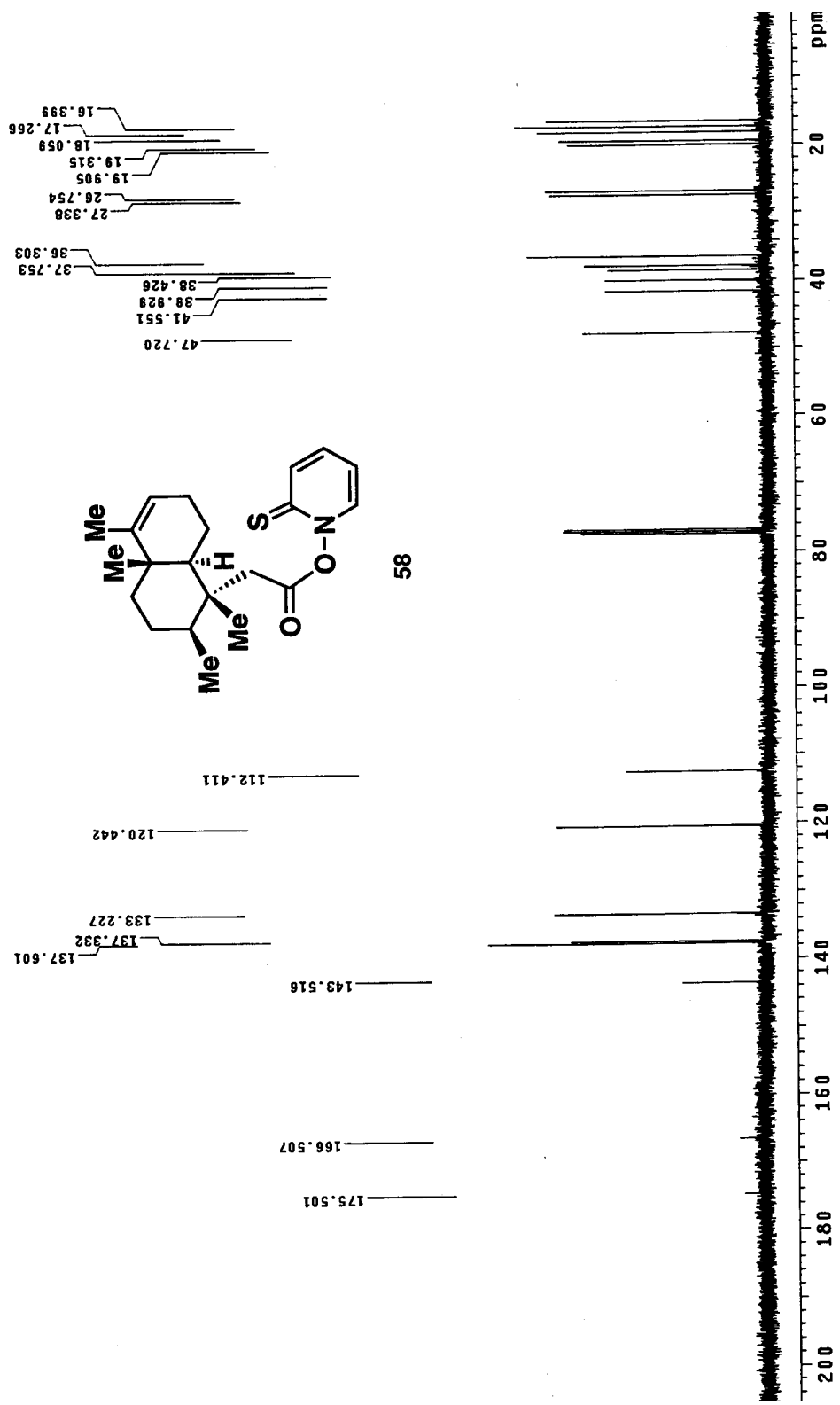


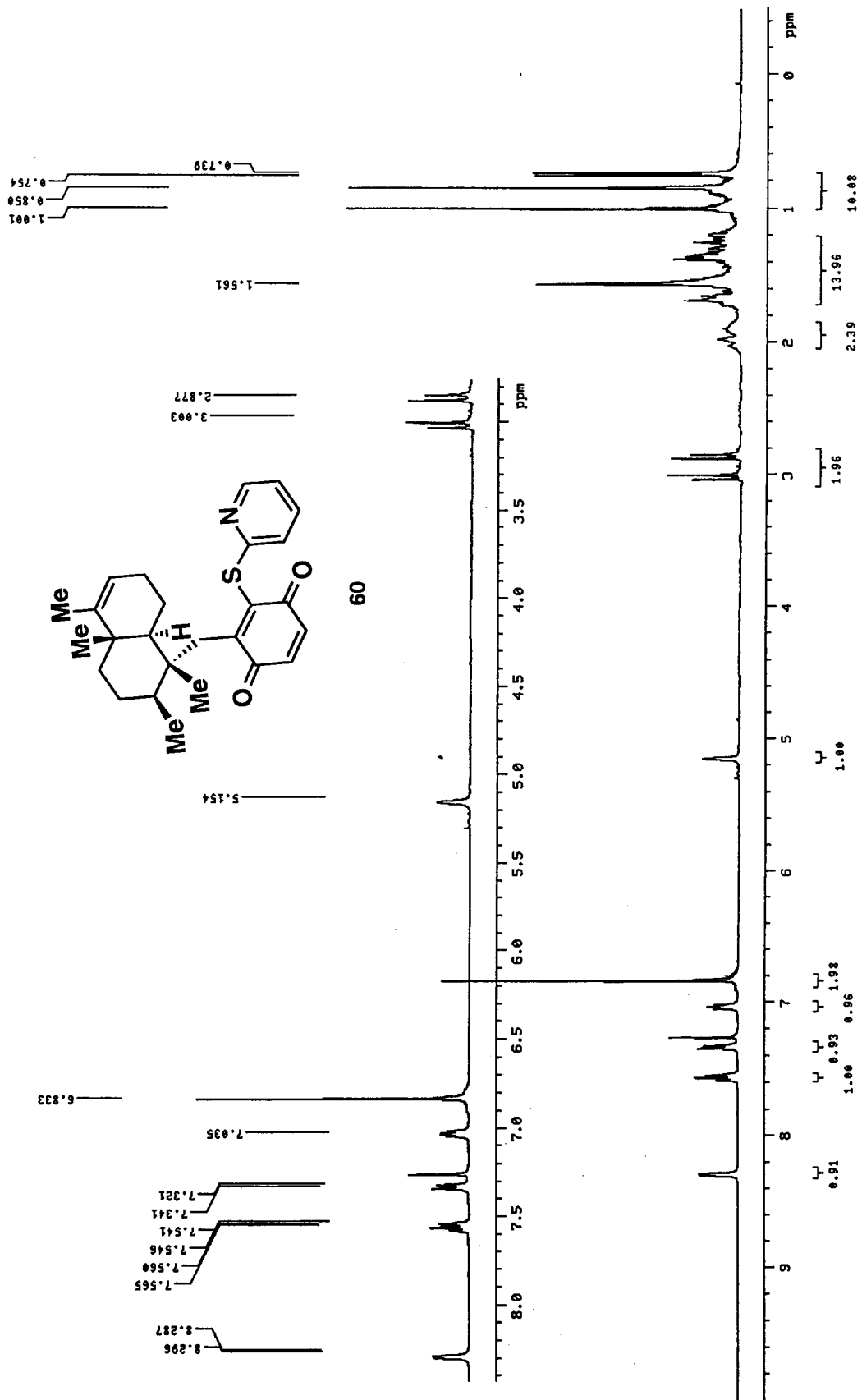


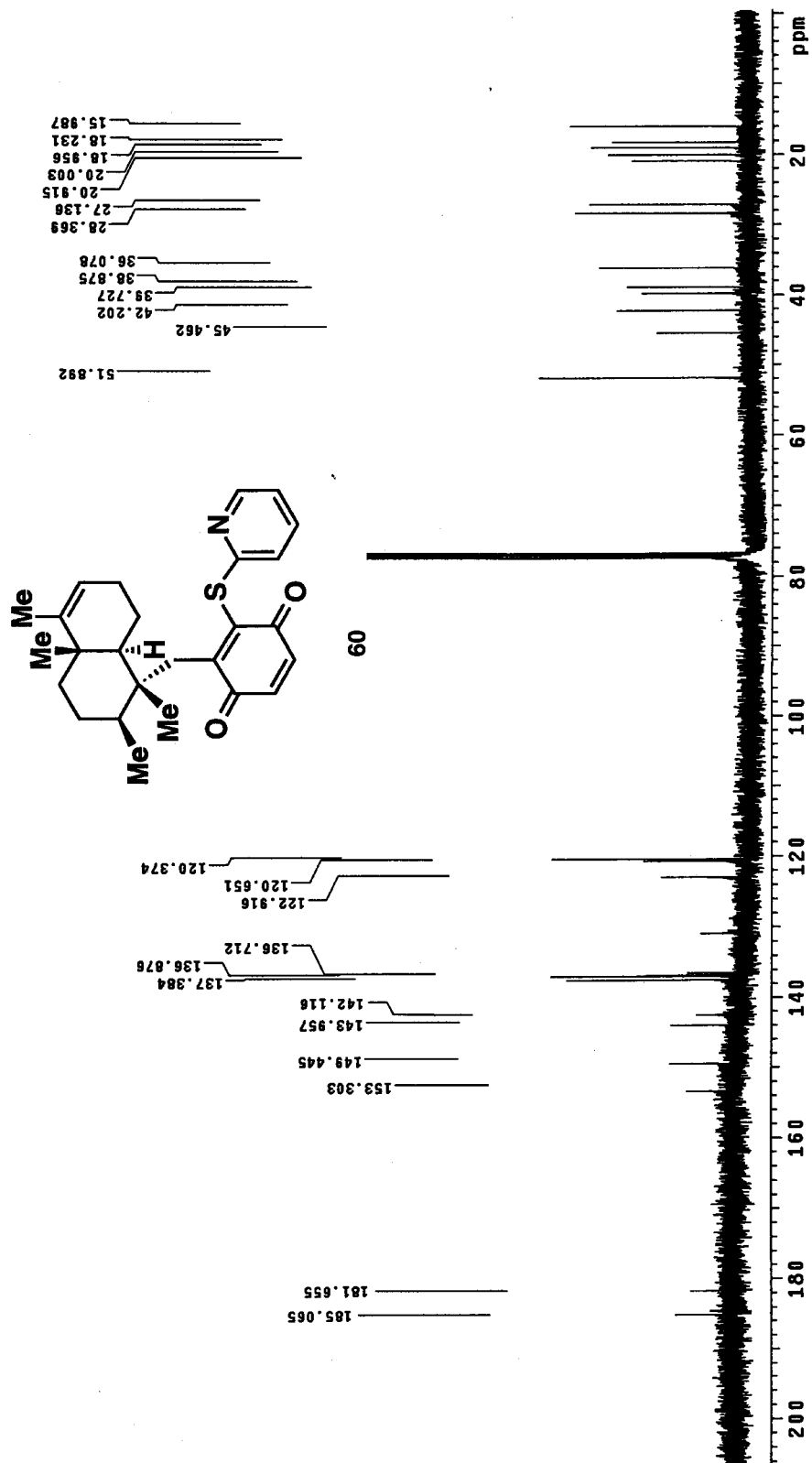


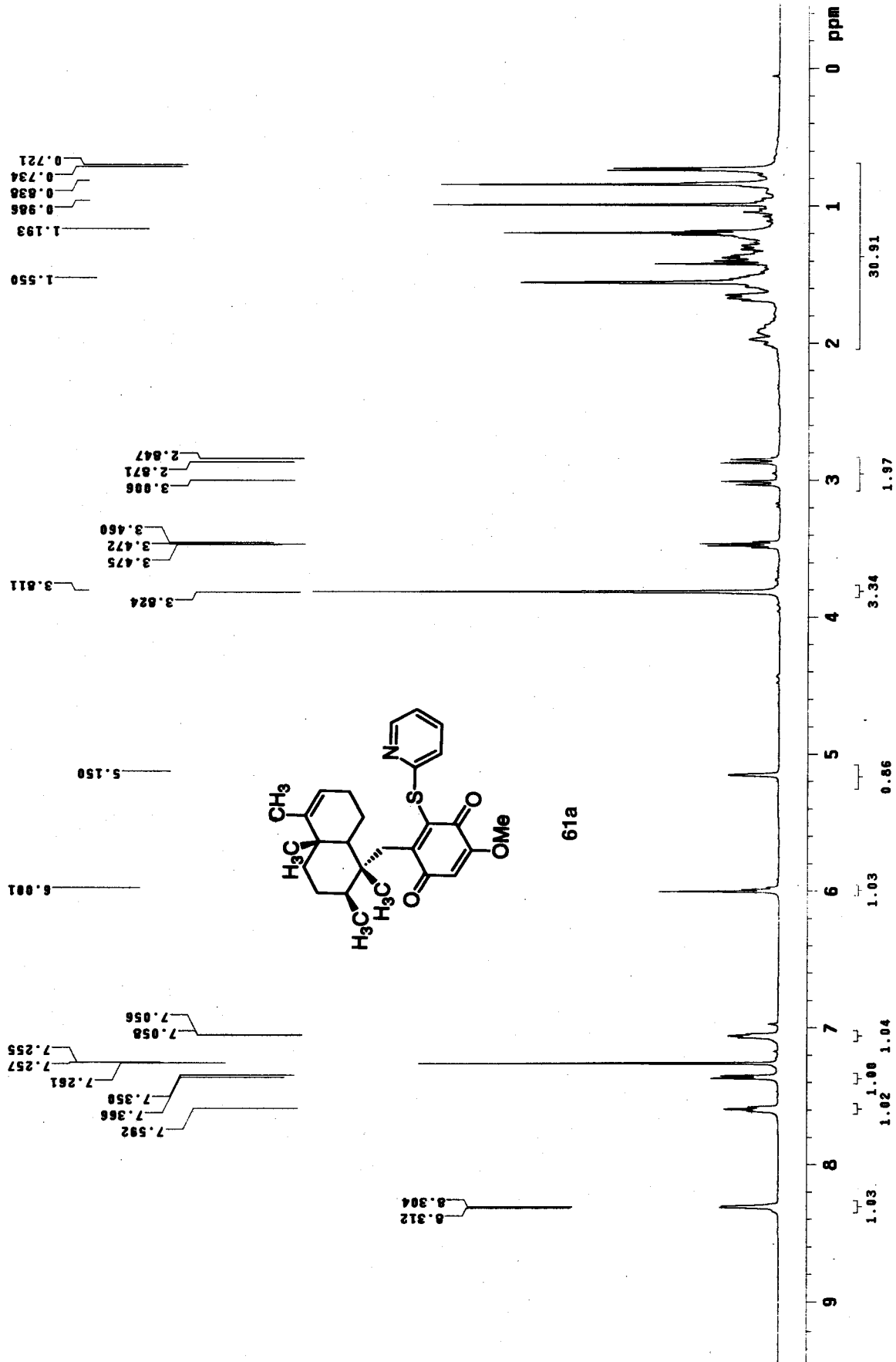


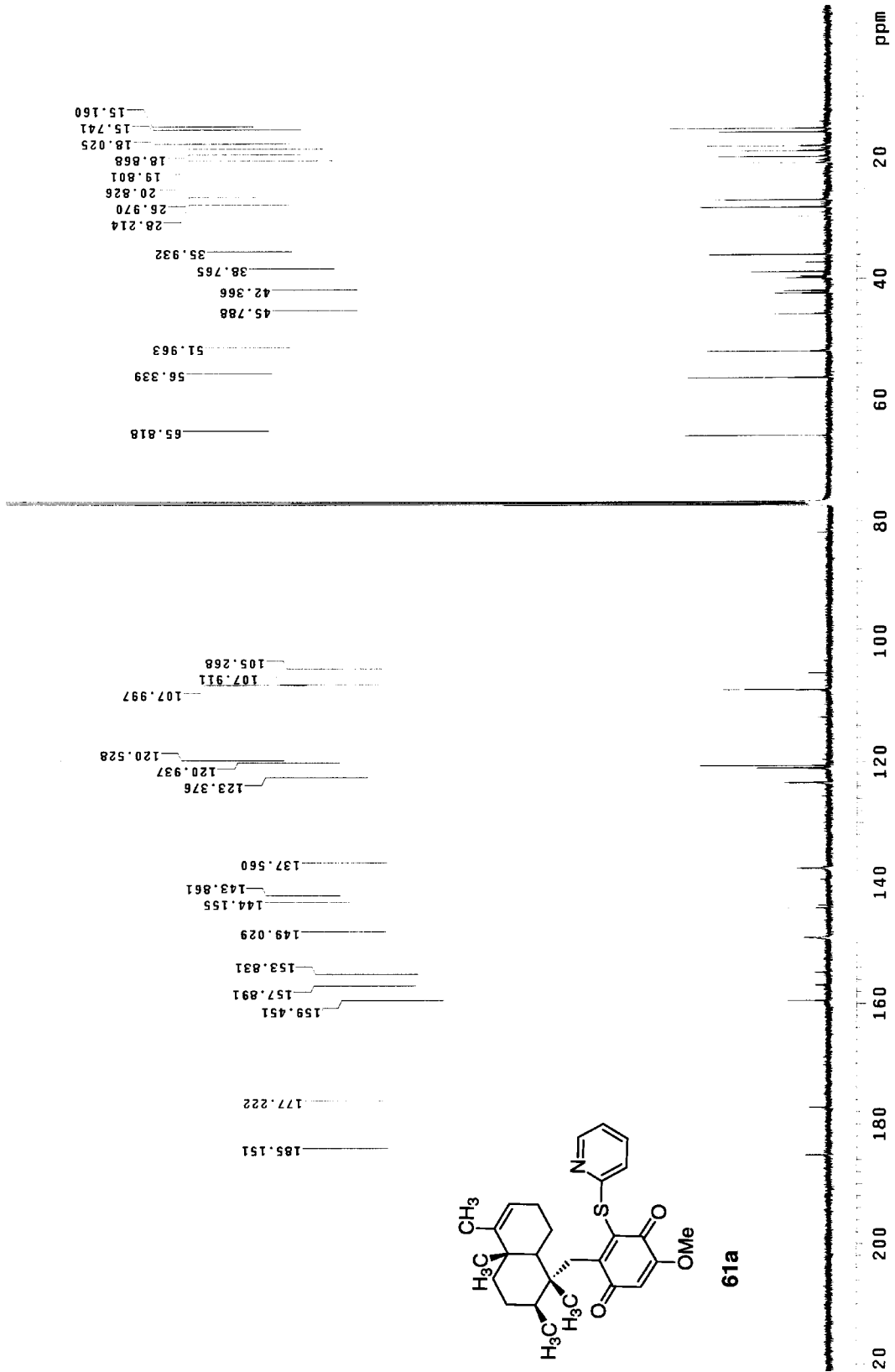


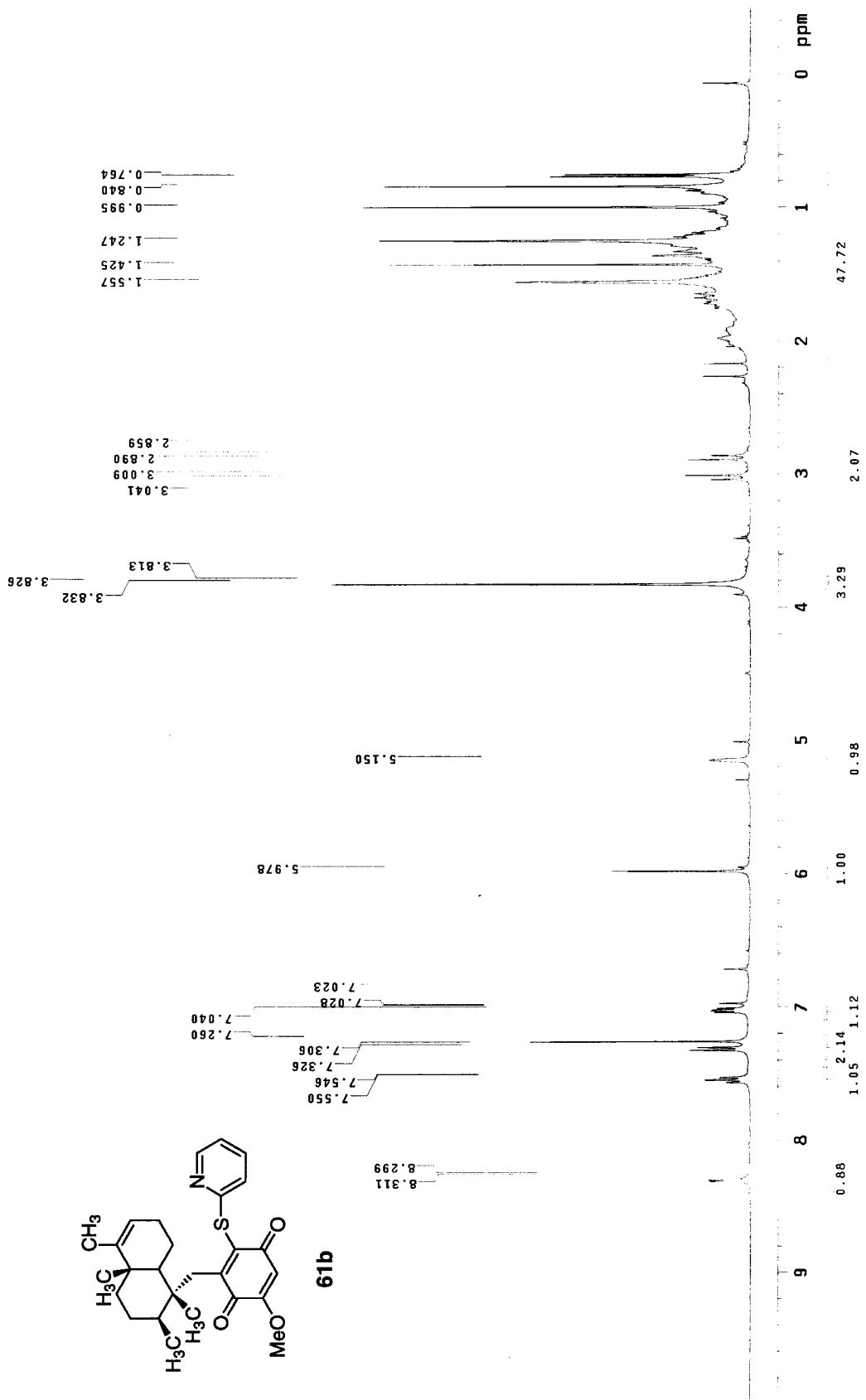


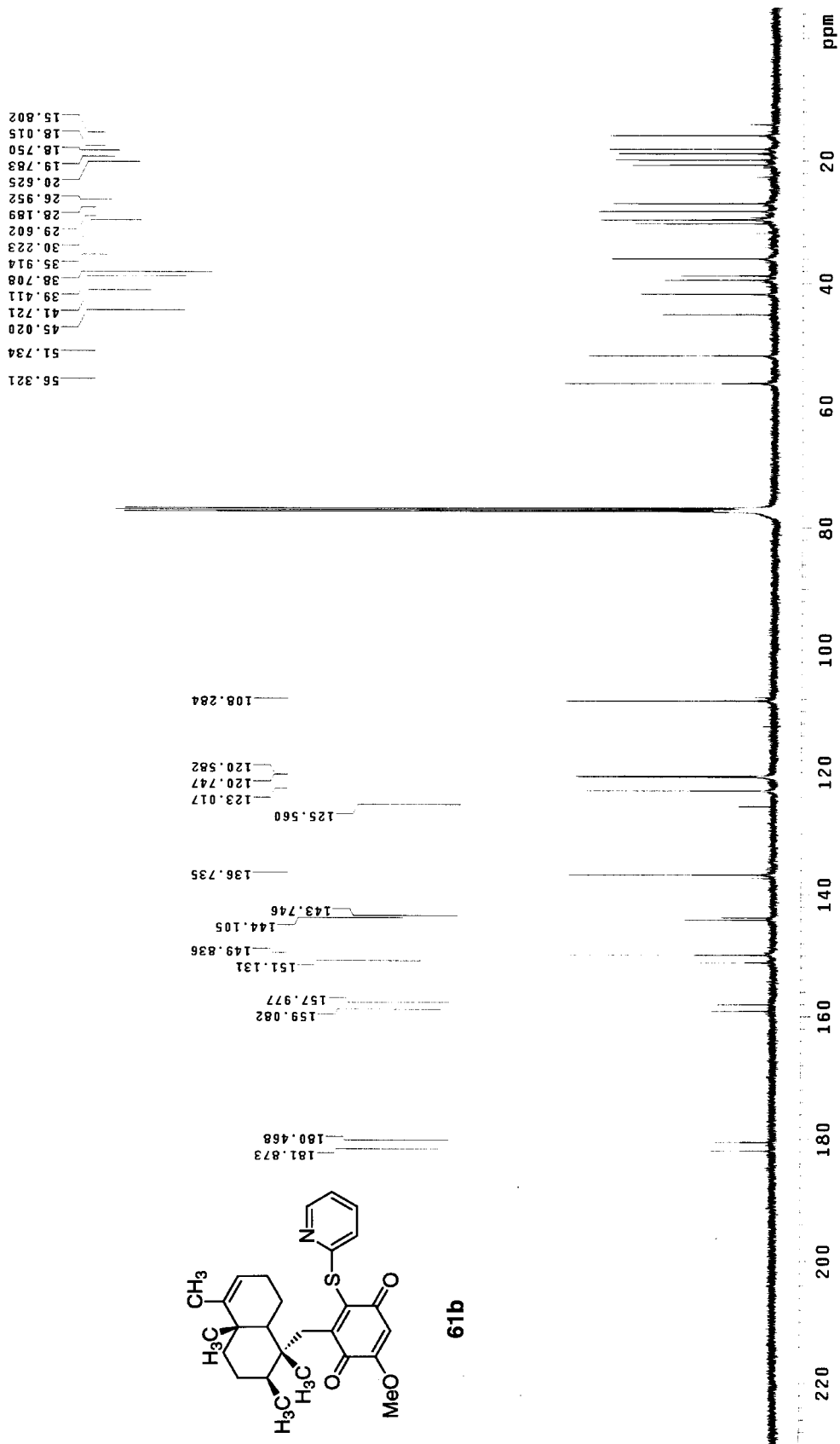


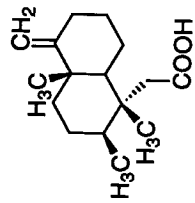




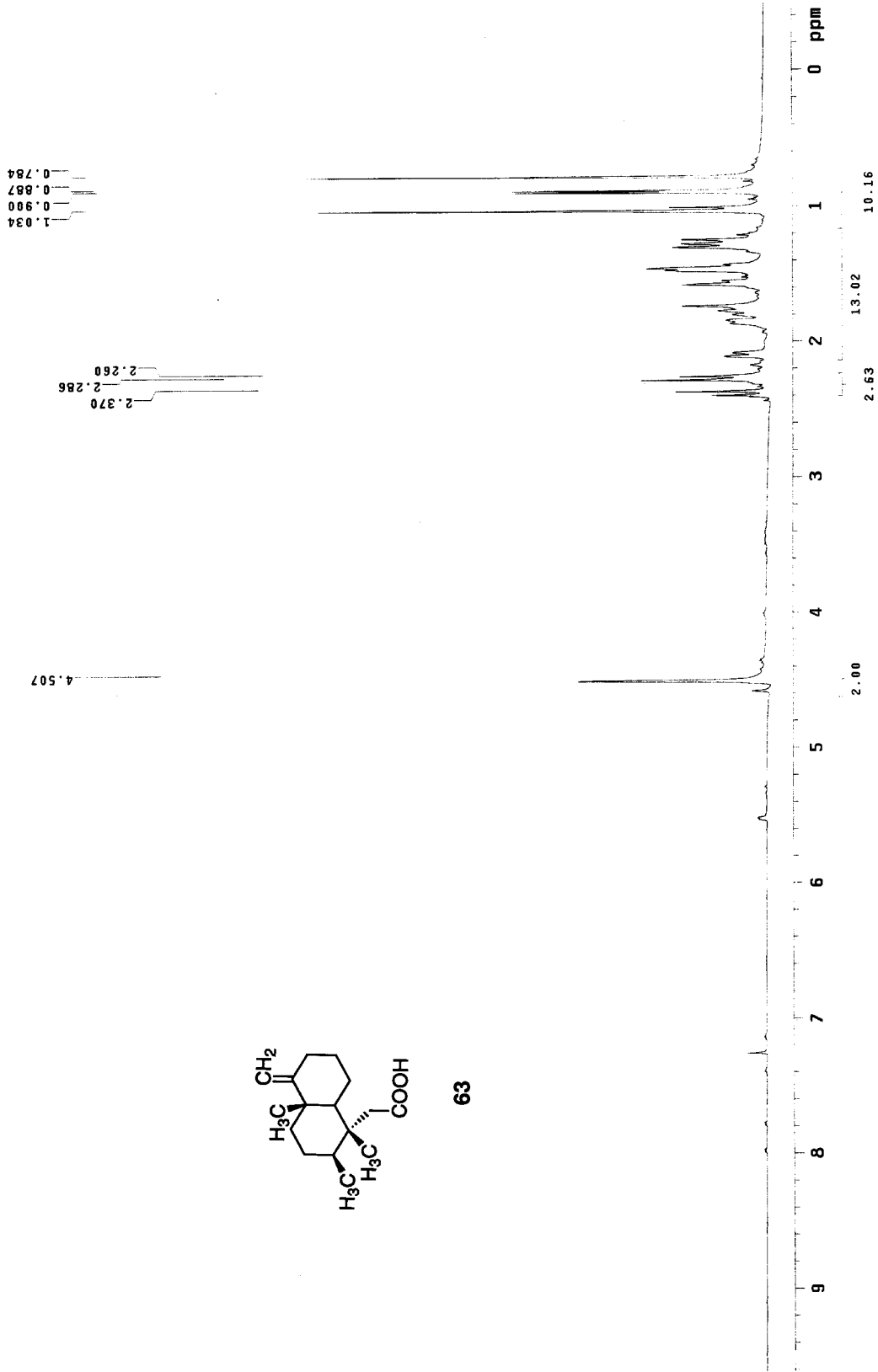


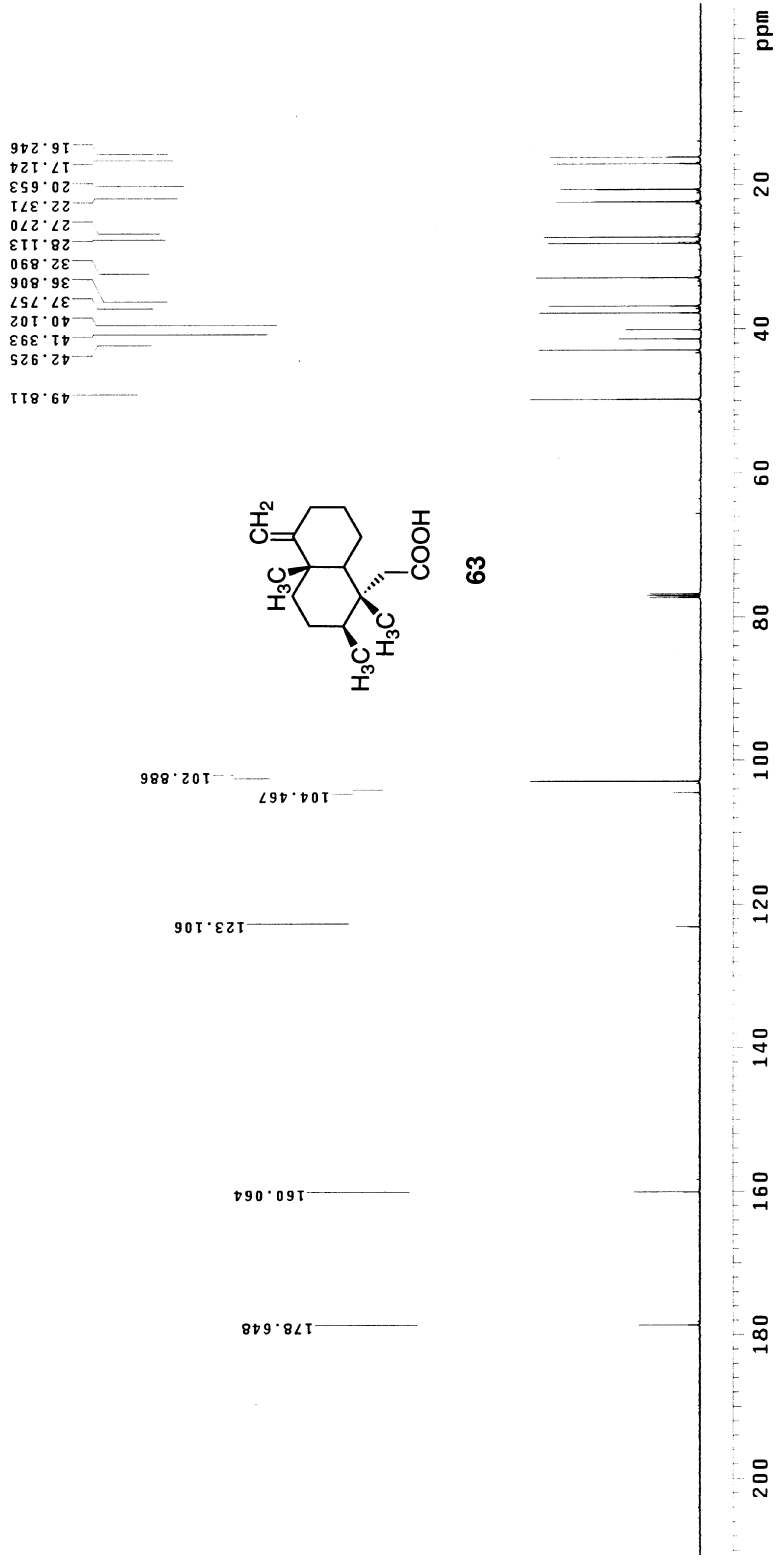


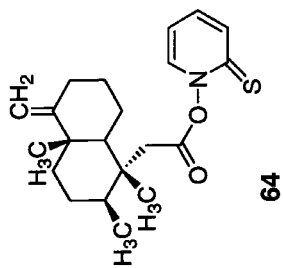
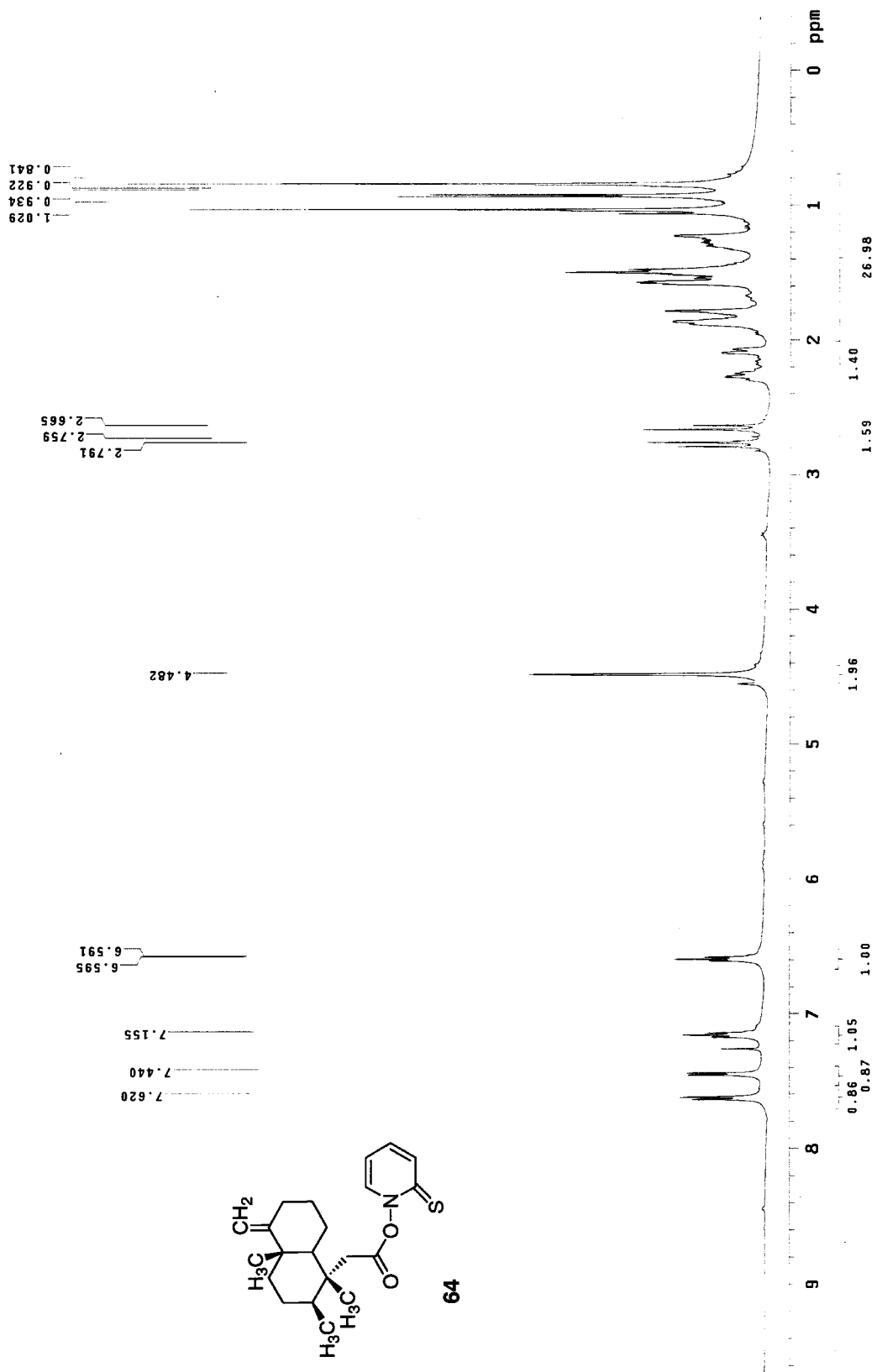


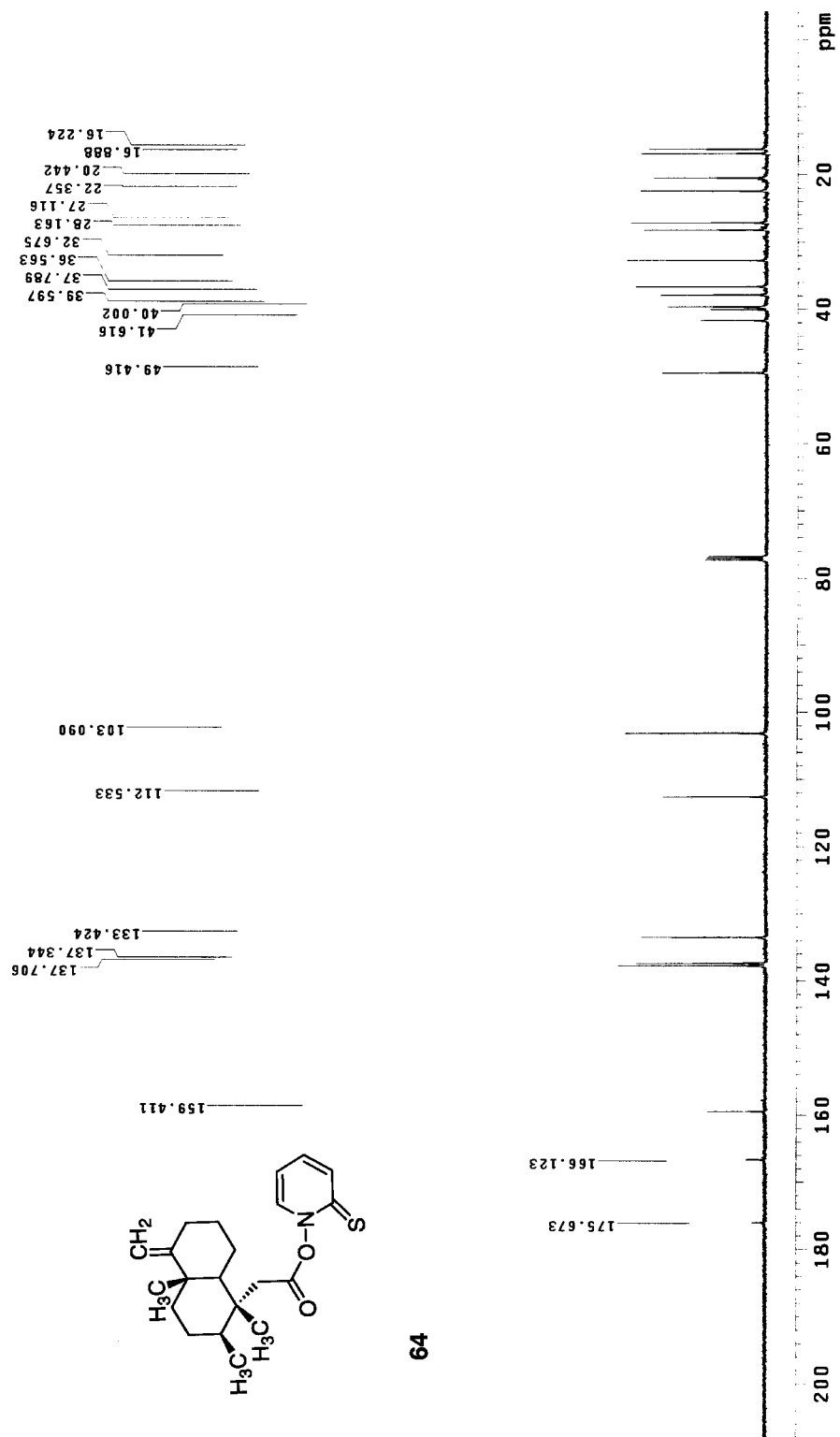


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