Supporting Information

Pd(II)-Catalyzed Cascade Wacker-Heck Reaction: Chemoselective Coupling of Two Electron Deficient Reactants

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Characterization of Products. All solvents were purified prior to use by passing through a column of activated alumina under inert atmosphere. All reactions were carried out under an argon or oxygen atmosphere respectively in dried glassware with magnetic stirring. Tetrahydrofuran (THF) was distilled from sodium and benzophenone and both 1,2-dimethoxyethane (DME) and diisopropylamine were distilled from calcium hydride. All other commercially obtained reagents were used as received. NMR spectra were recorded at 400 MHz for ^{1}H and at 100 MHz for ^{13}C. Chemical shifts (δ) are reported in parts per million (ppm) from tetramethylsilane with the undeuterated solvent resonance as an internal standard.. Absorption bands are reported in wavenumbers (cm^{-1}). Mass spectra (*m/z*) and HRMS were recorded in ElectronSpray Ionisation (ESI) and Field Ionisation (FI) or on a Micromass GCT (CI). Thin layer chromatography (TLC) was performed using Merck aluminium foil backed sheets precoated with Kieselgel $60F_{254}$ and visualized with a UV lamp or by staining with $KMnO_4$.

Synthesis of compounds 1b-1i

1-Hydroxy-1-(4-nitrophenyl)hept-4-yn-3-one (1b). 1b was obtained 4-nitrobenzaldehyde (151 mg, 1.0 mmol) and 3-hexyn-2-one (142 μL, 1.3 mmol) according to general procedure **A**. Purification by silica gel chromatography (hexane:EtOAc, 9:1) yielded the product (185 mg, 75% yield) as a pale yellow oil; R_f (hexane:EtOAc, 3:2) = 0.55. δ_{1H} (400 MHz, $CDCl_3$) 1.22 (3H, t, *J = 7.5* Hz), 2.40 (2H, q, *J = 7.5* Hz), 2.99 (2H, d, *J = 6.3* Hz), 3.34 (1H, d, *J = 3.4* Hz), 5.33 (1H, td, *J = 6.1, 3.4* Hz), 7.56 (2H, d, *J = 8.8* Hz), 8.22 (2H, d, *J = 8.6* Hz); δ_{13C} (100 MHz, $CDCl_3$) 12.5 (CH_2), 12.8 (CH_3), 53.5 (CH_2), 68.6 (CH), 79.3 (C), 97.8 (C), 123.8 (2 x CH), 126.4 (2 x CH), 147.4 (C), 149.5 (C), 186.1 (C); ν_{max} (film/cm^{-1}) 3454, 2983, 2213, 1670, 1605, 1520, 1347; *m/z* (HRMS, ESI) found 246.0755 ($[M-H]^-$), $C_{13}H_{12}NO_4$ requires 246.0766.

1-Hydroxy-1-(4-methoxyphenyl)hept-4-yn-3-one (1c). 1c was obtained from anisaldehyde (487 μL, 4 mmol) and 3-hexyn-2-one (568 μL, 5.2 mmol) according to general procedure **A**. Purification by silica gel chromatography (hexane:EtOAc, 5:1) yielded the product (750 mg, 81% yield) as a pale yellow oil; R_f (hexane:EtOAc, 3:1) = 0.21; δ_{1H} (400 MHz, $CDCl_3$) 1.23 (3H, t, *J = 7.5* Hz), 2.40 (2H, q, *J = 7.5* Hz), 2.89 (1H, br s), 2.95 (1H, dd, *J = 17.3, 3.9* Hz), 3.06 (1H, dd, *J = 17.4, 8.8* Hz), 3.81 (3H, s), 5.20 (1H, dd, *J = 8.6, 3.5* Hz), 6.89 (2H, d, *J = 8.8* Hz), 7.30 (2H, d, *J = 8.7* Hz); δ_{13C} (100 MHz, $CDCl_3$) 13.1 (CH_2), 13.2 (CH_3), 54.5 (CH_2), 55.8 (CH_3), 69.9 (CH), 80.2 (C), 83.4 (C), 114.4 (2 x CH), 127.5 (2 x CH), 137.0 (C), 159.8 (C), 187.3 (C); ν_{max} (film/cm^{-1}) 3445, 2940, 2838, 2212, 1668, 1613, 1514, 1461; *m/z* (HRMS, ESI) found 232.1096 ($[M+H]^+$), $C_{14}H_{16}O_3$ requires 232.1099.

7-Hydroxy-9-phenylnon-3-yn-5-one (1e). 1e was obtained from 3-phenylpropionaldehyde (198 μL, 1.5 mmol) and 3-hexyn-2-one (213 μL, 1.9 mmol) according to general procedure **A**.

Purification by silica gel chromatography (cyclohexane:EtOAc, 4:1) yielded the product (249 mg, 72% yield) as an orange oil; R_f (cyclohexane:EtOAc, 4:1) = 0.27; δ_{1H} (400 MHz, $CDCl_3$) 1.21 (3H, t, *J = 7.5* Hz), 1.73 (1H, dddd, *J = 16.6, 9.7, 6.9, 4.2* Hz), 1.85 (1H, dddd, *J = 18.1, 9.2, 8.8, 5.4* Hz), 2.38 (2H, q, *J = 7.5* Hz), 2.66-2.87 (5H, m), 4.16 (1H, dddd, *J = 12.1, 8.4, 4.6, 3.6* Hz), 7.16-7.33 (5H, m); δ_{13C} (400 MHz, $CDCl_3$) 12.65 (CH_3), 12.72 (CH_2), 31.7 (CH_2), 38.0 (CH_2), 52.3 (CH_2), 66.8 (CH), 80.3 (C), 96.8 (C), 125.9 (CH), 128.43 (2 x CH), 128.47 (2 x CH), 141.7, 187.7; ν_{max} (film/cm^{-1}) 3430, 2210, 1667, 1603; *m/z* (HRMS, ESI) found 231.1386 ($[M+H]^+$), $C_{15}H_{19}O_2$ requires 231.1385.

Synthesis of 1-(2-hydroxyphenyl)but-2-yn-1-one (1f)

Synthesis of 2-hydroxy-N-methoxy-N-methylbenzamide.

To a solution of salicylic acid (966 mg, 7 mmol) in anhydrous DMF (30 mL) was added at room temperature DMAP (1.11 g, 9.1 mmol) and DCC (1.87 g, 9.1 mmol). After 15 mins of stirring, N,O-dimethylhydroxylamine hydrochloride (1.02 g, 10.5 mmol) was added and the reaction was left to stir overnight at rt. The urea by-product was filtered off and the reaction mixture was poured into a mixture of EtOAc / water (2 x 60 mL). The organic layer was separated and the aqueous layer was further partitioned with ethyl acetate. The combined organic extracts were dried over $MgSO_4$, filtered under suction and solvent removed *in vacuo*. Purification of the resulting residue by silica gel chromatography (cyclohexane:EtOAc, 4:1) yielded the product (530 mg, 42%) as a colorless oil; R_f (cyclohexane:EtOAc, 4:1) = 0.21; δ_{1H} (400 MHz, $CDCl_3$) 3.42 (3H, s), 3.66 (3H, s), 6.86 (1H, ddd, *J = 8.4, 7.3, 1.2* Hz), 7.01 (1H, dd, *J = 8.4, 1.2* Hz), 7.39 (1H, ddd, *J = 8.8, 7.2, 1.7* Hz), 7.96 (1H, dd, *J = 8.1, 1.8* Hz), 11.18 (1H, br s); δ_{13C} (100 MHz, $CDCl_3$) 34.1, 61.2, 114.3, 118.0, 118.6, 129.5, 133.8, 161.0, 169.8; ν_{max} (film/cm^{-1}) 3057, 1738; *m/z* (HRMS, ESI) found 182.0827 ($[M+H]^+$), $C_9H_{12}NO_3$ requires 182.0817.

1-(2-hydroxyphenyl)but-2-yn-1-one (1f). 1f was obtained 2-hydroxy-N-methoxy-N-methylbenzamide (411 mg, 2.26 mmol) and 1-propynylmagnesium bromide (0.5M in THF, 13.5 mL) according to general procedure **B**. Purification by silica gel chromatography (cyclohexane:EtOAc, 9:1) yielded the product (320 mg, 88% yield) as a pale yellow solid; mp = 72°C; Rf (cyclohexane:EtOAc, 9:1) = 0.36; δ_{1H} (400 MHz, CDCl3) 2.20 (3H, s), 6.95 (1H, ddd, *J = 8.0, 7.2, 1.1* Hz), 6.98 (1H, dd, *J = 8.4, 0.6* Hz), 7.51 (1H, ddd, *J = 8.5, 7.2, 1.5* Hz), 8.03 (1H, dd, *J = 8.0, 1.6* Hz), 11.70 (1H, s); δ_{13C} (100 MHz, CDCl3) 4.5 (CH_3), 77.8 (C), 95.6 (C), 118.0 (CH), 119.3 (CH), 120.6 (C), 133.2 (CH), 137.0 (CH), 162.7 (C), 182.6 (C); ν_{max} (film/cm^{-1}) 3426, 2220, 1629, 1485; m/z (HRMS, ESI) found 161.0607 ([M+H]+), $C_{10}H_9O_2$ requires 161.0603.

Synthesis of (*S*)-6-Hydroxy-8-phenyloct-2-yn-4-one (1h).

Synthesis of (S)-3-hydroxy-N-methoxy-N-methyl-5-phenylpentanamide (5).[1]

To a suspension of N,O-dimethylhydroxylamine hydrochloride (1.08 g, 11.1 mmol) in THF (40 mL) was added trimethylaluminium (2M in toluene, 5.5 mL) at 0°C. The reaction was stirred for 40 mins, then cooled down to -40°C and (S)-ethyl 3-hydroxy-5-phenylpentanoate [2] (810 mg, 3.70 mmol) was added in THF (10 mL) via cannula for 10 mins. The mixture was warmed to room temperature, then stirred for 3h. Then, it was quenched with 1.5 N HCl (18 mL) at -40°C. The solution was extracted with ethyl acetate then dried over $MgSO_4$. After filtration, the organic layer was evaporated *in vacuo*. Purification of the resulting residue by silica gel chromatography (hexane:EtOAc, 2:3) yielded the product (1.4g, 82% yield) as a colorless oil. The NMR data of this compound are in agreement with the literature.[1]

(*S*)-6-Hydroxy-8-phenyloct-2-yn-4-one (1h). 1h was obtained from (*S*)-**5** (498 mg, 2.10 mmol) and 1-propynylmagnesium bromide (0.5M in THF, 12.6 mL) according to general procedure **B**.

Purification by silica gel chromatography (hexane:EtOAc, 4:1) yielded the product (420 mg, 92% yield) as a pale yellow oil; R_f (hexane:EtOAc, 6:1) = 0.15; The enantiomeric excess of the product **1h** was determined to be 96% ee by HPLC analysis [column, DAICEL CHIRALCEL OD (0.46 cmΦ x 25 cm); eluent, hexane/Pr^{i}OH = 99/1; flow rate, 1.0 mL/min; retention time: 77.3 min (major), 95.8 min (minor); $[a]_D^{18}$ +25.1 (c 1.0, $CHCl_3$); δ_{1H} (400 MHz, $CDCl_3$) 1.72 (1H, dddd, *J = 16.6, 9.8, 6.9, 4.0* Hz), 1.84 (1H, dddd, *J = 18.2, 9.2, 8.9, 5.5* Hz), 2.03 (3H, s), 2.65-2.87 (5H, m), 4.15 (1H, dddd, *J = 12.1, 8.4, 4.2, 3.9* Hz), 7.17-7.35 (5H, m); δ_{13C} (100 MHz, $CDCl_3$) 4.1 (CH_3), 31.7 (CH_2), 37.9 (CH_2), 52.1 (CH_2), 66.7 (CH), 80.3 (C), 91.5 (C), 125.9 (CH), 128.4 (2 x CH), 128.5 (2 x CH), 141.7 (C), 187.6 (C); ν_{max} (film/cm^{-1}) 3442, 3207, 2921, 2219, 1668, 1496, 1251; *m/z* (HRMS, ESI) found 217.1237 ($[M+H]^+$), $C_{14}H_{17}O_2$ requires 217.1229.

Synthesis of compounds 2b-i

(*E*)-Ethyl-3-(6-ethyl-2-(4-nitrophenyl)-4-oxo-3,4-dihydro-2H-pyran-5-yl)acrylate (2b). **2b** was obtained from **1b** (68 mg, 0.28 mmol) according to general procedure **E**. Purification by silica gel chromatography (cyclohexane:diethyl ether, 1:1) yielded the product (50 mg, 52% yield) as a pale yellow solid; mp = 116°C; R_f (cyclohexane:diethyl ether, 1:1) = 0.40. δ_{1H} (400 MHz, $CDCl_3$) 1.28 (3H, t, *J = 7.5* Hz), 1.32 (3H, t, *J = 7.1* Hz), 2.72 (2H, app nonuplet, *J = 15.0, 7.5* Hz), 2.80 (1H, dd, *J = 16.6, 3.8* Hz), 2.89 (1H, dd, *J = 16.6, 13.7* Hz), 4.23 (2H, q, *J = 7.1* Hz), 5.55 (1H, dd, *J = 13.6, 3.9* Hz), 6.96 (1H, d, *J = 15.8* Hz), 7.40 (1H, d, *J = 15.8* Hz), 7.60 (1H, d, *J = 8.70* Hz), 8.31 (1H, d, *J = 8.8* Hz); δ_{13C} (400 MHz, $CDCl_3$) 11.6 (CH_3), 14.3 (CH_3), 26.1 (CH_2), 43.3 (CH), 60.3 (CH_2), 79.0 (CH), 111.2 (C), 120.7 (CH), 124.2 (2 x CH), 126.7 (2 x CH), 134.6 (CH), 144.5 (C), 148.1 (C), 168.0 (C), 180.2 (C), 189.1 (C); ν_{max} (film/cm^{-1}) 2982, 1707, 1678, 1617, 1555, 1465; *m/z* (HRMS, ESI) found 368.1102 ($[M+Na]^+$), $C_{18}H_{19}NNaO_6$ requires 368.1105.

(*E*)-Ethyl-3-(6-ethyl-2-(4-methoxyphenyl)-4-oxo-3,4-dihydro-2H-pyran-5-yl)acrylate (2c). **2c** was obtained from **1c** (71 mg, 0.31 mmol) according to general procedure **E**. Purification by silica gel chromatography (cyclohexane:diethyl ether, 1:1) yielded the product (57 mg, 56% yield) as a pale yellow solid; mp = 67°C; R_f (cyclohexane:diethyl ether, 1:1) = 0.31. δ_{1H} (400 MHz, $CDCl_3$) 1.23 (3H, t, *J = 7.6* Hz), 1.31 (3H, t, *J = 7.1* Hz), 2.63 (1H, dq, *J = 14.3, 7.6* Hz), 2.68 (1H, dq, *J = 14.3, 7.6* Hz), 2.71 (1H, dd, *J = 16.6, 3.3* Hz), 2.96 (1H, dd, *J = 16.6, 14.1* Hz), 3.84 (3H, s), 4.23 (2H, q, *J = 7.1* Hz), 5.37 (1H, dd, *J = 14.1, 3.3* Hz), 6.95 (1H, d, *J = 8.70* Hz), 6.97 (1H, d, *J = 15.8* Hz), 7.33 (1H, d, *J = 8.7* Hz), 7.41 (1H, d, *J = 15.7* Hz); δ_{13C} (100 MHz, $CDCl_3$) 11.7 (CH_3), 14.3 (CH_3), 26.2 (CH_2), 43.2 (CH_2), 53.4 (CH_2), 60.2 (CH_2), 80.1 (CH), 110.9 (C), 114.2 (2 x CH), 119.7 (CH), 127.7 (2 x CH), 129.5 (C), 135.3 (CH), 160.2 (C), 168.3 (C), 181.2 (C), 190.6 (C); ν_{max} (film/cm^{-1}) 2982, 1705, 1673, 1615, 1550; *m/z* (HRMS, ESI) found 353.1358 ($[M+Na]^+$), $C_{19}H_{22}NaO_5$ requires 353.1203.

(*E*)-Ethyl-3-(2-(4-methoxyphenyl)-6-methyl-4-oxo-3,4-dihydro-2H-pyran-5-yl)acrylate (2d). **2d** was obtained from **1d** (77 mg, 0.35 mmol) according to general procedure **E**. Purification by silica gel chromatography (cyclohexane:diethyl ether, 1:1) yielded the product (61 mg, 55% yield) as a pale yellow solid; mp = 93°C; R_f (cyclohexane:diethyl ether, 1:1) = 0.25. δ_{1H} (400 MHz, $CDCl_3$) 1.31 (3H, t, *J = 7.1* Hz), 2.32 (3H, s), 2.70 (1H, dd, *J = 16.6, 3.2* Hz), 2.98 (1H, dd, *J = 16.6, 14.3* Hz), 3.84 (3H, s), 4.23 (2H, q, *J = 7.1* Hz), 5.38 (1H, dd, *J = 14.2, 3.2* Hz), 6.94 (1H, d, *J = 15.8* Hz), 6.95 (1H, d, *J = 8.70* Hz), 7.34 (1H, d, *J = 8.8* Hz), 7.41 (1H, d, *J = 15.8* Hz); δ_{13C} (100 MHz, $CDCl_3$) 14.3 (CH_3), 19.6 (CH_3), 43.0 (CH_2), 55.4 (CH_3), 60.2 (CH_2), 80.3 (CH), 111.7 (C), 114.2 (2 x CH), 119.6 (CH), 127.9 (2 x CH), 129.3 (C), 135.7 (CH), 160.2 (C), 168.3 (C), 176.9 (C), 190.2 (C); ν_{max} (film/cm^{-1}) 2985, 1706, 1669, 1614, 1551, 1517; *m/z* (HRMS, ESI) found 339.1202 ($[M+Na]^+$), $C_{18}H_{20}NaO_5$ requires 339.1203.

(*E*)-Ethyl-3-(6-ethyl-4-oxo-2-phenethyl-3,4-dihydro-2H-pyran-5-yl)acrylate (2e). 2e was obtained from **1e** (106 mg, 0.46 mmol) according to general procedure **E**. Purification by silica gel chromatography (cyclohexane:diethyl ether, 1:1) yielded the product (66 mg, 44% yield) as a pale yellow solid; mp = 67°C; R_f (cyclohexane:diethyl ether, 1:1) = 0.33. δ_{1H} (400 MHz, $CDCl_3$) 1.25 (3H, t, *J = 7.6* Hz), 1.31 (3H, t, *J = 7.1* Hz), 1.97 (1H, dddd, *J = 16.4, 9.1, 7.3, 4.5* Hz), 2.18 (1H, dddd, *J = 17.0, 8.5, 8.5, 5.7* Hz), 2.51 (1H, dd, *J = 16.5, 4.1* Hz), 2.58 (1H, dd, *J = 16.8, 12.7* Hz), 2.61 (1H, dq, *J = 14.2, 7.2* Hz), 2.67 (1H, dq, *J = 14.5, 7.3* Hz), 2.81 (2H, m), 4.21 (2H, q, *J = 7.1* Hz), 4.40 (1H, dddd, *J = 12.6, 8.5, 4.3, 4.1* Hz), 6.92 (1H, d, *J = 15.8* Hz), 7.17-7.25 (3H, m), 7.28-7.34 (2H, m), 7.37 (1H, d, *J = 15.7* Hz); δ_{13C} (100 MHz, $CDCl_3$) 11.6 (CH_3), 14.3 (CH_3), 26.1 (CH_2), 30.9 (CH_2), 35.8 (CH_2), 41.9 (CH_2), 60.1 (CH_2), 77.8 (CH), 110.5 (C), 119.4 (CH), 126.3 (CH), 128.4 (2 x CH), 128.6 (2 x CH), 135.4 (CH), 140.4 (C), 168.4 (C), 180.9 (C), 190.6 (C); ν_{max} (film/cm^{-1}) 2283, 1697, 1673, 1615, 1552; *m/z* (HRMS, ESI) found 329.1747 ($[M+H]^+$), $C_{20}H_{25}O_4$ requires 329.1753.

(*E*)-Ethyl-3-(2-methyl-4-oxo-4H-chromen-3-yl)acrylate (2f). 2f was obtained from **1f** (97.3 mg, 0.60 mmol) according to general procedure **E**. Purification by silica gel chromatography (cyclohexane:EtOAc, 4:1) yielded the product (77 mg, 50% yield) as a yellow oil; R_f (cyclohexane:EtOAc, 4:1) = 0.22. δ_{1H} (400 MHz, $CDCl_3$) 1.32 (3H, t, *J = 7.1* Hz), 2.61 (3H, s), 4.25 (2H, q, *J = 7.1* Hz), 7.36 (1H, d, *J = 15.8* Hz), 7.40 (2H, m), 7.56 (1H, d, *J = 15.8* Hz), 7.64 (1H, ddd, *J = 8.7, 7.2, 1.7* Hz), 8.21 (1H, ddd, *J = 7.8, 1.7, 0.7* Hz); δ_{13C} (100 MHz, $CDCl_3$) 14.3 (CH_3), 19.2 (CH_3), 60.4 (CH_2), 116.1 (C), 117.6 (CH), 123.1 (CH), 123.4 (C), 125.4 (CH), 126.2 (CH), 133.6 (CH), 134.8 (CH), 155.0 (C), 167.7 (C), 167.9 (C), 176.2 (C); ν_{max} (film/cm^{-1}) 1711, 1652; *m/z* (HRMS, ESI) found 259.0966 ($[M+H]^+$), $C_{15}H_{15}O_4$ requires 259.0970.

***Syn*-(E)-ethyl-3-(3,6-dimethyl-4-oxo-2-phenyl-3,4-dihydro-2H-pyran-5-yl)acrylate (2g). 2g** was obtained from **1g** (90.7 mg, 0.45 mmol) according to general procedure **E**. Purification by silica gel chromatography (hexane:diethyl ether, 3:2) yielded the product (63 mg, 47% yield, >99% de) as a pale yellow oil; R_f (hexane:diethyl ether, 1:1) = 0.60. δ_{1H} (400 MHz, $CDCl_3$) 0.92 (3H, d, *J = 7.3* Hz), 1.31 (3H, t, *J = 7.1* Hz), 2.39 (3H, s), 2.66 (1H, qd, *J = 7.3, 3.3* Hz), 4.23 (2H, q, *J = 7.1* Hz), 5.56 (1H, d, *J = 3.2* Hz), 6.94 (1H, d, *J = 15.7* Hz), 7.32-7.45 (5H, m), 7.43 (1H, d, *J = 15.8* Hz); δ_{13C} (100 MHz, $CDCl_3$) 9.3 (CH_3), 14.3 (CH_3), 19.4 (CH_3), 45.6 (CH), 60.2 (CH_2), 82.3 (CH), 110.1 (C), 119.9 (CH), 125.5 (2 x CH), 128.3 (CH), 128.6 (2 x CH), 135.87 (C), 135.92 (CH), 168.2 (C), 175.9 (C), 194.9 (C); ν_{max} (film/cm^{-1}) 2980, 2936, 1712, 1618, 1565, 1454, 1402, 1365; *m/z* (HRMS, ESI) found 323.1250 ($[M+Na]^+$), $C_{18}H_{20}NaO_4$ requires 323.1254.

(*S*)-(*E*)-Ethyl-3-(6-methyl-4-oxo-2-phenethyl-3,4-dihydro-2H-pyran-5-yl)acrylate (2h). 2h was obtained from **1h** (101.7 mg, 0.47 mmol) according to general procedure **E**. Purification by silica gel chromatography (hexane:EtOAc, 4:1) yielded the product (66 mg, 45% yield) as a pale yellow solid; mp = 70-74°C; R_f (hexane:EtOAc, 4:1) = 0.40; The enantiomeric excess of the product **2h** was determined to be 96% ee by HPLC analysis [column, DAICEL CHIRALCEL OD (0.46 cmΦ x 25 cm); eluent, hexane/Pr^iOH = 9/1; flow rate, 1.0 mL/min; retention time: 45.5 min (minor), 73.0 min (major); $[a]_D^{18}$ -209.1 (c 1.0, $CHCl_3$); δ_{1H} (400 MHz, $CDCl_3$) 1.30 (3H, t, *J = 7.2* Hz), 1.97 (1H, dddd, *J = 16.2, 9.2, 7.1, 4.8* Hz), 2.17 (1H, dddd, *J = 16.8, 8.3, 8.4, 6.1* Hz), 2.29 (3H, s), 2.51 (1H, dd, *J = 16.8, 4.0* Hz), 2.57 (1H, dd, *J = 16.5, 12.9* Hz), 2.73-2.86 (2H, m), 4.21 (2H, q, *J = 7.1* Hz), 4.40 (1H, dddd, *J = 12.4, 8.4, 4.2, 4.0* Hz), 6.89 (1H, d, *J = 15.8* Hz), 7.19-7.34 (5H, m), 7.36 (1H, d, *J = 15.8* Hz); δ_{13C} (100 MHz, $CDCl_3$) 14.3 (CH_3), 19.5 (CH_3), 30.9 (CH_2), 35.8 (CH_2), 41.8 (CH_2), 60.1 (CH_2), 77.9 (CH), 111.6 (C), 119.3 (CH), 126.3 (CH), 128.3 (2 x CH), 128.6 (2 x CH), 135.8 (C), 140.4 (CH), 168.3 (C), 176.8 (C), 190.2 (C);

ν_{max} (film/cm^{-1}) 1703, 1619, 1563; *m/z* (HRMS, ESI) found 315.1568 ($[M+H]^+$), $C_{19}H_{23}O_4$ requires 315.1596.

(*S*,*E*)-ethyl-3-(4-oxo-2-phenethyl-6-phenyl-3,4-dihydro-2H-pyran-5-yl)acrylate (2i). 2i was obtained from **1i** (102.4 mg, 0.37 mmol) according to general procedure **E**. Purification by silica gel chromatography (hexane:EtOAc, 9:1) yielded the product (65 mg, 47% yield) as a pale yellow; R_f (hexane:EtOAc, 9:1) = 0.35; The enantiomeric excess of the product **2i** was determined to be 96% ee by HPLC analysis [column, DAICEL CHIRALCEL OD (0.46 cmΦ x 25 cm); eluent, hexane/Pr^{i}OH = 9/1; flow rate, 1.0 mL/min; retention time: 45.5 min (minor), 73.0 min (major); $[a]_D^{18}$ -287.1 (c 1.0, $CHCl_3$); δ_{1H} (400 MHz, $CDCl_3$) 1.26 (3H, t, *J = 7.1* Hz), 2.06 (1H, dddd, *J = 16.3, 9.2, 7.1, 4.3* Hz), 2.27 (1H, dddd, *J = 17.3, 8.7, 8.6, 5.8* Hz), 2.63 (1H, dd, *J = 16.7, 3.3* Hz), 2.75 (1H, dd, *J = 16.7, 13.4* Hz), 2.81-3.00 (2H, m), 4.16 (2H, q, *J = 7.1* Hz), 4.40 (1H, dddd, *J = 13.0, 7.8, 3.8, 4.0* Hz), 7.05 (1H, d, *J = 15.8* Hz), 7.22-7.35 (5H, m), 7.24 (1H, d, *J = 15.8* Hz), 7.47-7.56 (5H, m); δ_{13C} (100 MHz, $CDCl_3$) 14.3 (CH_3), 31.2 (CH_2), 35.9 (CH_2), 42.2 (CH_2), 60.0 (CH_2), 78.4 (CH), 111.0 (C), 119.6 (CH), 126.4 (CH), 128.4 (2 x CH), 128.6 (2 x CH), 128.7 (2 x CH), 130.2 (2 x CH), 132.0 (CH), 133.0 (C), 137.4 (CH), 140.4 (C), 168.3 (C), 175.0 (C), 191.3 (C); ν_{max} (film/cm^{-1}) 3063, 3026, 2982, 2934, 1704, 1676, 1533, 1394; *m/z* (HRMS, ESI) found 399.1575 ($[M+Na]^+$), $C_{24}H_{24}NaO_4$ requires 399.1567.

Synthesis of hex-4-yn-3-one 4.[3] 4 was obtained from N-methoxy-N-methylpropionamide [4] (1.2g, 10.2 mmol) according to general procedure **B**. Purification by silica gel chromatography (petroleum ether 40/60:diethyl ether, 4:1) yielded the product (380 mg, 40% yield) as a colorless oil. The NMR data of this compound are in agreement with the literature.[3]

Synthesis of compounds 9a-c

Synthesis of N-methoxy-N,2-dimethyl-2-(tetrahydro-2H-pyran-2-yloxy)propanamide 10. To a suspension of N,O-dimethylhydroxylamine hydrochloride (6.5 g, 66.6 mmol) in THF (80 mL) was added *n*-BuLi (2.5M in hexanes, 53.3 mL) at -78°C. The reaction was stirred for 30 mins and warmed at room temperature for 60 mins. The mixture was cooled down to -78°C and **11**[5] (4.80g, 22.2 mmol) was added in THF (20 mL) via cannula for 10 mins. The mixture was warmed at 0°C, then stirred for 2h and allowed to warm at room temperature for 2h. Then, it was quenched with NH_4Cl (60 mL) at 0°C. The solution was extracted with ethyl acetate then dried over $MgSO_4$. After filtration, the organic layer was evaporated *in vacuo*. Purification of the resulting residue by silica gel chromatography (hexane:EtOAc, 3:2) yielded the product (3.28 g, 64%) as a colorless oil; R_f (hexane:EtOAc, 3:2) = 0.30. δ_{1H} (400 MHz, $CDCl_3$) 1.49 (3H, s), 1.51 (3H, s), 1.50-1-60 (4H, m), 1.74 (1H, m), 1.84 (1H, m), 3.33 (3H, s), 3.42 (1H, m), 3.71 (3H, s), 3.92 (1H, m), 4.67 (1H, dd, *J = 6.5, 2.7* Hz); δ_{13C} (100 MHz, $CDCl_3$) 21.2 (CH_2), 24.9 (CH_3), 25.0 (CH_2), 25.2 (CH_3), 26.5 (CH_2), 31.7 (CH_3), 60.2 (CH_3), 64.4 (CH_2), 78.6 (C), 96.3 (CH), 173.5 (C); ν_{max} (film/cm^{-1}) 2943, 1659, 1384, 1278; *m/z* (HRMS, ESI) found 254.1363 ($[M+Na]^+$), $C_{11}H_{21}NNaO_4$ requires 254.1363.

2-Methyl-2-(tetrahydro-2H-pyran-2-yloxy)hex-4-yn-3-one (9a). 9a was obtained from **10** (747 mg, 3.23 mmol) and 1-propynylmagnesium bromide (0.5M in THF, 19.4 mL) according to general procedure **B**. Purification by silica gel chromatography (hexane:EtOAc, 3:1) yielded the product (651 mg, 96% yield) as a colorless oil; R_f (hexane:EtOAc, 3:1) = 0.70. δ_{1H} (400 MHz, $CDCl_3$) 1.35 (3H, s), 1.39 (3H, s), 1.42-1.50 (3H, m), 1.51-1.60 (1H, m), 1.70-1.87 (2H, m), 2.00 (3H, s), 3.37 (1H, m), 3.89 (1H, m), 4.58 (1H, dd, *J = 5.9, 2.7* Hz); δ_{13C} (100 MHz, $CDCl_3$) 4.2 (CH_3), 20.4 (CH_2), 23.4 (CH_3), 24.5 (CH_3), 25.2 (CH_2), 31.6 (CH_2), 63.4 (CH_2), 78.4 (C), 81.8

(C), 92.6 (C), 96.1 (CH), 190.7 (C); ν_{max} (film/cm^{-1}) 2944, 2217, 1674, 1441, 1381, 1274; *m/z* (HRMS, ESI) found 233.1146 ([M+Na]$^+$), $C_{12}H_{18}NaO_3$ requires 233.1148.

2-Methyl-2-(tetrahydro-2H-pyran-2-yloxy)oct-4-yn-3-one (9b). 9b was obtained from **10** (677 mg, 2.93 mmol) and 1-pentyne (318 µL, 3.2 mmol) according to general procedure **C**. Purification by silica gel chromatography (cyclohexane:EtOAc, 4:1) yielded the product (627 mg, 90% yield) as a colorless oil; R_f (cyclohexane:EtOAc, 4:1) = 0.50. δ_{1H} (400 MHz, C_6D_6) 0.84 (3H, t, *J = 7.4* Hz), 1.30 (2H, qt, *J = 7.2, 7.1* Hz), 1.33-1.40 (3H, m), 1.56 (3H, s), 1.65 (3H, s), 1.79-1.87 (3H, m), 1.94 (2H, t, *J = 7.0* Hz), 3.36 (1H, m), 3.97 (1H, m), 4.89 (1H, m); δ_{13C} (100 MHz, C_6D_6) 13.3 (CH_3), 20.3 (CH_2), 20.8 (CH_2), 21.4 (CH_2), 23.9 (CH_3), 24.4 (CH_3), 25.5 (CH_2), 31.9 (CH_2), 62.7 (CH_2), 80.3 (C), 81.8 (C), 95.3 (C), 95.8 (CH), 189.9 (C); ν_{max} (film/cm^{-1}) 2940, 2210, 1677, 1023; *m/z* (HRMS, ESI) found 261.1458 ([M+Na]$^+$), $C_{14}H_{22}NaO_3$ requires 261.1461.

4-Methyl-1-phenyl-4-(tetrahydro-2H-pyran-2-yloxy)pent-1-yn-3-one (9c). 9c was obtained from **10** (756 mg, 3.27 mmol) and phenylacetylene (395 µL, 3.6 mmol) according to general procedure **C**. Purification by silica gel chromatography (cyclohexane:EtOAc, 4:1) yielded the product (818 mg, 92% yield) as a colorless oil; R_f (cyclohexane:EtOAc, 4:1) = 0.65. δ_{1H} (400 MHz, C_6D_6) 1.26-1.38 (3H, m), 1.60 (3H, s), 1.68 (3H, s), 1.77-1.92 (3H, m), 3.35 (1H, m), 4.0 (1H, m), 4.92 (1H, m), 6.95 (2H, m), 7.02 (1H, m), 7.41 (2H, m); δ_{13C} (100 MHz, C_6D_6) 20.3 (CH_2), 24.0 (CH_3), 24.2 (CH_3), 25.6 (CH_2), 32.0 (CH_2), 62.8 (CH_2), 81.9 (C), 87.6 (C), 92.2 (C), 95.7 (CH), 120.9 (C), 128.7 (2 x CH), 130.4 (CH), 133.1 (2 x CH), 190.1 (C); ν_{max} (film/cm^{-1}) 2943, 2853, 2280, 1672, 1490, 1443, 1381; *m/z* (HRMS, ESI) found 295.1305 ([M+Na]$^+$) $C_{17}H_{20}NaO_3$ requires 295.1305.

Synthesis of compounds 6b-c

2-Hydroxy-2-methyloct-4-yn-3-one (6b). 6b was obtained from **9b** (611 mg, 2.57 mmol) according to general procedure **D**. Purification by silica gel chromatography (hexane:EtOAc, 3:1) yielded the product (360 mg, 91% yield) as a colorless oil; R_f (hexane:EtOAc, 3:1) = 0.40. δ_{1H} (400 MHz, $CDCl_3$) 1.03 (3H, t, *J = 7.3* Hz), 1.44 (6H, s), 1.64 (2H, app sext, *J = 7.3* Hz), 2.41 (2H, t, *J = 7.0* Hz), 3.53 (1H, br s); δ_{13C} (100 MHz, $CDCl_3$) 13.4 (CH_3), 21.2 (2 x CH_2), 26.5 (2 x CH_3), 77.2 (C), 77.5 (C), 100.6 (C), 192.5 (C); ν_{max} (film/cm^{-1}) 3491, 2971, 2211, 1671, 1463, 1361; *m/z* (HRMS, GCT) found 155.1073 ($[M+H]^+$), $C_9H_{15}O_2$ requires 155.1072.

4-Hydroxy-4-methyl-1-phenylpent-1-yn-3-one (6c).[6] 6c was obtained from **9c** (700 mg, 2.57 mmol) according to general procedure **D**. Purification by silica gel chromatography (hexane:EtOAc, 3:1) yielded the product (450 mg, 93% yield) as a colorless oil. The NMR data of this compound are in agreement with the literature.[6]

Synthesis of compounds 7a-c

(*E*)-Ethyl-3-(2,5,5-trimethyl-4-oxo-4,5-dihydrofuran-3-yl)acrylate (7a). 7a was obtained from **6a** (49.7 mg, 0.4 mmol) according to general procedure **E**. Purification by silica gel chromatography (hexane:EtOAc, 9:1) yielded the product (46 mg, 52% yield) as a white solid; mp = 107 °C; R_f (hexane:EtOAc, 3:1) = 0.45. δ_{1H} (400 MHz, $CDCl_3$) 1.29 (3H, t, *J = 7.1* Hz), 1.40 (6H, s), 2.44 (3H, s), 4.21 (2H, q, *J = 7.1* Hz), 6.88 (1H, d, *J = 15.7* Hz), 7.28 (1H, d, *J = 15.7* Hz); δ_{13C} (100 MHz, $CDCl_3$) 14.3 (CH_3), 15.4 (CH_3), 22.9 (2 x CH_3), 60.2 (CH_2), 88.6 (C), 109.4 (C), 117.7 (CH), 131.4 (CH), 167.8 (C), 187.8 (C), 203.4 (C); ν_{max} (film/cm^{-1}) 2988, 1695, 1637, 1580; *m/z* (HRMS, ESI) found 225.1120 ($[M+H]^+$), $C_{12}H_{17}O_4$ requires 225.1121.

(*E*)-Ethyl-3-(5,5-dimethyl-4-oxo-2-propyl-4,5-dihydrofuran-3-yl)acrylate (7b). 7b was obtained from **6b** (61.5 mg, 0.40 mmol) according to general procedure **E**. Purification by silica gel chromatography (hexane:EtOAc, 4:1) yielded the product (58 mg, 58%) as a pale yellow oil; R_f (hexane:EtOAc, 4:1) = 0.50. δ_{1H} (400 MHz, $CDCl_3$) 1.00 (3H, t, *J = 7.4* Hz), 1.29 (3H, t, *J = 7.1* Hz), 1.39 (6H, s), 1.73 (2H, app sext, *J = 7.4* Hz), 2.66 (2H, t, *J = 7.4* Hz), 4.21 (2H, q, *J = 7.1* Hz), 6.91 (1H, d, *J = 15.7* Hz), 7.28 (1H, d, *J = 15.7* Hz); δ_{13C} (100 MHz, $CDCl_3$) 13.6 (CH_3), 14.3 (CH_3), 20.0 (CH_2), 22.9 (2 x CH_3), 30.7 (CH_2), 60.2 (CH_2), 88.3 (C), 109.1 (C), 117.7 (CH), 131.4 (CH), 167.9 (C), 191.1 (C), 203.8 (C); ν_{max} (film/cm^{-1}) 2977, 2935, 2876, 1705, 1633, 1577; *m/z* (HRMS, ESI) found 275.1252 ($[M+Na]^+$), $C_{14}H_{20}NaO_4$ requires 275.1254.

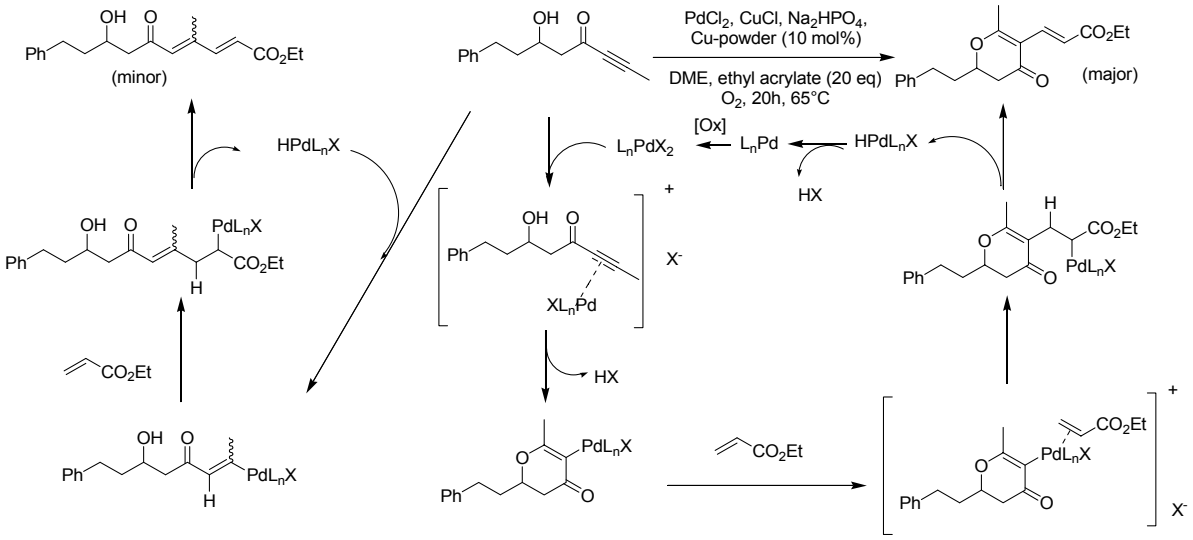
(*E*)-Ethyl 3-(5,5-dimethyl-4-oxo-2-phenyl-4,5-dihydrofuran-3-yl)acrylate (7c). 7c was obtained from **6c** (76.5 mg, 0.41 mmol) according to general procedure **E**. Purification by silica gel chromatography (cyclohexane:EtOAc, 4:1) yielded the product (76 mg, 65% yield) as a pale yellow oil; R_f (cyclohexane:EtOAc, 4:1) = 0.50. δ_{1H} (400 MHz, $CDCl_3$) 1.29 (3H, t, *J = 7.1* Hz), 1.51 (6H, s), 4.22 (2H, q, *J = 7.1* Hz), 7.07 (1H, d, *J = 15.7* Hz), 7.55 (1H, d, *J = 15.8* Hz), 7.51-7.63 (3H, m), 7.75 (2H, m); δ_{13C} (100 MHz, $CDCl_3$) 14.3 (CH_3), 23.1 (2 x CH_3), 60.2 (CH_2), 88.2 (C), 108.4 (C), 119.5 (CH), 128.7 (2 x CH), 129.0 (2 x CH), 129.4 (CH), 132.2 (C), 132.6 (CH), 167.8 (C), 182.9 (C), 204.2 (C); ν_{max} (film/cm^{-1}) 2981, 1705, 1626, 1561; *m/z* (HRMS, ESI) found 309.1097 ($[M+Na]^+$), $C_{17}H_{18}NaO_4$ requires 309.1097.

2,2-Dimethyl-5-phenylfuran-3(2H)-one (8).[7] Isolated side product of the above reaction in 26% yield. Purification by silica gel chromatography (cyclohexane:EtOAc, 4:1) yielded the product as a white solid. The NMR data of this compound are in agreement with the literature. [7]

Synthesis of (2E)-ethyl 8-hydroxy-4-methyl-6-oxo-10-phenyldeca-2,4-dienoate. Isolated side product of the domino Wacker Heck reaction of (±)-**1h** in 9% yield. R_f (hexane:EtOAc, 1:1) = 0.44. δ_{1H} (400 MHz, $CDCl_3$) 1.33 (3H, t, *J = 7.0* Hz), 1.73 (1H, dddd, *J = 16.8, 9.8, 6.9, 4.2* Hz), 1.86 (1H, dddd, *J = 18.0, 9.3, 8.9, 5.4* Hz), 2.26 (3H, d, *J = 1.2* Hz), 2.66 (1H, d, *J = 17.6, 8.3* Hz), 2.72 (1H, d, *J = 17.6, 3.2* Hz), 2. 73 (1H, m), 2.80-2.88 (1H, m), 3.16 (1H, br s), 4.09 (1H, m), 4.25 (2H, q, *J = 7.0* Hz), 6.28 (1H, d, *J = 15.6* Hz), 6.32 (1H, br s), 7.18-7.29 (5H, m), 7.29 (1H, d, *J = 15.6* Hz); δ_{13C} (100 MHz, $CDCl_3$) 14.1, 14.2, 31.8, 38.1, 51.0, 60.9, 67.1, 125.0, 125.9, 128.4 (2C), 128.5 (2C), 131.3, 141.8, 147.1, 148.1, 166.3, 201.8; ν_{max} (film/cm^{-1}) 2935, 1714, 1650, 1367; *m/z* (HRMS, FI) found 316.1688 ($[M]^+$), $C_{19}H_{24}O_4$ requires 316.1675.

Mechanistic details: Side product formation for the cyclization of (±)-1h

For the cyclization of (±)-**1h**, a minor product was isolated in 9% yield and its formation could be rationalised in the following manner. In the catalytic cycle, ligand exchange can occur prior to β-hydride elimination allowing transfer and regioselective *syn* addition of the palladium hydride species onto the starting ynone. The resulting intermediate can undergo β-hydride elimination to afford this acyclic side product. Noteworthy, although this ring closure has been repeated several times, we observed the side-product only once.



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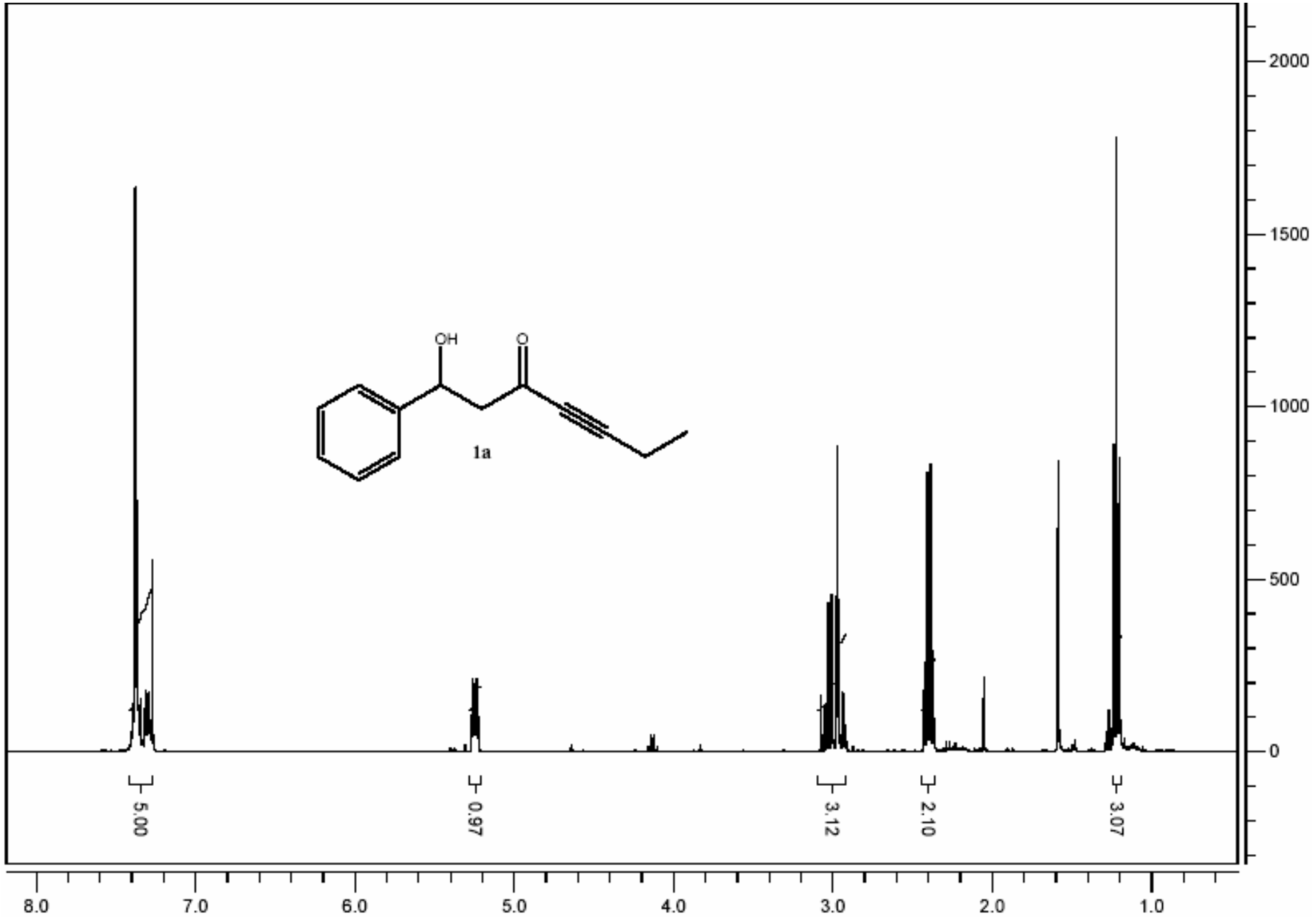
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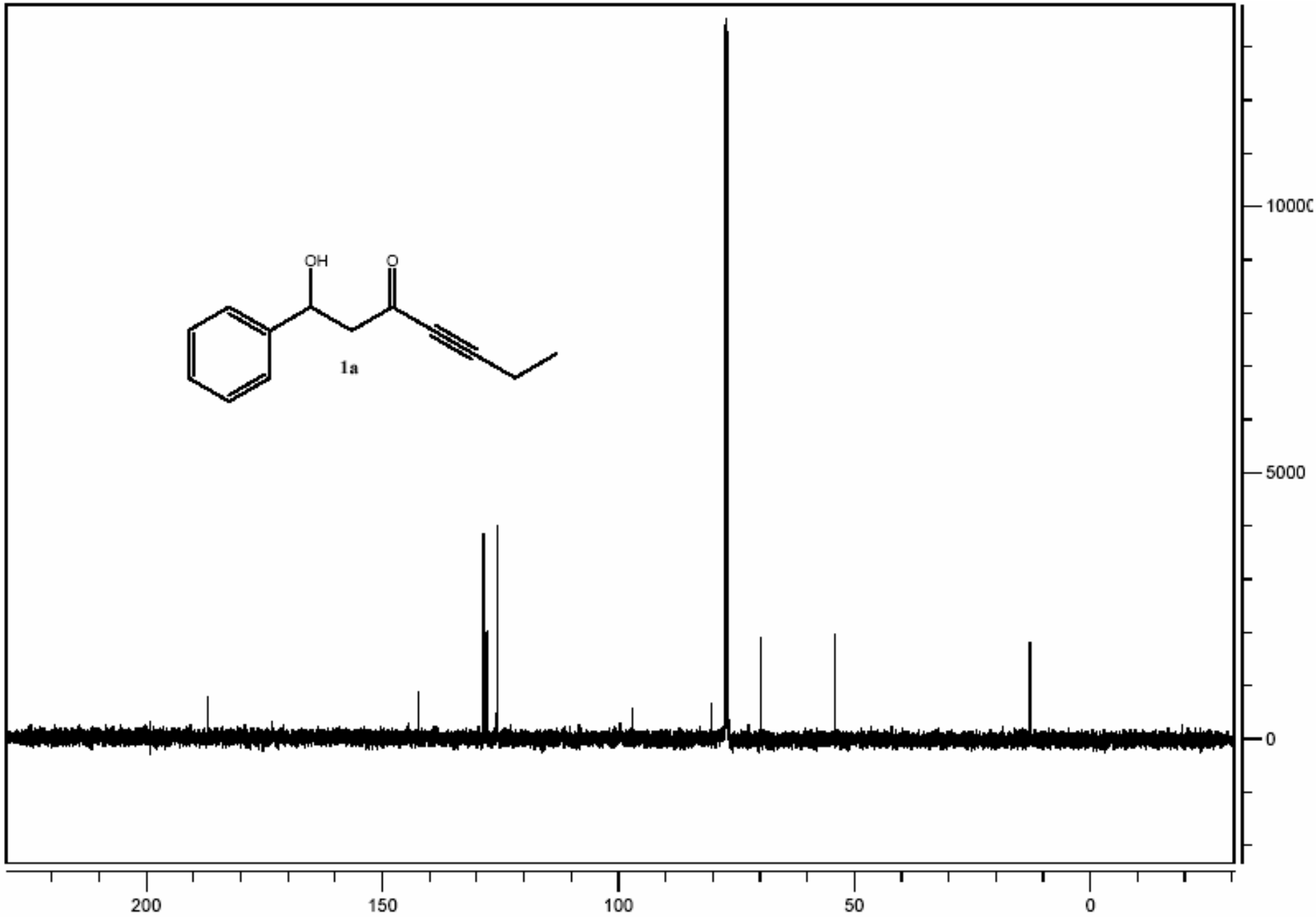
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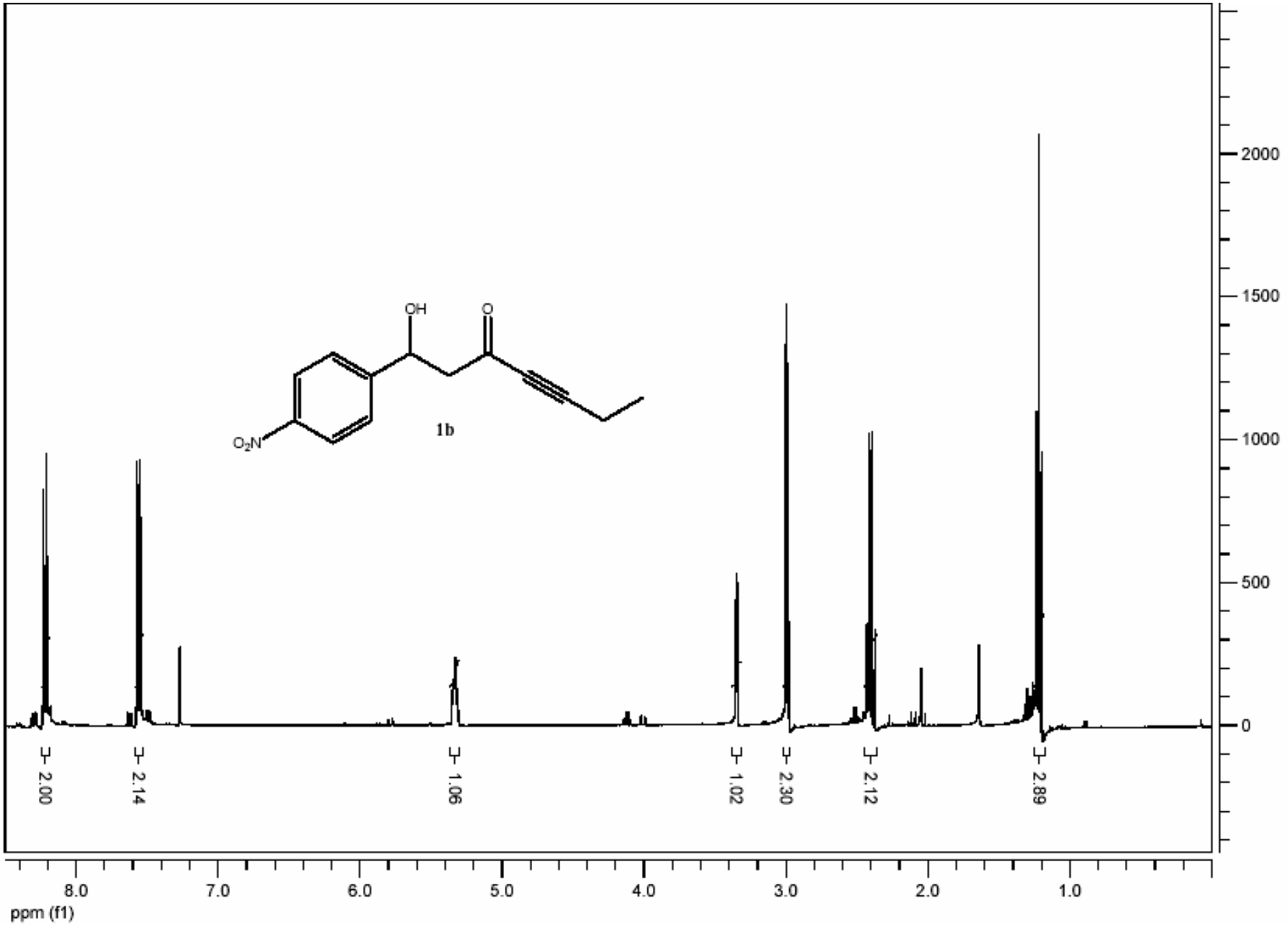
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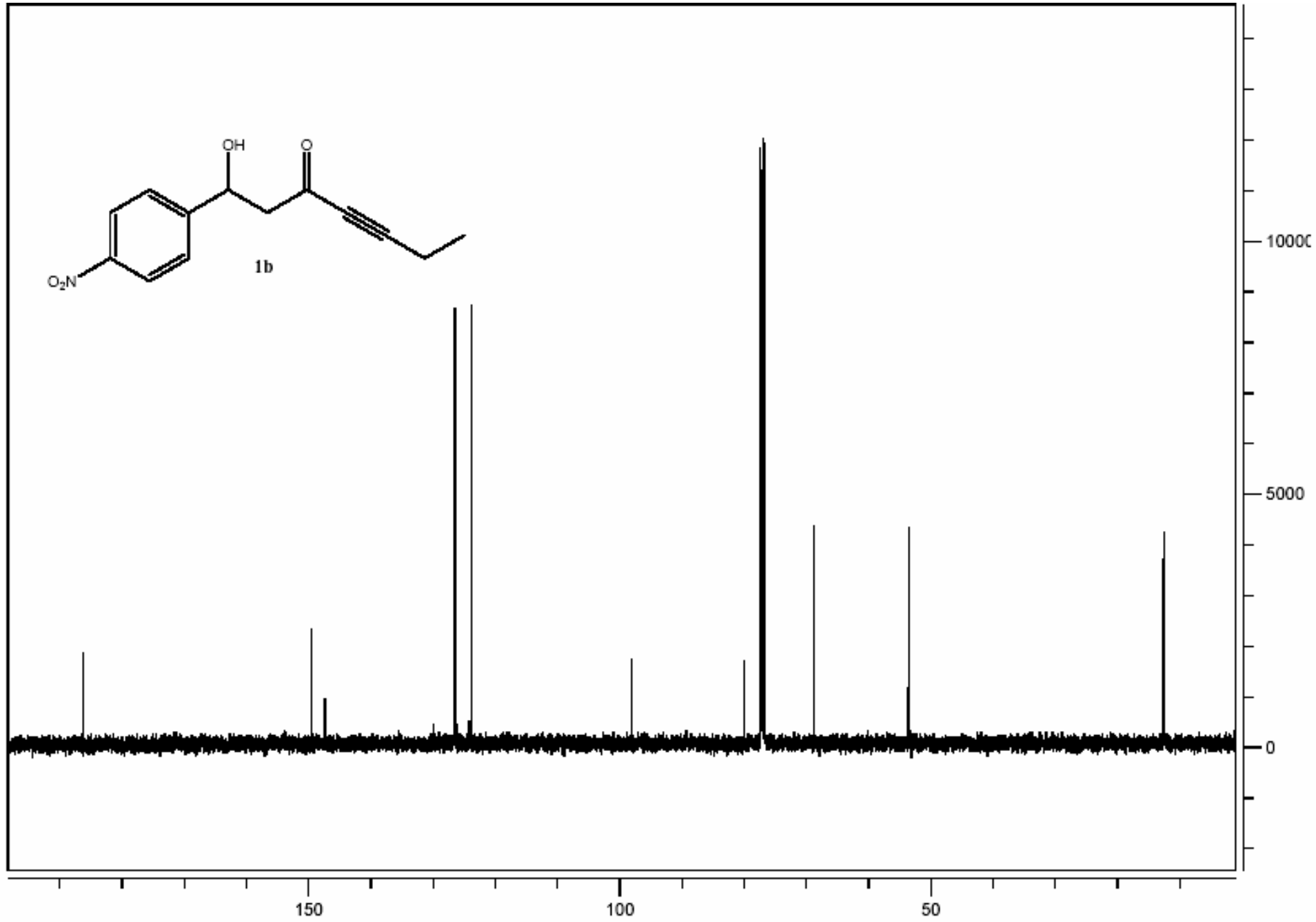
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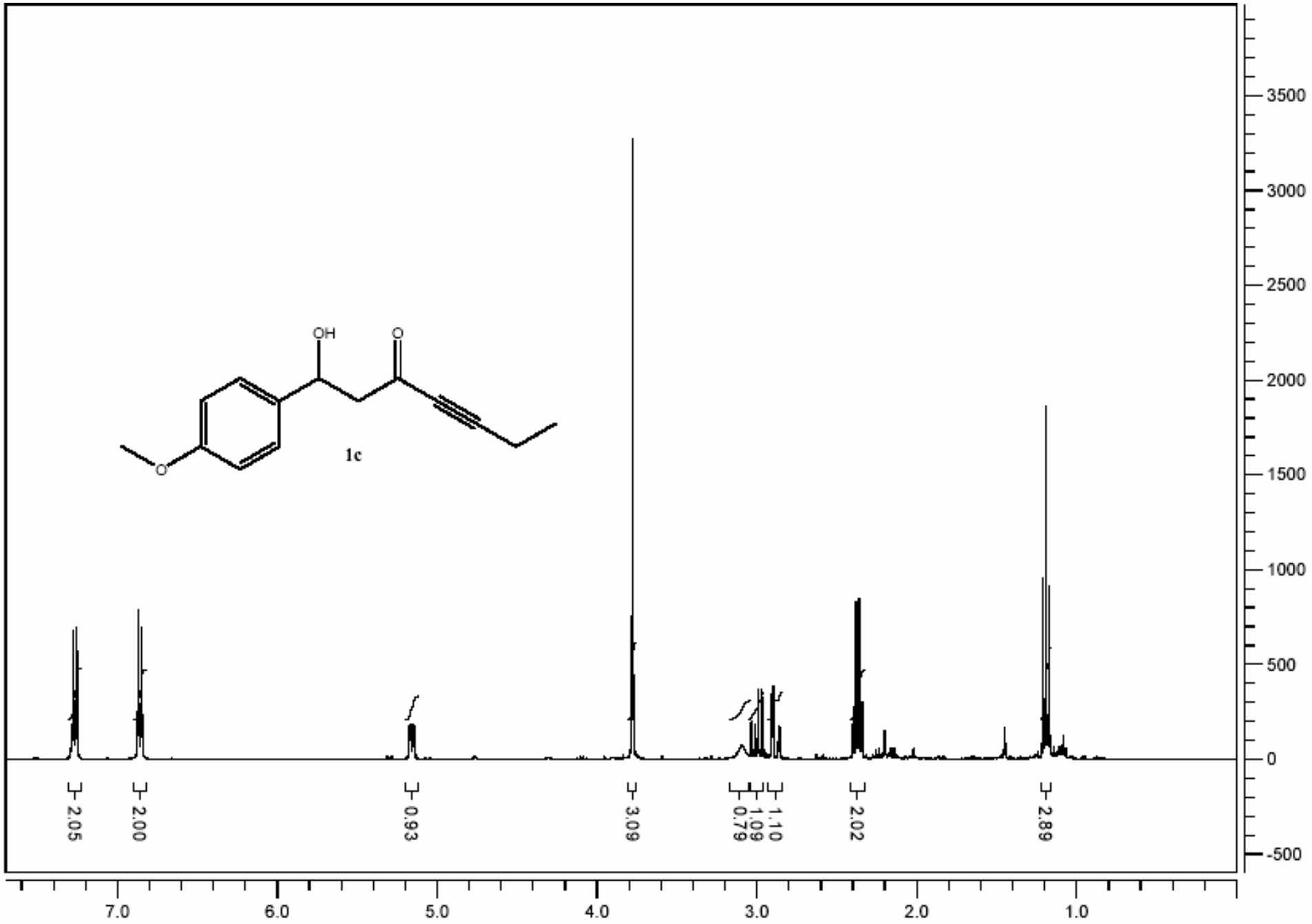
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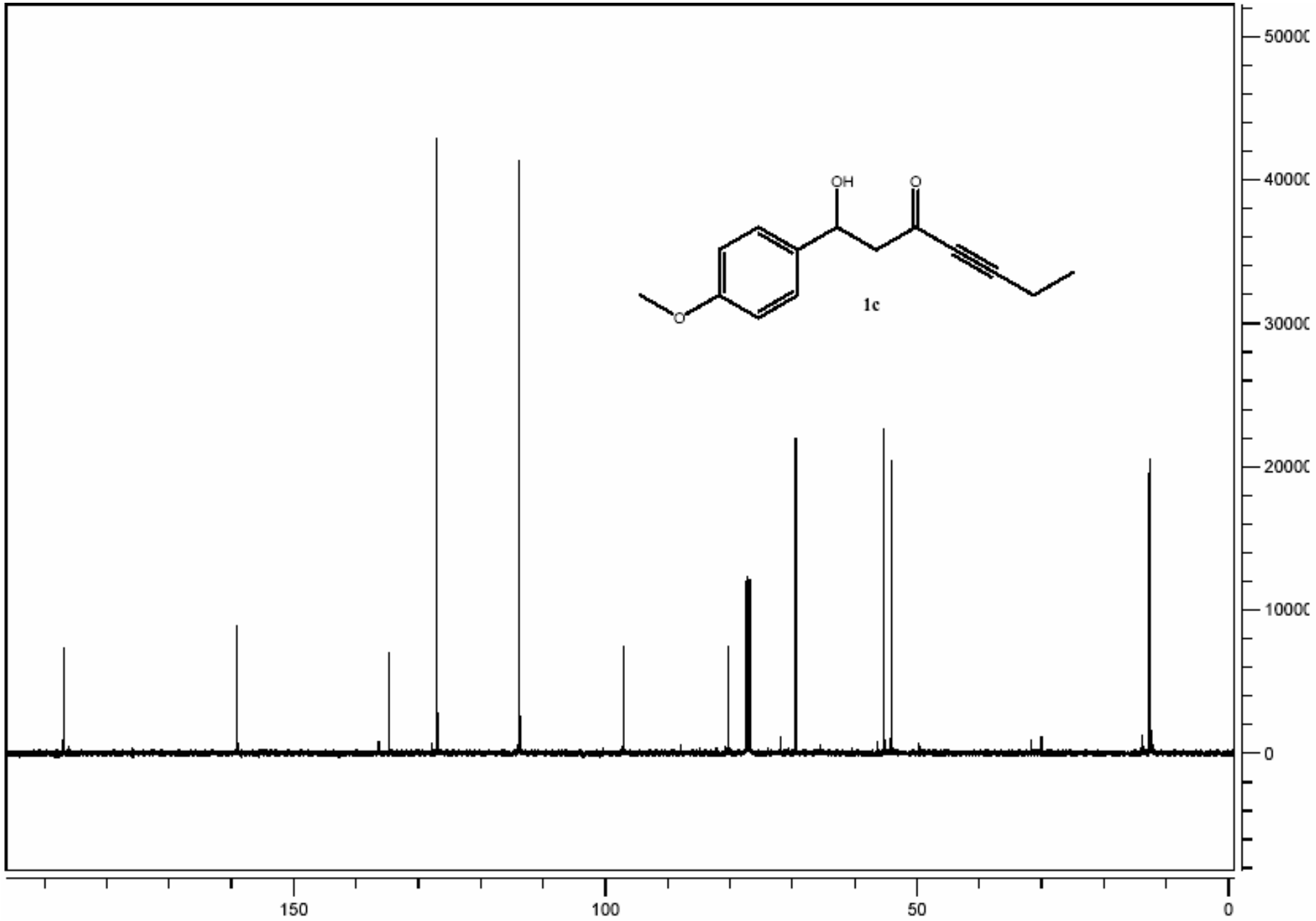
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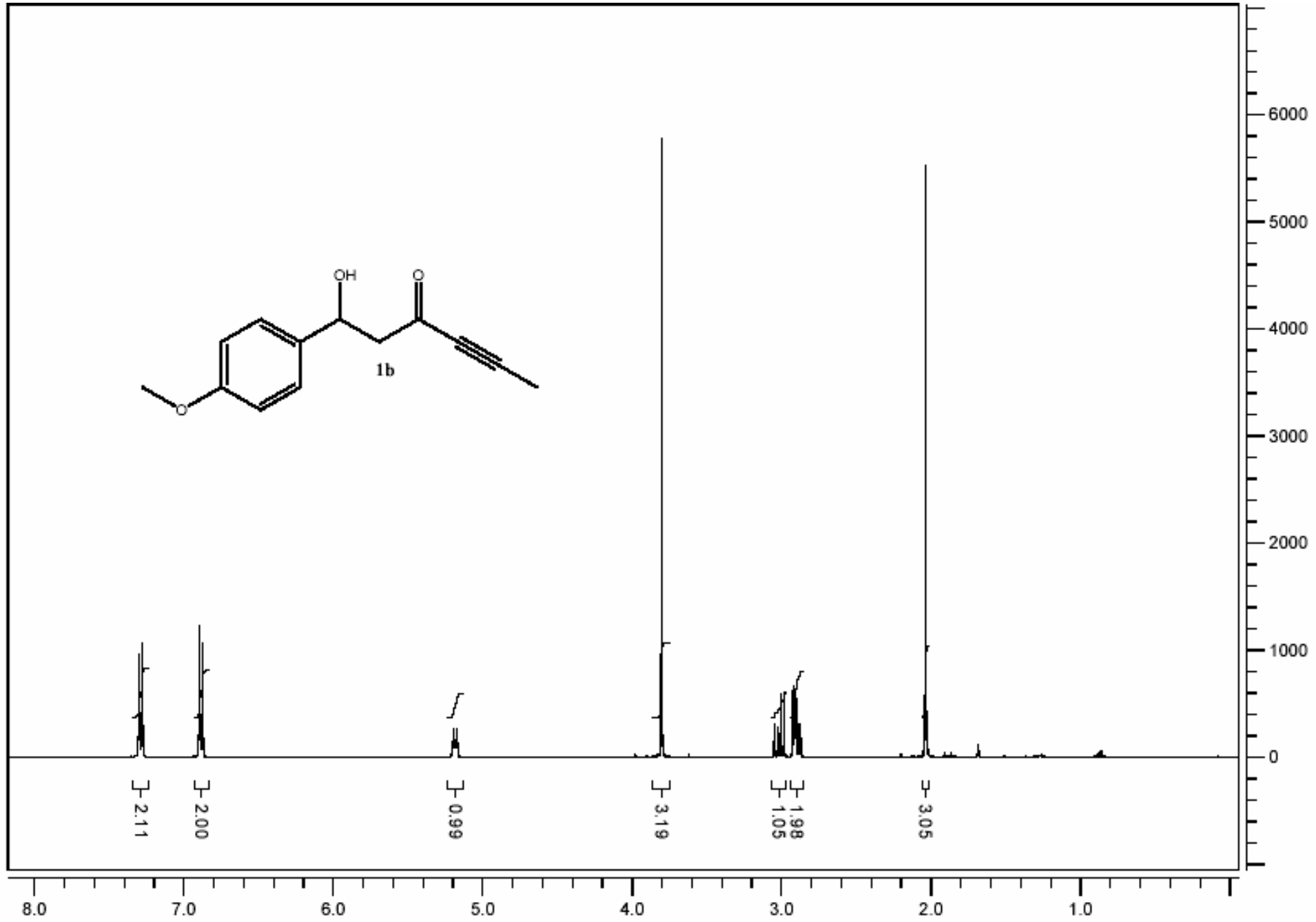
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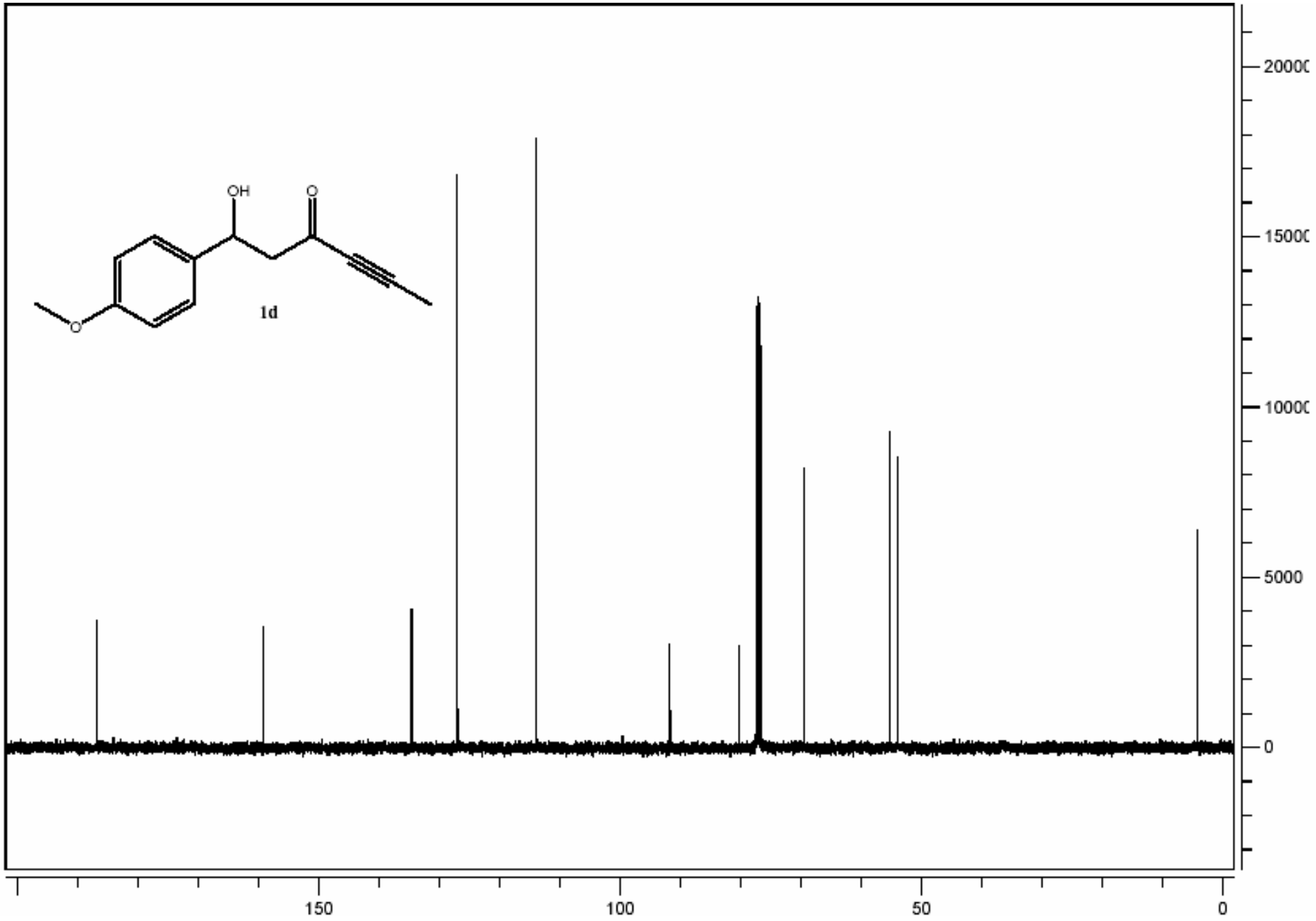
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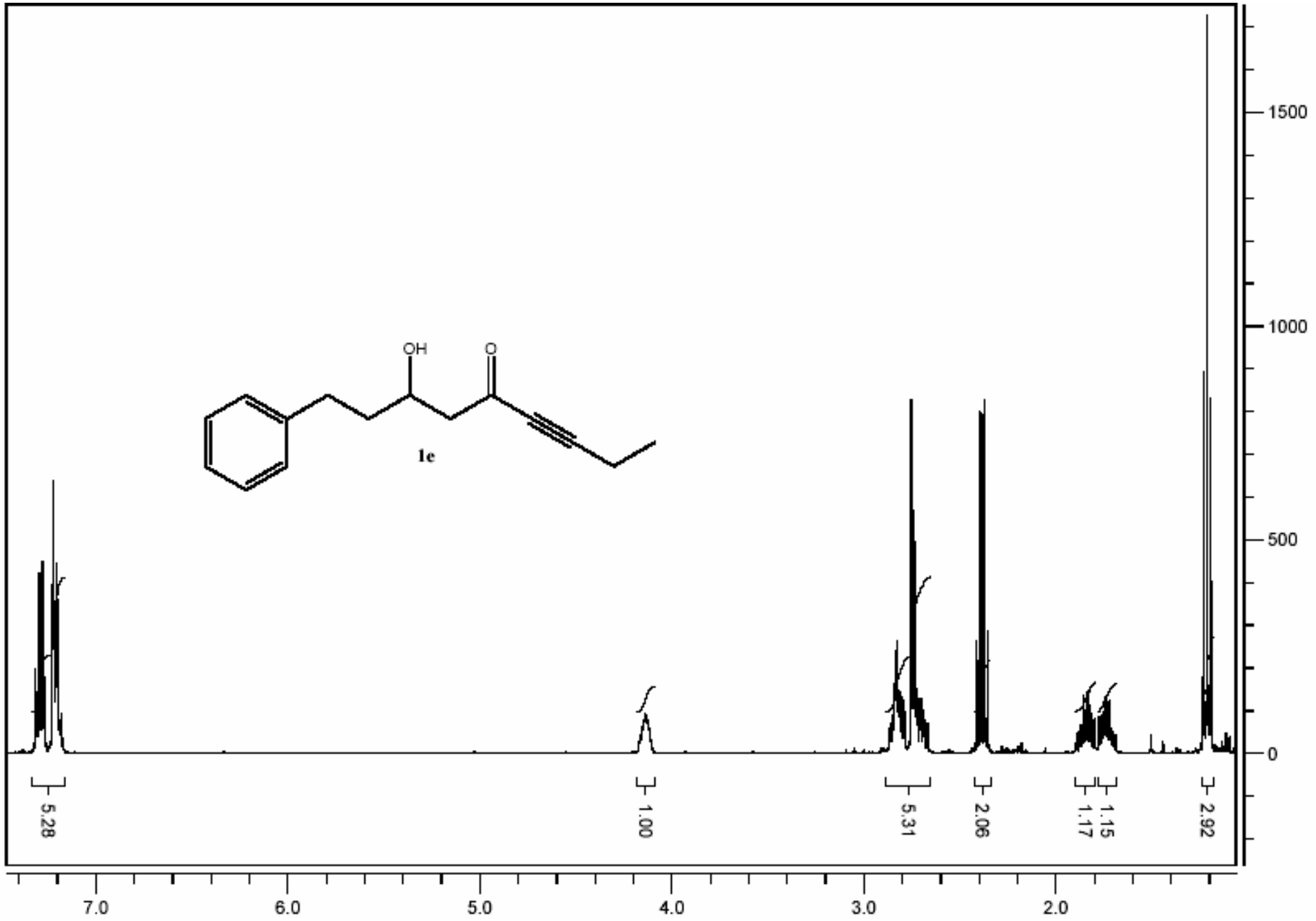
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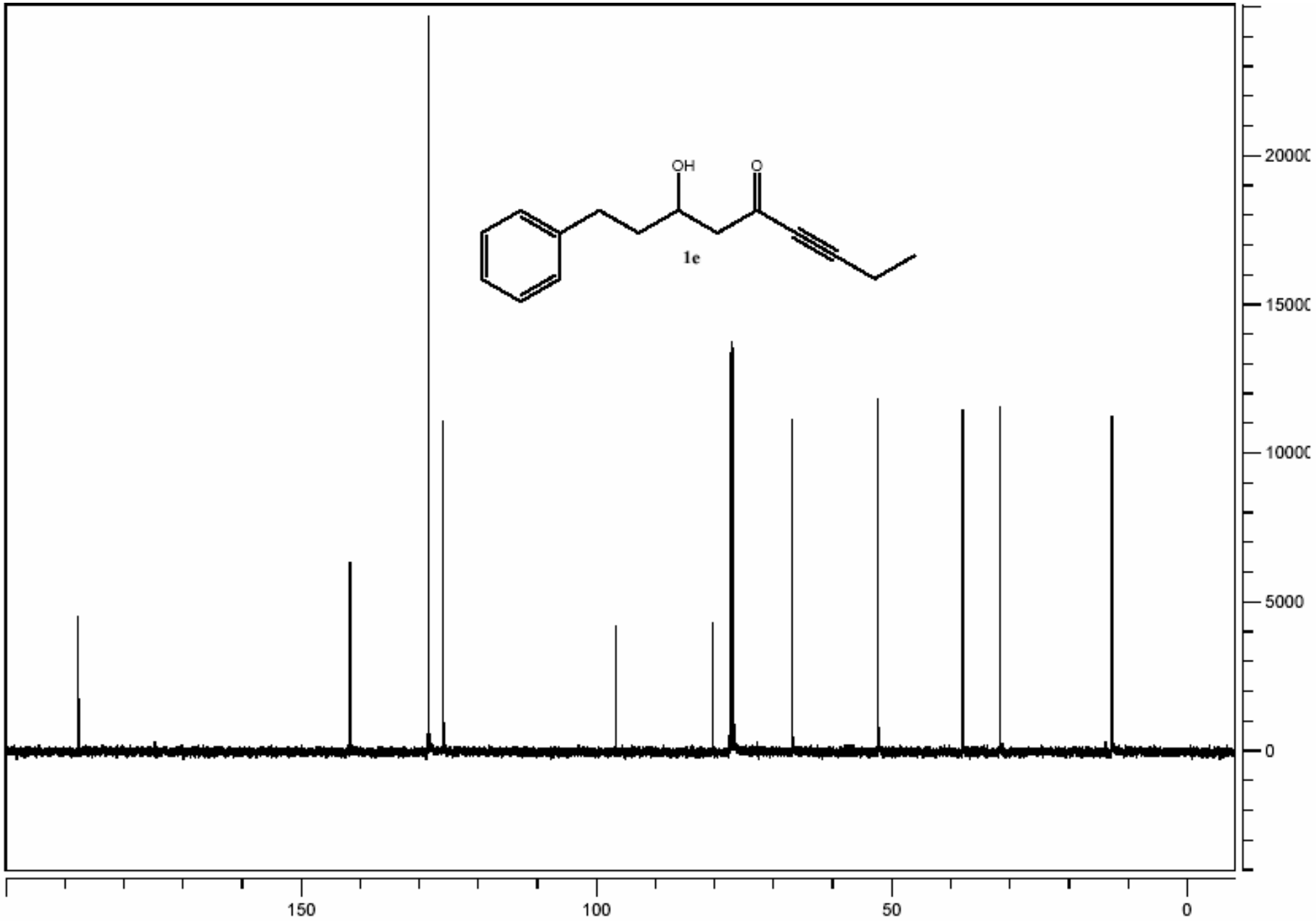
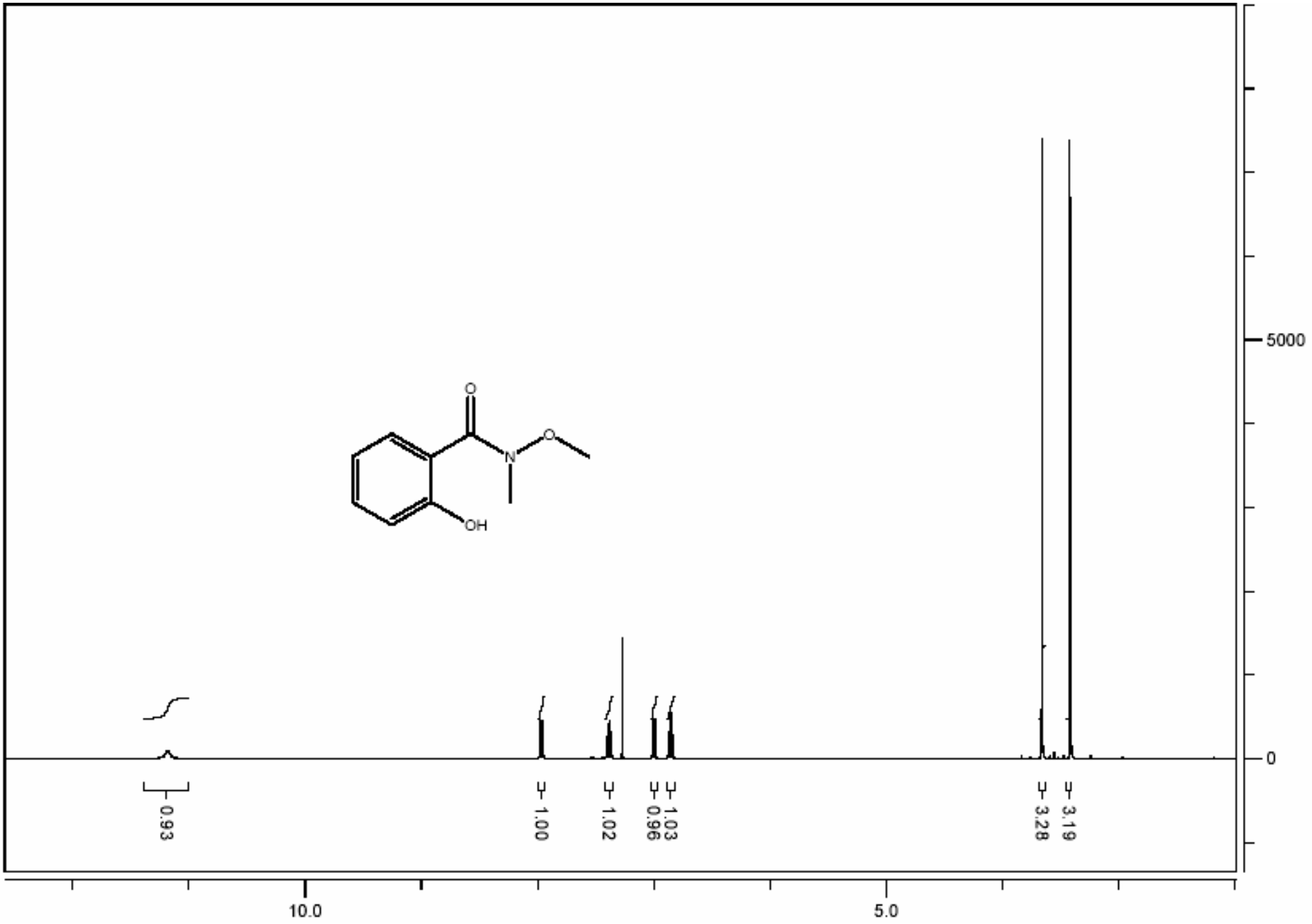
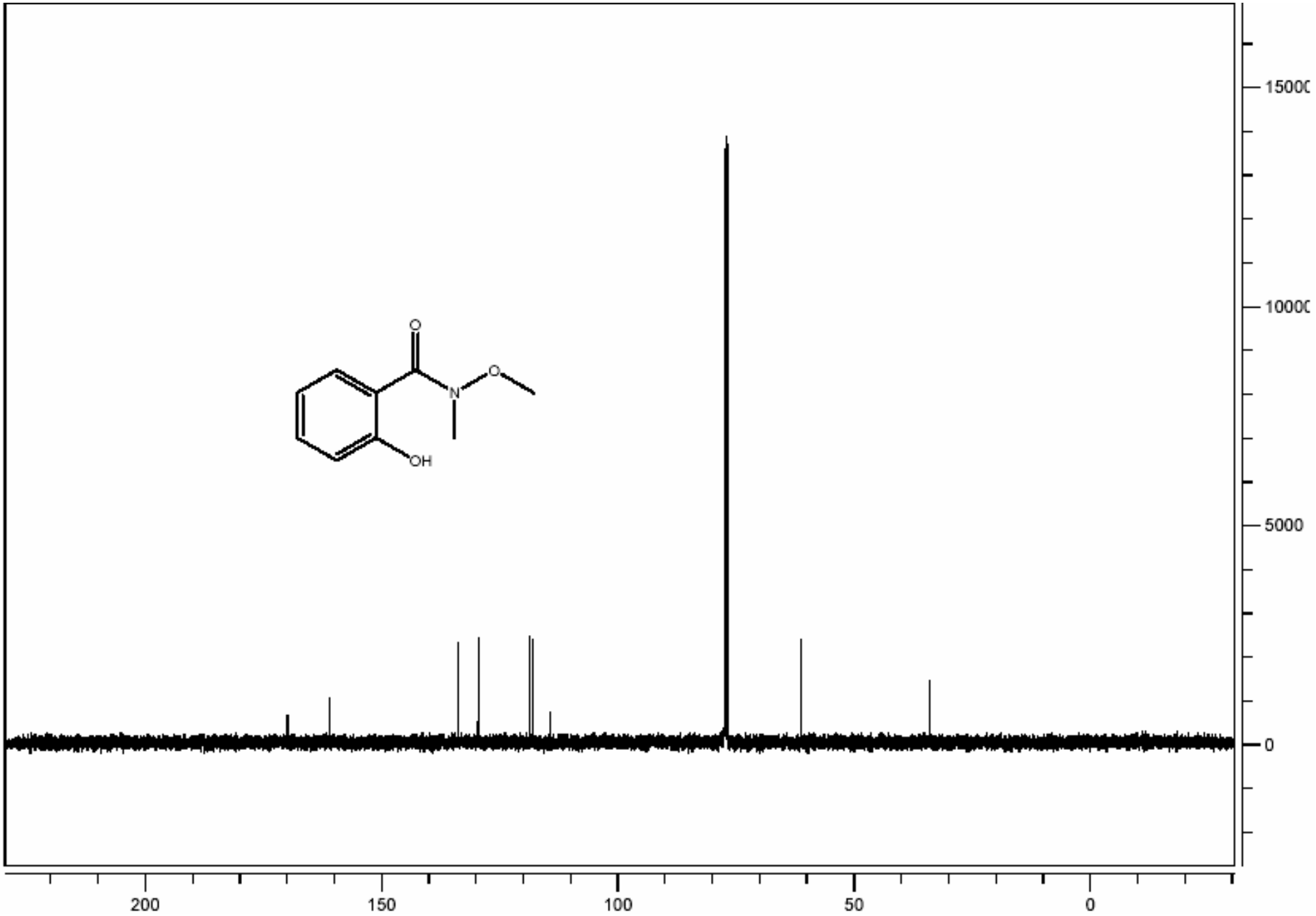
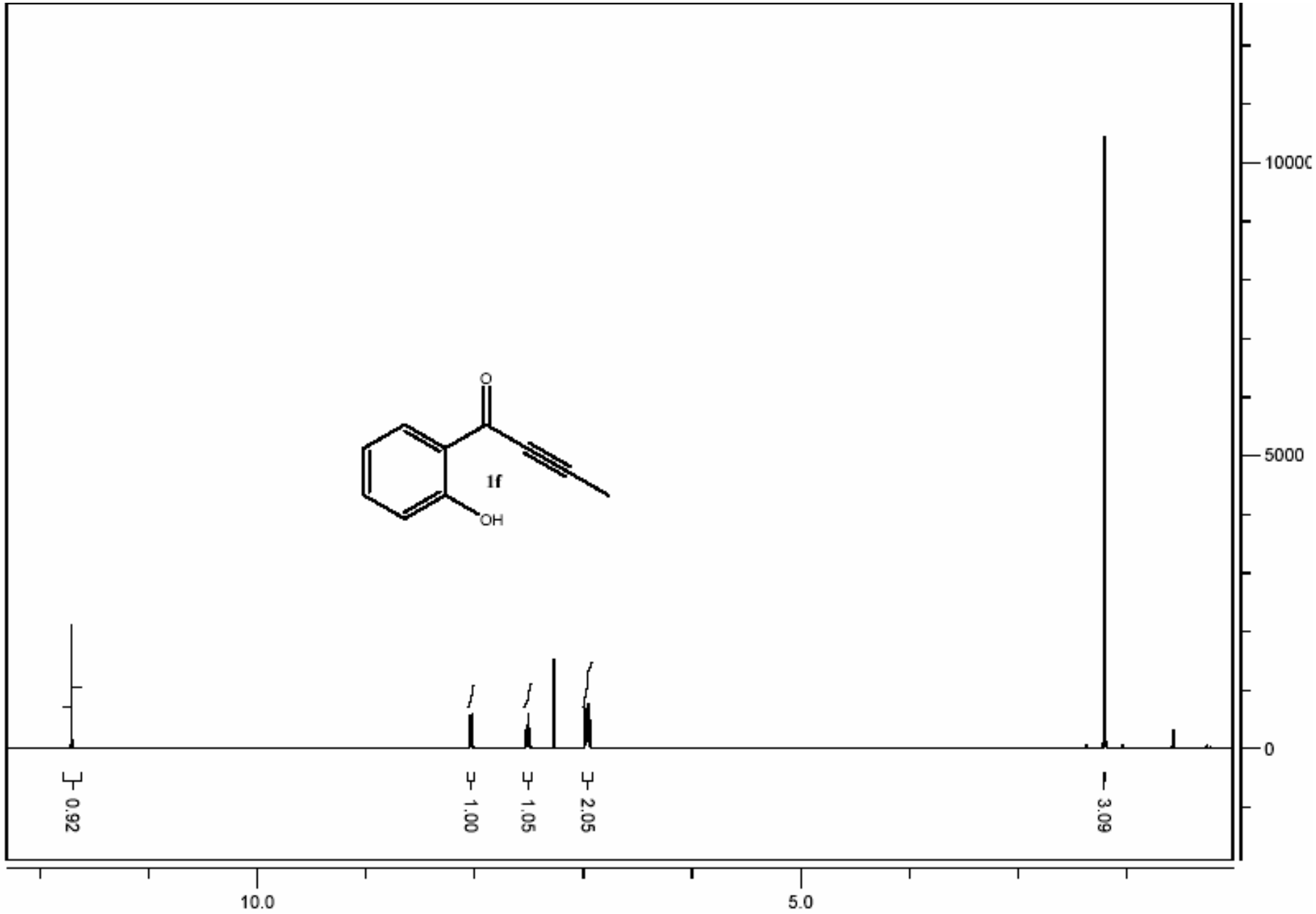
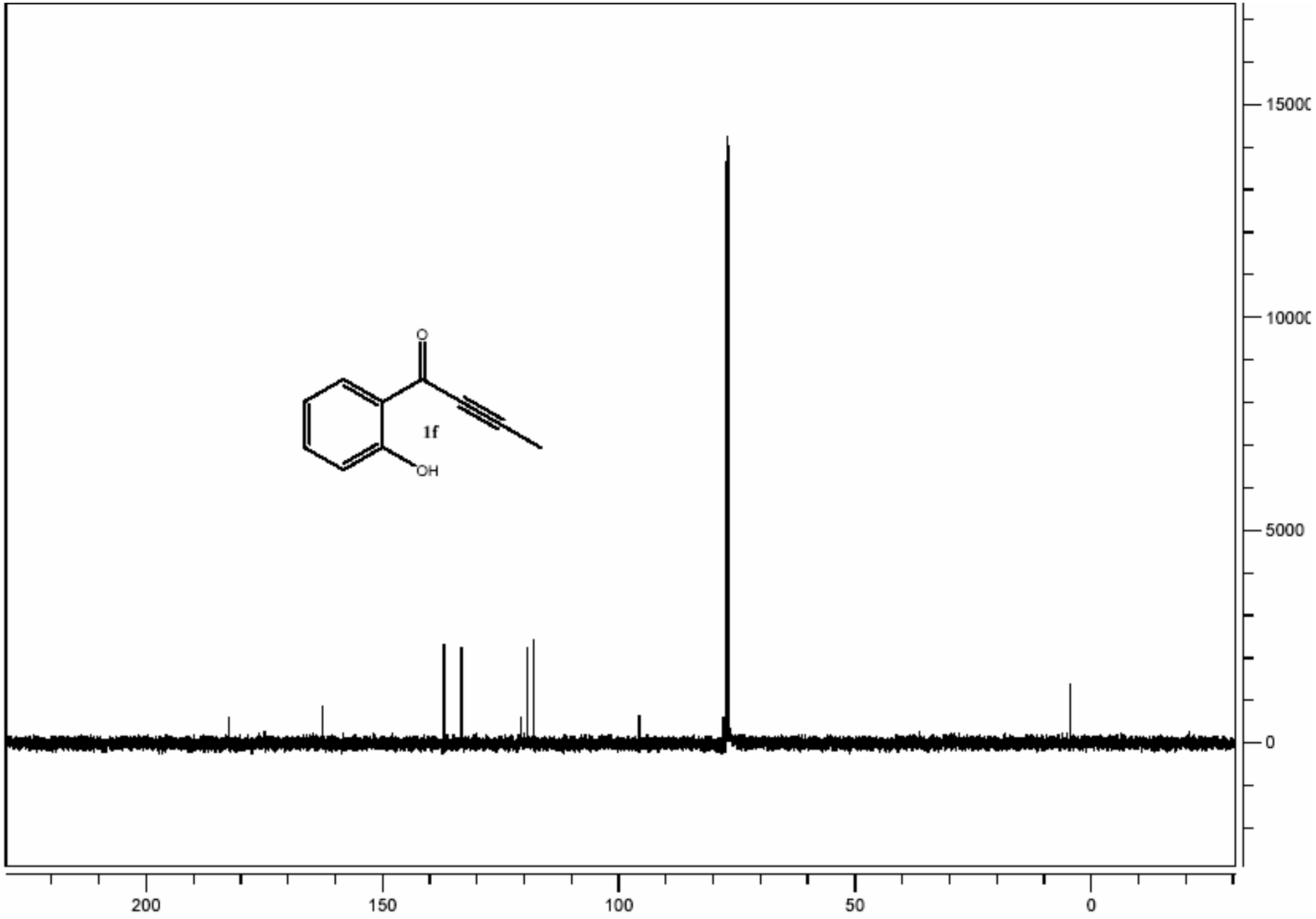
500
0
7.0
6.0
5.0
4.0
3.0
2.0

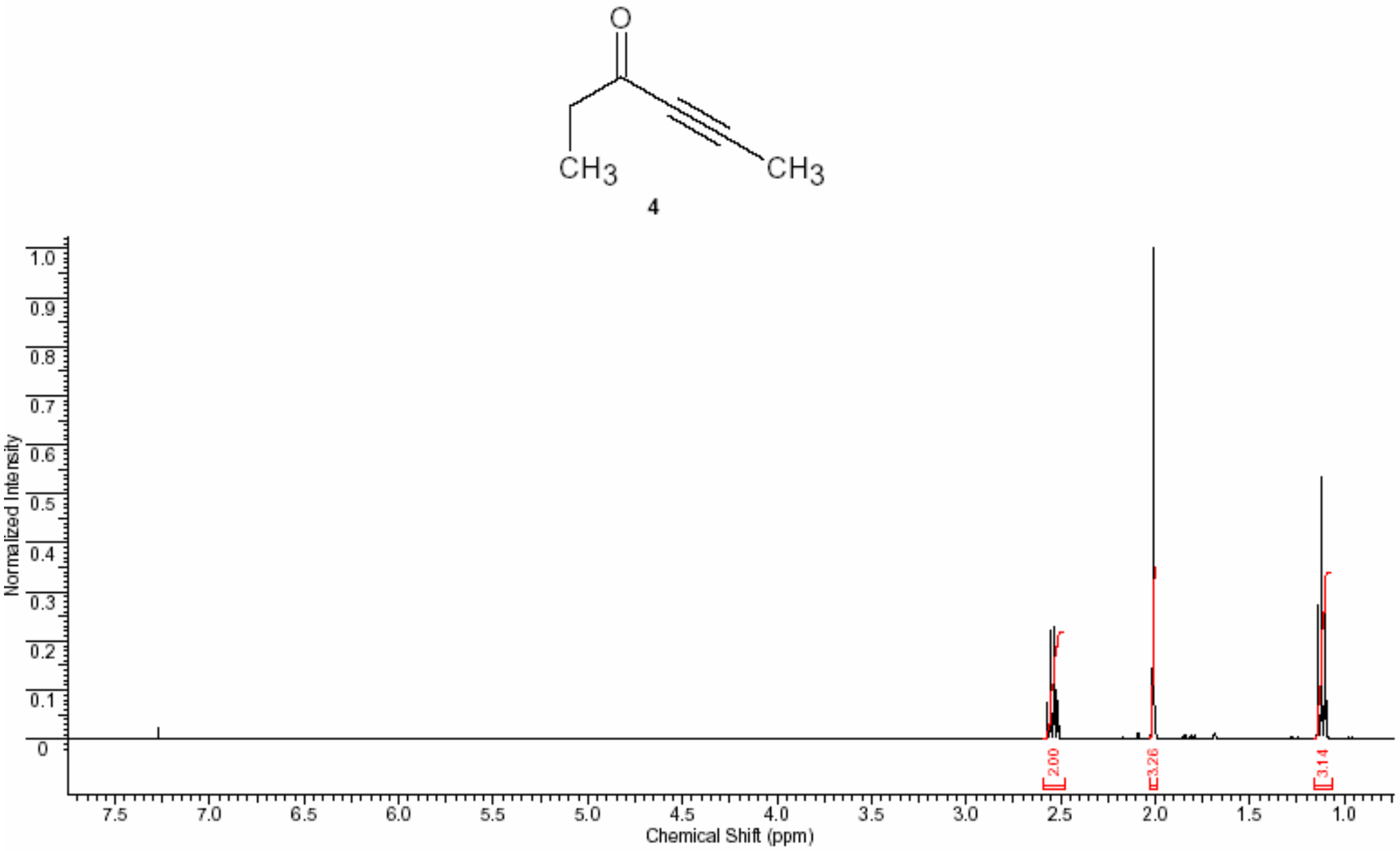

OH
O
1e
150
100
50
0
20000
15000
10000
5000
0

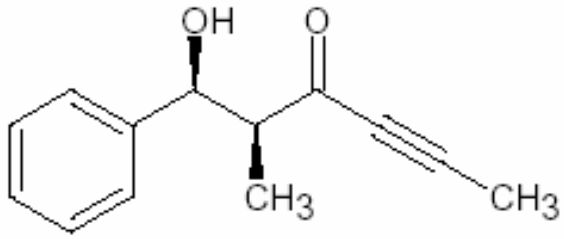

O
N
O
OH
5000
0
0.93
1.00
1.02
0.96
1.03
3.28
3.19
10.0
5.0


O
N
O
OH
15000
10000
5000
0
200
150
100
50
0

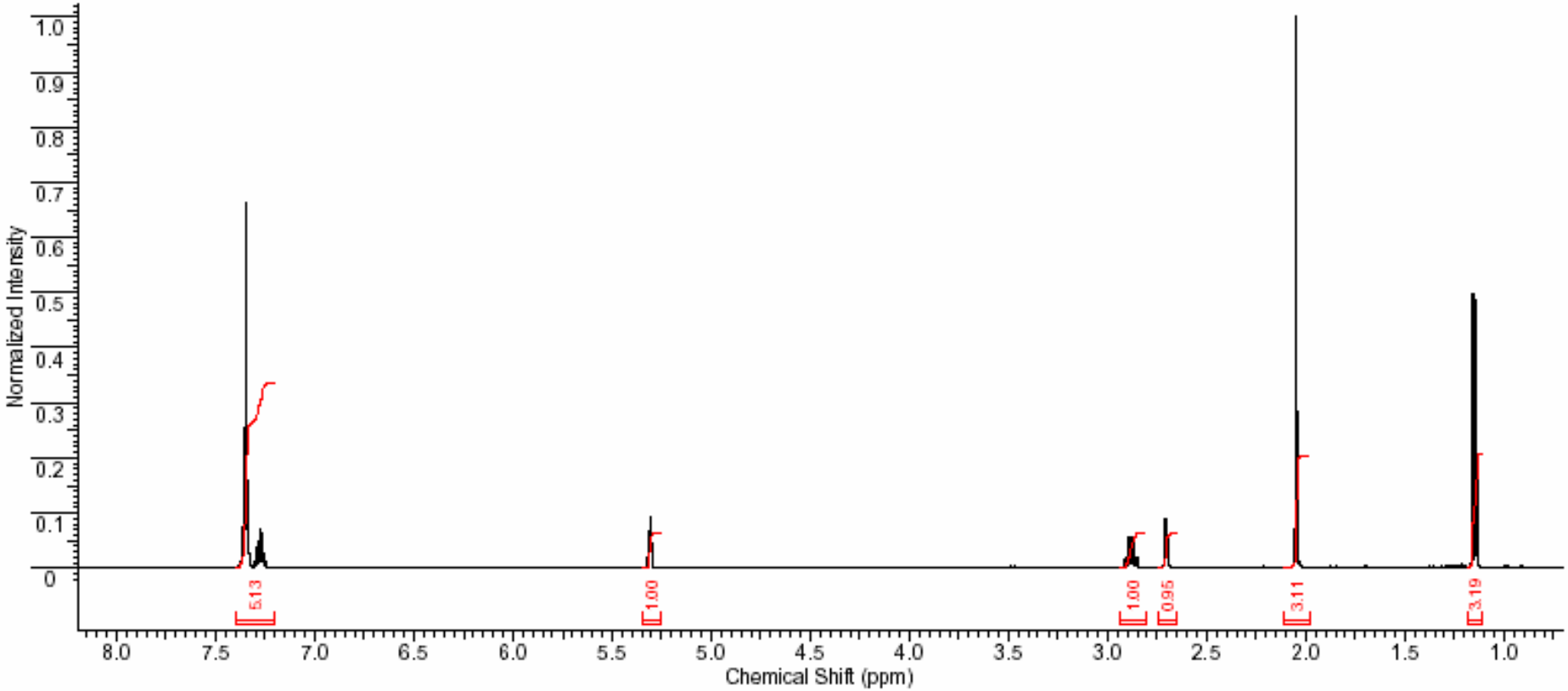

O
1f
OH
10000
5000
0
0.92
1.00
1.05
2.05
3.09
10.0
5.0

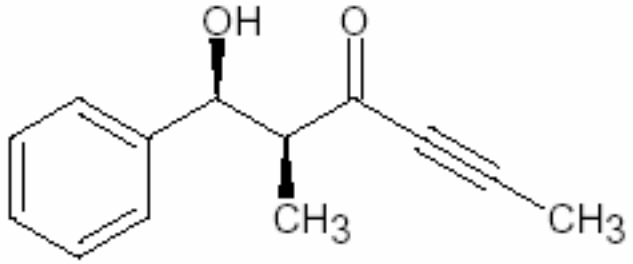

O
1f
OH
15000
10000
5000
0
200
150
100
50
0


O
CH3
CH3
4
Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2.00
3.26
3.14
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Chemical Shift (ppm)

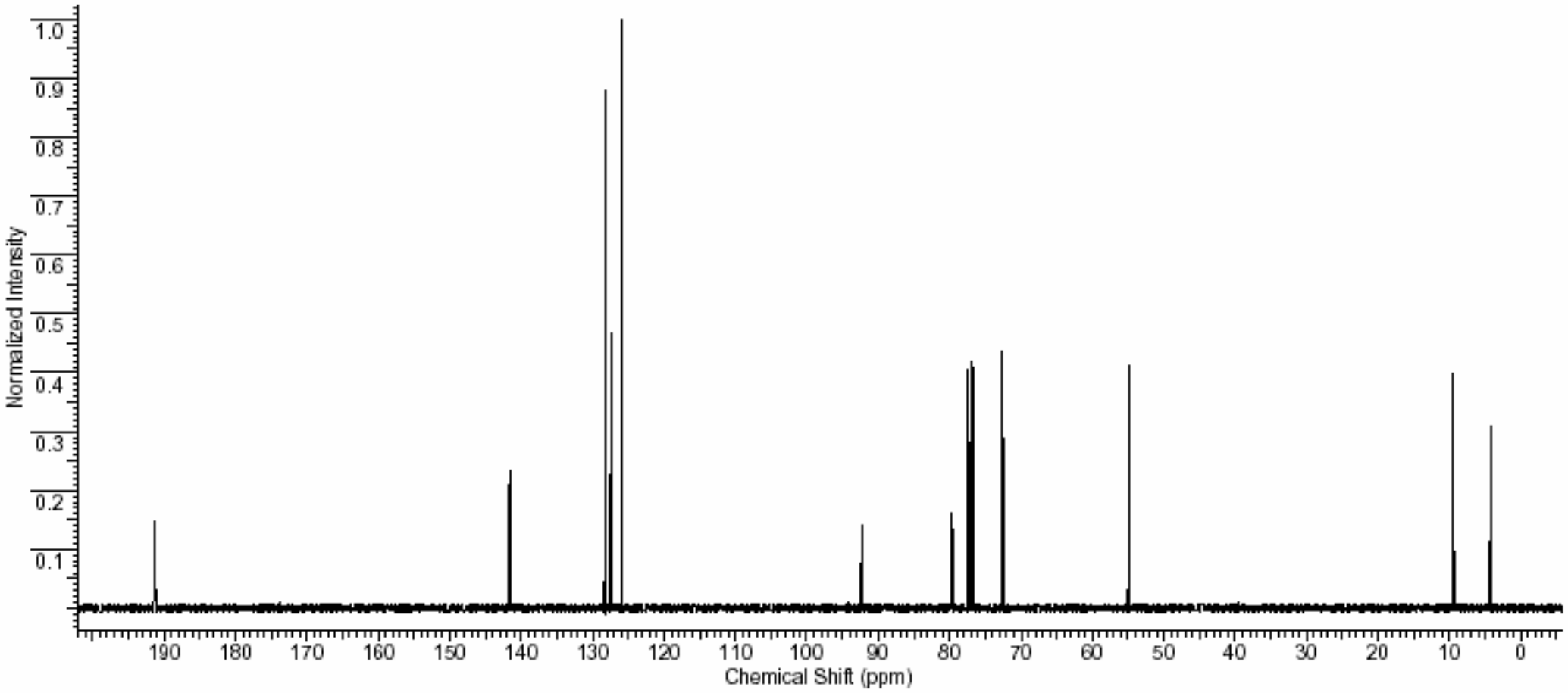

OH
O
CH3
CH3

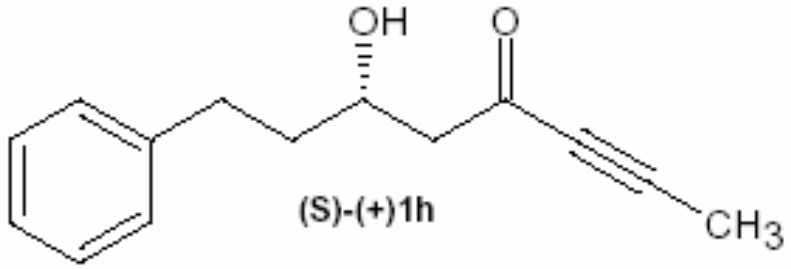
1g


Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5.13
1.00
1.00
0.95
3.11
3.19
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Chemical Shift (ppm)

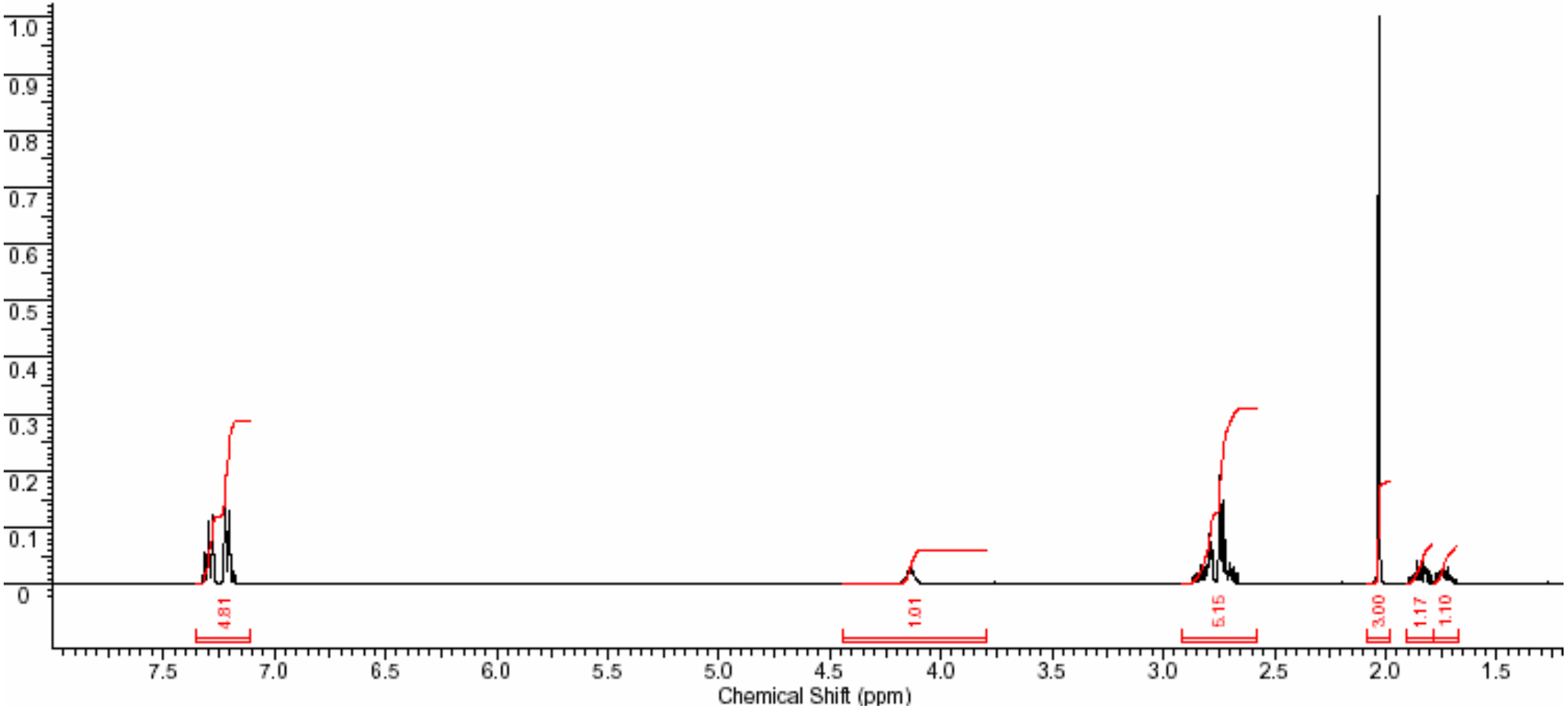

OH
O
CH3
CH3

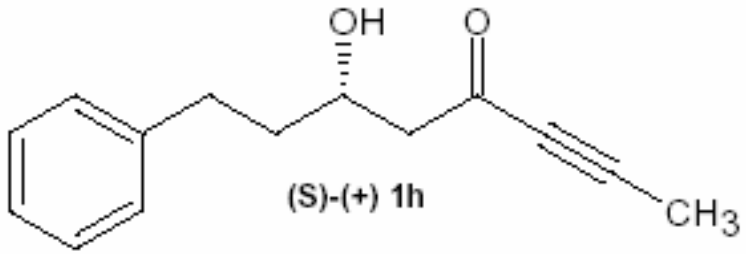
1g


Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Chemical Shift (ppm)

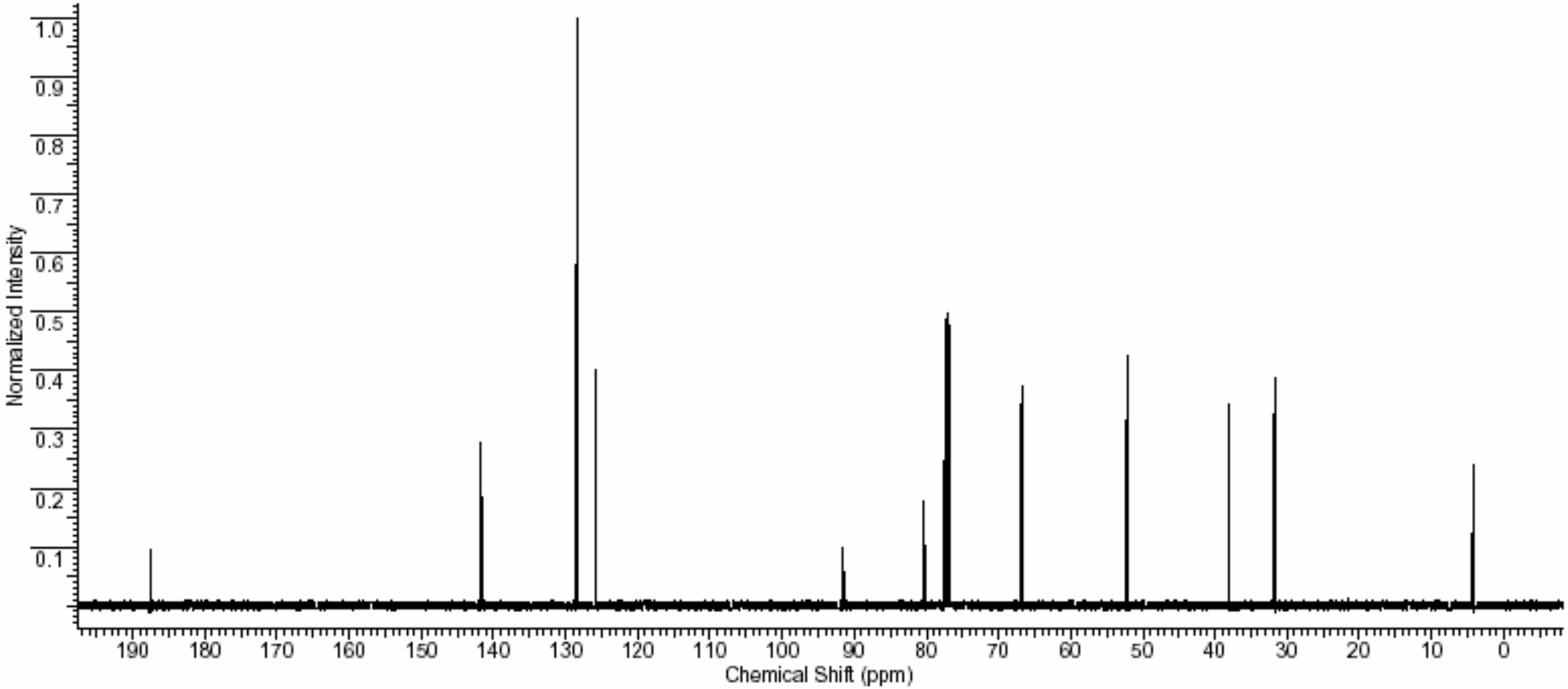

OH
O
CH3

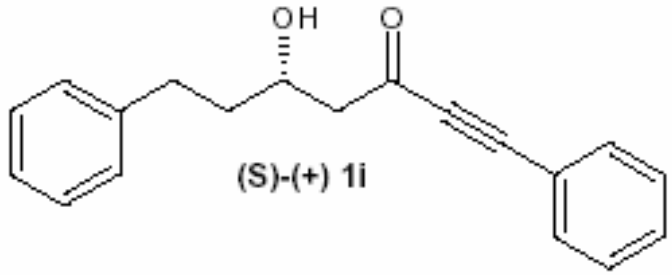
(S)-(+)1h


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4.81
1.01
5.15
3.00
1.17
1.10
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
Chemical Shift (ppm)

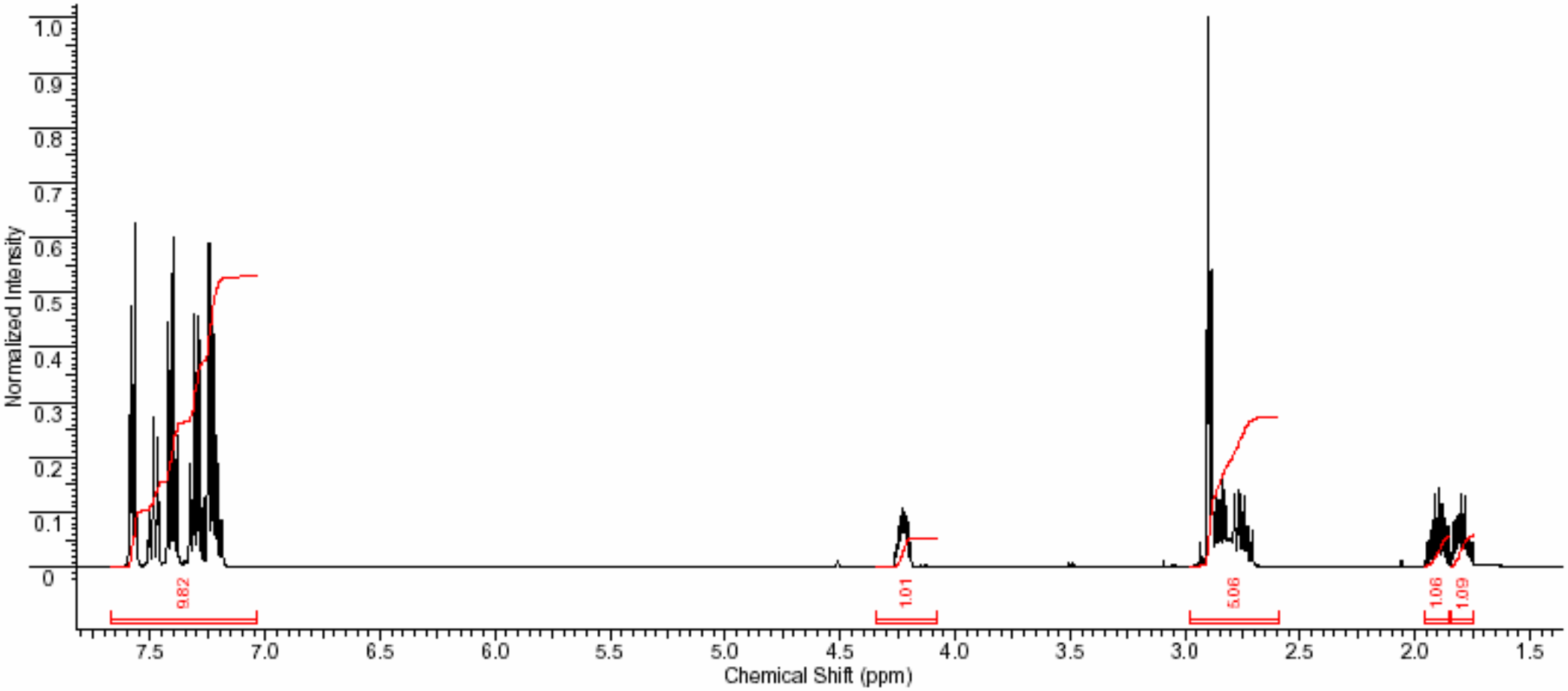

OH
O
CH3

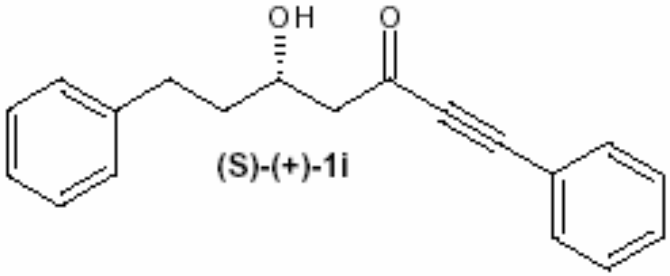
(S)-(+) **1h**


Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Chemical Shift (ppm)

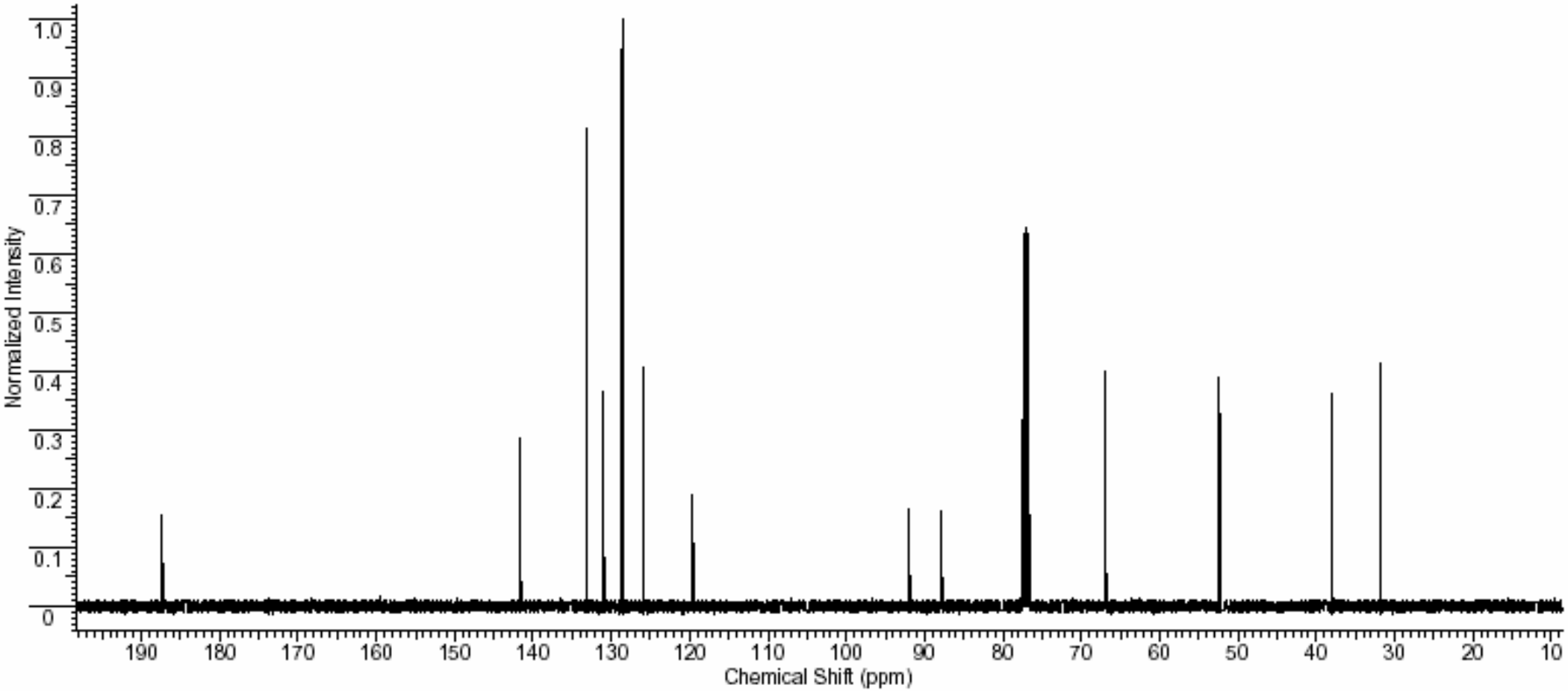

OH
O

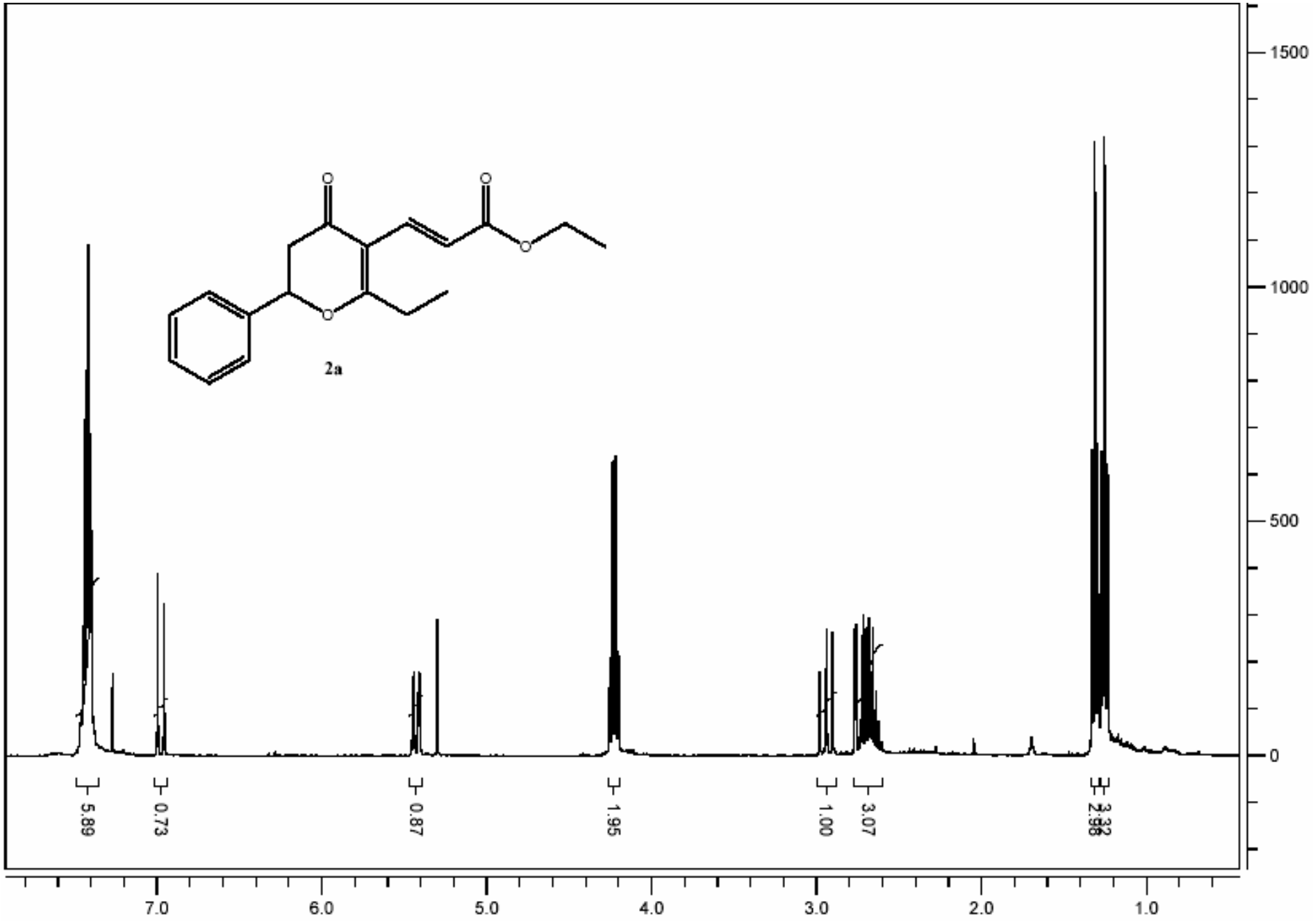
(S)-(+) 1i

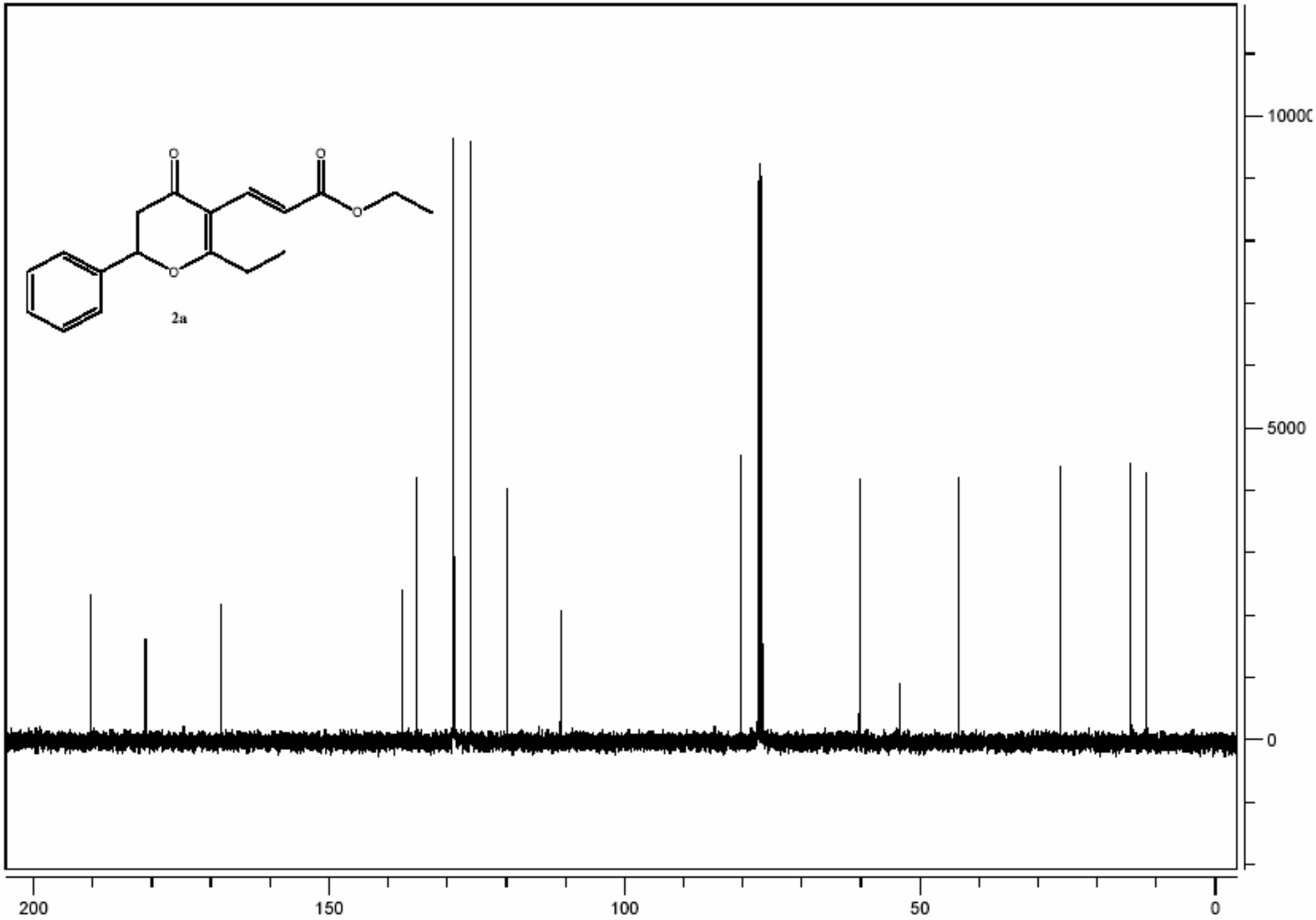

Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
9.82
1.01
5.06
1.06
1.09
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
Chemical Shift (ppm)

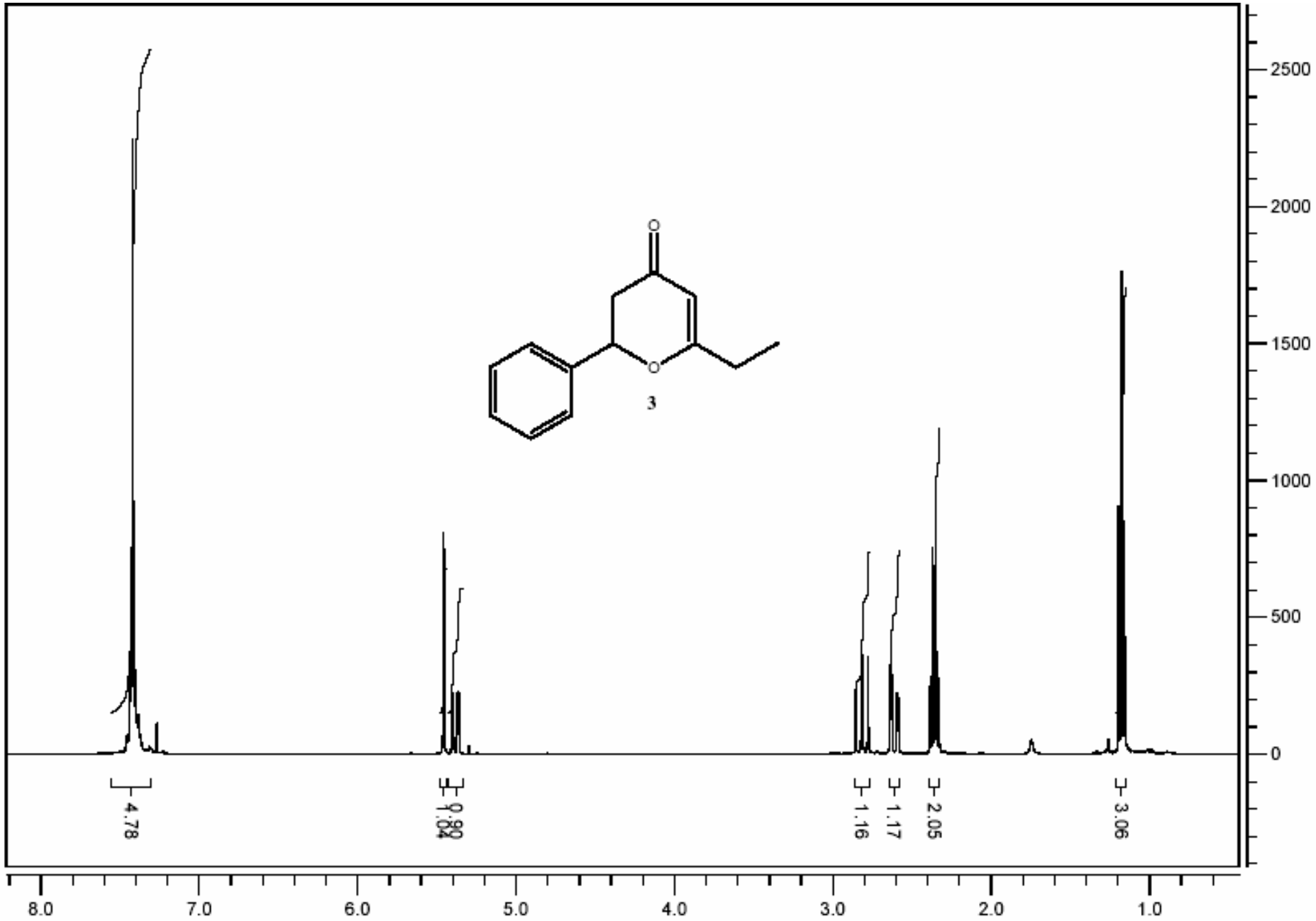

OH
O

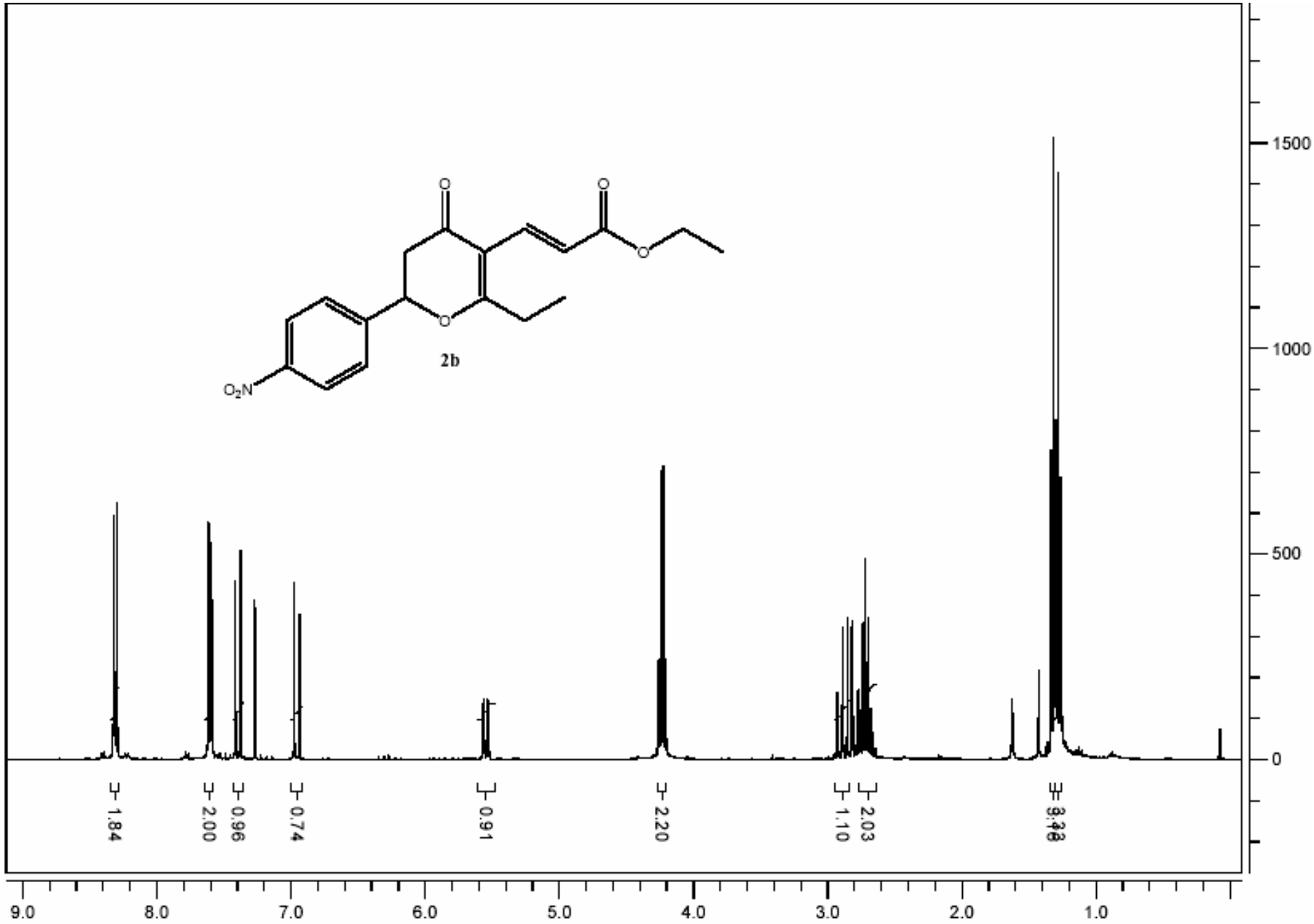
(S)-(+)-1i

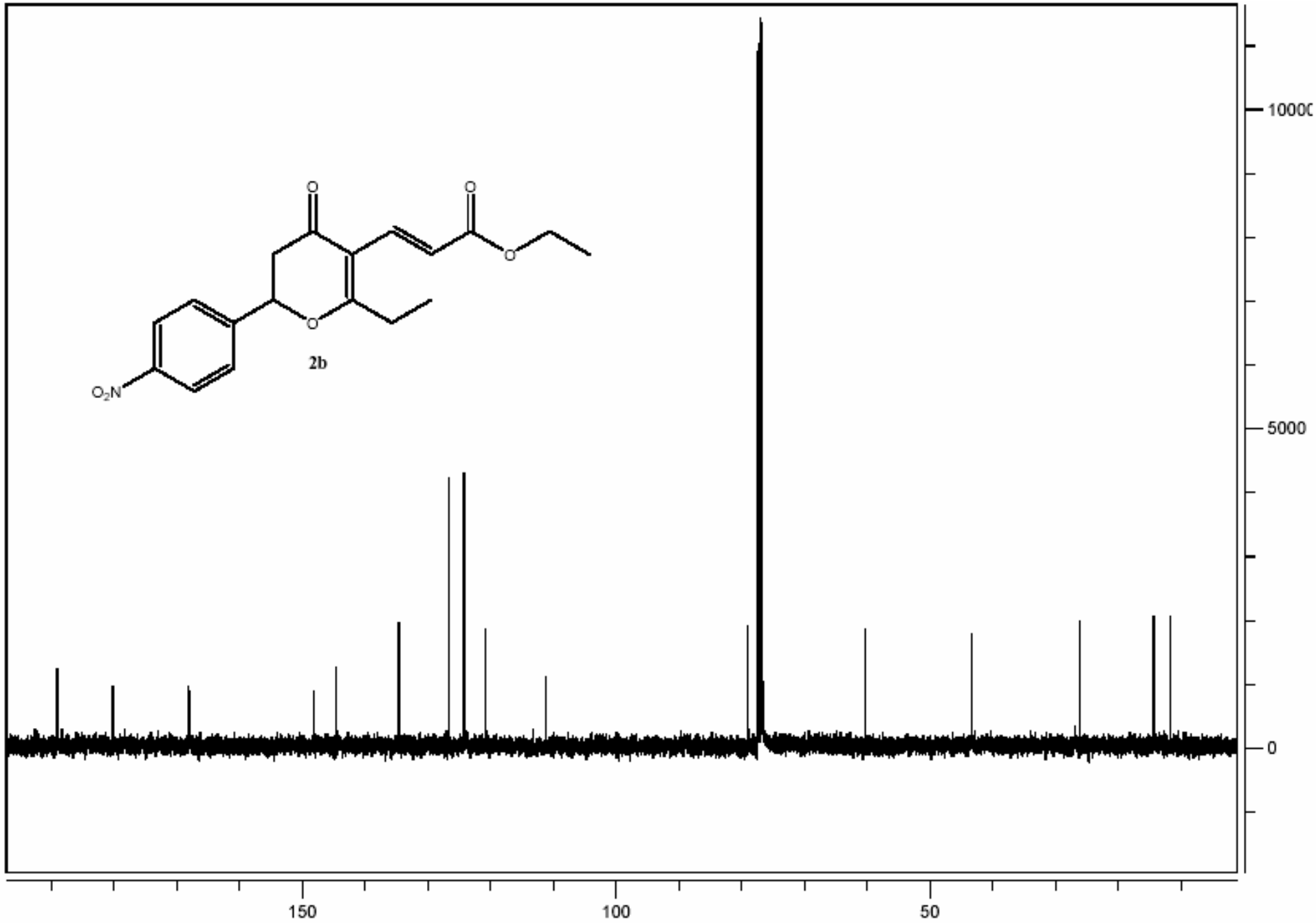

Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Chemical Shift (ppm)

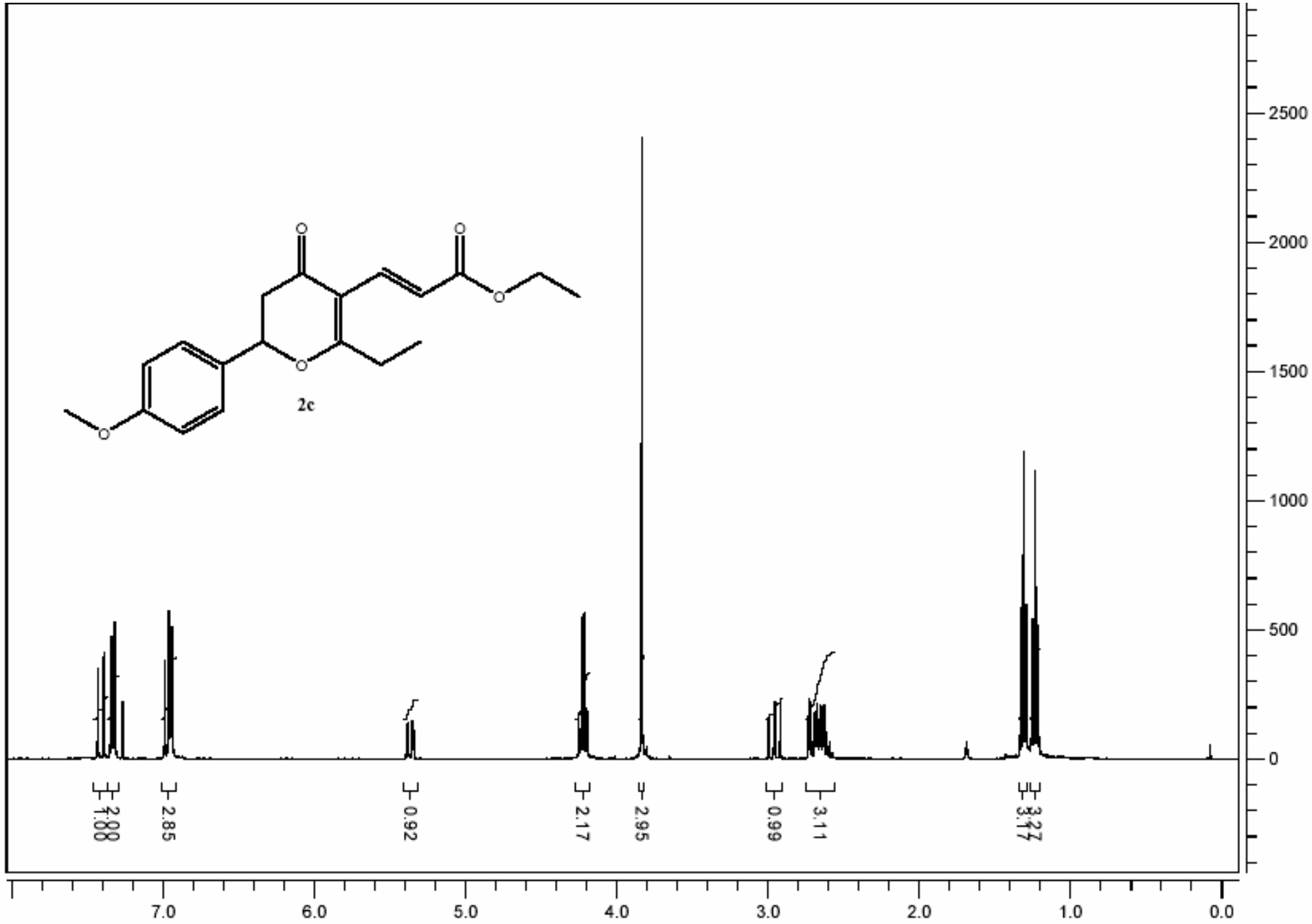

2a
1500
1000
500
0
5.89
0.73
0.87
1.95
1.00
3.07
2.96
3.32
7.0
6.0
5.0
4.0
3.0
2.0
1.0

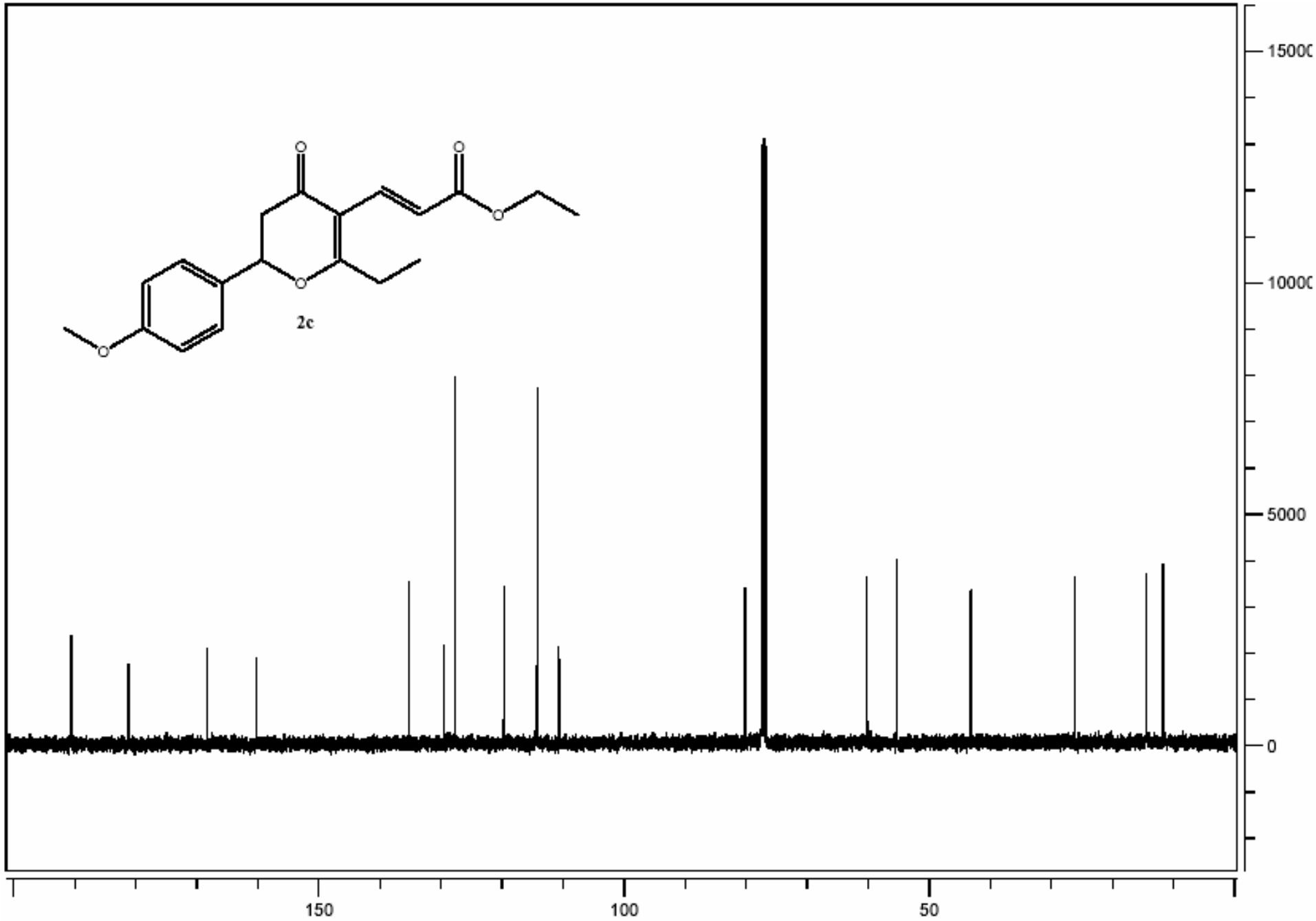

O
O
O
O
2a
10000
5000
0
200
150
100
50
0

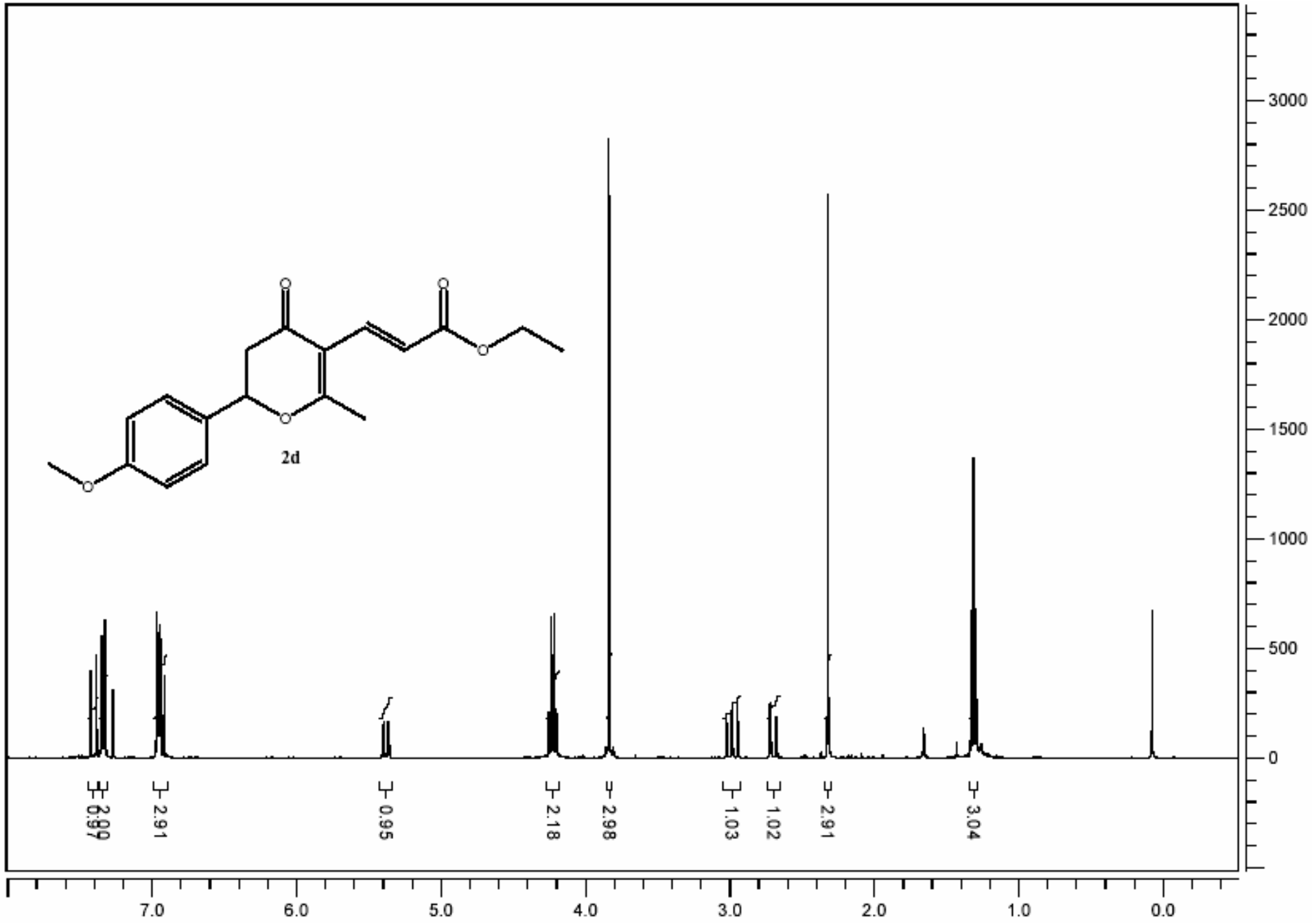

O
O
3
2500
2000
1500
1000
500
0
4.78
0.80
1.04
1.16
1.17
2.05
3.06
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

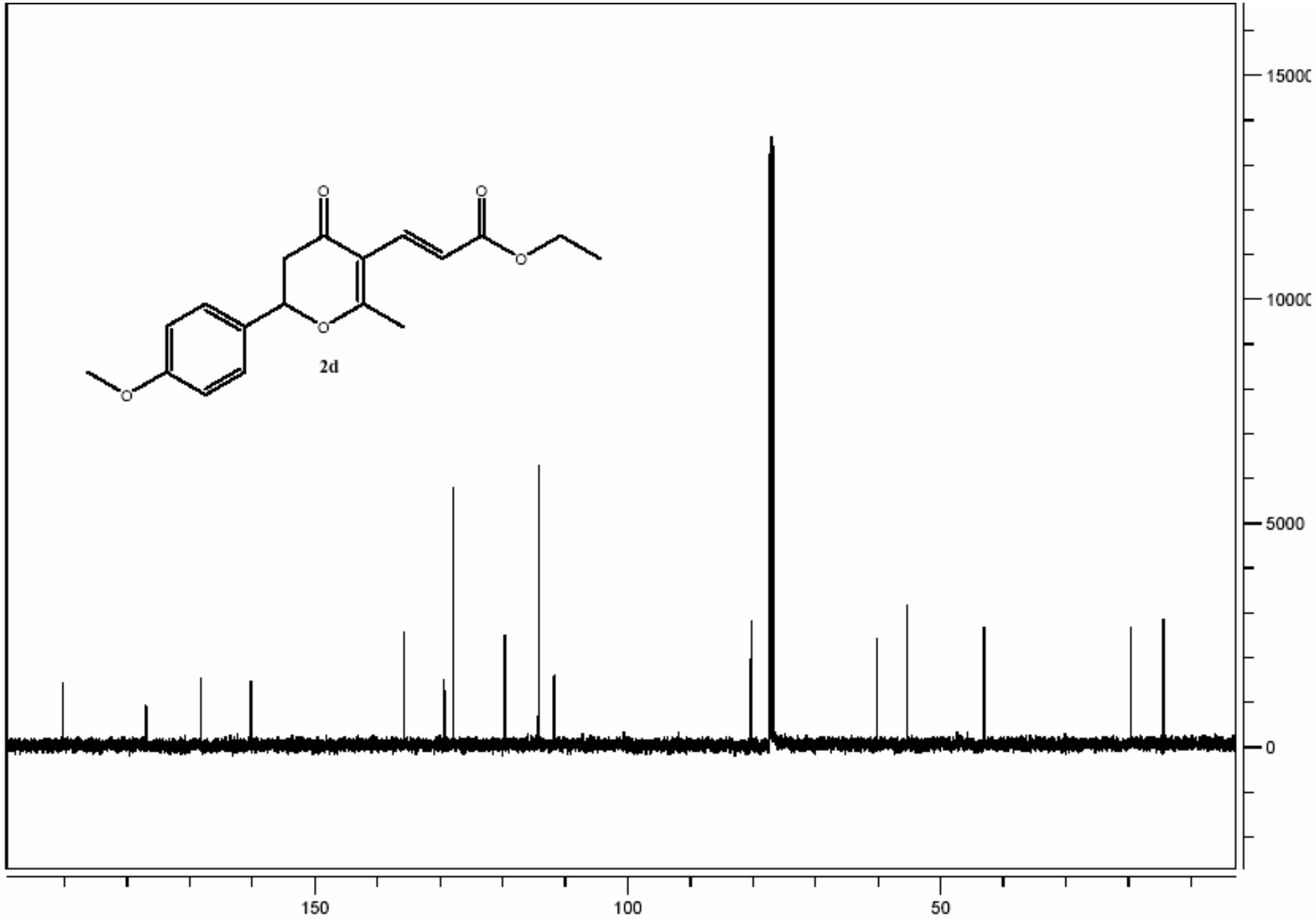

O
O
O
O
O2N
2b
1.84
2.00
0.96
0.74
0.91
2.20
1.10
2.03
9.33
1500
1000
500
0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

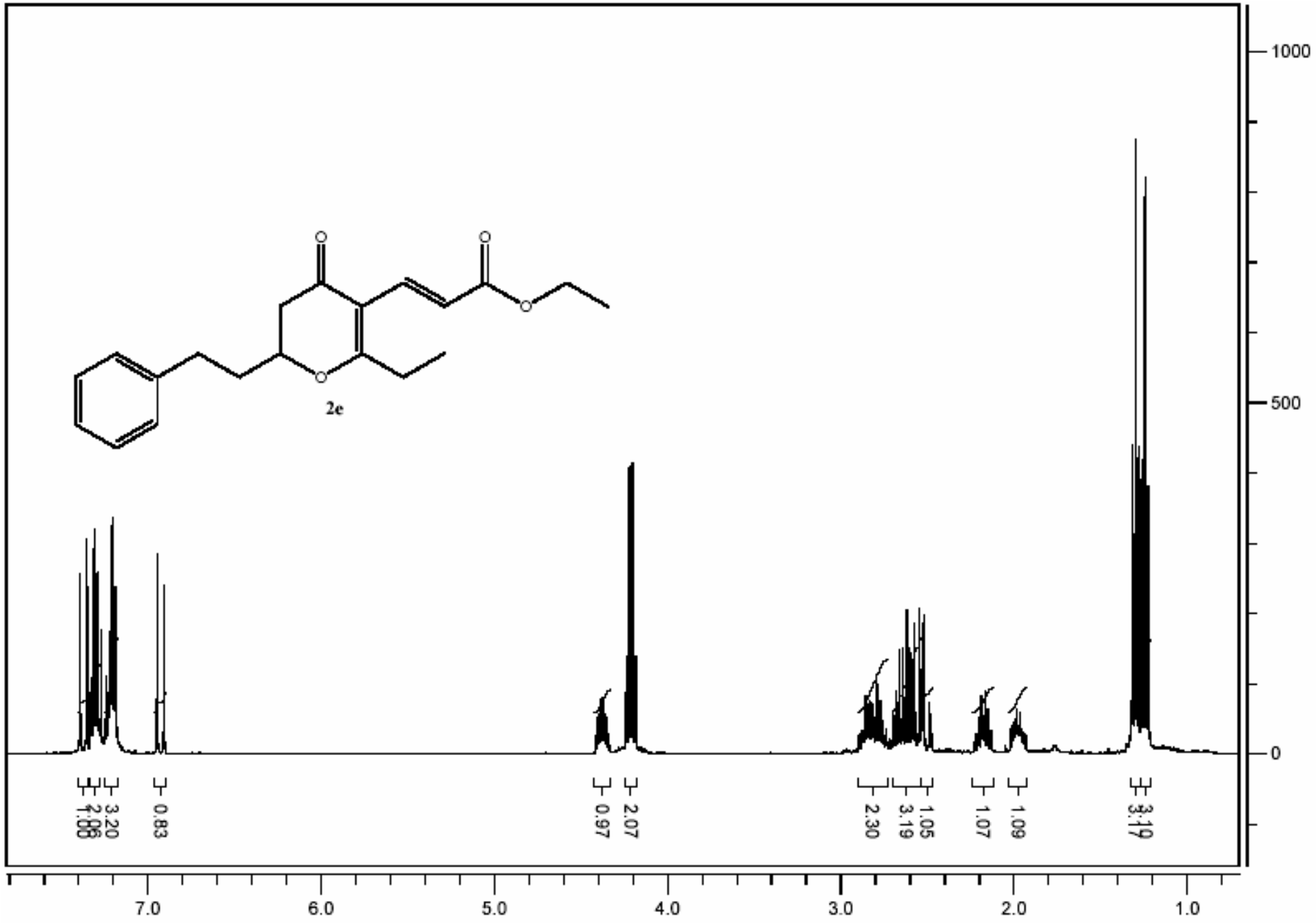

O
O
O
O
O2N
2b
10000
5000
0
150
100
50

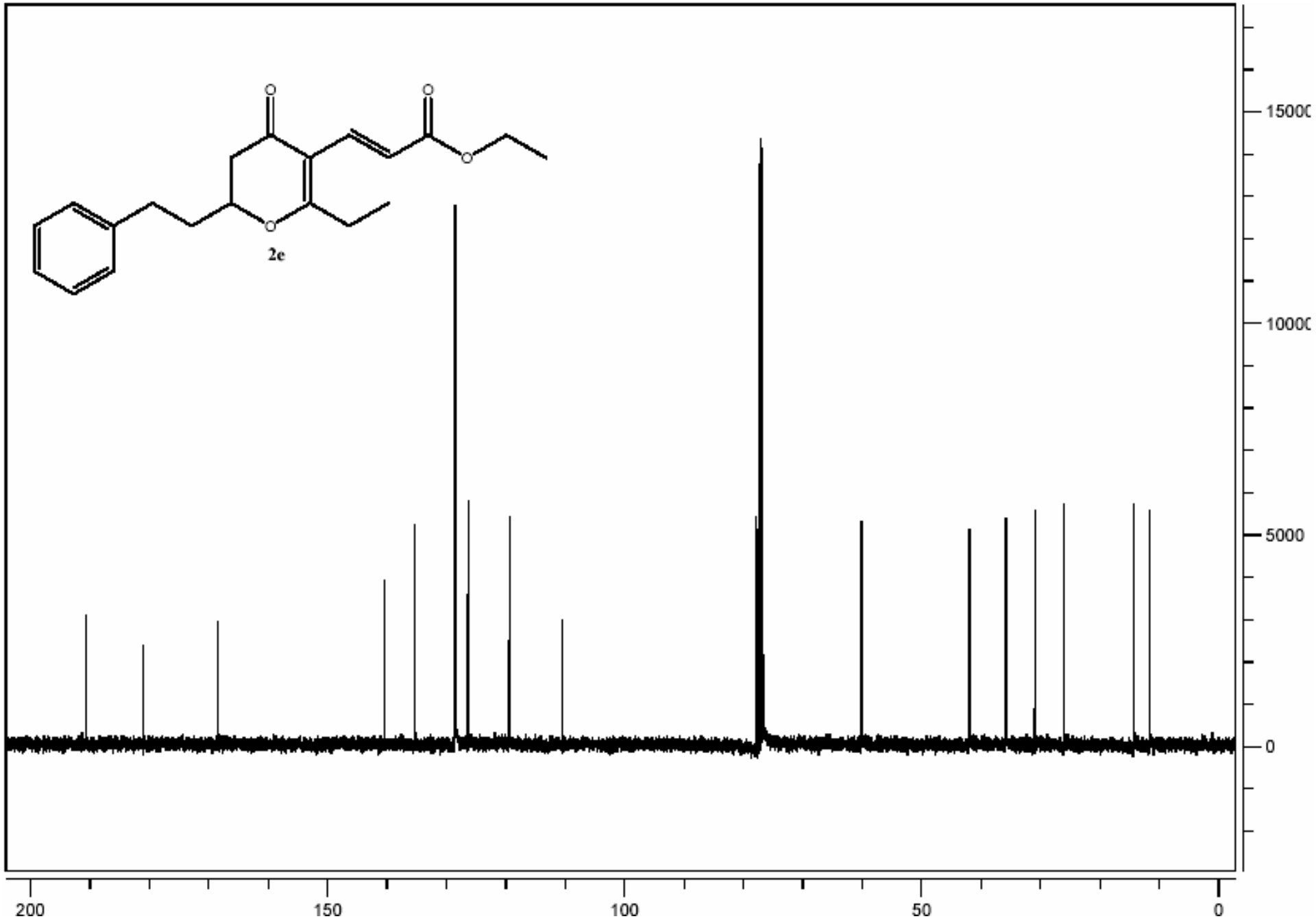

2c
2500
2000
1500
1000
500
0
1.00
2.85
0.92
2.17
2.95
0.99
3.11
3.27
3.17
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

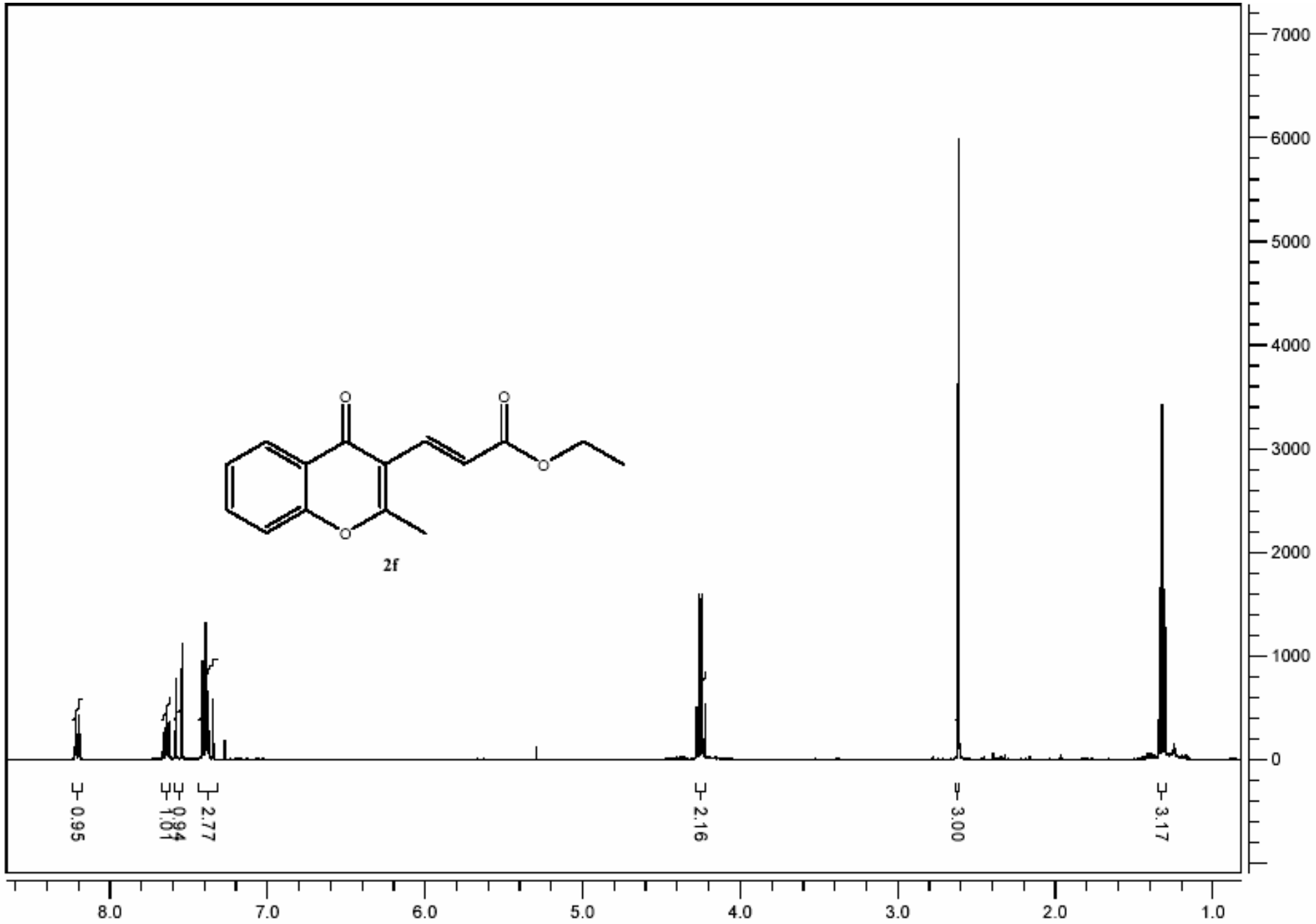

2c
15000
10000
5000
0
150
100
50

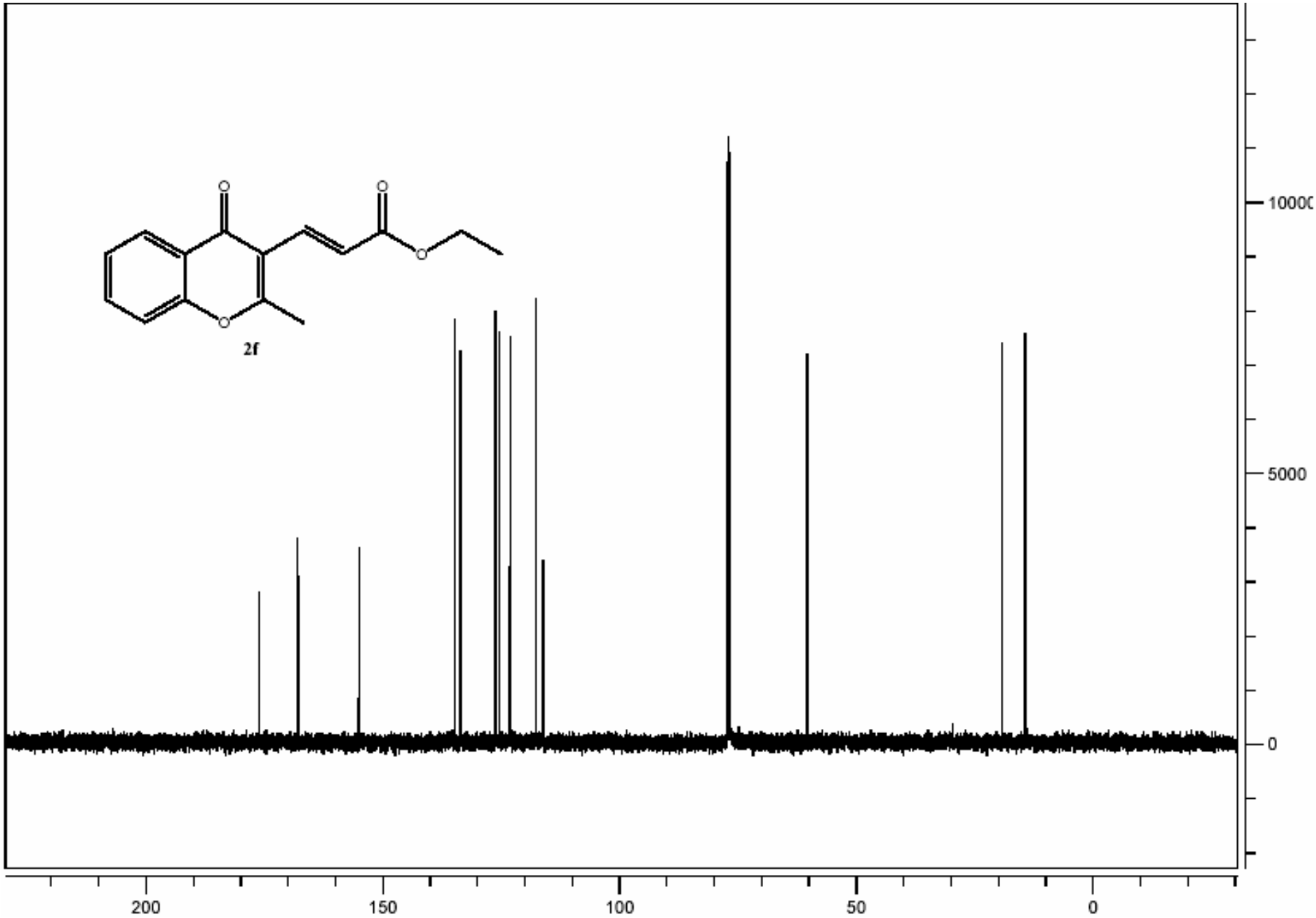

2d
0.97
2.99
2.91
0.95
2.18
2.98
1.03
1.02
2.91
3.04
3000
2500
2000
1500
1000
500
0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

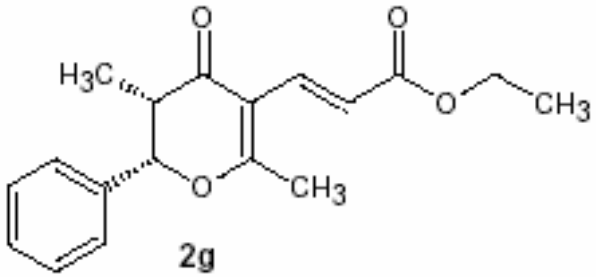

2d
15000
10000
5000
0
150
100
50


2e
1000
500
0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
1.00
1.06
3.20
0.83
0.97
2.07
2.30
3.19
1.05
1.07
1.09
3.17
3.19

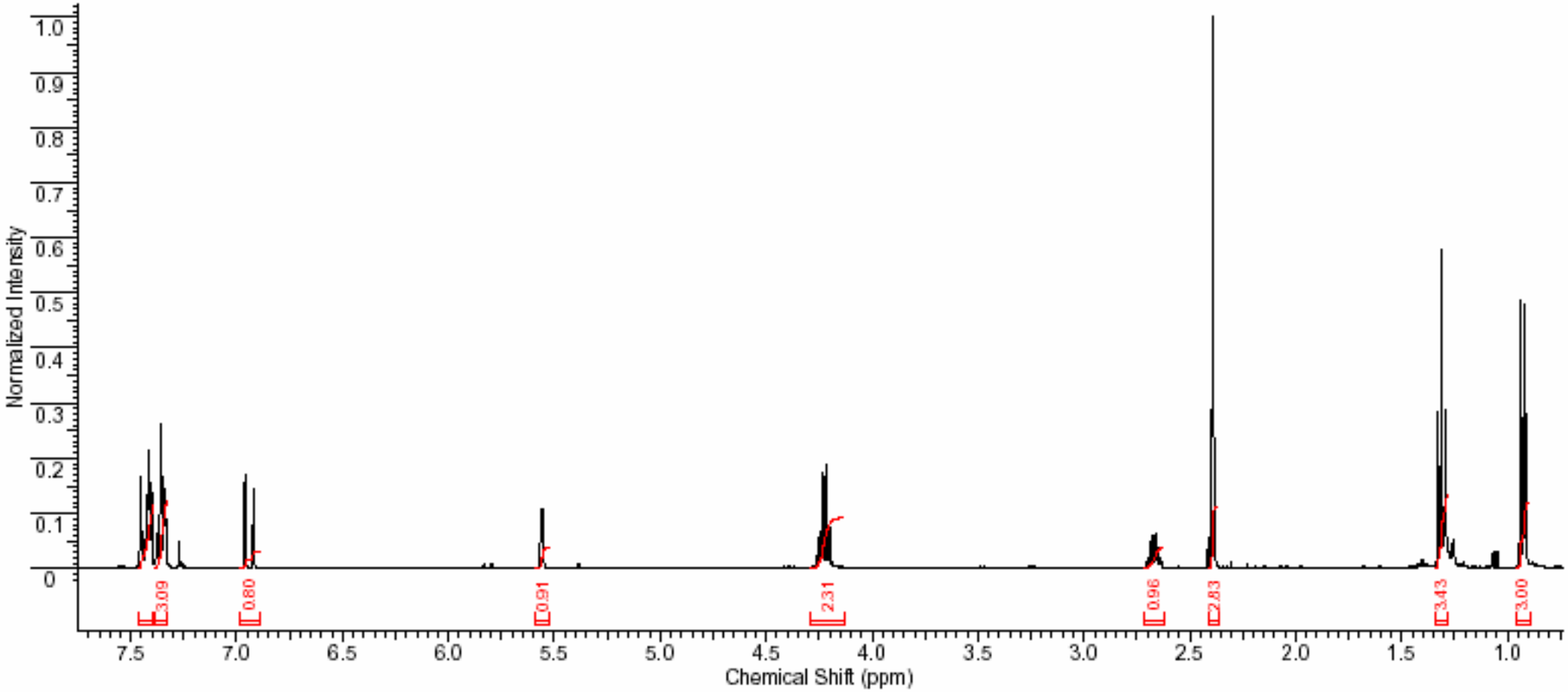

2e
15000
10000
5000
0
200
150
100
50
0

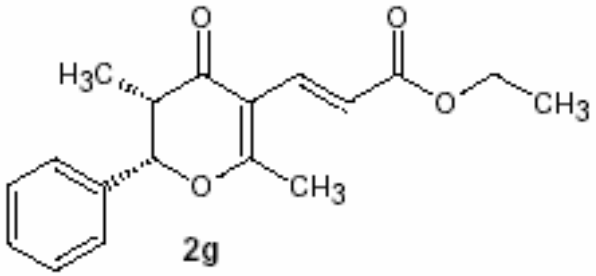

2f
0.95
0.84
1.01
2.77
2.16
3.00
3.17
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
7000
6000
5000
4000
3000
2000
1000
0


2f
10000
5000
0
200
150
100
50
0

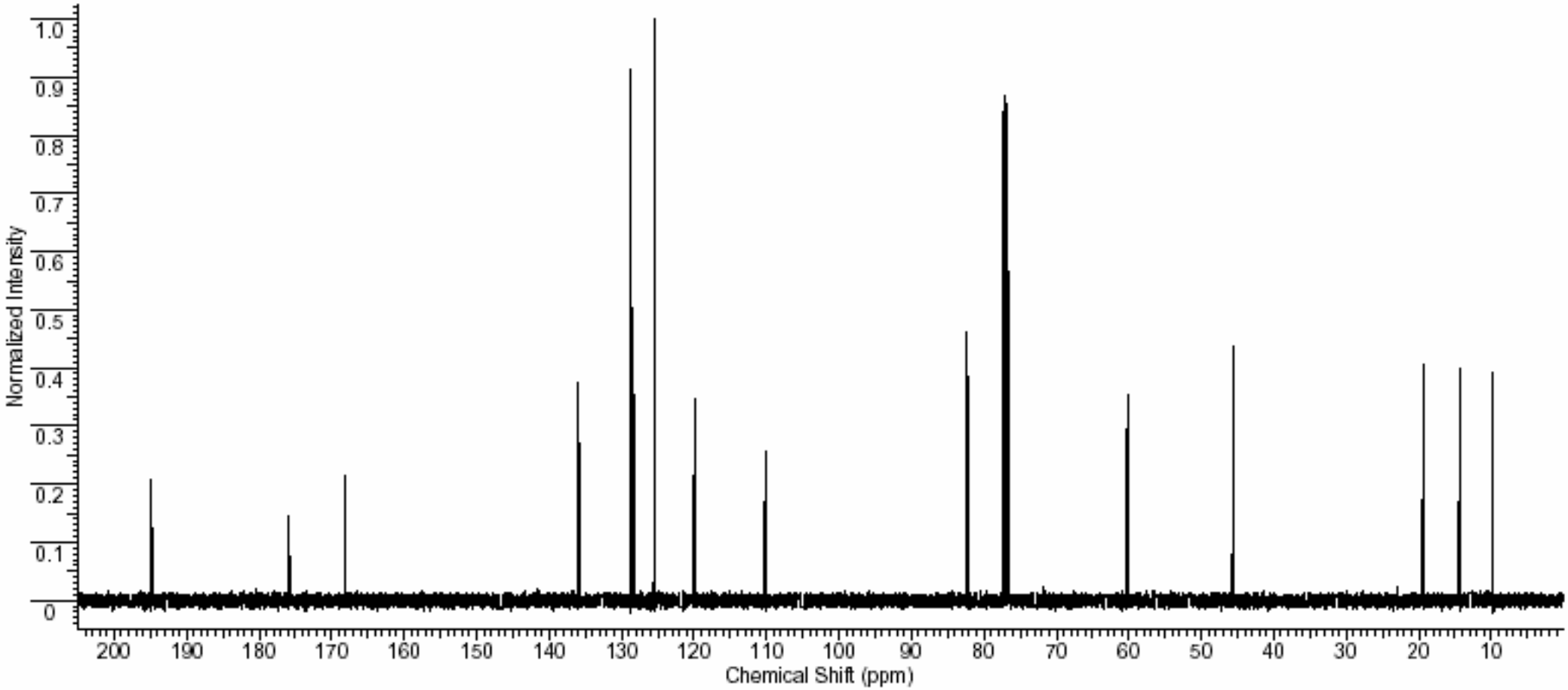

O
O
H3C
O
CH3
O
CH3

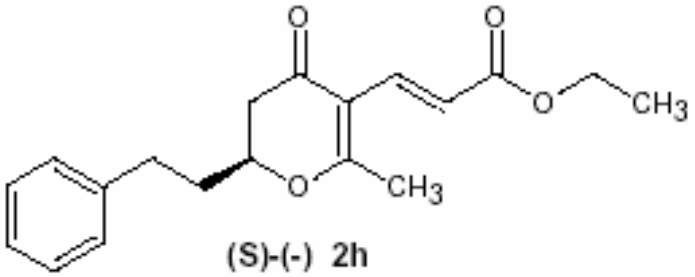
2g


Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3.09
0.80
0.91
2.31
0.96
2.83
3.43
3.00
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Chemical Shift (ppm)

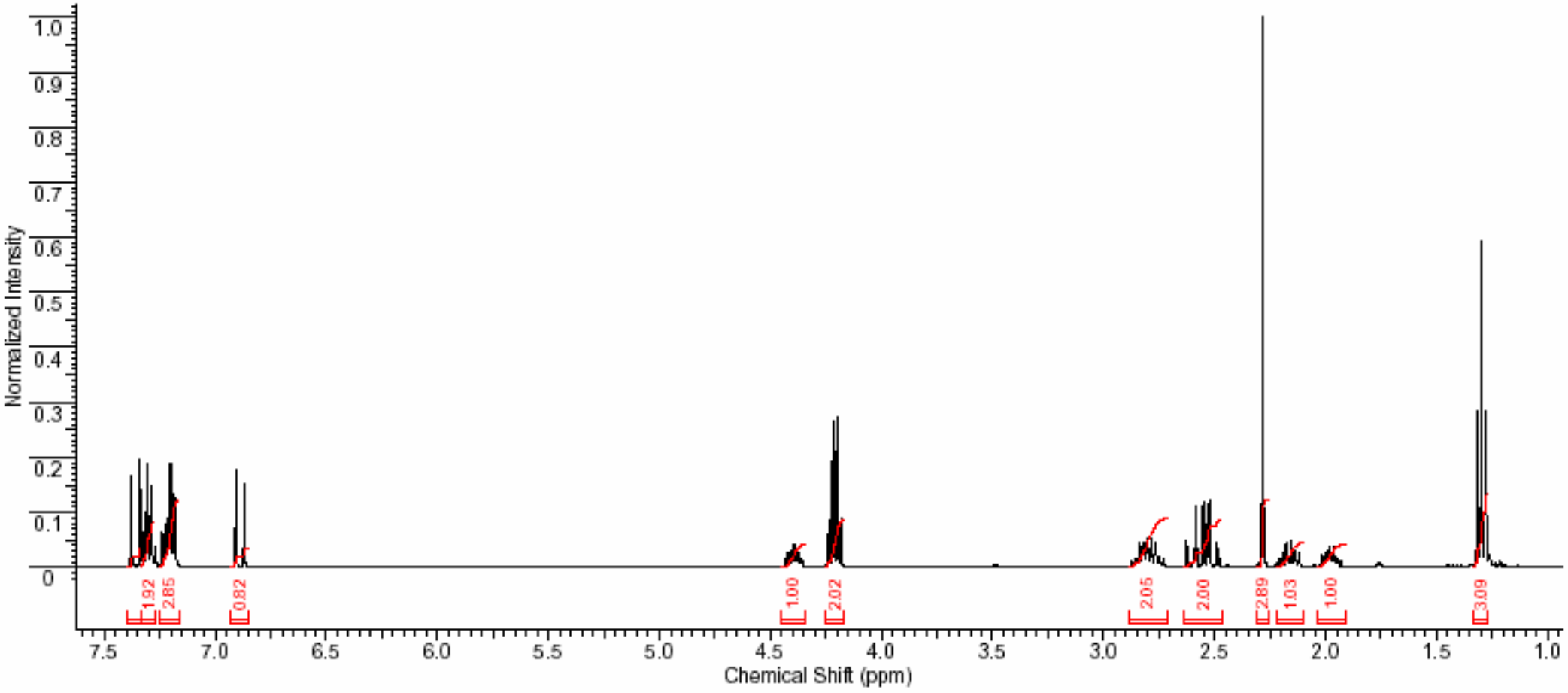

O
O
H3C
O
CH3
O
CH3

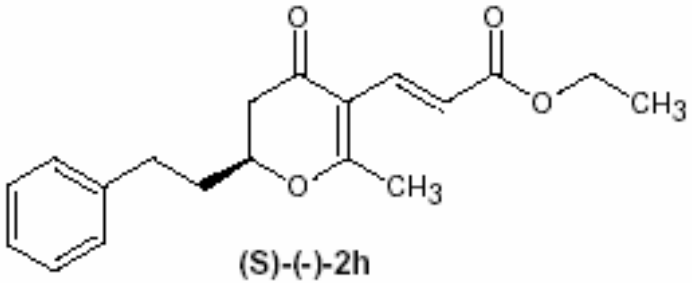
2g


Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Chemical Shift (ppm)

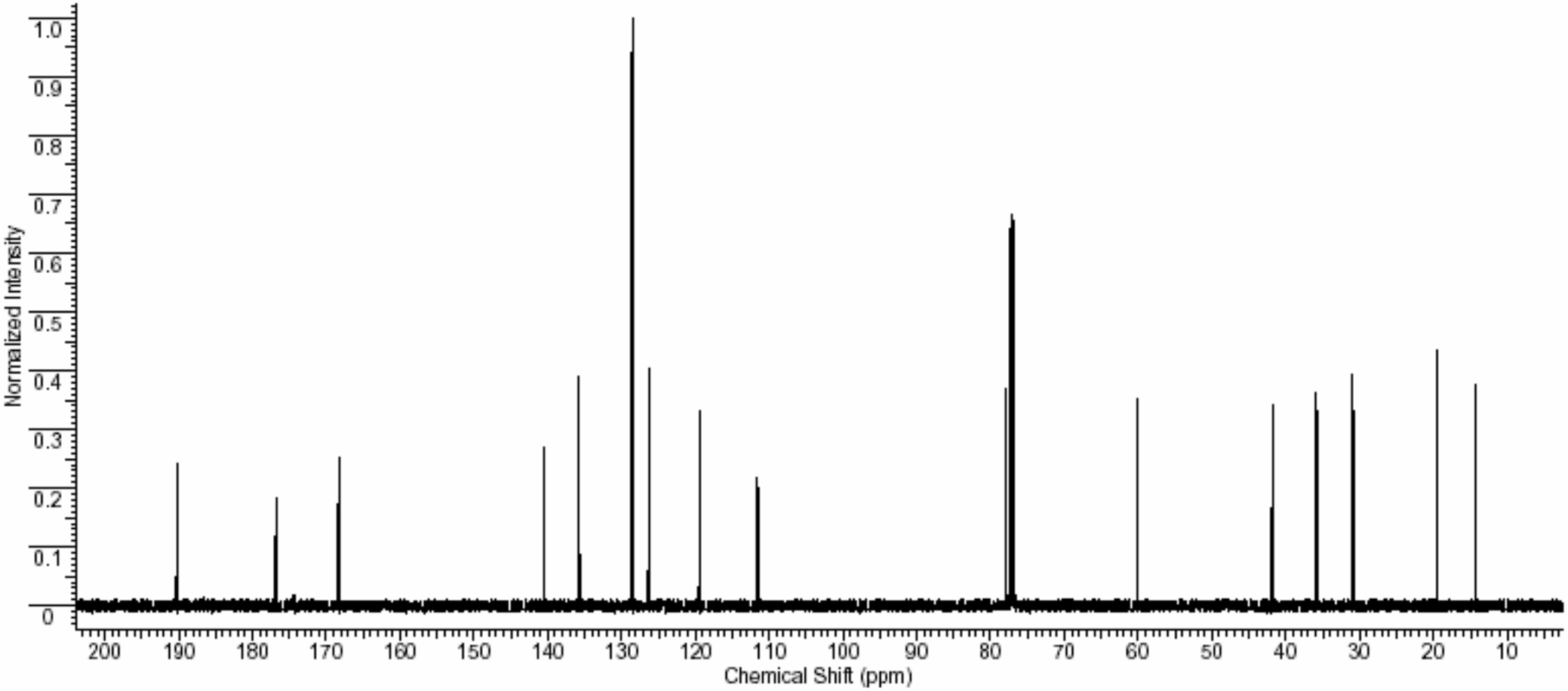

O
O
O
CH3
O
CH3

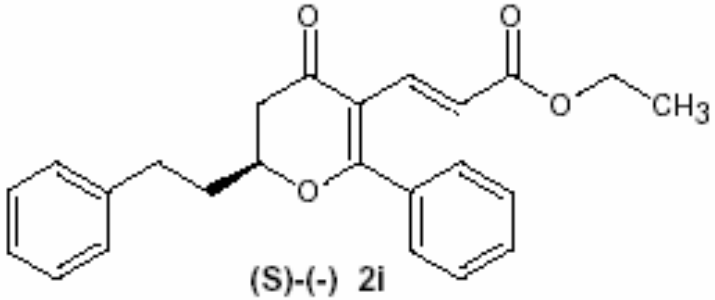
(S)-(-) **2h**


Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1.92
2.85
0.82
1.00
2.02
2.05
2.00
2.89
1.03
1.00
3.09
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Chemical Shift (ppm)

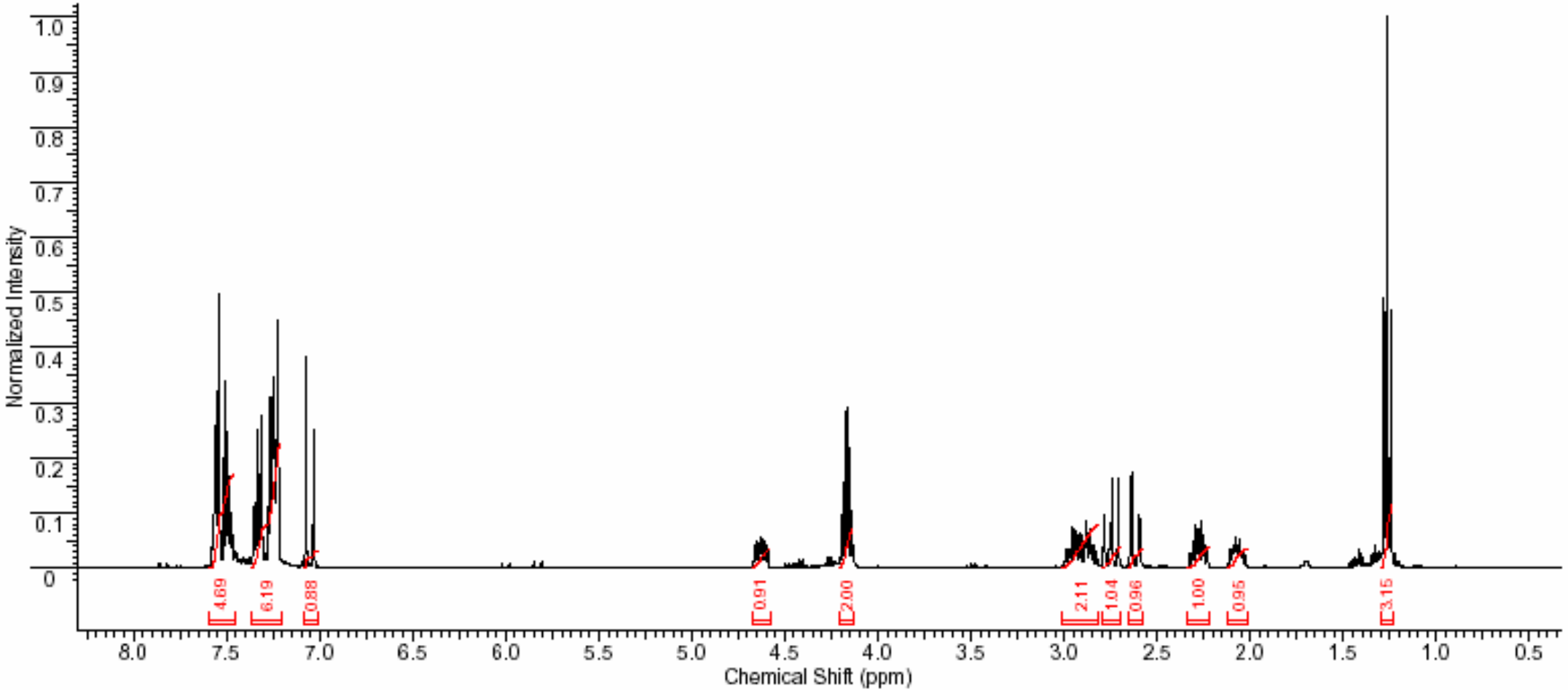

O
O
O
CH3
O
CH3

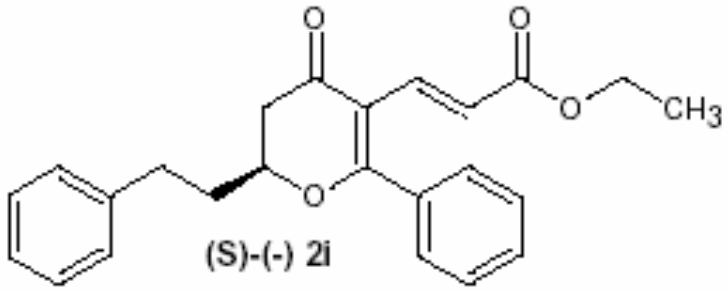
(S)-(-)-2h


Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Chemical Shift (ppm)

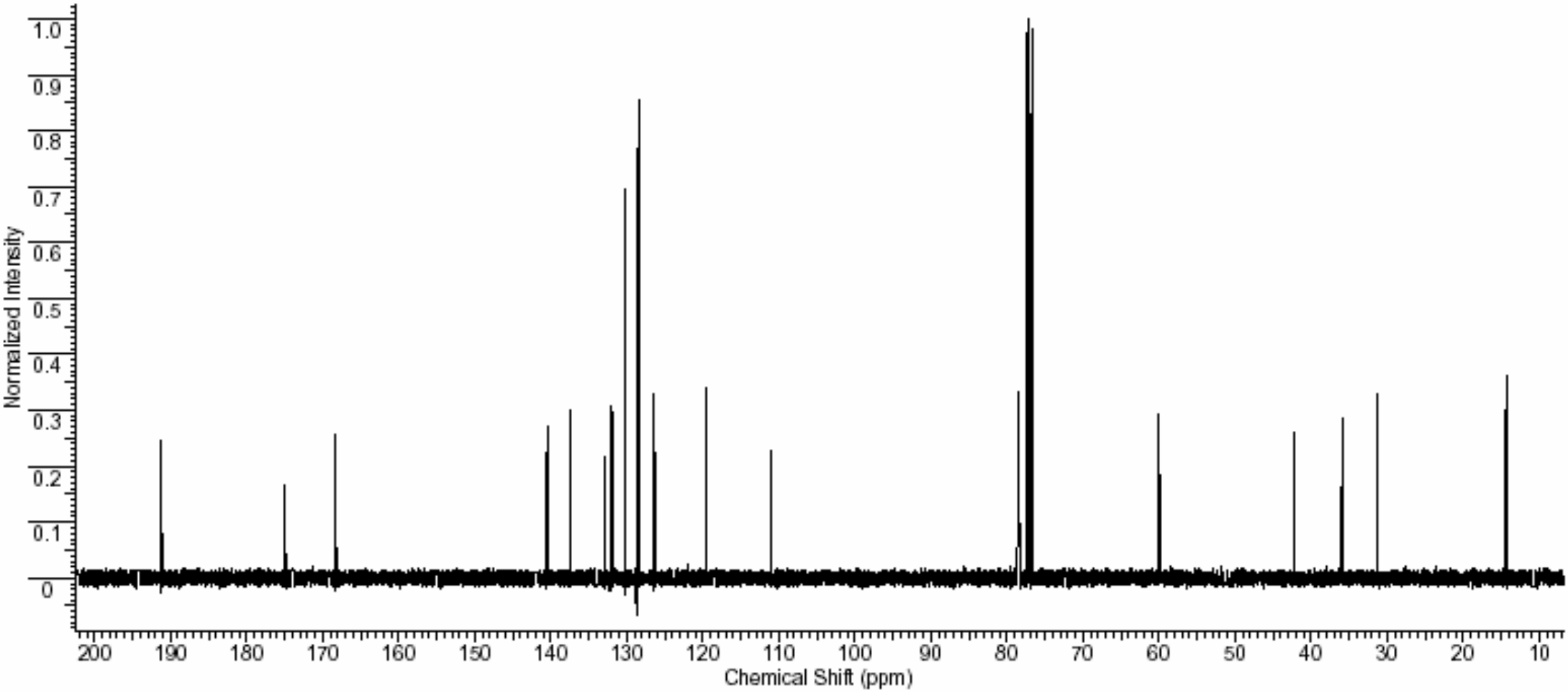

O
O
O
O
CH3

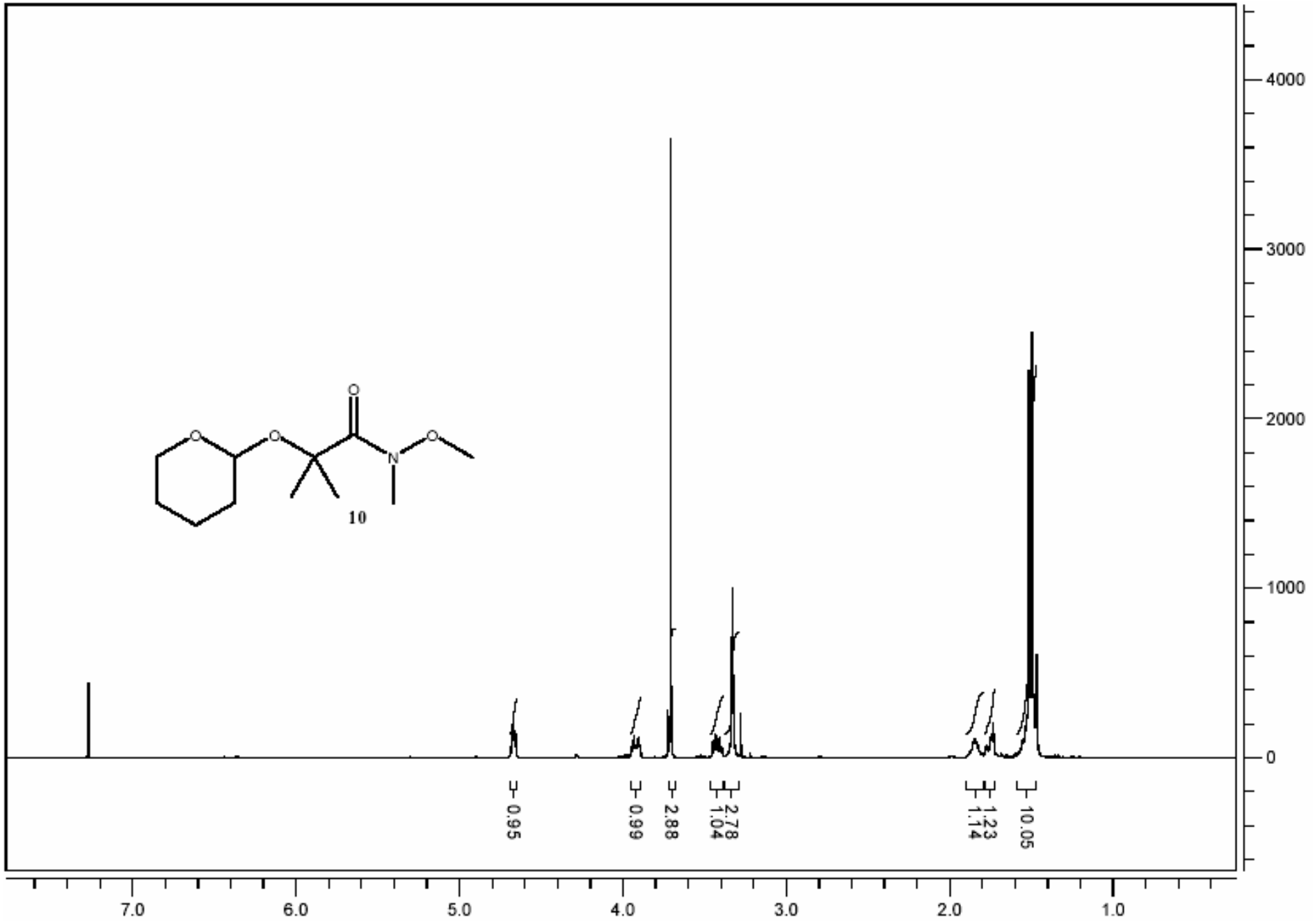
(S)-(-) 2i

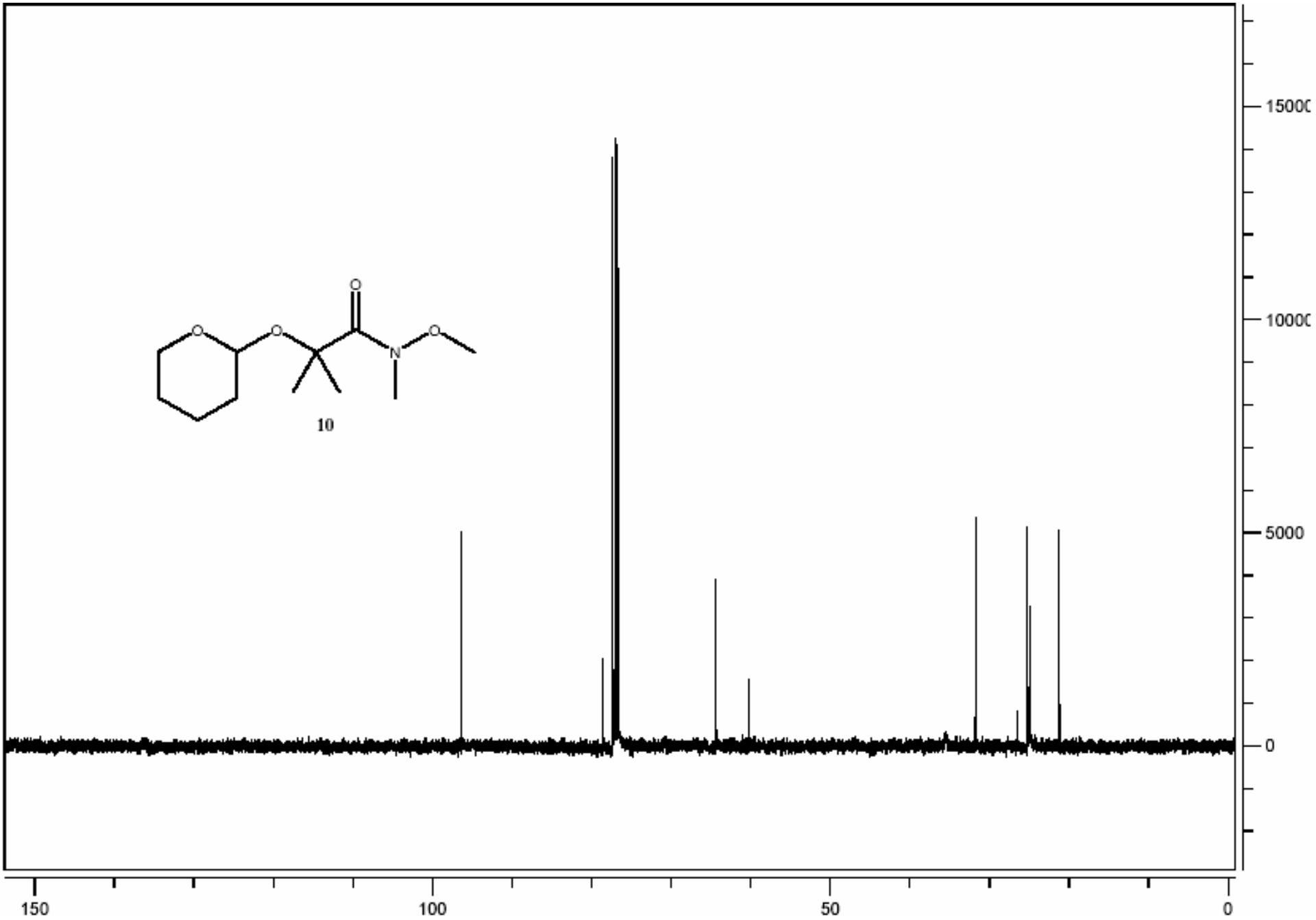

Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4.69
6.19
0.88
0.91
2.00
2.11
1.04
0.96
1.00
0.95
3.15
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Chemical Shift (ppm)

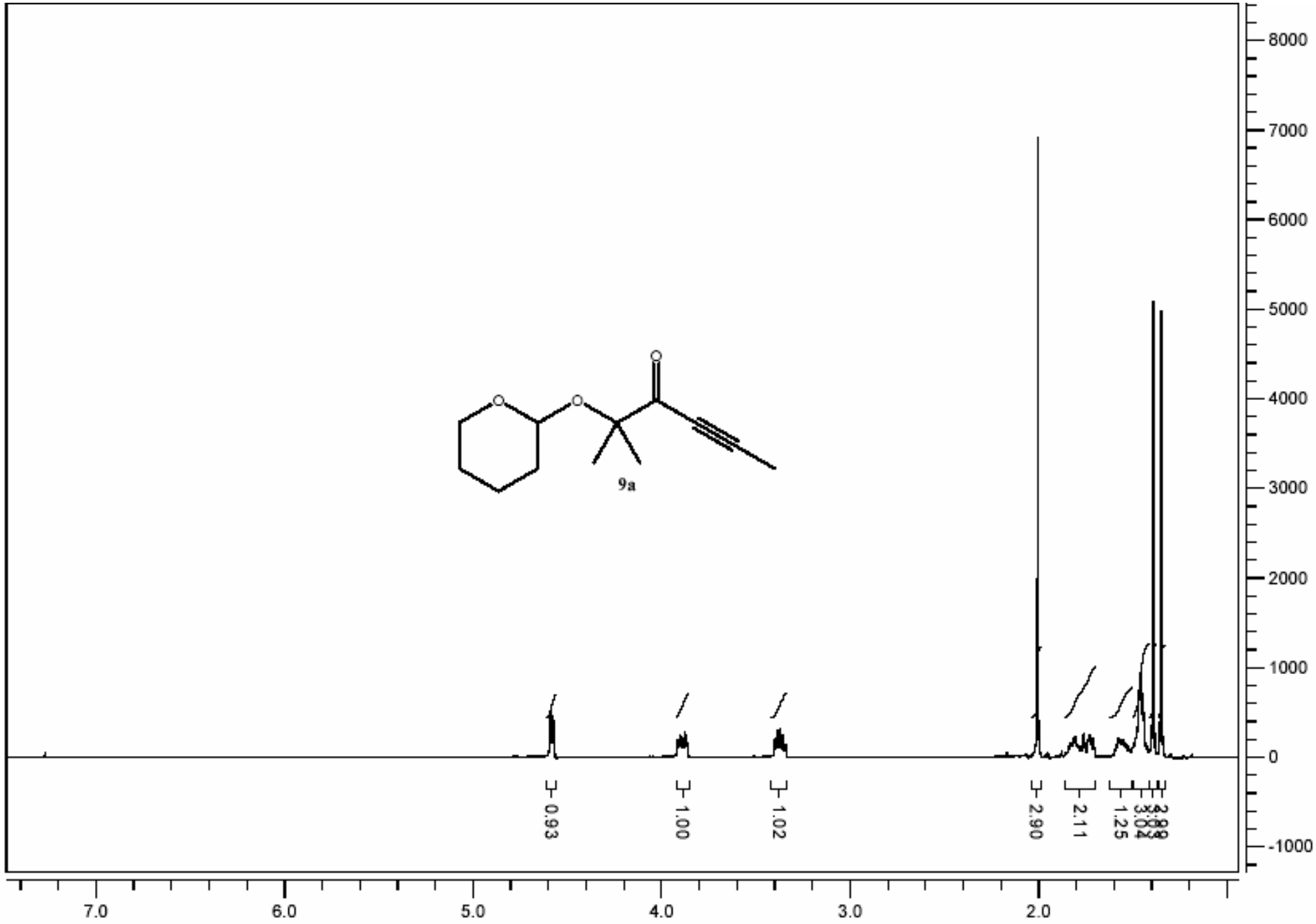

O
O
O
O
CH3

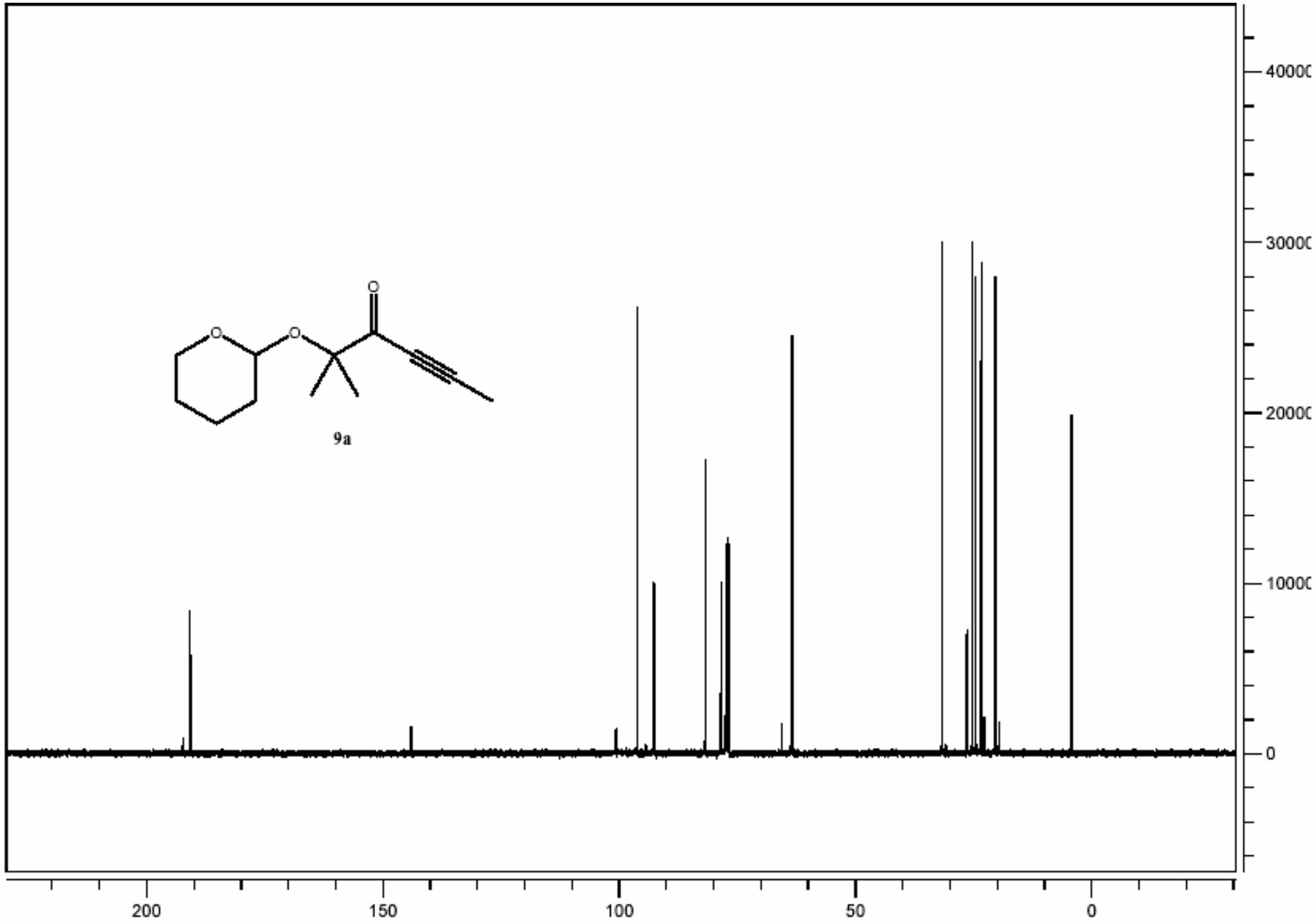
(S)-(-) 2i

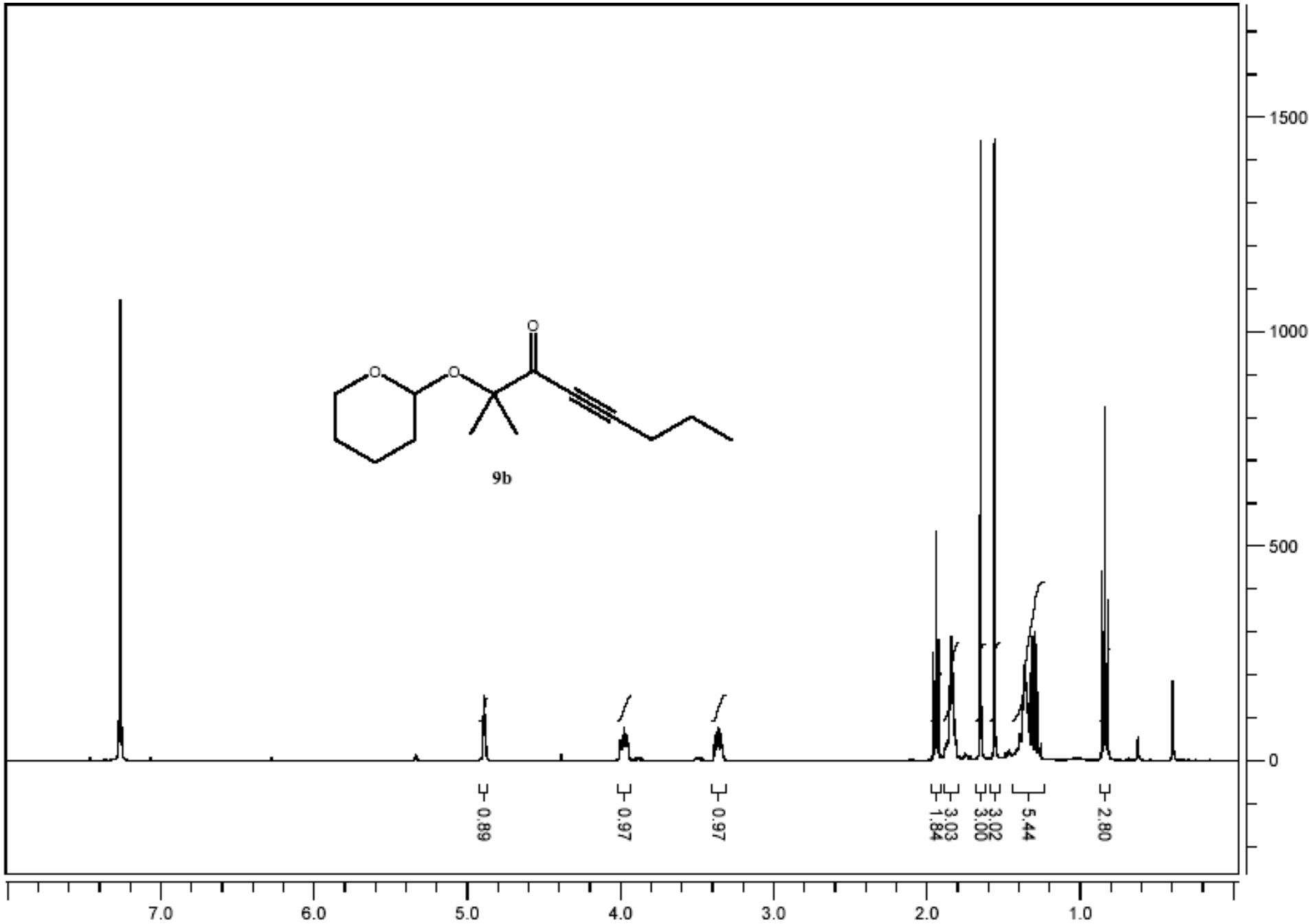

Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Chemical Shift (ppm)

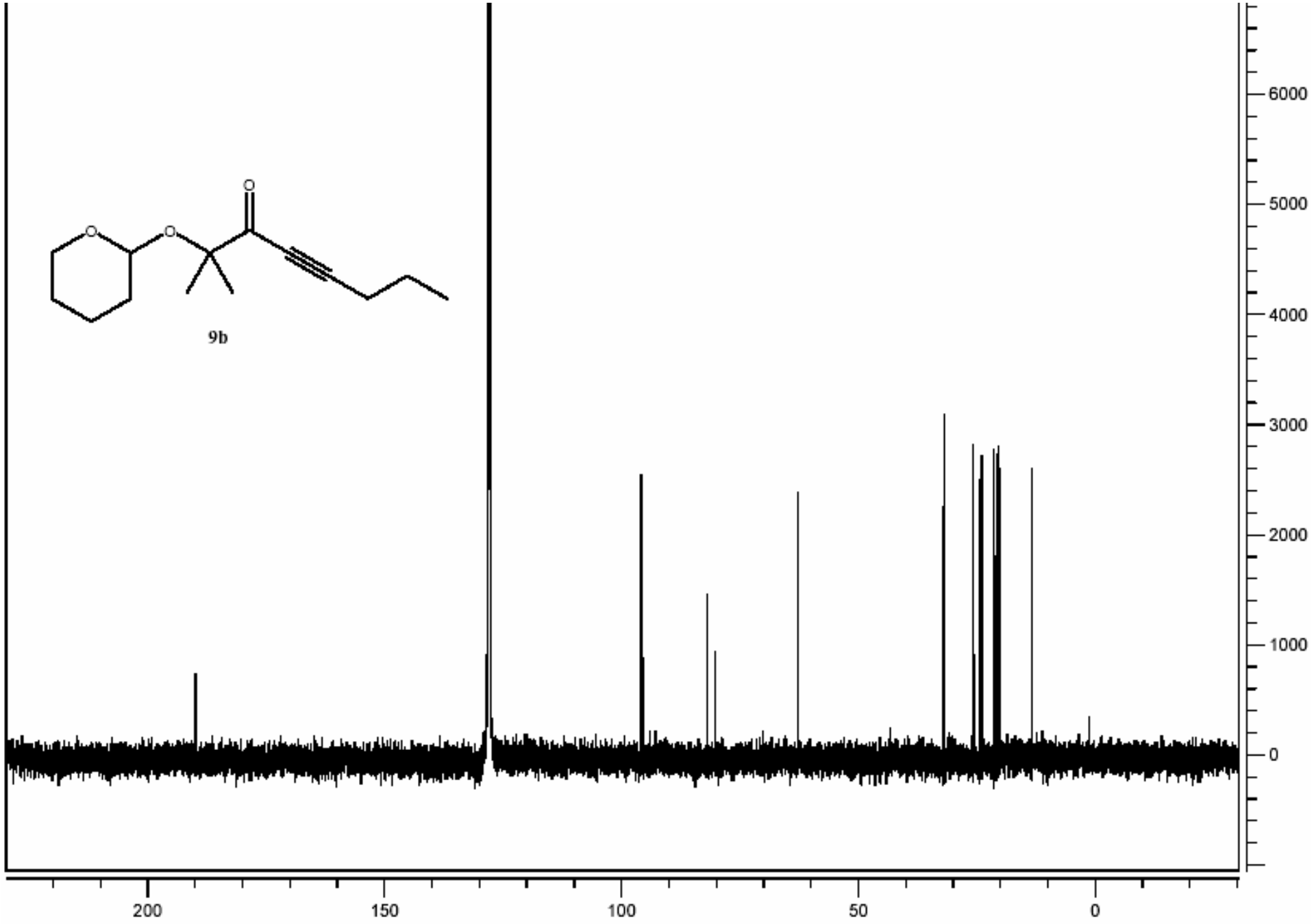

10
0.95
0.99
2.88
1.04
2.78
1.14
1.23
10.05
4000
3000
2000
1000
0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

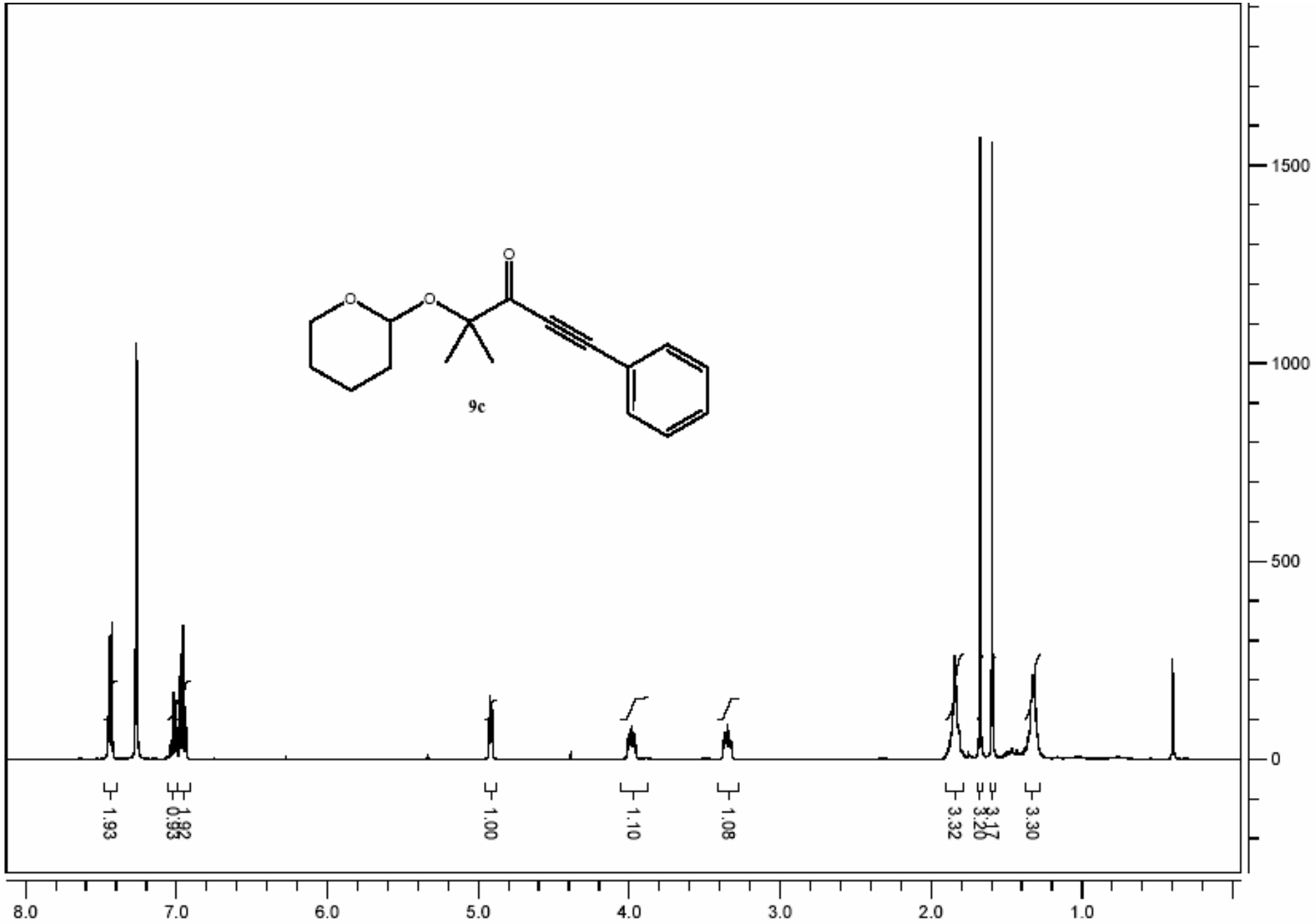

O
O
O
N
O
10
15000
10000
5000
0
150
100
50
0

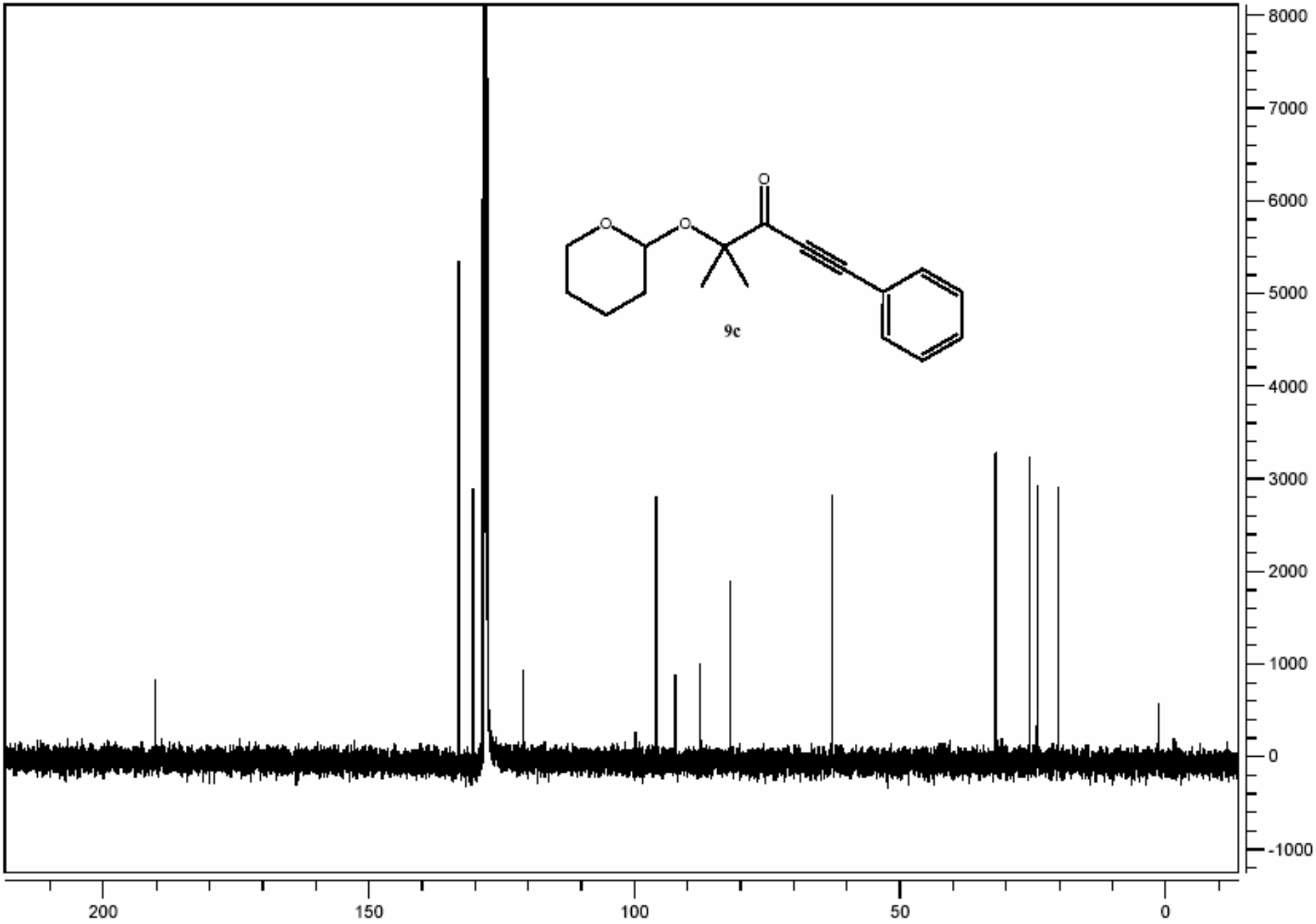

9a
0.93
1.00
1.02
2.90
2.11
1.25
3.04
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
7.0
6.0
5.0
4.0
3.0
2.0

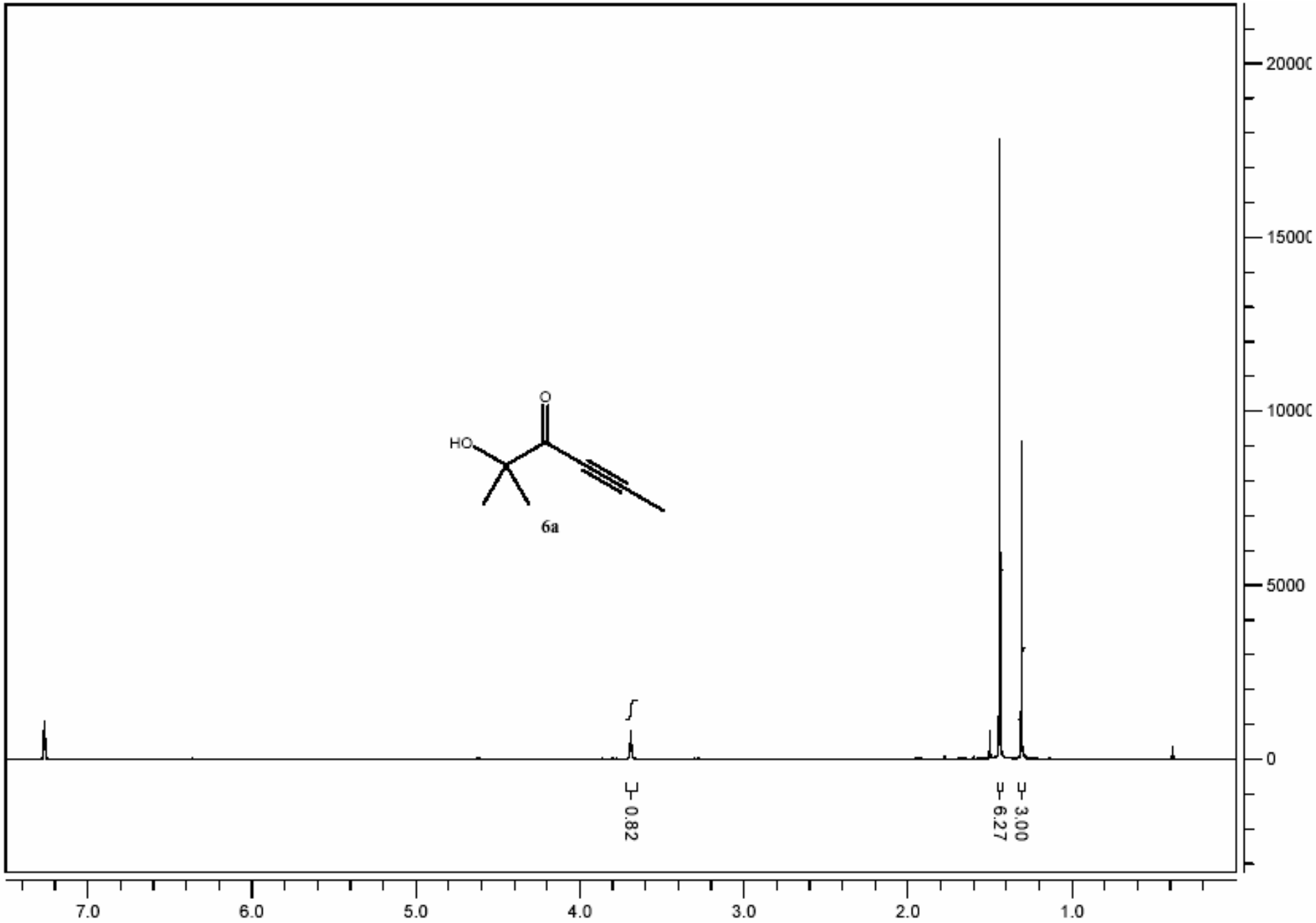

9a
4000
3000
2000
1000
0
200
150
100
50
0

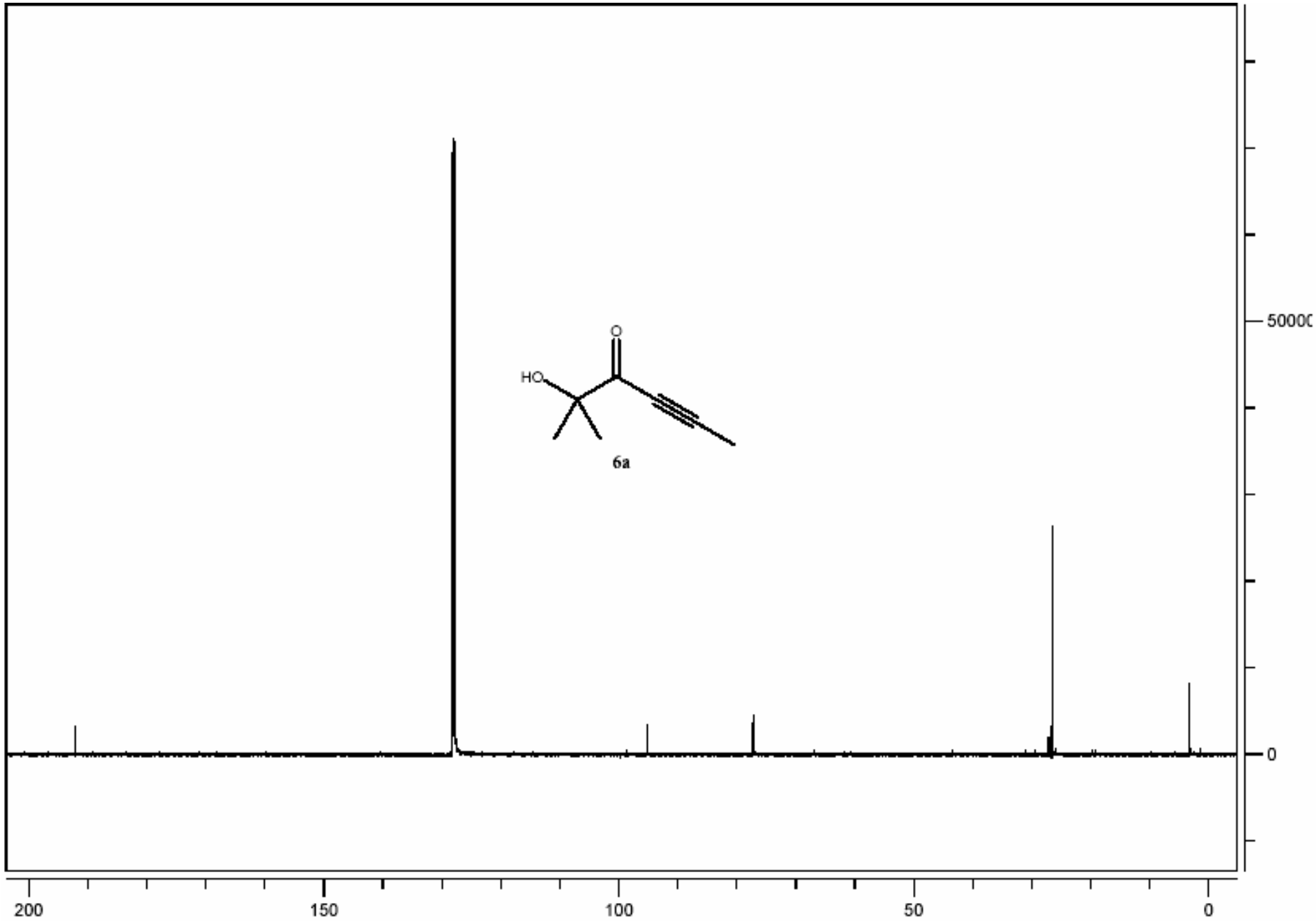

9b
1500
1000
500
0
0.89
0.97
0.97
1.84
3.03
3.00
3.02
5.44
2.80
7.0
6.0
5.0
4.0
3.0
2.0
1.0

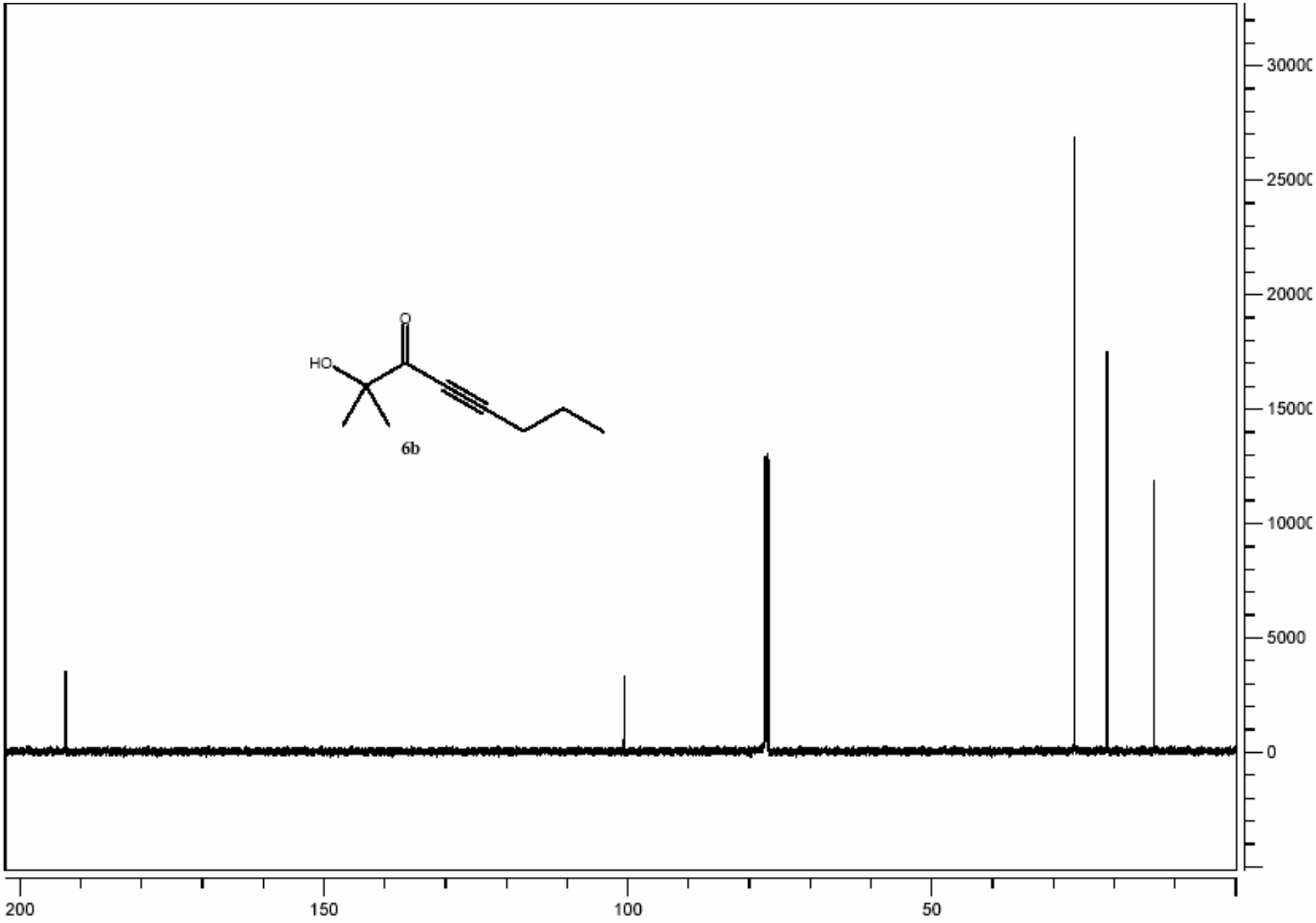

9b
6000
5000
4000
3000
2000
1000
0
200
150
100
50
0

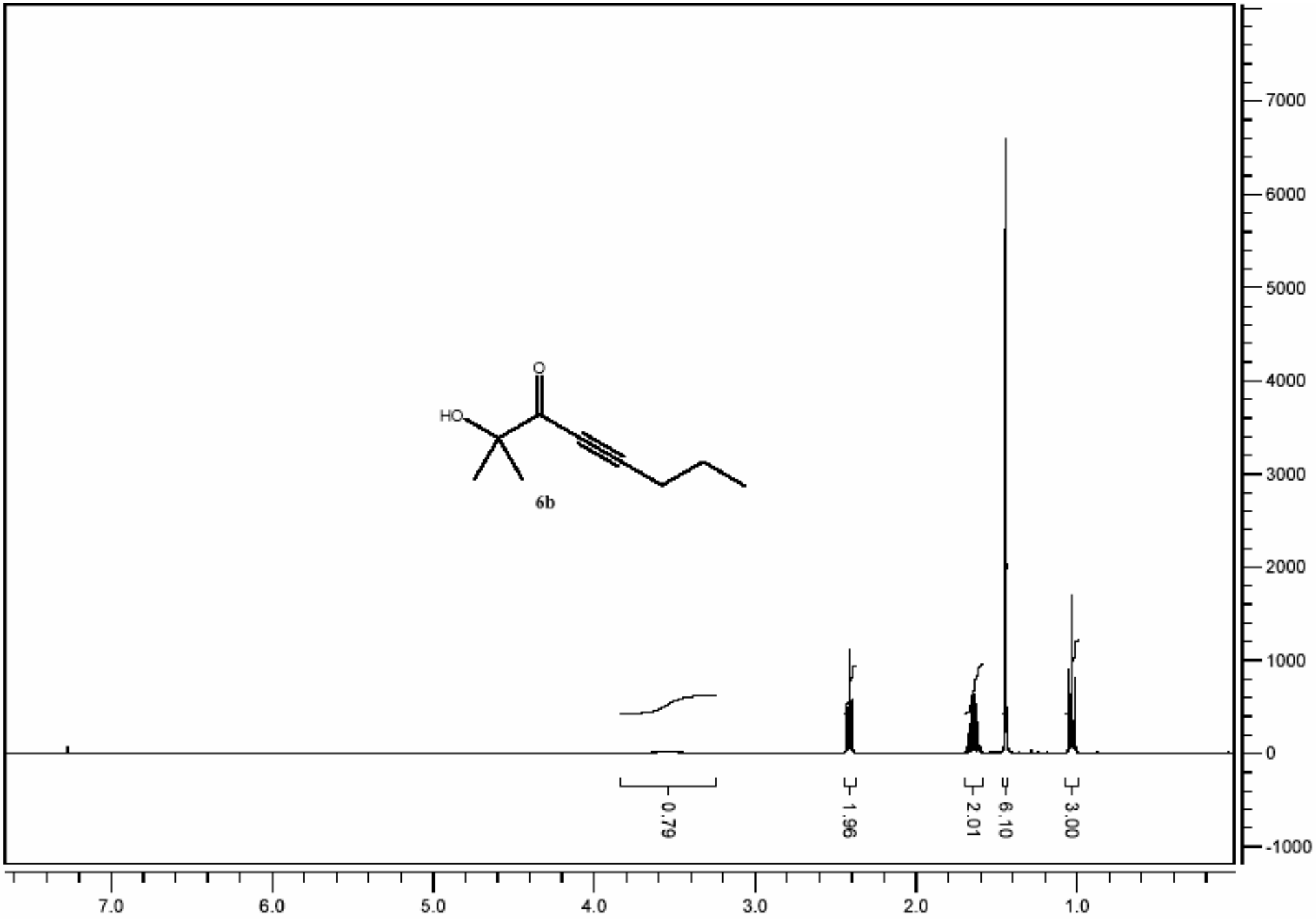

9c
1500
1000
500
0
1.93
0.93
1.00
1.10
1.08
3.32
3.20
3.30
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

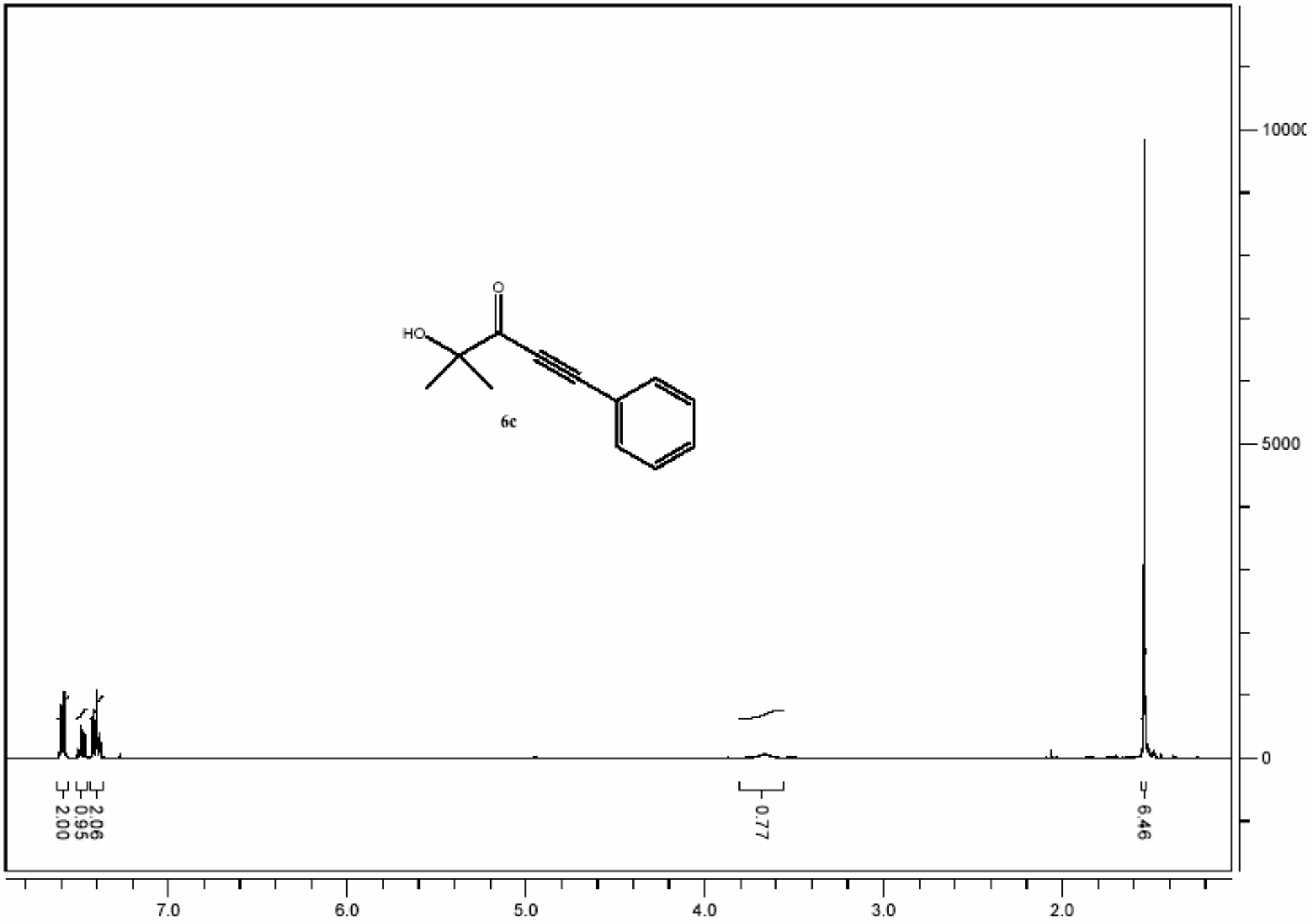

9c
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200
150
100
50
0

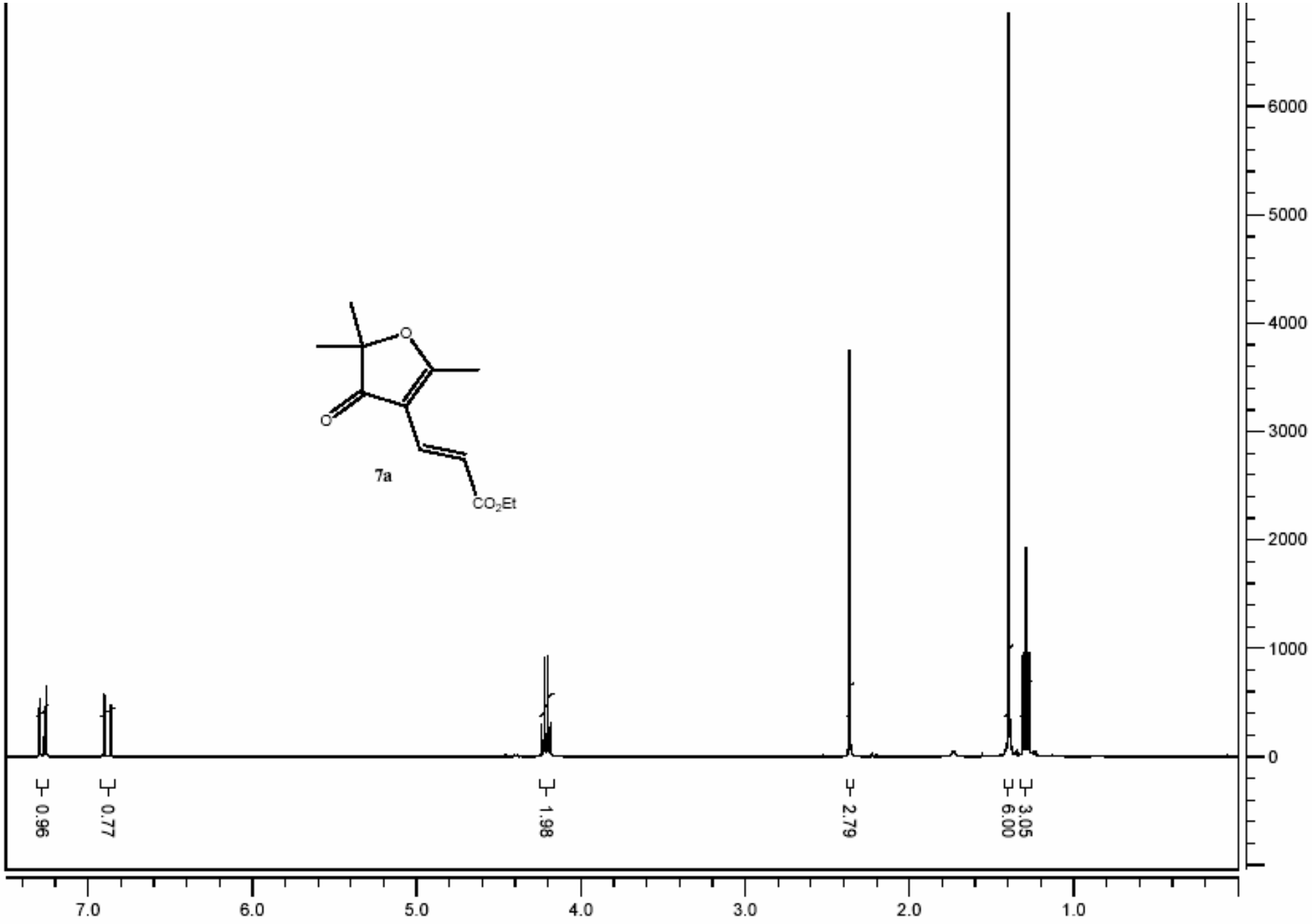

HO
O
6a
0.82
6.27
3.00
20000
15000
10000
5000
0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

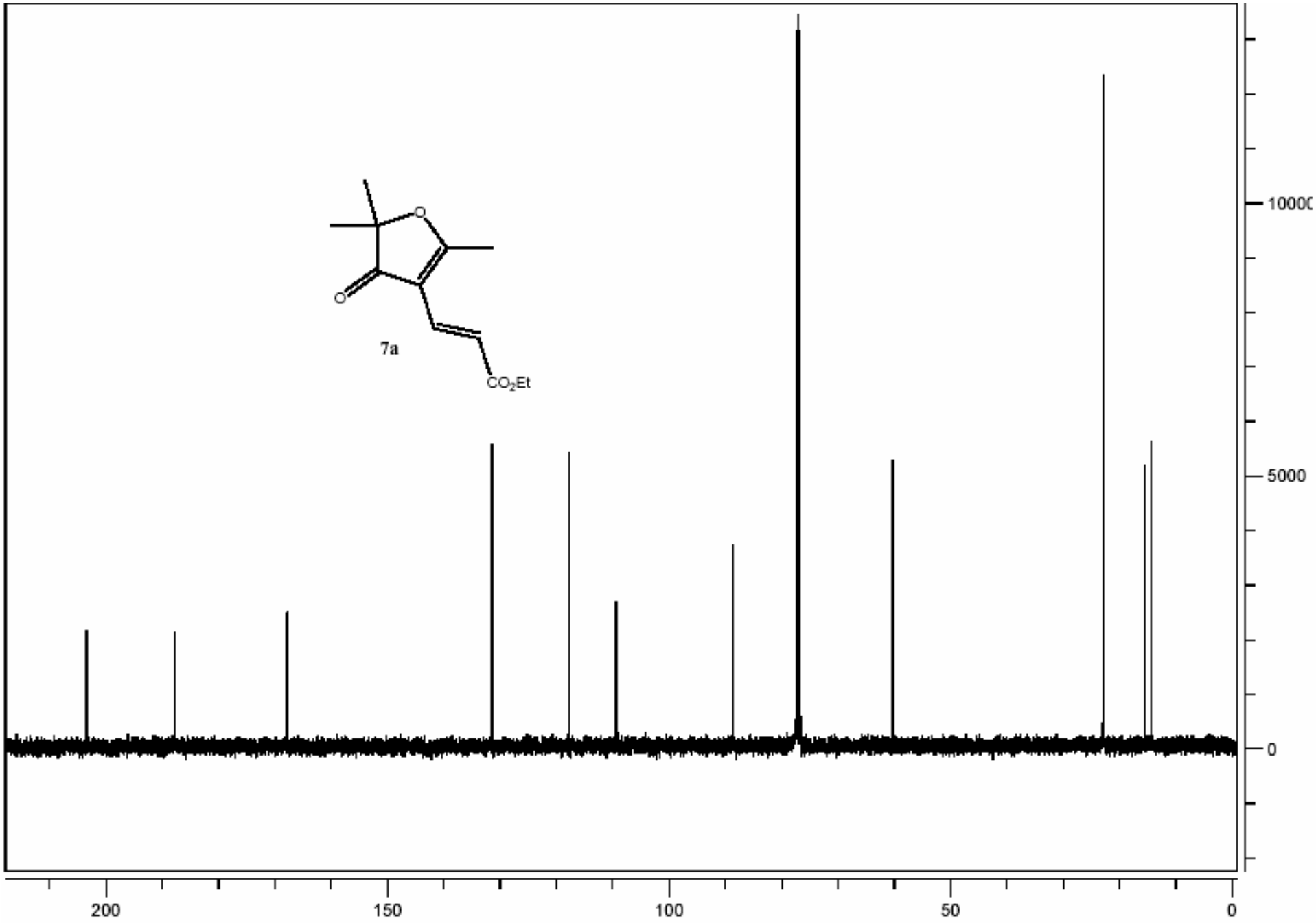

O
HO
6a
50000
0
200
150
100
50
0

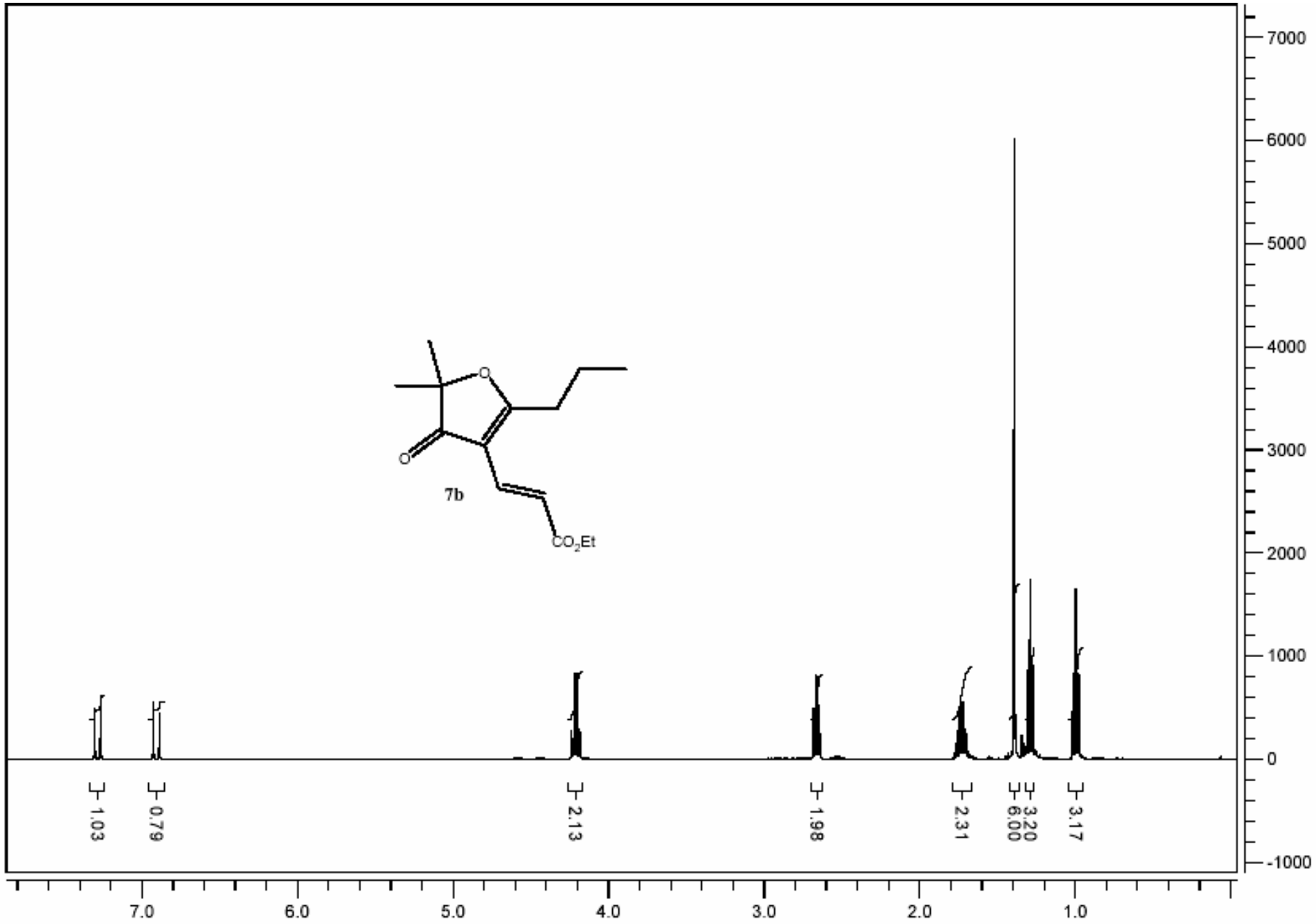

HO
O
6b
200
150
100
50
0
5000
10000
15000
20000
25000
30000

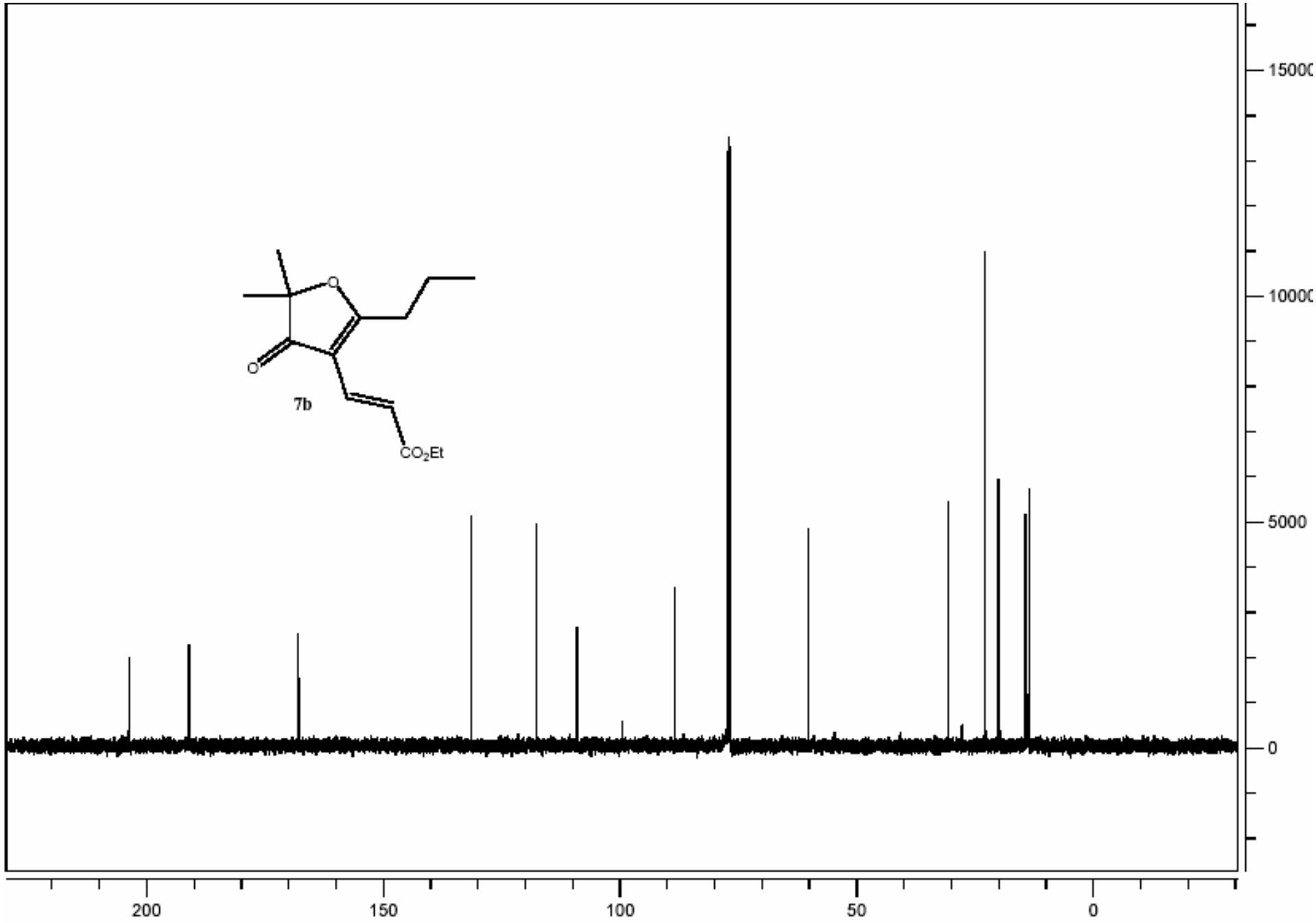

HO
O
6b
0.79
1.96
2.01
6.10
3.00
7000
6000
5000
4000
3000
2000
1000
0
-1000
7.0
6.0
5.0
4.0
3.0
2.0
1.0

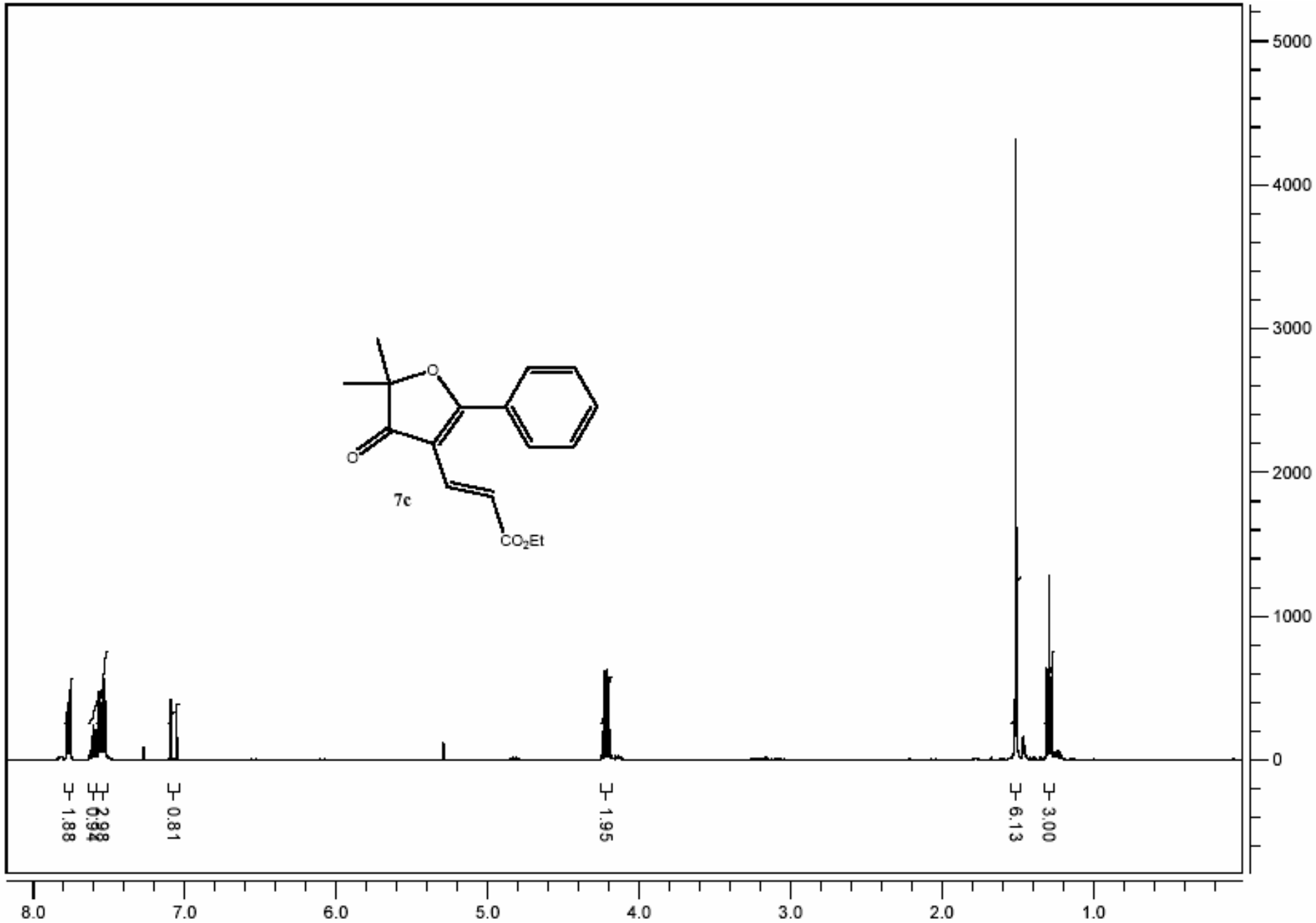

HO
O
6c
10000
5000
0
2.00
0.95
2.06
0.77
6.46
7.0
6.0
5.0
4.0
3.0
2.0

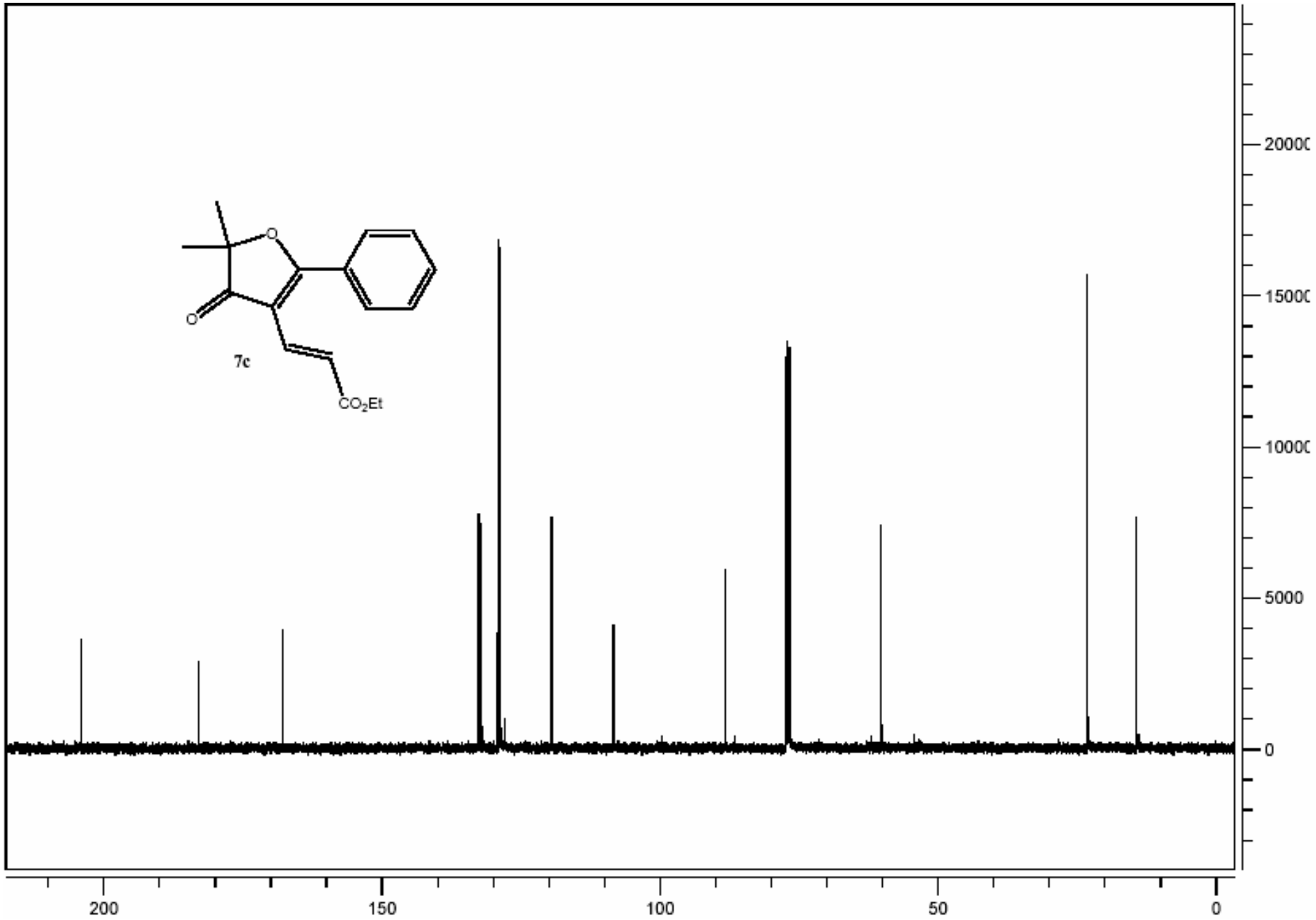

7a
CO2Et
0.96
0.77
1.98
2.79
6.00
3.05
6000
5000
4000
3000
2000
1000
0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

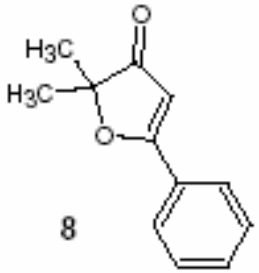

7a
CO2Et
10000
5000
0
200
150
100
50
0


7b
CO2Et
O
O
1.03
0.79
2.13
1.98
2.31
6.00
3.20
3.17
7000
6000
5000
4000
3000
2000
1000
0
-1000
7.0
6.0
5.0
4.0
3.0
2.0
1.0

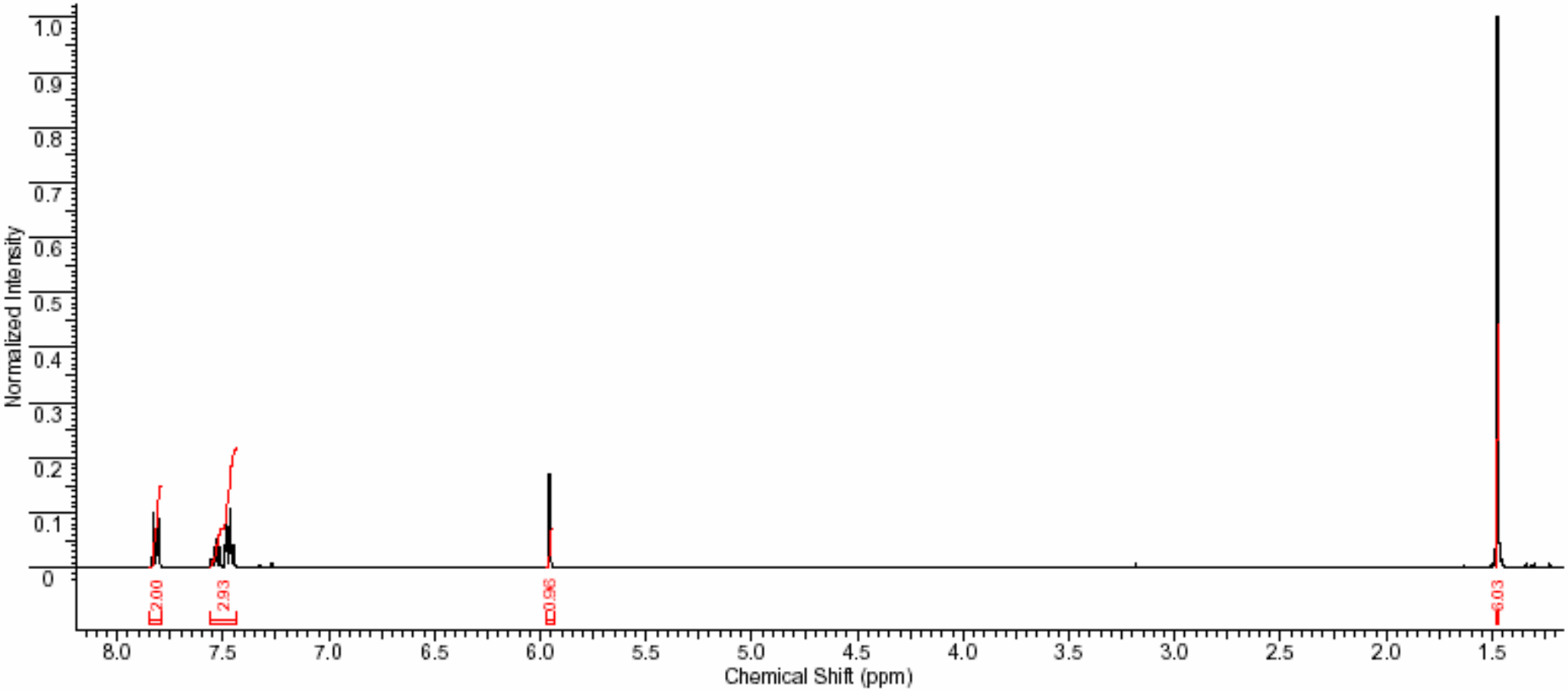

7b
CO2Et
15000
10000
5000
0
200
150
100
50
0

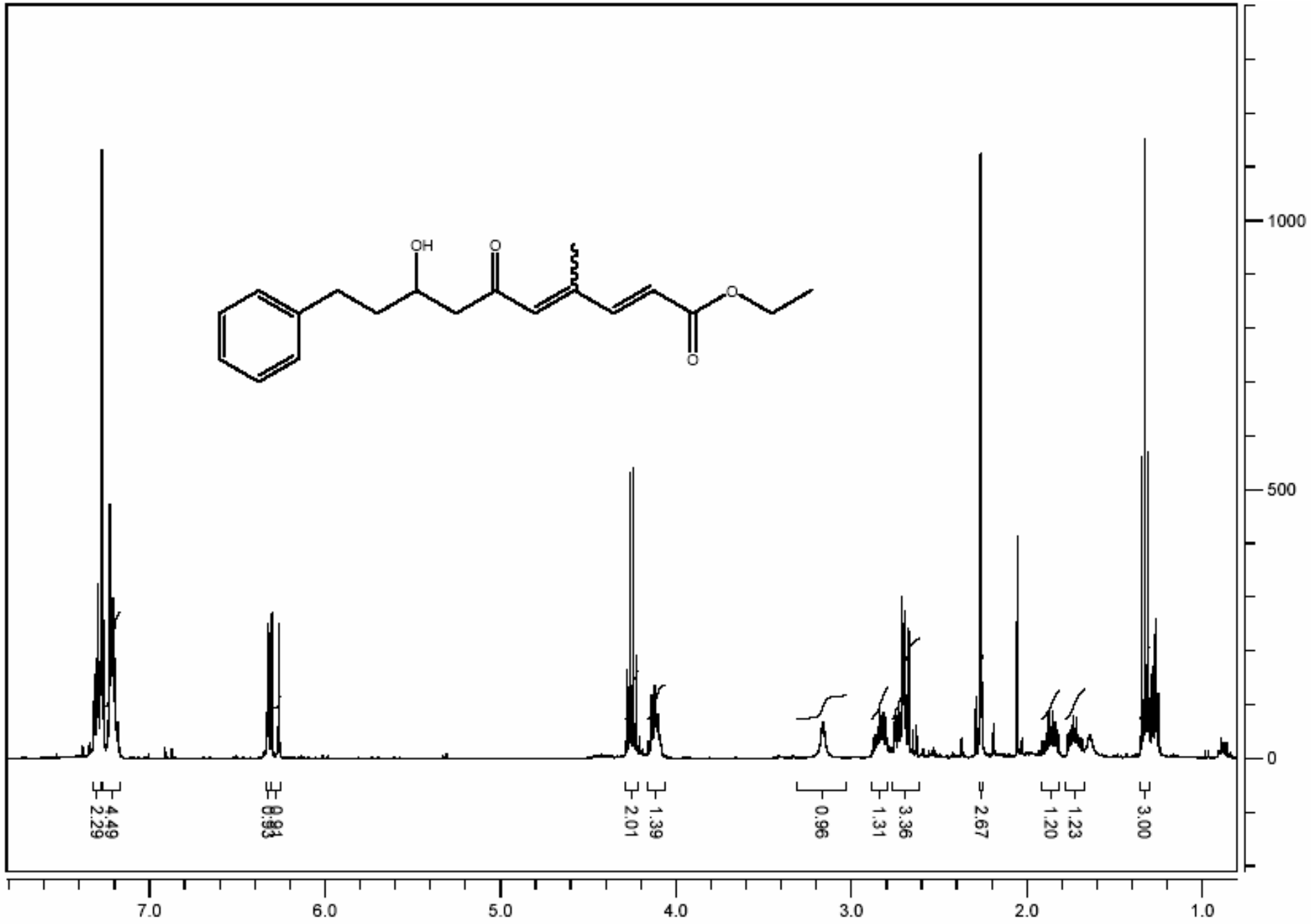

7c
CO2Et
1.88
0.94
2.98
0.81
1.95
6.13
3.00
5000
4000
3000
2000
1000
0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

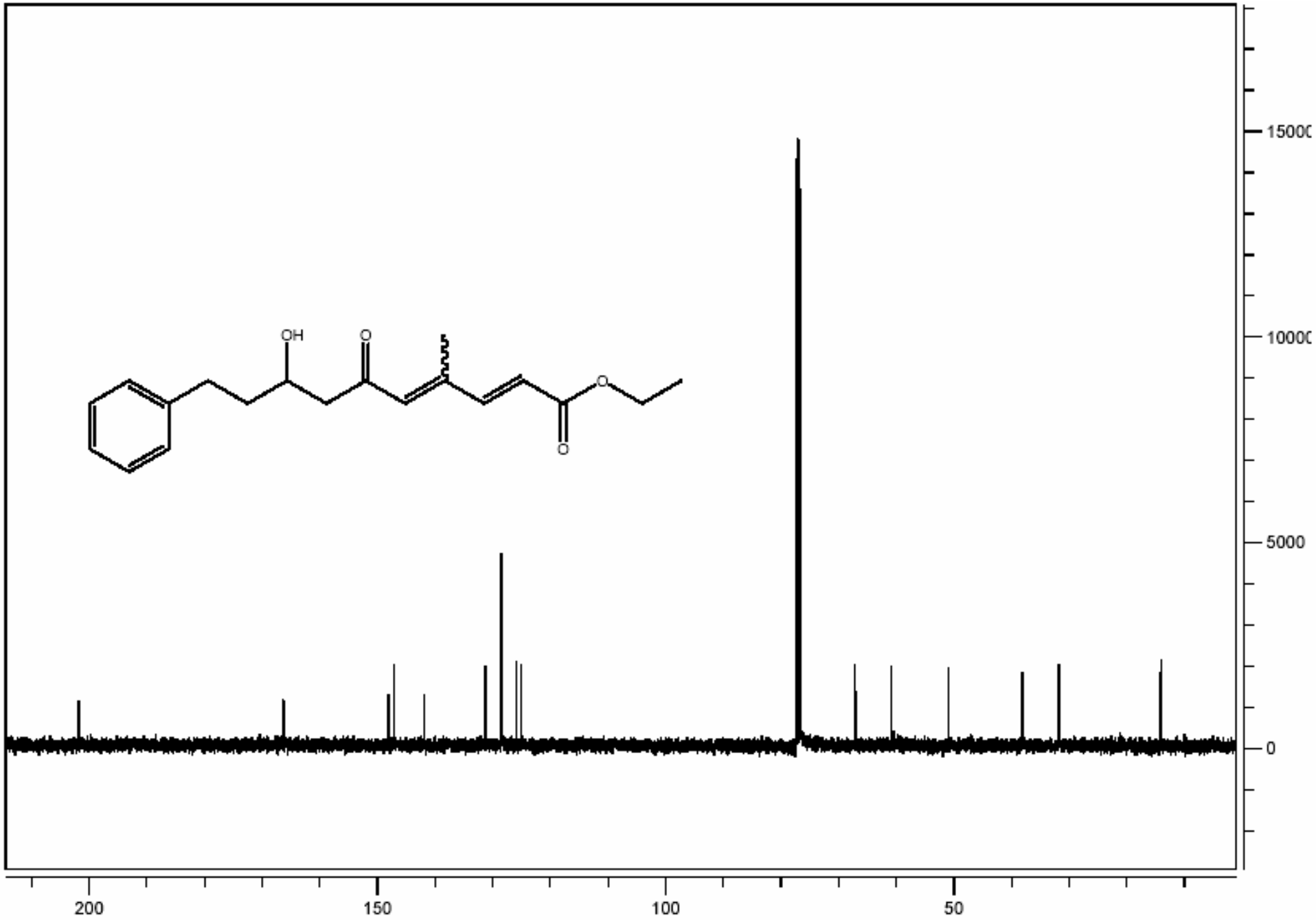

7c
CO2Et
20000
15000
10000
5000
0
200
150
100
50
0

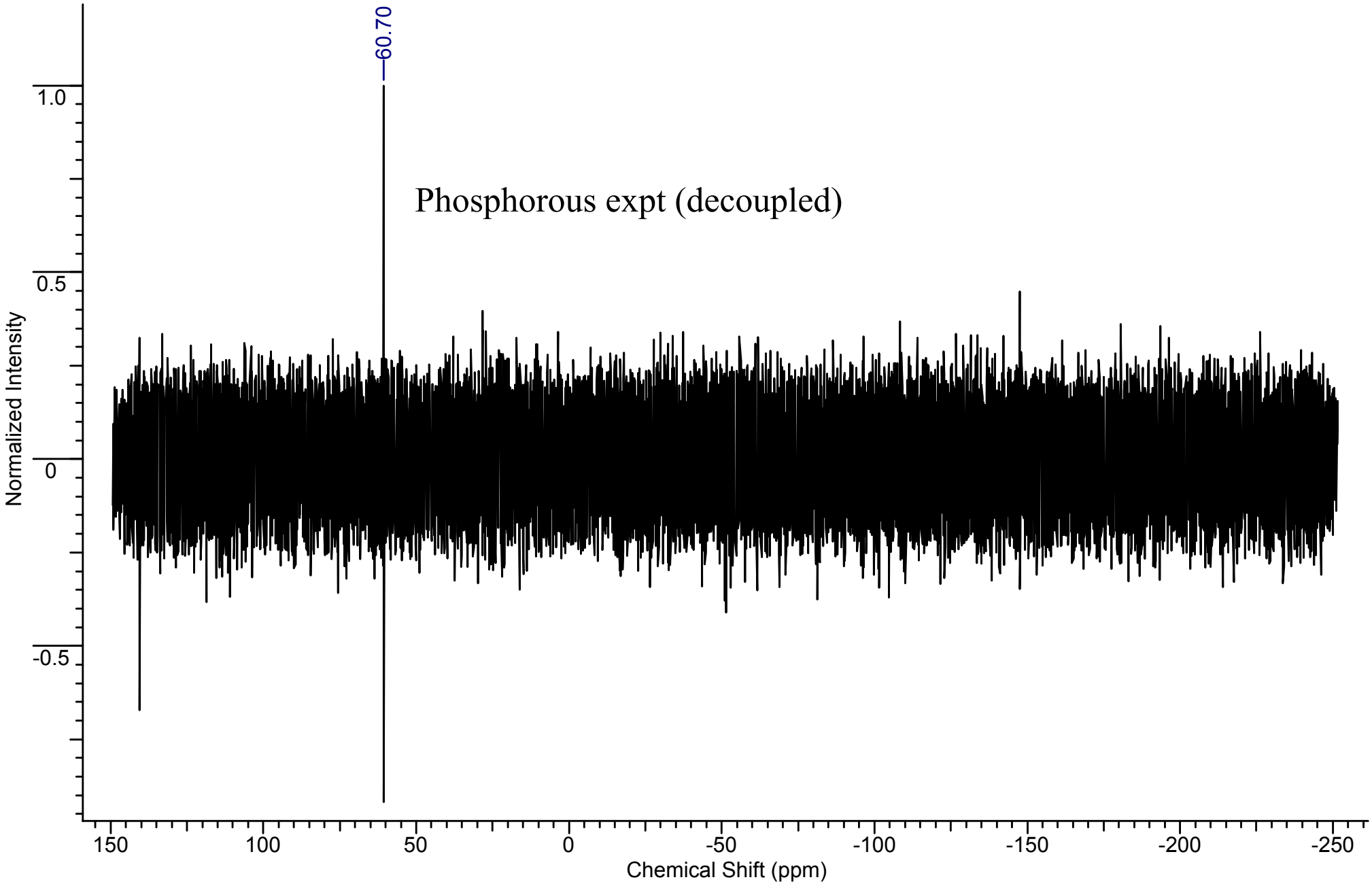

H3C
H3C
O
O

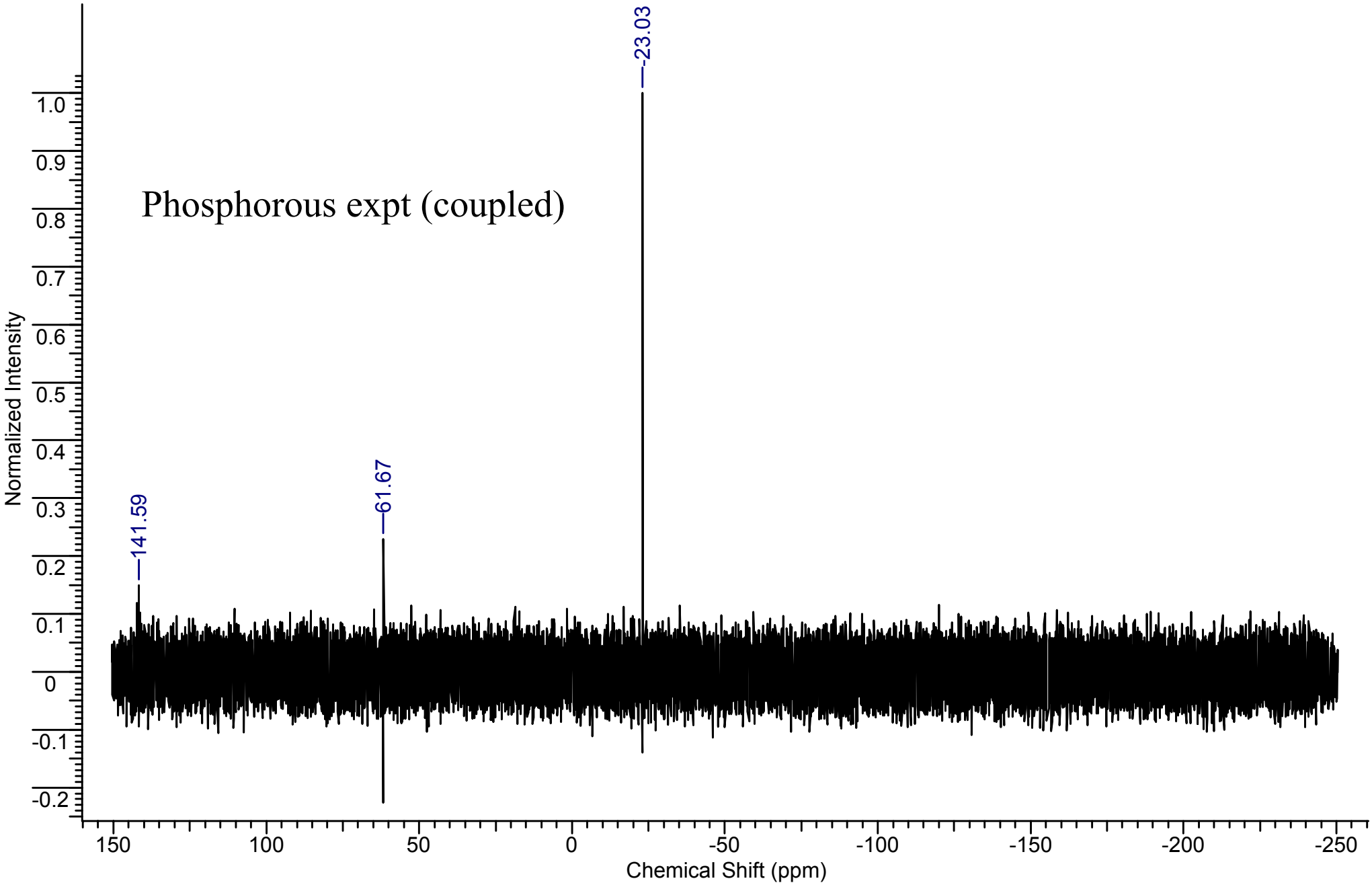
8


Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2.00
2.93
0.96
6.03
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
Chemical Shift (ppm)


OH
O
O
O
1000
500
0
4.49
2.29
0.91
2.01
1.39
0.96
1.31
3.36
2.67
1.20
1.23
3.00
7.0
6.0
5.0
4.0
3.0
2.0
1.0


OH
O
O
O
15000
10000
5000
0
200
150
100
50


60.70
Phosphorous expt (decoupled)
1.0
0.5
0
-0.5
Normalized Intensity
150
100
50
0
-50
-100
-150
-200
-250
Chemical Shift (ppm)


Phosphorous expt (coupled)
-23.03
61.67
141.59
Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
150
100
50
0
-50
-100
-150
-200
-250
Chemical Shift (ppm)