Supporting Information

Enantioselective Synthesis of 3,4-Chromanediones *via* Asymmetric Rearrangement of 3-Allyloxyflavones

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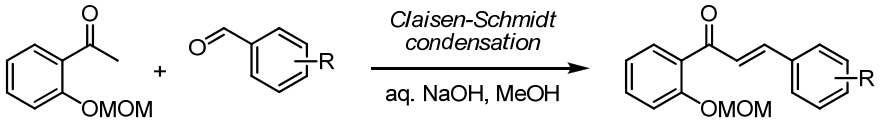
I. General Information

^{1}H NMR spectra were recorded on a 400 MHz spectrometer at ambient temperature with $CDCl_3$ as the solvent otherwise stated. ^{13}C NMR spectra were recorded on a 100 MHz spectrometer at ambient temperature with complete proton decoupling using $CDCl_3$ as the solvent otherwise stated. Chemical shifts for characterized compounds are reported in parts per million relative to $CDCl_3$ (^{1}H, δ 7.26; ^{13}C, δ 77.00). Data for ^{1}H NMR are reported as follows: chemical shift, multiplicity (app = apparent, par obsc = partially obscure, br = broad, ovrlp = overlapping, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), integration and coupling constants. Infrared spectra were recorded on FT-IR spectrophotometer. Optical rotations were recorded on a digital polarimeter at 589 nm and are recorded as $[\alpha]_D$ (concentration in grams/100 mL solvent). Enantiomeric ratio values were determined by chiral HPLC analysis performed on a high pressure liquid chromatography (HPLC) instrument equipped with a quaternary pump using a ChiralPak AD-H or Chiralcel OD-H column (15 cm x 4.6 mm) with UV detection monitored at 254 nm or 280 nm. High-resolution mass spectra were obtained in the Boston University Mass Spectrometry Laboratory using a Q-TOF mass spectrometer. Analytical thin layer chromatography was performed on 0.25 mm silica gel 60-F plates. Visualization was accomplished with UV light and aqueous ceric ammonium molybdate solution or basic aqueous potassium permanganate solution. UV and CD spectra of **7b** and **25** were measured using a spectrophotometer and spectropolarimeter, respectively as acetonitrile solutions of under an ambient temperature. Solution data were corrected by solvent (acetonitrile) spectra obtained using the same experimental condition. CD data were normalized to er = 100:0 according to the results obtained by chiral HPLC analysis. Flash chromatography was performed using 200-400 mesh silica gel. Yields refer to chromatographically and spectroscopically pure materials, unless otherwise stated. 1,2-Dichloroethane was dried over 4Å molecular sieves. Scandium trifluoromethylsulfonate (scandium triflate) was stored in a dry atmosphere box. All reactions were performed in flame-dried glassware under an argon atmosphere unless otherwise noted.

II. Experimental Procedures and Characterization Data for the Preparation of Chalcones 54-60.

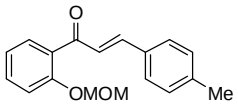


54-60

General Procedure: To a solution of 2'-methoxymethoxy-acetophenone[S1] (500 mg, 2.77 mmol, 1.0 equiv) in methanol (5 mL) was added at 0 °C an aqueous solution of sodium hydroxide (30 % wt, 0.70 mL, 8.32 mmol, 3.0 equiv). After stirring for 30 minutes, a solution of the benzaldehyde derivative (3.33 mmol, 1.2 equiv) in methanol (3 mL) was added dropwise *via* cannula. The reaction was slowly warmed up to ambient temperature and stirred overnight. The mixture was then diluted with Et_2O (15 mL) and

[S1] Topolski, M. *J. Org. Chem.* **1995**, *60*, 5588-5594.

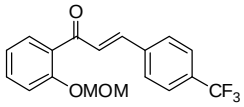
washed twice with a saturated aqueous solution of ammonium chloride (2 x 15 mL). After separation of the layers and reextraction of the aqueous phase in Et_2O (15 mL), the organic layers were combined and washed with brine (20 mL). The ethereal phase was dried over $MgSO_4$ and concentrated *in vacuo* to afford a crude mixture that was purified by column chromatography on silica gel.



54

***(E)*-1-(2-(Methoxymethoxy)phenyl)-3-*p*-tolylprop-2-en-1-one (54):**

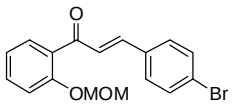
The title compound **54** was synthesized according to the general procedure using *p*-tolualdehyde and was purified by silica gel chromatography (petroleum ether : ethyl acetate = 90 : 10) affording a bright yellow oil (778 mg, 2.75 mmol, 99 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.57 (d, *J* = 15.9 Hz, 1H), 7.49-7.41 (m, 3H), 7.29 (d, *J* = 15.9 Hz, 1H), 7.22-7.18 (m, 3H), 7.09 (tt, *J* = 7.5, 0.8 Hz, 1H), 5.23 (s, 2H), 3.47 (s, 3H), 2.38 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.5, 155.4, 143.9, 140.8, 132.4, 132.2, 130.5, 129.9, 129.6 (2C), 128.3 (2C), 126.2, 121.9, 115.3, 94.9, 56.4, 21.5. IR ν_{max} (film): 2951, 2921, 1658, 1600, 1482, 1452, 1328, 1201, 1153, 1082, 1025, 982, 814 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{18}NaO_3$ 305.1154 found 305.1160 (M+Na).



55

***(E)*-1-(2-(Methoxymethoxy)phenyl)-3-(4-(trifluoromethyl)phenyl)prop-2-en-1-one (55):**

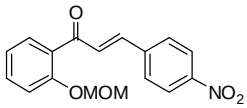
The title compound **55** was synthesized according to the general procedure using *p*-CF_3-benzaldehyde and was purified by silica gel chromatography (petroleum ether : ethyl acetate = 90 : 10) to afford a bright yellow oil (607 mg, 1.80 mmol, 65 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70-7.65 (m, 4H), 7.63 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.62 (d, *J* = 15.6 Hz, 1H), 7.50-7.45 (m, 1H), 7.44 (d, *J* = 15.9 Hz, 1H), 7.22 (d, *J* = 8.3 Hz, 1H), 7.11 (t, *J* = 7.5 Hz, 1H), 5.26 (s, 2H), 3.48 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.4, 155.6, 140.9, 138.4, 133.0, 132.0-131.0 (q, *J* = 32.7 Hz, 1C), 130.2, 129.6, 129.0, 128.3 (2C), 125.8-125.7 (q, *J* = 3.8 Hz, 2C), 127.8-119.7 (q, *J* = 272.2 Hz, 1C), 121.7, 115.1, 94.8, 56.3. IR ν_{max} (film): 2957, 2829, 1664, 1608, 1482, 1453, 1323, 1207, 1165, 1125, 1068, 981, 832 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{15}F_3NaO_3$ 359.0871 found 359.0865 (M+Na).



56

***(E)*-3-(4-Bromophenyl)-1-(2-(methoxymethoxy)phenyl)prop-2-en-1-one (56):**

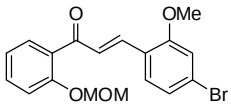
The brominated chalcone **56** (920 mg, 2.65 mmol, 96 %) was synthesized according to the general procedure using *p*-bromobenzaldehyde and was obtained as a bright yellow oil after silica gel chromatography (petroleum ether : ethyl acetate = 90 : 10). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 (dd, *J* = 7.6, 1.8 Hz, 1H), 7.53 (d, *J* = 15.4, 1H), 7.55-7.50 (m, 1H), 7.52 (d, *J* = 8.8 Hz, 1H), 7.48-7.41 (m, 2H), 7.43 (d, *J* = 8.3 Hz, 1H), 7.34 (d, *J* = 16.0 Hz, 1H), 7.20 (d, *J* = 8.4 Hz, 1H), 7.10 (tt, *J* = 7.5, 0.8 Hz, 1H), 5.24 (s, 2H), 3.47 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.8, 155.5, 141.9, 133.8, 132.8, 132.1 (2C), 130.0, 129.9, 129.6 (2C), 127.4, 124.5, 121.9, 115.2, 94.8, 56.4. IR ν_{max} (film): 2955, 2826, 1659, 1604, 1586, 1486, 1452, 1325, 1203, 1153, 1073, 980, 818 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{17}H_{16}BrO_3$ 347.0283 found 347.0273 (M+H).



57

***(E)*-1-(2-(Methoxymethoxy)phenyl)-3-(4-nitrophenyl)prop-2-en-1-one (57):**

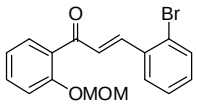
Chalcone **57** was synthesized according to the general procedure using *p*-NO_2-benzaldehyde and was purified by silica gel chromatography (petroleum ether : ethyl acetate = 85 : 15) affording bright yellow needles (633 mg, 2.02 mmol, 73 %). M.p. (petroleum ether : CH_2Cl_2) = 125-126 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.25 (d, *J* = 8.8 Hz, 2H), 7.72 (d, *J* = 8.9 Hz, 2H), 7.64 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.64 (d, *J* = 15.9 Hz, 1H), 7.51 (d, *J* = 16.4 Hz, 1H), 7.51-7.45 (m, 1H), 7.21 (d, *J* = 8.4 Hz, 1H), 7.11 (t, *J* = 7.5 Hz, 1H), 5.26 (s, 2H), 3.48 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.0, 155.8, 148.3, 141.3, 139.5, 133.4, 130.5, 130.3 129.4, 128.7 (2C), 124.1 (2C), 122.1, 115.2, 94.9, 56.5. IR ν_{max} (film): 2955, 2925, 2851, 1661, 1598, 1518, 1482, 1453, 1344, 1206, 1154, 1110, 1082, 979, 855 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{17}H_{15}NNaO_5$ 336.0848 found 336.0879 (M+Na).



58

***(E)*-3-(4-Bromo-2-methoxyphenyl)-1-(2-(methoxymethoxy)phenyl)prop-2-en-1-one (58):**

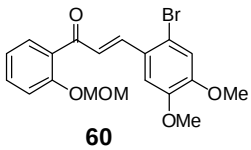
The compound **58** was prepared according to the general procedure using 4-bromo-2-methoxybenzaldehyde and was purified by silica gel chromatography (petroleum ether : ethyl acetate = 90 : 10) to afford a yellow oil (961 mg, 2.55 mmol, 92 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, *J* = 16.1 Hz, 1H), 7.57 (dd, *J* = 7.6, 1.8 Hz, 1H), 7.46-7.42 (m, 1H), 7.42 (d, *J* = 8.3 Hz, 1H), 7.38 (d, *J* = 16.0 Hz, 1H), 7.20 (d, *J* = 8.0 Hz, 1H), 7.11 (dd, *J* = 8.2, 1.8 Hz, 1H), 7.09 (dt, *J* = 7.5, 0.7 Hz, 1H), 7.06 (d, *J* = 1.8 Hz, 1H), 5.23 (s, 2H), 3.87 (s, 3H), 3.47 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.3, 158.8, 155.4, 137.7, 132.4, 130.3, 130.0, 129.6, 127.8, 125.1, 123.9, 123.0, 121.9, 115.2, 114.8, 94.8, 56.2, 55.7. IR ν_{max} (film): 2963, 2934, 2851, 1673, 1599, 1586, 1484, 1452, 1246, 1154, 1083, 985, 853 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{17}BrNaO_4$ 399.0208 found 399.0246 (M+Na).



59

***(E)*-3-(2-Bromophenyl)-1-(2-(methoxymethoxy)phenyl)prop-2-en-1-one (59):**

The *ortho*-brominated chalcone **59** was synthesized following the general procedure using 2-bromobenzaldehyde. After purification by silica gel chromatography (petroleum ether : ethyl acetate = 90 : 10), the product was obtained as a yellow gum (843 mg, 2.43 mmol, 88 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, *J* = 15.9 Hz, 1H), 7.67 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.60 (dd, *J* = 7.6, 1.8 Hz, 1H), 7.59 (dd, *J* = 8.0, 1.3 Hz, 1H), 7.44 (ddd, *J* = 8.4, 7.4, 1.8 Hz, 1H), 7.32 (t, *J* = 7.3 Hz, 1H), 7.28 (d, *J* = 15.9 Hz, 1H), 7.23-7.18 (m, 2H), 7.09 (dt, *J* = 7.5, 1.0 Hz, 1H), 5.24 (s, 2H), 3.46 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.8, 155.5, 141.7, 134.9, 133.4, 132.8, 131.1, 130.1, 129.7, 129.4, 127.6 (2C), 125.7, 121.9, 115.1, 94.8, 56.3. IR ν_{max} (film): 3068, 2954, 2826, 1659, 1601, 1482, 1465, 1452, 1440, 1324, 1281, 1232, 1153, 1110, 1082, 977 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{17}H_{15}BrNaO_3$ 369.0102 found 369.0121 (M+Na).



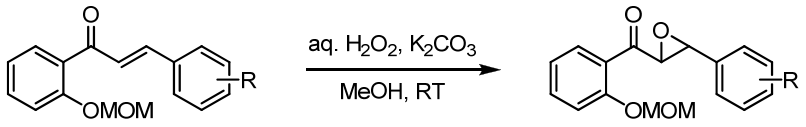
60

***(E)*-3-(2-Bromo-4,5-dimethoxyphenyl)-1-(2-(methoxymethoxy)phenyl)prop-2-en-1-one (60):**

The title chalcone **60** was prepared according to the general procedure using 6-bromoveratraldehyde and was purified by silica gel chromatography (petroleum

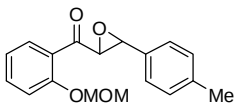
ether : ethyl acetate = 75 : 25) to afford a yellow solid (983 mg, 2.41 mmol, 87 %). M.p. (petroleum ether : Et_2O) = 94-95 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (d, *J* = 15.9 Hz, 1H), 7.56 (d, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.8 Hz, 1H), 7.20 (d, *J* = 8.4 Hz, 1H), 7.16 (s, 1H), 7.14 (d, *J* = 15.9 Hz, 1H), 7.10 (t, *J* = 7.5 Hz, 1H), 7.05 (s, 1H), 5.23 (s, 2H), 3.90 (s, 3H), 3.89 (s, 3H), 3.46 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.3, 155.3, 151.3, 148.5, 142.3, 132.5, 130.1, 129.9, 127.4, 126.7, 121.9, 117.9, 115.6, 115.1, 109.2, 94.9, 56.4, 56.2, 55.9. IR ν_{max} (film): 3001, 2952, 2842, 1653, 1597, 1505, 1438, 1389, 1292, 1264, 1204, 1165, 1025, 981, 848 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{19}BrNaO_5$ 429.0314 found 429.0296 (M+Na).

III. Experimental Procedures and Characterization Data for the Preparation of Epoxides (61-67).



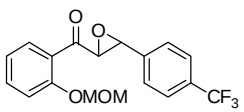
54-60 **61-67**

General Procedure:[S2] To a solution of the *p*-methyl chalcone **54** (205 mg, 0.73 mmol, 1.0 equiv) in methanol (15 mL) was added K_2CO_3 (301.0 mg, 2.18 mmol, 3.0 equiv) at room temperature in one portion followed by an aqueous solution of hydrogen peroxide (30 % wt, 0.59 mL, 5.81 mmol, 8.0 equiv), over 15 minutes. After completion of the reaction (monitored by TLC, 10 minutes), the mixture was diluted with Et_2O (15 mL) and washed twice with a saturated aqueous solution of ammonium chloride (2 x 15 mL). After extraction of the combined aqueous layers in Et_2O (15 mL), the organic layers were combined and washed with brine (20 mL). The ethereal phase was dried over $MgSO_4$ and concentrated *in vacuo* to afford a crude mixture that was purified by silica gel chromatography.



61

(2-(Methoxymethoxy)phenyl)(3-*p*-tolyloxiran-2-yl)methanone (61):
Epoxide **61** was isolated as white needles (210 mg, 0.70 mmol, 97 %) after silica gel chromatography (petroleum ether : ethyl acetate = 85 : 15). M.p. (petroleum ether : CH_2Cl_2) = 91-92 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.47 (ddd, *J* = 8.5, 7.3, 1.8 Hz, 1H), 7.25 (d, *J* = 8.0 Hz, 2H), 7.19 (d, *J* = 8.0 Hz, 2H), 7.15 (d, *J* = 8.4 Hz, 1H), 7.08 (dt, *J* = 7.7, 0.9 Hz, 1H), 4.93 (d, *J* = 7.0 Hz, 1H), 4.85 (d, *J* = 7.0 Hz, 1H), 4.29 (d, *J* = 1.9 Hz, 1H), 3.98 (d, *J* = 1.7 Hz, 1H), 3.11 (s, 3H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.9, 157.1, 138.7, 134.6, 133.3, 130.4, 129.2 (2C), 126.4, 125.7 (2C), 121.9, 114.3, 94.3, 64.8, 59.8, 56.2, 21.2. IR ν_{max} (film): 2924, 2851, 1682, 1598, 1482, 1456, 1281, 1215, 1154, 1083, 979, 896, 822 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{18}NaO_4$ 321.1103 found 321.1108 (M+Na).

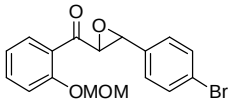


62

(2-(Methoxymethoxy)phenyl)(3-(4-(trifluoromethyl)phenyl)oxiran-2-yl) methanone (62):

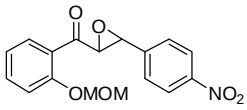
[S2] LeBlanc, R.; Dickson, J.; Brown, T.; Stewart, M.; Pati, H. N.; VanDerveer, D.; Arman, H.; Harris, J.; Pennington, W.; Holt, H. L.; Lee, M. *Bioorg. Med. Chem.* **2005**, *13*, 6025-6034.

Epoxyketone **62** was synthesized starting from the chalcone **55** (293 mg, 0.87 mmol) and was purified by silica gel chromatography (petroleum ether : ethyl acetate = 85 : 15) to afford a white solid (295 mg, 0.84 mmol, 96 %). M.p. (petroleum ether : CH_2Cl_2) = 101-102 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.67 (d, *J* = 8.3 Hz, 2H), 7.53-7.47 (m, 3H), 7.16 (d, *J* = 8.4 Hz, 1H), 7.11 (t, *J* = 7.5 Hz, 1H), 4.97 (d, *J* = 7.0 Hz, 1H), 4.86 (d, *J* = 7.0 Hz, 1H), 4.29 (d, *J* = 1.9 Hz, 1H), 4.09 (d, *J* = 1.8 Hz, 1H), 3.11 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.1, 157.1, 140.6, 134.9, 131.4-130.4 (q, *J* = 32.5 Hz, 1C), 130.5, 126.2, 126.0 (2C), 125.6-125.5 (q, *J* = 3.8 Hz, 2C), 127.9-119.8 (q, *J* = 272.0 Hz, 1C), 122.1, 114.5, 94.5, 64.6, 58.8, 56.2. IR ν_{max} (film): 2959, 2829, 1685, 1598, 1482, 1457, 1326, 1282, 1165, 1125, 1068, 1018, 979, 834 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{15}F_3NaO_4$ 375.0820 found 375.0830 (M+Na).



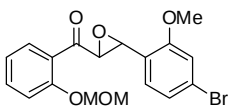
63

(3-(4-Bromophenyl)oxiran-2-yl)(2-(methoxymethoxy)phenyl)methanone (63):
The title compound **63** was synthesized starting from the chalcone **56** (330.0 mg, 0.95 mmol) and was purified on silica gel (petroleum ether : ethyl acetate = 90 : 10) affording a white solid (339 mg, 0.93 mmol, 98 %). M.p. (petroleum ether : CH_2Cl_2) = 108-109 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (dd, *J* = 7.8, 1.8 Hz, 1H), 7.52 (d, *J* = 8.5 Hz, 2H), 7.50-7.46 (m, 1H), 7.25 (d, *J* = 8.6 Hz, 2H), 7.16 (d, *J* = 8.4 Hz, 1H), 7.09 (t, *J* = 7.5 Hz, 1H), 4.97 (d, *J* = 7.0 Hz, 1H), 4.88 (d, *J* = 7.0 Hz, 1H), 4.26 (d, *J* = 1.9 Hz, 1H), 3.98 (d, *J* = 1.8 Hz, 1H), 3.14 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.3, 157.1, 135.5, 134.8, 131.7 (2C), 130.5, 127.3 (2C), 126.3, 122.7, 122.0, 114.4, 94.4, 64.5, 59.1, 56.2. IR ν_{max} (film): 2954, 2904, 2853, 1681, 1597, 1481, 1455, 1282, 1153, 1082, 979, 895, 825 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{17}H_{15}BrNaO_4$ 385.0051 found 385.0102 (M+Na).



64

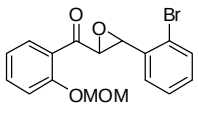
(2-(Methoxymethoxy)phenyl)(3-(4-nitrophenyl)oxiran-2-yl)methanone (64):
Epoxyketone **64** was synthesized starting from the chalcone **57** (748 mg, 2.39 mmol) and was purified by silica gel chromatography (petroleum ether : ethyl acetate = 65 : 35) to afford a light yellow solid (717 mg, 2.18 mmol, 91 %). M.p. (petroleum ether : CH_2Cl_2) = 166-169 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, *J* = 8.6 Hz, 2H), 7.81 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.56 (d, *J* = 8.7 Hz, 2H), 7.51 (td, *J* = 7.4, 1.8, 0.6 Hz, 1H), 7.17 (d, *J* = 8.4 Hz, 1H), 7.11 (t, *J* = 7.5 Hz, 1H), 4.98 (d, *J* = 6.9 Hz, 1H), 4.90 (d, *J* = 6.9 Hz, 1H), 4.31 (dd, *J* = 1.8, 0.6 Hz, 1H), 4.14 (d, *J* = 1.8 Hz, 1H), 3.16 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.8, 157.1, 148.1, 143.8, 135.1, 130.6, 126.5 (2C), 126.2, 123.9 (2C), 122.2, 114.6, 94.6, 64.4, 58.4, 56.4. IR ν_{max} (film): 2935, 2852, 1683, 1598, 1522, 1482, 1457, 1347, 1282, 1154, 1112, 1083, 978, 836 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{17}H_{15}NNaO_6$ 352.0797 found 352.0826 (M+Na).



65

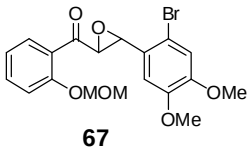
(3-(4-Bromo-2-methoxyphenyl)oxiran-2-yl)(2-(methoxymethoxy)phenyl)methanone (65):
The title compound **65** was synthesized starting from the chalcone **58** (800 mg, 2.12 mmol) and was purified on silica gel (petroleum ether : ethyl acetate = 85 : 15), affording a white solid (832 mg, 2.12 mmol, 99 %). M.p. (petroleum ether : CH_2Cl_2) = 104-105 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.48 (ddd, *J* = 8.4, 7.3, 1.8 Hz, 1H), 7.16 (d, *J* = 8.4 Hz, 1H), 7.10 (s, 2H), 7.09 (t, *J* = 7.77 Hz, 1H), 7.04 (br s, 1H), 5.02 (d, *J* = 6.9 Hz, 1H), 4.93 (d,

J = 6.9 Hz, 1H), 4.34 (d, J = 1.9 Hz, 1H), 4.20 (dd, J = 1.9, 0.4 Hz, 1H), 3.82 (s, 3H), 3.18 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.9, 158.7, 157.1, 134.6, 130.4, 126.6, 126.4, 124.0, 123.9, 122.7, 122.0, 114.5, 113.9, 94.4, 64.0, 56.1, 55.7, 55.0. IR ν_{max} (film): 2930, 2852, 1683, 1596, 1490, 1456, 1398, 1281, 1252, 1154, 1083, 1018, 981, 853 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{17}BrNaO_5$ 415.0157 found 415.0178 (M+Na).



66

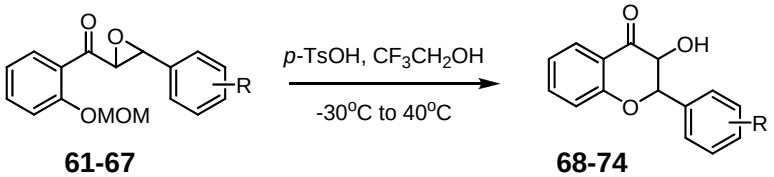
(3-(2-Bromophenyl)oxiran-2-yl)(2-(methoxymethoxy)phenyl)methanone (66): Starting from the chalcone **59** (895 mg, 2.58 mmol), the epoxide **66** was isolated after column chromatography on silica gel (petroleum ether : ethyl acetate = 85 : 15) as white needles (892 mg, 2.45 mmol, 95 %). M.p. (petroleum ether : Et_2O) = 93-94 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (dd, J = 7.8, 1.8 Hz, 1H), 7.58 (d, J = 8.1 Hz, 1H), 7.49 (ddd, J = 8.4, 7.3, 1.8 Hz, 1H), 7.38-7.30 (m, 2H), 7.22 (ddd, J = 8.1, 7.0, 2.3 Hz, 1H), 7.19 (d, J = 8.4 Hz, 1H), 7.10 (app t, J = 7.5 Hz, 1H), 5.09 (d, J = 7.0 Hz, 1H), 4.95 (d, J = 7.0 Hz, 1H), 4.40 (d, J = 1.9 Hz, 1H), 4.15 (d, J = 1.9 Hz, 1H), 3.14 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.4, 157.2, 135.8, 134.7, 132.5, 130.4, 129.8, 127.8, 126.5, 125.8, 122.6, 122.0, 114.5, 94.5, 64.1, 59.2, 56.2. IR ν_{max} (film): 3070, 2956, 2827, 1683, 1598, 1481, 1456, 1282, 1238, 1215, 1198, 1154, 1082, 1015, 977, 895 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{17}H_{15}BrNaO_4$ 385.0051 found 385.0080 (M+Na).



67

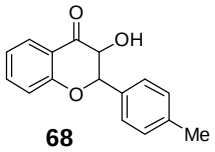
(3-(2-Bromo-4,5-dimethoxyphenyl)oxiran-2-yl)(2-(methoxymethoxy)phenyl)methanone (67): Epoxide **67** was prepared starting from the chalcone **60** (900 mg, 2.21 mmol) and was isolated as a white solid (820 mg, 1.94 mmol, 88 %) after purification by column chromatography (petroleum ether : ethyl acetate = 60 : 40). M.p. (petroleum ether : CH_2Cl_2) = 109-111 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (dd, J = 7.7, 1.8 Hz, 1H), 7.49 (ddd, J = 8.4, 7.4, 1.8 Hz, 1H), 7.19 (d, J = 8.3 Hz, 1H), 7.09 (app t, J = 7.6 Hz, 1H), 7.02 (s, 1H), 6.78 (s, 1H), 5.08 (d, J = 7.0 Hz, 1H), 4.99 (d, J = 7.0 Hz, 1H), 4.32 (d, J = 1.9 Hz, 1H), 4.14 (d, J = 1.9 Hz, 1H), 3.89 (s, 3H), 3.85 (s, 3H), 3.19 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.4, 157.2, 149.7, 149.0, 134.7, 130.4, 127.6, 126.6, 122.0, 115.1, 114.5, 112.7, 107.9, 94.5, 64.1, 59.3, 56.3, 56.2, 56.1. IR ν_{max} (film): 3002, 2936, 2842, 1683, 1598, 1509, 1482, 1456, 1412, 1386, 1267, 1212, 1158, 1082, 1016, 976, 892 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{19}BrNaO_6$ 445.0263 found 445.0254 (M+Na).

IV. Experimental Procedures and Characterization Data for the Preparation of 3-Hydroxy-2-Phenylchroman-4-ones (68-74).



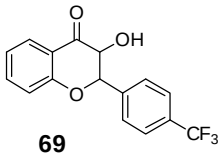
61-67 **68-74**

General Procedure:[S3] To a solution of the *p*-tolylepoxide **61** (210 mg, 0.70 mmol, 1.0 equiv) in CF_3CH_2OH (25 mL) at -30 °C, *p*-TsOH•H_2O (67.0 mg, 0.35 mmol, 0.50 equiv) was added in one portion and the reaction mixture was allowed to warm up progressively to 40 °C. The mixture was then diluted with water (20 mL) and a saturated solution of $NaHCO_3$ (20 mL) was added. After extraction with CH_2Cl_2 (3 x 30 mL), the organic layer was washed with brine (50 mL), dried over $MgSO_4$, filtered, and evaporated. The crude product was purified by silica gel chromatography.



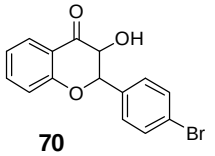
68

3-Hydroxy-2-*p*-tolylchroman-4-one (68):
Following the general procedure described above, the title compound **68** was obtained as white needles (169 mg, 0.66 mmol, 94 %). M.p. (petroleum ether : CH_2Cl_2) = 172-174 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (dd, *J* = 7.9, 1.8 Hz, 1H), 7.56 (ddd, *J* = 8.6, 7.2, 1.7 Hz, 1H), 7.48 (d, *J* = 8.1 Hz, 2H), 7.29 (d, *J* = 8.1 Hz, 2H), 7.11 (t, *J* = 7.5 Hz, 1H), 7.05 (d, *J* = 8.5 Hz, 1H), 5.11 (d, *J* = 12.4 Hz, 1H), 4.65 (d, *J* = 12.4 Hz, 1H), 3.66 (br s, 1H), 2.41 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.3, 161.7, 139.3, 136.9, 133.2, 129.4 (2C), 127.5 (2C), 127.3, 122.0, 118.5, 118.1, 83.8, 73.6, 21.3. IR ν_{max} (film): 3464, 2915, 2839, 1701, 1608, 1461, 1273, 1215, 1141, 1105, 1007, 812 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{16}H_{14}NaO_3$ 277.0841 found 277.0834 (M+Na).



69

3-Hydroxy-2-(4-(trifluoromethyl)phenyl)chroman-4-one (69):
Starting from the epoxide **62** (825 mg, 2.34 mmol, 1.0 equiv), the chromanone **69** was obtained as white needles (565 mg, 1.83 mmol, 78 %). M.p. (petroleum ether : CH_2Cl_2) = 179-182 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (dd, *J* = 8.0, 1.3 Hz, 1H), 7.75-7.72 (m, 4H), 7.59 (ddd, *J* = 8.4, 7.3, 1.6 Hz, 1H), 7.15 (t, *J* = 7.5 Hz, 1H), 7.08 (d, *J* = 8.4 Hz, 1H), 5.21 (d, *J* = 12.3 Hz, 1H), 4.57 (d, *J* = 12.3 Hz, 1H), 3.78 (br s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.6, 161.4, 140.2, 137.1, 131.7-130.7 (q, *J* = 32.5 Hz, 1C), 127.8 (2C), 127.4, 125.6-125.5 (q, *J* = 3.8 Hz, 2C), 128.0-119.9 (q, *J* = 272.3 Hz, 1C), 122.4, 118.4, 118.1, 82.9, 73.6. IR ν_{max} (film): 3463, 2902, 2850, 1696, 1608, 1465, 1325, 1277, 1137, 1109, 1066, 1011, 835 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{16}H_{12}F_3O_3$ 309.0739 found 309.0760 (M+H).

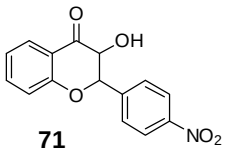


70

2-(4-Bromophenyl)-3-hydroxychroman-4-one (70):
The title compound **70** was obtained from epoxide **63** (230 mg, 0.63 mmol, 1.0 equiv) and was isolated as a white solid (192 mg, 0.60 mmol, 95 %). M.p. (petroleum ether : CH_2Cl_2) = 192-194 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.60 (d, *J* = 8.5 Hz, 2H), 7.57 (ddd, *J* = 8.5, 7.2, 1.7 Hz, 1H), 7.47 (d, *J* = 8.7 Hz, 2H), 7.13 (t, *J* = 7.5 Hz, 1H), 7.05 (d, *J* = 8.4 Hz, 1H), 5.11 (d, *J* = 12.3 Hz, 1H), 4.56 (d, *J* = 12.3 Hz, 1H), 4.10-3.04 (br s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.9, 161.5, 137.1, 135.4, 131.8 (2C), 129.1 (2C), 127.4, 123.4, 122.3, 118.4, 118.1, 83.1, 73.6. IR ν_{max} (film): 3464, 2941, 2860, 1699, 1605, 1461, 1290,

[S3] Su, S.; Acquilano, D. E.; Arumugasamy, J.; Beeler, A. B.; Eastwood, E. L.; Giguere, J. R.; Lan, P.; Lei, X.; Min, G. K.; Yeager, A. R.; Zhou, Y.; Panek, J. S.; Snyder, J. K.; Schaus, S. E.; Porco, J. A. Jr. *Org. Lett.* **2005**, *7*, 2751-2754.

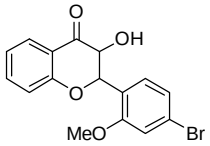
1214, 1136, 1104, 1008, 819 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{15}H_{11}BrNaO_3$ 340.9789 found 340.9805 (M+Na).



71

3-Hydroxy-2-(4-nitrophenyl)chroman-4-one (71):

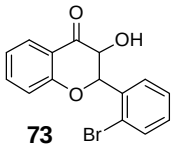
Starting from the epoxide **64** (560 mg, 1.70 mmol, 1.0 equiv), the compound **71** was obtained as a light yellow solid (441 mg, 1.55 mmol, 91 %). M.p. (petroleum ether : CH_2Cl_2) = 180-181 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31 (d, *J* = 8.9 Hz, 2H), 7.94 (dd, *J* = 7.9, 1.8 Hz, 1H), 7.79 (d, *J* = 8.9 Hz, 2H), 7.61 (ddd, *J* = 8.6, 7.2, 1.8 Hz, 1H), 7.16 (ddd, *J* = 8.0, 7.3, 1.0 Hz, 1H), 7.09 (d, *J* = 8.4 Hz, 1H), 5.25 (d, *J* = 12.2 Hz, 1H), 4.52 (d, *J* = 12.2 Hz, 1H), 3.81 (br s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.3, 161.1, 148.2, 143.4, 137.2, 128.2 (2C), 127.4, 123.7 (2C), 122.6, 118.3, 118.0, 82.4, 73.5. IR ν_{max} (film): 3466, 3110, 3079, 1695, 1608, 1520, 1466, 1348, 1277, 1229, 1139, 1105, 1014, 852 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{15}H_{11}NNaO_5$ 308.0535 found 308.0526 (M+Na).



72

2-(4-Bromo-2-methoxyphenyl)-3-hydroxychroman-4-one (72):

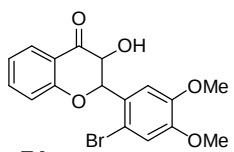
Chromanone **72** was prepared from the epoxide **65** (1.08 g, 2.75 mmol, 1.0 equiv) and was obtained as a white solid (770 mg, 2.20 mmol, 80 %). M.p. (petroleum ether : CH_2Cl_2) = 177-179 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.54 (ddd, *J* = 8.9, 7.2, 1.7 Hz, 1H), 7.49 (d, *J* = 8.2 Hz, 1H), 7.23 (dd, *J* = 8.2, 1.7 Hz, 1H), 7.12 (d, *J* = 1.9 Hz, 1H), 7.10 (t, *J* = 7.1 Hz, 1H), 7.01 (d, *J* = 8.4 Hz, 1H), 5.61 (d, *J* = 12.6 Hz, 1H), 4.79 (d, *J* = 12.6 Hz, 1H), 3.85 (s, 3H), 3.60 (br s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.4, 161.9, 158.5, 136.8, 129.7, 127.3, 124.1, 124.0, 123.4, 122.0, 118.6, 118.1, 115.0, 77.3, 72.8, 56.1. IR ν_{max} (film): 3460, 2939, 2851, 1695, 1609, 1595, 1492, 1465, 1398, 1279, 1250, 1226, 1138, 1104, 1007, 895, 848 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{16}H_{13}BrNaO_4$ 370.9895 found 370.9874 (M+Na).



73

2-(2-Bromophenyl)-3-hydroxychroman-4-one (73):

Chromanone **73** was prepared from the epoxide **66** (500 mg, 1.38 mmol, 1.0 equiv) and was obtained as a colorless gum (440 mg, 1.38 mmol, 99 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, *J* = 7.9 Hz, 1H), 7.75 (d, *J* = 7.8 Hz, 1H), 7.67 (d, *J* = 8.1 Hz, 1H), 7.57 (dd, *J* = 8.4, 7.2 Hz, 1H), 7.47 (app t, *J* = 7.7 Hz, 1H), 7.30 (dd, *J* = 8.1, 7.4 Hz, 1H), 7.14 (dd, *J* = 8.0, 7.2 Hz, 1H), 7.05 (d, *J* = 8.4 Hz, 1H), 5.72 (d, *J* = 12.5 Hz, 1H), 4.78 (dd, *J* = 12.4, 2.4 Hz, 1H), 3.65 (d, *J* = 2.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.0, 161.6, 137.0, 135.3, 133.3, 130.7, 128.8, 127.9, 127.4, 124.9, 122.3, 118.6, 118.1, 81.9, 73.5. IR ν_{max} (film): 3473, 3066, 2909, 2844, 1695, 1608, 1465, 1302, 1229, 1140, 1105, 1012 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{15}H_{11}BrNaO_3$ 340.9789 found 340.9790 (M+Na).



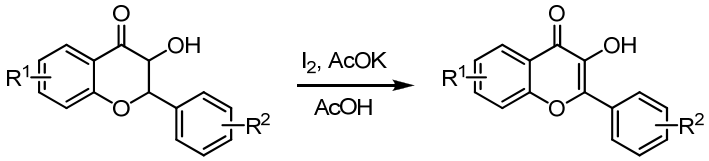
74

2-(2-Bromo-4,5-dimethoxyphenyl)-3-hydroxychroman-4-one (74):

Starting from the epoxide **67** (313 mg, 0.74 mmol, 1.0 equiv), the chromanone **74** was obtained as a white solid (220 mg, 0.58 mmol, 78 %). M.p. (petroleum ether : CH_2Cl_2) = 187-189 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (dd, *J* = 7.8, 1.7 Hz, 1H),

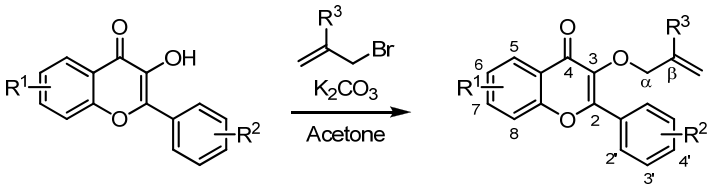
7.58 (ddd, *J* = 8.4, 7.2, 1.8 Hz, 1H), 7.19 (s, 1H), 7.13 (ddd, *J* = 7.8, 7.3, 1.0 Hz, 1H), 7.10 (s, 1H), 7.06 (dd, *J* = 8.4, 2.0 Hz, 1H), 5.65 (d, *J* = 12.4 Hz, 1H), 4.73 (dd, *J* = 12.4, 2.3 Hz, 1H), 3.94 (s, 3H), 3.91 (s, 3H), 3.64 (d, *J* = 2.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.0, 161.6, 150.1, 148.8, 136.9, 127.3, 127.0, 122.2, 118.6, 118.1, 115.5, 115.2, 110.6, 82.1, 73.7, 56.2, 56.1. IR ν_{max} (film): 3384, 2933, 2839, 1696, 1609, 1507, 1465, 1262, 1211, 1168, 1134, 1009, 760 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{17}H_{15}BrNaO_5$ 401.0001 found 401.0040 (M+Na).

V. Experimental Procedures for the Preparation of 3-Hydroxyflavones.



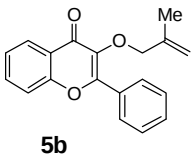
The 3-hydroxyflavones (flavonols) were synthesized following a literature procedure and were used directly in the allylation step without purification.[S4]

VI. Experimental Procedures and Characterization Data for the Preparation of allyloxyflavones 5b, 11-21, and 73-77.



5b, 11-21, 75-79

General Procedure: To a suspension of commercially available 3-hydroxyflavone (1.00 g, 4.20 mmol, 1.0 equiv) in dry acetone (100 mL) was added at room temperature allyl bromide (0.54 mL, 6.30 mmol, 1.5 equiv, filtered through a plug of basic alumina), followed by K_2CO_3 (870.0 mg, 6.30 mmol, 1.5 equiv). The temperature was slowly increased to 65 °C and the reaction mixture was stirred overnight. The mixture was then cooled to room temperature and 30 mL of Et_2O was added. After filtration of the salts through a pad of Celite®, the solvent was removed *in vacuo* and the crude product was purified by column chromatography on silica gel.

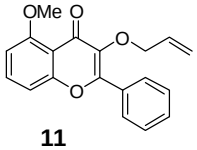


5b

3-(β-Methylallyloxy)-2-phenyl-4*H*-chromen-4-one (5b):
Following the same procedure, the methylated allyloxy flavone **5b** was obtained starting from commercially available flavonol (476 mg, 2.00 mmol, 1.0 equiv) using methallyl bromide (0.30 mL, 3.00 mmol, 1.5 equiv) as allylating agent. The methallyloxy derivative **5b** was isolated as a colorless oil (579 mg, 1.98 mmol, 99 %) after purification on silica gel (petroleum ether : EtOAc = 90 : 10). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (dd, *J* = 8.0, 1.7 Hz, 1H), 8.12-8.06 (m, 2H), 7.68 (ddd, *J* = 8.6, 7.1, 1.6 Hz, 1H), 7.54 (d, *J* = 8.4 Hz,

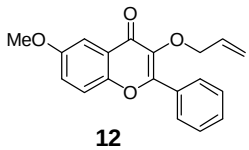
[S4] Džubák, P.; Hajdúch, M.; Gažák, R.; Svobodová, A.; Psotová, J.; Walterová, D.; Sedmera, P.; Křen, V. *Bioorg. Med Chem.* **2006**, *14*, 3793-3810.

1H), 7.52-7.49 (m, 3H), 7.41 (ddd, *J* = 8.0, 7.1, 0.9 Hz, 1H), 5.01 (s, 1H), 4.89 (s, 1H), 4.53 (s, 2H), 1.70 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 155.9, 155.2, 141.1, 140.1, 133.3, 131.0, 130.6, 128.8 (2C), 128.3, 125.8 (2C), 124.6, 124.1, 117.9, 113.8, 75.9, 19.6. IR ν_{max} (film): 3070, 2972, 2945, 2915, 2854, 1642, 1615, 1468, 1396, 1236, 1200, 1146, 996, 901, 692 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{16}NaO_3$ 315.0997 found 315.0999 (M+Na).



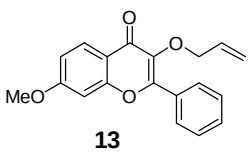
11

3-(Allyloxy)-5-methoxy-2-phenyl-4*H*-chromen-4-one (11):
5-Methoxy-3-allyloxyflavone **11** was prepared using the general procedure described above starting from the commercially available 5-methoxyflavonol (100.0 mg, 0.37 mmol, 1.0 equiv). The product was obtained as a white solid (114 mg, 0.37 mmol, 99 %) after purification on silica gel (petroleum ether : ethyl acetate = 60 : 40). M.p. (petroleum ether : CH_2Cl_2) = 90-92 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12-8.09 (br s, 1H), 8.08 (d, *J* = 1.3 Hz, 1H), 7.52 (t, *J* = 8.4 Hz, 1H), 7.49-7.43 (m, 3H), 7.07 (d, *J* = 8.4 Hz, 1H), 6.76 (d, *J* = 8.2 Hz, 1H), 5.96 (tdd, *J* = 16.7, 10.6, 6.1 Hz, 1H), 5.27 (dd, *J* = 17.2, 0.9 Hz, 1H), 5.13 (dd, *J* = 10.3, 0.6 Hz, 1H), 4.62 (d, *J* = 6.1 Hz, 2H), 3.99 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.7, 159.8, 157.2, 153.4, 140.4, 133.7, 133.4, 130.8, 130.3, 128.4 (2C), 128.2 (2C), 118.3, 114.6, 110.0, 105.5, 73.0, 56.4. IR ν_{max} (film): 3076, 2936, 2842, 1644, 1619, 1604, 1477, 1329, 1263, 1201, 1101, 997, 808 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{16}NaO_4$ 331.0946 found 331.0956 (M+Na).



12

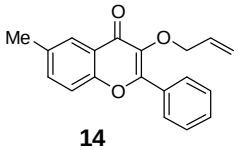
3-(Allyloxy)-6-methoxy-2-phenyl-4H-chromen-4-one (12):
Starting from the commercially available 6-methoxyflavonol (200 mg, 0.75 mmol, 1.0 equiv), the title compound **12** was obtained as colorless flakes (228 mg, 0.74 mmol, 99 %) after purification on silica gel (petroleum ether : ethyl acetate = 70 : 30). M.p. (petroleum ether : Et_2O) = 91-92 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12-8.09 (m, 1H), 8.10 (d, *J* = 3.1 Hz, 1H), 7.61 (d, *J* = 3.1 Hz, 1H), 7.53-7.49 (m, 3H), 7.47 (d, *J* = 9.1 Hz, 1H), 7.28 (dd, *J* = 9.3, 3.3 Hz, 1H), 5.94 (app tdd, *J* = 17.1, 10.3, 6.1 Hz, 1H), 5.27 (d, *J* = 17.2 Hz, 1H), 5.15 (d, *J* = 10.3 Hz, 1H), 4.63 (d, *J* = 6.1 Hz, 2H), 3.92 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.8, 156.5, 155.7, 150.1, 139.5, 133.5, 131.1, 130.5, 128.6 (2C), 128.3 (2C), 124.6, 123.7, 119.4, 118.4, 104.4, 73.2, 55.8. IR ν_{max} (film): 3076, 2939, 2836, 1635, 1616, 1565, 1488, 1449, 1385, 1275, 1214, 1170, 1031, 930, 783, 692 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{16}NaO_4$ 331.0946 found 331.0933 (M+Na).



13

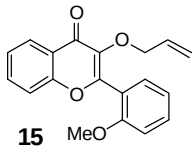
3-(Allyloxy)-7-methoxy-2-phenyl-4*H*-chromen-4-one (13):
7-Methoxy-3-allyloxyflavone **13** was prepared using the general procedure described above starting from commercially available 7-methoxyflavonol (450 mg, 1.68 mmol, 1.0 equiv). The product was obtained as light yellow flakes (503 mg, 1.63 mmol, 97 %) after purification on silica gel (petroleum ether : ethyl acetate = 60 : 40). M.p. (petroleum ether : Et_2O) = 125-127 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.9 Hz, 1H), 8.10-8.06 (m, 2H), 7.51-7.46 (m, 3H), 6.96 (dd, *J* = 8.9, 2.3 Hz, 1H), 6.90 (d, *J* = 2.3 Hz, 1H), 5.93 (tdd, *J* = 16.4, 10.4, 6.1 Hz, 1H), 5.26 (d, *J* = 17.1 Hz, 1H), 5.13 (d, *J* = 10.4 Hz, 1H), 4.63 (d, *J* = 6.1 Hz, 2H), 3.90 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.5, 164.0, 157.0, 155.4, 139.8, 133.6, 131.1,

130.4, 128.5 (2C), 128.3 (2C), 127.1, 118.3, 118.0, 114.4, 99.8, 73.2, 55.8. IR ν_{max} (film): 3073, 2942, 2836, 1637, 1622, 1446, 1391, 1256, 1205, 1173, 1105, 997, 693 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{16}NaO_4$ 331.0946 found 331.0921 (M+Na).



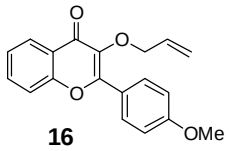
14

3-(Allyloxy)-6-methyl-2-phenyl-4*H*-chromen-4-one (14):
The title compound **14** was prepared following the general allylation procedure starting from commercially available 6-methylflavonol (300 mg, 1.19 mmol, 1.0 equiv). The product was obtained after purification on silica gel (petroleum ether : ethyl acetate = 90 : 10) as a colorless gum (345 mg, 1.18 mmol, 99 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 4.3 Hz, 1H), 8.09 (d, *J* = 2.1 Hz, 1H), 8.03 (s, 1H), 7.52-7.45 (m, 4H), 7.42 (d, *J* = 8.5 Hz, 1H), 5.93 (tdd, *J* = 16.5, 10.4, 6.1 Hz, 1H), 5.26 (dd, *J* = 17.2, 1.4 Hz, 1H), 5.14 (dd, *J* = 10.3, 1.0 Hz, 1H), 4.62 (d, *J* = 6.1 Hz, 1H), 2.46 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.1, 155.8, 153.5, 139.8, 134.7, 134.5, 133.5, 131.1, 130.5, 128.6 (2C), 128.3 (2C), 124.9, 123.7, 118.4, 117.7, 73.2, 20.9. IR ν_{max} (film): 3060, 2923, 2868, 1640, 1619, 1564, 1488, 1447, 1382, 1282, 1213, 1168, 993, 932, 815 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{17}O_3$ 293.1176 found 293.1178 (M+H).



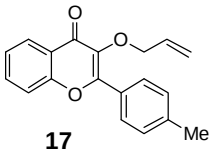
15

3-(Allyloxy)-2-(2'-methoxyphenyl)-4*H*-chromen-4-one (15):
Starting from commercially available 2'-methoxy flavonol (268 mg, 1.00 mmol, 1.0 equiv), the allyloxy flavone **15** was purified by column chromatography on silica gel (petroleum ether : EtOAc = 90:10) and was obtained as a colorless gum (300 mg, 0.97 mmol, 97 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 (dd, *J* = 8.0, 1.7 Hz, 1H), 7.65 (ddd, *J* = 8.7, 7.1, 1.7 Hz, 1H), 7.48 (ddd, *J* = 8.3, 7.4, 1.8 Hz, 1H), 7.46 (d, *J* = 7.8 Hz, 2H), 7.39 (ddd, *J* = 8.1, 7.1, 1.1 Hz, 1H), 7.07 (dt, *J* = 7.5, 1.0 Hz, 1H), 7.03 (d, *J* = 8.3 Hz, 1H), 5.79 (tdd, *J* = 17.2, 10.4, 5.9 Hz, 1H), 5.12 (dd, *J* = 17.2, 1.7 Hz, 1H), 5.05 (dd, *J* = 10.4, 1.7 Hz, 1H), 4.58 (d, *J* = 5.9 Hz, 2H), 3.84 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.8, 157.3, 156.4, 155.6, 140.5, 133.8, 133.1, 131.8, 130.8, 125.7, 124.5, 124.4, 120.2 (2C), 118.1, 117.5, 111.2, 73.1, 55.6. IR ν_{max} (film): 3073, 2936, 2839, 1643, 1622, 1466, 1396, 1278, 1257, 1200, 1146, 1111, 1024, 995, 902 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{16}NaO_4$ 331.0946 found 331.0933 (M+Na).



16

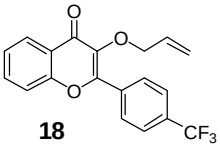
3-(Allyloxy)-2-(4'-methoxyphenyl)-4*H*-chromen-4-one (16):
Starting from commercially available 4'-methoxy flavonol (300 mg, 1.12 mmol, 1.0 equiv), the allylated flavone **16** was obtained as white needles (339 mg, 1.10 mmol, 98 %). M.p. (petroleum ether : Et_2O) = 88-89 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (dd, *J* = 8.0, 1.6 Hz, 1H), 8.12 (d, *J* = 9.1 Hz, 2H), 7.64 (ddd, *J* = 8.6, 7.1, 1.7 Hz, 1H), 7.50 (d, *J* = 8.4 Hz, 1H), 7.37 (app t, *J* = 7.6 Hz, 1H), 7.00 (d, *J* = 9.1 Hz, 2H), 5.97 (tdd, *J* = 16.5, 10.4, 6.1 Hz, 1H), 5.29 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.15 (dd, *J* = 10.3, 1.6 Hz, 1H), 4.63 (d, *J* = 6.1 Hz, 2H), 3.88 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.9, 161.4, 155.9, 155.1, 139.3, 133.7, 133.1, 130.4 (2C), 125.7, 124.5, 124.1, 123.4, 118.3, 117.8, 113.8 (2C), 73.0, 55.3. IR ν_{max} (film): 3073, 2936, 2832, 1636, 1605, 1509, 1468, 1391, 1259, 1200, 1181, 1147, 1033, 834 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{16}NaO_4$ 331.0946 found 331.0977 (M+Na).



17

3-(Allyloxy)-2-*p*-tolyl-4*H*-chromen-4-one (17):

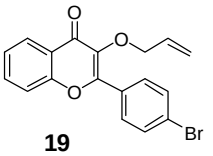
The title compound **17** was synthesized starting from chromanone **68** (221 mg, 0.87 mmol, 1.0 equiv) *via* the oxidation/allylation sequence and was isolated as a colorless oil (203 mg, 0.69 mmol, 80 %, two steps) after column chromatography on silica gel (petroleum ether : Et_2O = 70:30). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (dd, *J* = 8.0, 1.7 Hz, 1H), 8.03 (d, *J* = 8.3 Hz, 2H), 7.67 (ddd, *J* = 8.6, 7.1, 1.7 Hz, 1H), 7.53 (d, *J* = 8.5 Hz, 1H), 7.39 (ddd, *J* = 8.1, 7.1, 1.1 Hz, 1H), 7.31 (d, *J* = 8.1 Hz, 2H), 5.96 (tdd, *J* = 16.4, 10.3, 6.1 Hz, 1H), 5.29 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.15 (dd, *J* = 10.3, 1.6 Hz, 1H), 4.64 (d, *J* = 6.1 Hz, 2H), 2.44 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.1, 156.2, 155.2, 141.1, 139.7, 133.6, 133.3, 129.1, 128.6 (2C), 128.2, 125.8 (2C), 124.6, 124.1, 118.4, 117.9, 73.2, 21.5. IR ν_{max} (film): 3079, 2924, 2866, 1639, 1613, 1468, 1391, 1200, 1146, 994, 821 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{16}NaO_3$ 315.0997 found 315.1021 (M+Na).



18

3-(Allyloxy)-2-(4'-(trifluoromethyl)phenyl)-4*H*-chromen-4-one (18):

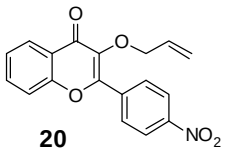
The title compound **18** was synthesized in two steps starting from 3-hydroxychromanone **69** (250 mg, 0.81 mmol, 1.0 equiv) after oxidation of the latter to the intermediate flavonol followed by allylation of the 3-hydroxyl group. The product was obtained after column chromatography (petroleum ether : ethyl acetate = 85 : 15) as a white powder (245 mg, 0.71 mmol, 87 % over two steps). M.p. (petroleum ether : Et_2O) = 72-74 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.25 (dd, *J* = 8.0, 1.7 Hz, 1H), 8.24 (d, *J* = 8.2 Hz, 2H), 7.76 (d, *J* = 8.3 Hz, 2H), 7.70 (ddd, *J* = 8.7, 7.1, 1.7 Hz, 1H), 7.54 (d, *J* = 8.5 Hz, 1H), 7.41 (ddd, *J* = 8.1, 7.1, 1.0 Hz, 1H), 5.91 (tdd, *J* = 17.0, 10.3, 6.1 Hz, 1H), 5.28 (dd, *J* = 17.2, 1.5 Hz, 1H), 5.16 (dd, *J* = 10.3, 1.5 Hz, 1H), 4.69 (d, *J* = 6.1 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 155.2, 154.0, 140.5, 134.4, 133.7, 133.1, 132.5-131.5 (q, *J* = 32.8 Hz, 1C), 129.0 (2C), 125.8, 125.3-125.2 (q, *J* = 3.8 Hz, 2C), 124.9, 124.0, 127.8-119.6 (q, *J* = 272.5 Hz, 1C), 119.0, 118.0, 73.4. IR ν_{max} (film): 3079, 2937, 2874, 1645, 1615, 1469, 1413, 1393, 1325, 1288, 1238, 1203, 1170, 1127, 1070, 1017, 993, 850 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{14}F_3O_3$ 347.0895 found 347.0925 (M+H).



19

3-(Allyloxy)-2-(4'-bromophenyl)-4*H*-chromen-4-one (19):

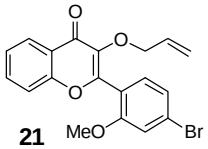
Starting from chromanone **70** (192 mg, 0.60 mmol, 1.0 equiv), and following the same sequence of oxidation/allylation, the 4'-brominated allyloxyflavone **19** was isolated as white needles (190 mg, 0.53 mmol, 88 % over two steps) after purification by silica gel chromatography (petroleum ether : ethyl acetate = 90 : 10). M.p. (petroleum ether : Et_2O) = 85-87 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (dd, *J* = 8.0, 1.7 Hz, 1H), 8.01 (d, *J* = 8.7 Hz, 2H), 7.68 (ddd, *J* = 8.7, 7.1, 1.7 Hz, 1H), 7.63 (d, *J* = 8.7 Hz, 2H), 7.52 (d, *J* = 8.4 Hz, 1H), 7.40 (ddd, *J* = 8.0, 7.3, 1.0 Hz, 1H), 5.92 (tdd, *J* = 16.5, 10.3, 6.1 Hz, 1H), 5.27 (dd, *J* = 17.1, 1.5 Hz, 1H), 5.16 (dd, *J* = 10.4, 1.1 Hz, 1H), 4.65 (d, *J* = 6.1 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 155.1, 154.7, 140.0, 133.5, 133.3, 131.6 (2C), 130.2 (2C), 129.9, 125.8, 125.2, 124.8, 124.0, 118.8, 117.9, 73.2. IR ν_{max} (film): 3077, 2927, 1643, 1614, 1469, 1403, 1386, 1292, 1238, 1201, 1147, 1011, 992, 828 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{14}BrO_3$ 357.0126 found 357.0107 (M+H).



20

3-(Allyloxy)-2-(4'-nitrophenyl)-4*H*-chromen-4-one (20):

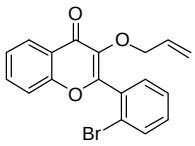
4'-Nitro allyloxyflavone **20** was prepared starting from the chromanone **71** (300 mg, 1.05 mmol, 1.0 equiv) following the oxidation/allylation sequence described above, and was isolated as yellow needles (185 mg, 0.57 mmol, 54 % over two steps) after silica gel chromatography (petroleum ether : ethyl acetate = 70 : 30). M.p. (petroleum ether : ethyl acetate) = 124-125 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.37-8.30 (m, 4H), 8.25 (dd, *J* = 8.0, 1.7 Hz, 1H), 7.72 (ddd, *J* = 8.8, 7.5, 1.7 Hz, 1H), 7.56 (d, *J* = 8.5 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 1H), 5.90 (tdd, *J* = 16.7, 10.3, 6.1 Hz, 1H), 5.28 (dd, *J* = 17.1, 1.5 Hz, 1H), 5.17 (dd, *J* = 10.3, 1.0 Hz, 1H), 4.73 (d, *J* = 6.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.9, 155.1, 152.8, 148.4, 141.0, 137.0, 134.0, 132.9, 129.6 (2C), 125.9, 125.1, 124.0, 123.4 (2C), 119.3, 118.0, 73.5. IR ν_{max} (film): 3078, 2935, 1646, 1521, 1470, 1347, 1203, 1148, 1110, 855, 703 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{14}NO_5$ 324.0872 found 324.0880 (M+H).



21

3-(Allyloxy)-2-(4'-bromo-2'-methoxyphenyl)-4*H*-chromen-4-one (21):

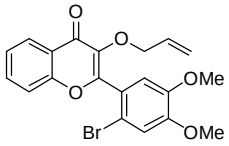
Starting from the 3-hydroxychromanone **72** (300 mg, 0.86 mmol, 1.0 equiv), the title compound **21** was synthesized in two steps using the oxidation/allylation sequence described above and was purified by chromatography on silica gel (petroleum ether : ethyl acetate = 85 : 15), affording a colorless oil (322 mg, 0.83 mmol, 97 %, two steps). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (dd, *J* = 8.0, 1.6 Hz, 1H), 7.64 (ddd, *J* = 8.7, 7.1, 1.7 Hz, 1H), 7.44 (d, *J* = 9.0 Hz, 1H), 7.38 (ddd, *J* = 8.0, 7.1, 1.0 Hz, 1H), 7.32 (d, *J* = 8.1 Hz, 1H), 7.20 (dd, *J* = 8.1, 1.8 Hz, 1H), 7.16 (d, *J* = 1.7 Hz, 1H), 5.78 (tdd, *J* = 17.2, 10.4, 5.9 Hz, 1H), 5.13 (ddt, *J* = 17.2, 1.6, 1.6 Hz, 1H), 5.07 (app ddt, *J* = 10.4, 1.4, 1.2 Hz, 1H), 4.58 (d, *J* = 5.9 Hz, 2H), 3.82 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.7, 157.8, 155.6, 155.1, 140.5, 133.7, 133.2, 131.9, 125.7, 125.5, 124.5, 124.4, 123.4, 119.3, 118.1, 177.8, 114.9, 73.1, 55.9. IR ν_{max} (film): 3076, 2941, 1644, 1621, 1588, 1489, 1466, 1404, 1253, 1201, 1148, 1118, 1027, 902 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{19}H_{16}BrO_4$ 387.0232 found 387.0213 (M+H).



75

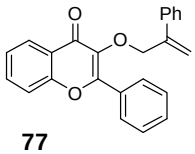
3-(Allyloxy)-2-(2'-bromophenyl)-4*H*-chromen-4-one (75):

The title compound **75** was synthesized in two steps starting from 3-hydroxychromanone **73** (440.0 mg, 1.38 mmol, 1.0 equiv) after oxidation to the intermediate flavonol followed by allylation of the 3-hydroxyl group. The product was obtained after column chromatography (petroleum ether : ethyl acetate = 90 : 10) as light yellow needles (425 mg, 1.19 mmol, 86 %, two steps). M.p. (petroleum ether : Et_2O) = 102-103 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30 (d, *J* = 8.0 Hz, 1H), 7.73 (d, *J* = 8.0 Hz, 1H), 7.69 (dd, *J* = 8.6, 7.1 Hz, 1H), 7.54 (d, *J* = 7.6 Hz, 1H), 7.49 (d, *J* = 8.4 Hz, 1H), 7.46 (d, *J* = 7.1 Hz, 1H), 7.42 (d, *J* = 7.1 Hz, 1H), 7.38 (app t, *J* = 7.5 Hz, 1H), 5.74 (app tdd, *J* = 16.4, 10.3, 6.1 Hz, 1H), 5.12 (d, *J* = 17.2 Hz, 1H), 5.07 (d, *J* = 10.3 Hz, 1H), 4.57 (d, *J* = 6.1 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 157.0, 155.5, 140.2, 133.5, 133.4, 133.1, 132.2, 131.8, 131.5, 127.1, 125.8, 124.8, 124.6, 122.8, 118.4, 118.1, 73.5. IR ν_{max} (film): 3070, 2927, 2866, 1647, 1623, 1466, 1396, 1266, 1235, 1199, 1150, 993, 906 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{14}BrO_3$ 357.0126 found 357.0112 (M+H).



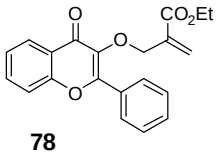
76

3-(Allyloxy)-2-(2'-bromo-4',5'-dimethoxyphenyl)-4*H*-chromen-4-one (76):
The allyloxyflavone **76** was synthesized in two steps after oxidation of chromanone **74** (451 mg, 1.19 mmol, 1.0 equiv) and allylation of the intermediate flavonol. After purification *via* column chromatography on silica gel (petroleum ether : ethyl acetate = 80 : 20), the title compound was isolated as a white solid (325 mg, 0.78 mmol, 65 %, two steps). M.p. (petroleum ether : Et_2O) = 108-110 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (dd, *J* = 8.0, 1.7 Hz, 1H), 7.67 (ddd, *J* = 8.5, 7.1, 1.7 Hz, 1H), 7.49 (d, *J* = 8.4 Hz, 1H), 7.41 (app t, *J* = 7.6 Hz, 1H), 7.15 (s, 1H), 7.04 (s, 1H), 5.77 (tdd, *J* = 16.4, 10.3, 6.1 Hz, 1H), 5.15 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.08 (dd, *J* = 10.3, 1.6 Hz, 1H), 4.56 (d, *J* = 6.1 Hz, 2H), 3.95 (s, 3H), 3.88 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 157.0, 155.4, 150.8, 147.9, 140.0, 133.5, 133.4, 125.8, 124.7, 124.5, 124.0, 118.4, 118.1, 115.6, 114.1, 113.5, 73.5, 56.3, 56.2. IR ν_{max} (film): 3079, 2933, 2836, 1645, 1623, 1505, 1466, 1406, 1261, 1213, 1200, 1146, 760 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{20}H_{18}BrO_5$ 417.0338 found 417.0378 (M+H).



77

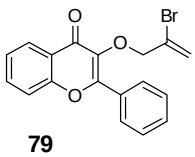
3-(β-Phenylallyloxy)-2-phenyl-4*H*-chromen-4-one (77):
Allyloxyflavone **77** was obtained starting from commercially available flavonol (300.0 mg, 1.26 mmol, 1.0 equiv) and using α-bromomethylstyrene[S5] (50 mol % as a mixture with 1-bromo-2-phenyl-propene, 744 mg, 1.89 mmol, 1.5 equiv) as allylating agent. The title compound was isolated as white needles (384 mg, 1.08 mmol, 86 %). M.p. (petroleum ether : CH_2Cl_2) = 93-94 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30 (d, *J* = 8.0 Hz, 1H), 7.96 (d, *J* = 8.3 Hz, 2H), 7.68 (app t, *J* = 7.8 Hz, 1H), 7.53 (d, *J* = 8.5 Hz, 1H), 7.48-7.44 (m, 2H), 7.41 (app t, *J* = 7.2 Hz, 2H), 7.35 (app t, *J* = 7.5 Hz, 2H), 7.27-7.20 (m, 3H), 5.54 (s, 1H), 5.39 (s, 1H), 5.09 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.1, 156.1, 155.2, 143.4, 139.9, 138.0, 133.3, 130.6, 130.5, 128.7 (2C), 128.1 (4C), 127.6, 126.0 (2C), 125.7, 124.6, 124.1, 117.9, 116.2, 73.6. IR ν_{max} (film): 3055, 2942, 2878, 1639, 1615, 1468, 1395, 1237, 1199, 1146, 992, 900, 709, 691 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{24}H_{18}NaO_3$ 377.1154 found 377.1188 (M+Na).



78

3-(β-Ethylesterallyloxy)-2-phenyl-4*H*-chromen-4-one (78):
Starting from commercially available flavonol (600 mg, 2.52 mmol, 1.0 equiv) and using ethyl 2-(bromomethyl)acrylate as the allylating agent (0.52 mL, 3.78 mmol, 1.5 equiv), the title compound **78** was obtained as a white solid (879 mg, 2.51 mmol, 99 %). M.p. (petroleum ether : CH_2Cl_2) = 77-78 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, *J* = 8.0 Hz, 1H), 8.05 (br s, 2H), 7.69 (t, *J* = 7.8 Hz, 1H), 7.54 (d, *J* = 8.5 Hz, 1H), 7.49 (br s, 3H), 7.42 (t, *J* = 7.5 Hz, 1H), 6.30 (s, 1H), 5.95 (s, 1H), 4.89 (s, 2H), 4.01 (q, *J* = 7.1 Hz, 2H), 1.18 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.9, 165.3, 156.1, 155.2, 139.7, 136.3, 133.4, 130.7, 130.6, 128.7 (2C), 128.3 (2C), 127.8, 125.7, 124.7, 124.0, 117.9, 70.2, 60.6, 14.0. IR ν_{max} (film): 3061, 2979, 2850, 1718, 1641, 1615, 1467, 1397, 1200, 1144, 1035, 693 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{21}H_{18}NaO_5$ 373.1052 found 373.1066 (M+Na).

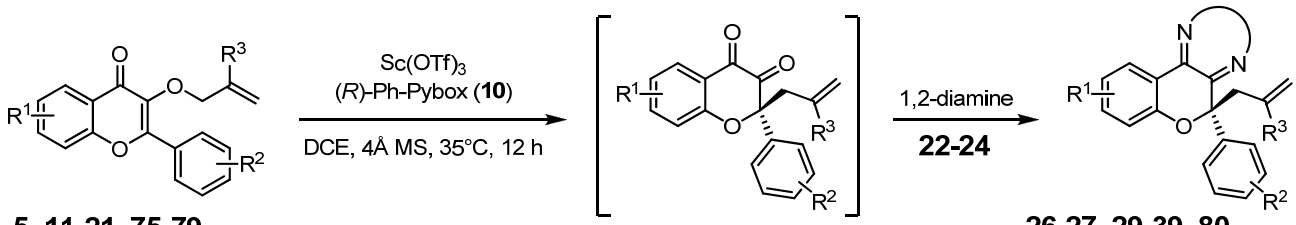
[S5]Vaccher, C.; Berthelot, P.; Flouquet, N.; Vaccher, M.-P.; Debaert, M. *Synth. Commun*. **1993**, *23*, 671-679.



79

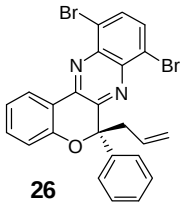
3-(β-Bromoallyloxy)-2-phenyl-4*H*-chromen-4-one (79):
2,3-Dibromopropene (0.46 mL, 3.78 mmol, 1.5 equiv) was used for the allylation of non-substituted flavonol (600 mg, 2.52 mmol, 1.0 equiv). The brominated allyloxy flavone **79** was obtained as colorless gum (877 mg, 2.45 mmol, 98 %), after purification on silica gel (petroleum ether : Et_2O = 85 : 15). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (d, *J* = 8.3 Hz, 1H), 8.12-8.08 (m, 2H), 7.70 (ddd, *J* = 8.7, 7.1, 1.9 Hz, 1H), 7.55 (d, *J* = 8.5 Hz, 1H), 7.54-7.50 (m, 3H), 7.42 (t, *J* = 7.5 Hz, 1H), 5.96 (s, 1H), 5.59 (s, 1H), 4.84 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.7, 156.2, 155.2, 139.2, 133.5, 130.8, 130.6, 129.0 (2C), 128.3 (2C), 127.3, 125.7, 124.8, 124.0, 119.8, 118.0, 75.5. IR ν_{max} (film): 3061, 2921, 2860, 1639, 1615, 1467, 1395, 1198, 1147, 899, 691 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{18}H_{13}BrNaO_3$ 378.9946 found 378.9945 (M+Na).

VII. Experimental Procedures and Characterization Data for Sc(OTf)$_3$-*(R)*-Pybox-Ph-mediated Rearrangement Products.



5, 11-21, 75-79 **26-27, 29-39, 80**

General Procedure: To a suspension of molecular sieves (4Å, 250.0 mg, flame-dried under high vacuum) was added, *via* cannula, a pre-stirred solution of $Sc(OTf)_3$ (23 mg, 0.05 mmol, 0.30 equiv) and (*R*,*R*)-(+)-2,6-bis(4-phenyl-2-oxazolinyl)pyridine **10** (20 mg, 0.05 mmol, 0.33 equiv) in DCE (3 mL). After stirring the suspension at rt for 2 h, a solution of allyloxyflavone **5a** (0.16 mmol, 1.0 equiv) in DCE (2 mL) was slowly added *via* cannula. The mixture was stirred at room temperature for 30 min and stirred overnight at 35 °C. 1,2-Ethylene diamine **24** (27 μL, 0.40 mmol, 2.50 equiv) was added in one portion and the mixture was allowed to stir for an additional 2 h at room temperature. After removal of the molecular sieves by filtration of the crude mixture through a pad of Celite, the solvent was evaporated *in vacuo* and the pyrazines **26-30** or dihydropyrazines **31-39**, and **80** were isolated by flash column chromatography on silica gel.

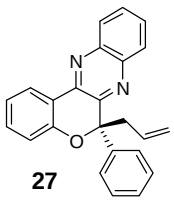


26

***(S)*-6-Allyl-8,11-dibromo-6-phenyl-6*H*-chromeno[3,4-*b*]quinoxaline (26):**
Pyrazine **26** was obtained using 3,6-dibromo-*o*-phenylenediamine[S6] **22b** (106 mg, 0.40 mmol, 2.5 equiv) for the condensation step. Purification on silica gel (petroleum ether : dichloromethane = 80 : 20) afforded the pyrazine **26** as a light yellow solid (80 mg, 0.16 mmol, 98 %). M.p. (petroleum ether : Et_2O) = 152-154 °C. $[\alpha]_D^{25}$ (*c* 0.9, $CHCl_3$) = – 96.2°. The er value could not be determined using HPLC analysis due to inseparable peaks. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.38 (d, *J* = 7.8 Hz, 1H), 7.89 (d, *J* = 3.8 Hz, 2H), 7.47 (t, *J* = 7.6 Hz, 1H), 7.39 (d, *J* = 7.5 Hz, 2H), 7.25-7.22 (m, 1H), 7.20 (d, *J* = 7.9 Hz, 2H), 7.16 (d, *J* = 7.1 Hz, 1H), 7.11

[S6]Mancilha, F. S.; DaSilveira Neto, B. A.; Lopes, A. S.; Moreira, P. F., Jr.; Quina, F. H.; Gonçalves, R. S.; Dupont, J. *Eur. J. Org. Chem.* **2006**, *21*, 4924-4933.

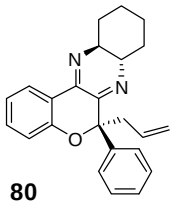
(t, *J* = 7.5 Hz, 1H), 5.95 (app tdd, *J* = 17.3, 10.2, 7.0 Hz, 1H), 5.25 (br d, *J* = 17.2 Hz, 1H), 5.06 (br d, *J* = 10.3 Hz, 1H), 3.66 (dd, *J* = 14.4, 7.6 Hz, 1H), 3.29 (dd, *J* = 14.4, 6.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.5, 152.3, 144.6, 141.2, 140.6, 140.0, 133.9, 133.4, 132.8, 132.4, 128.2 (2C), 127.6, 126.4, 125.9 (2C), 124.1, 123.7, 122.7, 120.2, 119.5, 118.2, 85.7, 45.9. IR ν_{max} (film): 3073, 2921, 2851, 1607, 1473, 1442, 1388, 1314, 1226, 1183, 1107, 936, 875, 827, 753, 717 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{24}H_{17}Br_2N_2O$ 506.9708 found 506.9701 (M+H).



27

***(S)*-6-Allyl-6-phenyl-6*H*-chromeno[4,3-*b*]quinoxaline (27):**

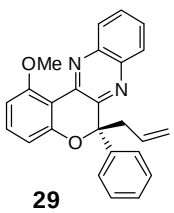
Pyrazine **27** was obtained using 1,2-phenylene diamine **22c** (43 mg, 0.40 mmol, 2.5 equiv) for the condensation step. Purification on silica gel (petroleum ether : ethyl acetate = 80 : 20) afforded the title compound **27** as a pale yellow oil (52 mg, 0.15 mmol, 93 %). $[\alpha]_D^{25}$ (*c* 2.9, $CHCl_3$) = – 174.0°. er = 93:7 (ChiralPak AD 1% IPA in hexane, retention time 3.55 : 4.06 min, major : minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 (dd, *J* = 7.8, 1.7 Hz, 1H), 8.20-8.15 (m, 1H), 8.13-8.08 (m, 1H), 7.79-7.71 (m, 2H), 7.42 (ddd, *J* = 8.2, 7.2, 1.7 Hz, 1H), 7.37 (dd, *J* = 8.4, 1.4 Hz, 2H), 7.22 (dd, *J* = 8.2, 1.1 Hz, 1H), 7.21-7.11 (m, 3H), 7.08 (ddd, *J* = 7.8, 7.3, 1.1 Hz, 1H), 5.95 (app tdd, *J* = 17.1, 10.2, 6.9 Hz, 1H), 5.18 (dd, *J* = 17.2, 2.2 Hz, 1H), 5.05 (dd, *J* = 10.2, 2.2 Hz, 1H), 3.61 (dd, *J* = 14.6, 6.7 Hz, 1H), 3.27 (dd, *J* = 14.6, 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.9, 151.1, 143.4, 142.1, 141.8, 141.5, 133.2, 132.8, 130.0, 129.3, 129.1 (2C), 128.0 (2C), 127.4, 126.0 (2C), 125.5, 122.4, 121.3, 118.7, 118.2, 85.4, 45.6. IR ν_{max} (film): 3063, 2980, 2918, 1606, 1588, 1557, 1491, 1461, 1346, 1228, 1109, 1028, 920, 712, 697 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{24}H_{19}N_2O$ 351.1497 found 351.1511 (M+H).



80

***(6R,7aS,11aS)*-6-Allyl-6-phenyl-7a,8,9,10,11,11a-hexahydro-6*H*-chromeno[3,4-*b*]-quinoxaline (80):**

Diastereomer **80** of dihydropyrazine **28** was obtained using racemic conditions for the rearrangement of allyloxyflavone **5a**. Separation of the two diastereomers was readily accomplished by silica gel chromatography (petroleum ether : ethyl acetate = 90 : 10) affording the title compound **80** as a yellow oil (28 mg, 0.08 mmol, 49 %), along with diastereomer **28** (28 mg, 0.08 mmol, 49 %). $[\alpha]_D^{25}$ (*c* 1.3, $CHCl_3$) = + 94.2°. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, *J* = 7.8 Hz, 1H), 7.58 (d, *J* = 7.4 Hz, 2H), 7.40-7.33 (m, 1H), 7.29 (t, *J* = 7.4 Hz, 2H), 7.22 (t, *J* = 7.3 Hz, 1H), 7.10 (d, *J* = 8.3 Hz, 1H), 6.99 (t, *J* = 7.5 Hz, 1H), 5.79 (dddd, *J* = 17.6, 10.8, 7.2, 6.7 Hz, 1H), 5.05 (d, *J* = 16.3 Hz, 1H), 5.04 (d, *J* = 10.1 Hz, 1H), 3.11 (dd, *J* = 14.4, 7.3 Hz, 1H), 2.97-2.80 (m, 3H), 2.46 (d, *J* = 11.3 Hz, 2H), 1.90 (d, *J* = 8.2 Hz, 2H), 1.61-1.36 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.7, 156.2, 148.9, 140.8, 132.6, 132.4, 127.9 (2C), 127.4, 126.6 (2C), 125.3, 122.5, 121.7, 119.0, 118.8, 85.3, 59.4, 59.2, 45.2, 33.8 (2C), 30.3, 25.7. IR ν_{max} (film): 3070, 2933, 2857, 1607, 1586, 1575, 1462, 1447, 1320, 1256, 1221, 1055, 992, 918, 697 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{24}H_{25}N_2O$ 357.1967 found 357.1977 (M+H).

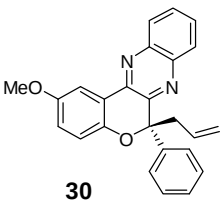


29

(*S*)-6-Allyl-1-methoxy-6-phenyl-6*H*-chromeno[3,4-*b*]quinoxaline (29):

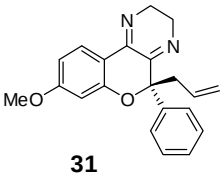
Starting from allyloxyflavone **11** (50 mg, 0.16 mmol, 1.0 equiv), pyrazine **29** was prepared after condensation of the intermediate 3,4-chromanedione with 1,2-phenylene diamine **22c** (43 mg, 0.40 mmol, 2.5 equiv). After purification on silica gel (petroleum ether : ethyl

acetate = 60 : 40), the title compound was obtained as colorless flakes (55 mg, 0.14 mmol, 91 %). M.p. (petroleum ether : Et_2O) = 184-185 °C. $[\alpha]_D^{25}$ (*c* 1.0, $CHCl_3$) = – 75.4°. er = 97:3 (ChiralPak AD 1% IPA in hexane, retention time 8.45 : 10.92 min, major : minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (d, *J* = 7.2 Hz, 2H), 7.79-7.70 (m, 2H), 7.35-7.29 (m, 3H), 7.20-7.10 (m, 3H), 6.89 (d, *J* = 8.2 Hz, 1H), 6.62 (d, *J* = 8.4 Hz, 1H), 5.96 (app tdd, *J* = 17.3, 10.2, 7.0 Hz, 1H), 5.17 (d, *J* = 17.2 Hz, 1H), 5.05 (d, *J* = 10.3 Hz, 1H), 3.93 (s, 3H), 3.55 (dd, *J* = 14.6, 6.6 Hz, 1H), 3.27 (dd, *J* = 14.6, 7.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.5, 157.7, 151.4, 144.3, 141.8, 141.2, 140.2, 133.3, 132.5, 129.7, 129.5, 129.2, 129.1, 127.9 (2C), 127.3, 126.2 (2C), 118.4, 111.6, 111.4, 106.0, 85.1, 56.3, 45.6. IR ν_{max} (film): 3064, 2973, 2832, 1601, 1586, 1489, 1461, 1472, 1351, 1244, 1102, 1081, 1027, 919, 787, 710 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{25}H_{21}N_2O_2$ 381.1603 found 381.1621 (M+H).



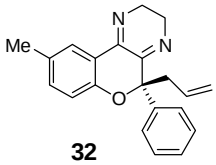
30

(*S*)-6-Allyl-2-methoxy-6-phenyl-6*H*-chromeno[3,4-*b*]quinoxaline (30):
Pyrazine **30** was prepared following the general procedure described above starting from allyloxyflavone **12** (49 mg, 0.16 mmol, 1.0 equiv) and using 1,2-phenylene diamine **22c** (44.0 mg, 0.40 mmol, 2.5 equiv) for the condensation step. After purification on silica gel (petroleum ether : ethyl acetate = 90 : 10), the title compound was obtained as a bright yellow oil (54.8 mg, 0.14 mmol, 90 %). $[\alpha]_D^{25}$ (*c* 1.1, $CHCl_3$) = – 153.8°. The er value was not determined. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 7.1 Hz, 1H), 8.11 (d, *J* = 7.1 Hz, 1H), 7.80-7.71 (m, 3H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.21-7.12 (m, 4H), 7.00 (dd, *J* = 8.9, 3.1 Hz, 1H), 5.95 (app tdd, *J* = 17.0, 10.2, 6.9 Hz, 1H), 5.17 (d, *J* = 17.2 Hz, 1H), 5.04 (d, *J* = 10.3 Hz, 1H), 3.86 (s, 3H), 3.58 (dd, *J* = 14.6, 6.7 Hz, 1H), 3.25 (dd, *J* = 14.6, 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.9, 151.4, 150.2, 143.5, 142.1, 141.8, 141.5, 133.3, 130.0, 129.4, 129.1 (2C), 128.0 (2C), 127.4, 126.1 (2C), 121.6, 120.9, 119.5, 118.5, 107.5, 85.2, 55.8, 45.5. IR ν_{max} (film): 3067, 2915, 2832, 1495, 1472, 1435, 1273, 1215, 1036, 989, 917, 823, 700 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{25}H_{21}N_2O_2$ 381.1603 found 381.1612 (M+H).



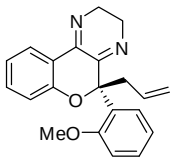
31

***(S)*-5-Allyl-8-methoxy-5-phenyl-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (31):**
Starting from the 7-methoxy-allyloxyflavone **13** (49 mg, 0.16 mmol, 1.0 equiv) and following the general procedure described above using 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv) for the condensation step, dihydropyrazine **31** was obtained after purification on silica gel (petroleum ether : ethyl acetate = 50 : 50) as a yellow gum (49 mg, 0.15 mmol, 93 %). $[\alpha]_D^{25}$ (*c* 1.3, $CHCl_3$) = + 134.1°. er = 90:10 (ChiralPak AD 8% IPA in hexane, retention time 4.82 : 7.68 min, major : minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.74 (d, *J* = 8.8 Hz, 1H), 7.30-7.15 (m, 5H), 6.61 (d, *J* = 2.4 Hz, 1H), 6.54 (dd, *J* = 8.8, 2.5 Hz, 1H), 5.92-5.79 (m, 1H), 5.05 (d, *J* = 16.5 Hz, 1H), 5.05 (d, *J* = 10.9 Hz, 1H), 4.08 (ddd, *J* = 15.7, 5.1, 2.2 Hz, 1H), 3.92 (ddd, *J* = 16.3, 5.2, 2.2 Hz, 1H), 3.85 (s, 3H), 3.40 (ddd, *J* = 17.3, 16.1, 5.2 Hz, 1H), 3.26 (ddd, *J* = 17.3, 16.1, 5.1 Hz, 1H), 3.12 (dd, *J* = 14.7, 6.5 Hz, 1H), 2.90 (dd, *J* = 14.7, 7.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 159.0, 157.5, 149.1, 139.6, 132.8, 128.4 (2C), 127.7, 126.2, 125.9 (2C), 118.4, 113.3, 110.2, 101.8, 85.9, 55.5, 46.1, 44.4, 43.7. IR ν_{max} (film): 3074, 2927, 2840, 1615, 1590, 1502, 1432, 1329, 1268, 1162, 1116, 1034, 996, 836 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{21}H_{21}N_2O_2$ 333.1603 found 333.1610 (M+H).



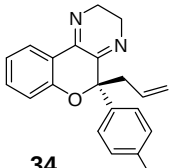
32

***(S)*-5-Allyl-9-methyl-5-phenyl-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (32):** Starting from the 6-methyl-allyloxyflavone **14** (47 mg, 0.16 mmol) and following the general procedure described above using 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv) for the condensation step, dihydropyrazine **32** was obtained after purification on silica gel (petroleum ether : ethyl acetate = 80 : 20) as a yellow gum (45 mg, 0.14 mmol, 88 %). $[\alpha]_D^{25}$ (*c* 1.2, $CHCl_3$) = + 53.5°. er = 96:4 (ChiralPak AD 1% IPA in Hexane, retention time 7.82 : 9.32 min, minor : major). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (br s, 1H), 7.29-7.15 (m, 6H), 7.03 (d, *J* = 8.4 Hz, 1H), 5.92-5.80 (m, 1H), 5.05 (d, *J* = 15.7 Hz, 1H), 5.05 (d, *J* = 11.8 Hz, 1H), 4.13-4.06 (m, 1H), 4.01-3.93 (m, 1H), 3.47-3.25 (m, 2H), 3.11 (dd, *J* = 14.7, 6.5 Hz, 1H), 2.90 (dd, *J* = 14.7, 7.3 Hz, 1H), 2.24 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.2, 154.0, 149.8, 139.4, 134.1, 132.7, 131.4, 128.2 (2C), 127.6, 126.0 (2C), 124.6, 119.5, 118.3, 118.1, 85.4, 45.8, 44.5, 43.6, 20.5. IR ν_{max} (film): 3074, 3025, 2944, 2841, 1591, 1487, 1447, 1221, 1131, 990, 915, 818 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{21}H_{21}N_2O$ 317.1654 found 317.1640 (M+H).



33

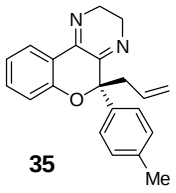
***(S)*-5-Allyl-5-(2-methoxyphenyl)-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (33):** Starting from the *o*-methoxy-allyloxyflavone **15** (49.3 mg, 0.16 mmol) and following the general procedure described above using 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv) for the condensation step, the title compound **33** was obtained after purification on silica gel (petroleum ether : ethyl acetate = 50 : 50) as a bright yellow oil (51 mg, 0.15 mmol, 96 %). $[\alpha]_D^{25}$ (*c* 1.0, $CHCl_3$) = + 29.4°. er = 96:4 (ChiralPak AD 8% IPA in hexane, retention time 4.60 : 5.59 min, minor : major). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (br d, *J* = 7.5 Hz, 1H), 7.42 (d, *J* = 7.8 Hz, 1H), 7.34 (t, *J* = 7.8 Hz, 1H), 7.23 (t, *J* = 7.8 Hz, 1H), 7.00-6.93 (m, 2H), 6.89 (t, *J* = 7.6 Hz, 1H), 6.82 (d, *J* = 8.2 Hz, 1H), 5.85 (app tdd, *J* = 13.9, 10.1, 7.0 Hz, 1H), 5.07 (d, *J* = 17.2 Hz, 1H), 5.00 (d, *J* = 10.2 Hz, 1H), 3.79 (app d, *J* = 10.8 Hz, 2H), 3.60 (s, 3H), 3.41 (app d, *J* = 10.3 Hz, 2H), 3.22 (dd, *J* = 14.1, 6.7 Hz, 1H), 3.15 (dd, *J* = 14.0, 7.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.0, 157.1, 156.5, 150.2, 132.7, 132.4, 129.5, 128.8, 127.7, 124.7, 121.5, 120.4, 119.9, 118.7, 117.8, 111.6, 84.1, 55.0, 45.7, 44.6, 42.0. IR ν_{max} (film): 3074, 2940, 2836, 1595, 1576, 1490, 1460, 1435, 1330, 1248, 1116, 1028, 991, 917 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{21}H_{21}N_2O_2$ 333.1603 found 333.1625 (M+H).



34

***(S)*-5-Allyl-5-(4-methoxyphenyl)-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (34):** Starting from the *p*-methoxy-allyloxyflavone **16** (49 mg, 0.16 mmol) and following the general procedure described above using 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv) for the condensation step, the title compound **34** was obtained as a yellow oil (50 mg, 0.15 mmol, 94 %) after purification on silica gel (petroleum ether : ethyl acetate = 20 : 80). $[\alpha]_D^{25}$ (*c* 1.0, $CHCl_3$) = + 9.0°. er = 98:2 (ChiralCel OD 1% IPA in hexane, retention time 6.21 : 7.75 min, major : minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.37 (ddd, *J* = 8.6, 7.4, 1.6 Hz, 1H), 7.18 (d, *J* = 8.6 Hz, 2H), 7.10 (d, *J* = 8.3 Hz, 1H), 6.95 (app t, *J* = 7.5 Hz, 1H), 6.76 (d, *J* = 8.7 Hz, 2H), 5.94-5.81 (m, 1H), 5.05 (d, *J* = 15.9 Hz, 1H), 5.05 (d, *J* = 11.5 Hz, 1H), 4.10-3.93 (m, 2H), 3.72 (s, 3H), 3.47-3.25 (m, 2H), 3.10 (dd, *J* = 14.7, 6.5 Hz, 1H), 2.90 (dd, *J* = 14.7, 7.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.0 (2C), 156.0, 149.8, 133.0, 132.8, 131.2, 127.3 (2C), 124.8, 121.9, 120.1,

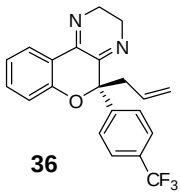
118.3 (2C), 113.8 (2C), 85.3, 55.1, 45.9, 44.6, 43.7. IR ν_{max} (film): 3074, 2948, 2836, 1608, 1594, 1510, 1461, 1331, 1251, 1177, 1033, 993, 829 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{21}H_{21}N_2O_2$ 333.1603 found 333.1570 (M+H).



35

***(S)*-5-Allyl-5-*p*-tolyl-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (35):**

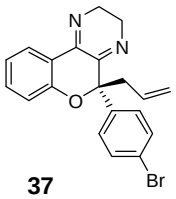
Starting from the *p*-tolyl-allyloxyflavone **17** (47 mg, 0.16 mmol) and following the general procedure described above using 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv) for the condensation step, the title compound **35** was obtained after purification on silica gel (petroleum ether : ethyl acetate = 75 : 15) as a yellow oil (48 mg, 0.15 mmol, 94 %). $[\alpha]_D^{25}$ (*c* 1.0, $CHCl_3$) = + 14.4°. er = 96:4 (ChiralCel OD 1% IPA in Hexane, retention time 3.88 : 4.55 min, major : minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (br d, *J* = 6.1 Hz, 1H), 7.37 (app t, *J* = 7.7 Hz, 1H), 7.15 (dd, *J* = 8.2, 2.3 Hz, 2H), 7.11 (d, *J* = 8.4 Hz, 1H), 7.03 (d, *J* = 8.2 Hz, 2H), 6.95 (app t, *J* = 7.5 Hz, 1H), 5.87 (dddd, *J* = 17.2, 10.5, 7.2, 6.6 Hz, 1H), 5.06 (d, *J* = 17.5 Hz, 1H), 5.05 (d, *J* = 10.2 Hz, 1H), 4.08 (br d, *J* = 14.6 Hz, 1H), 3.98 (br d, *J* = 14.0 Hz, 1H), 3.50-3.22 (m, 2H), 3.10 (dd, *J* = 14.7, 6.5 Hz, 1H), 2.89 (dd, *J* = 14.7, 7.3 Hz, 1H), 2.24 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.0, 156.0, 149.7, 137.4, 136.3, 133.0, 132.8, 129.1 (2C), 128.3, 125.9 (2C), 124.8, 121.9, 120.0, 118.3, 85.5, 45.9, 44.5, 43.6, 20.9. IR ν_{max} (film): 3073, 2939, 2839, 1608, 1594, 1576, 1462, 1330, 1220, 1117, 992, 917, 813 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{21}H_{21}N_2O$ 317.1654 found 317.1645 (M+H).



36

(*S*)-5-Allyl-5-(4-(trifluoromethyl)phenyl)-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (36):

Dihydropyrazine **36** was obtained from the rearrangement of the *p*-trifluoromethylphenyl-allyloxyflavone **18** (55 mg, 0.16 mmol, 1.0 equiv), after condensation of the intermediate 3,4-chromanedione with 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv). Purification on silica gel (petroleum ether : ethyl acetate = 80 : 20) afforded the title compound **36** as a bright yellow oil (51 mg, 0.14 mmol, 86 %).$[\alpha]_D^{25}$ (*c* 1.0, $CHCl_3$) = + 24.0°. er = 95:5 (ChiralPak AD 1% IPA in hexane, retention time 4.79 : 5.42 min, major : minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.9 Hz, 1H), 7.51 (d, *J* = 8.8 Hz, 2H), 7.42 (d, *J* = 8.9 Hz, 2H), 7.39 (d, *J* = 8.9 Hz, 1H), 7.14 (d, *J* = 8.3 Hz, 1H), 6.99 (app t, *J* = 7.6 Hz, 1H), 5.83 (app tdd, *J* = 17.2, 10.1, 6.8 Hz, 1H), 5.05 (d, *J* = 9.5 Hz, 1H), 5.04 (d, *J* = 17.0 Hz, 1H), 4.12-3.94 (m, 2H), 3.45 (app dt, *J* = 16.5, 5.6 Hz, 1H), 3.32 (app dt, *J* = 16.5, 5.3 Hz, 1H), 3.13 (dd, *J* = 14.7, 6.5 Hz, 1H), 2.91 (dd, *J* = 14.7, 7.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.6, 155.6, 149.2, 143.6, 133.3, 132.0, 130.5-129.5 (q, *J* = 32.6 Hz, 1C), 126.5 (2C), 125.4-125.3 (q, *J* = 3.7 Hz, 2C), 125.0, 127.9-119.8 (q, *J* = 272.2 Hz, 1C), 122.4, 120.0, 119.1, 118.2, 85.4, 45.8, 44.6, 43.6. IR ν_{max} (film): 3076, 2948, 2839, 1608, 1594, 1461, 1410, 1327, 1219, 1167, 1125, 1068, 1017, 994, 834 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{21}H_{18}F_3N_2O$ 371.1371 found 371.1380 (M+H).

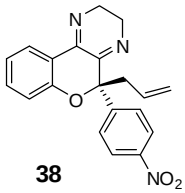


37

(*S*)-5-Allyl-5-(4-bromophenyl)-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (37):

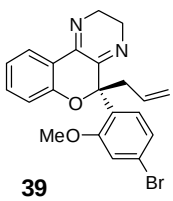
Dihydropyrazine **37** was obtained from the rearrangement of *p*-bromophenyl-allyloxyflavone **19** (57 mg, 0.16 mmol, 1.0 equiv), after condensation of

the intermediate 3,4-chromanedione with 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv). Purification on silica gel (petroleum ether : ethyl acetate = 80 : 20) afforded the title compound **37** as a bright yellow oil (57 mg, 0.15 mmol, 93 %).$[\alpha]_D^{25}$ (*c* 1.0, $CHCl_3$) = – 13.9°; er = 91:9 (ChiralCel OD 1% IPA in h exane, retention time 4.51 : 5.45 min, major : minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.6 Hz, 1H), 7.39 (app t, *J* = 7.8 Hz, 1H), 7.37 (d, *J* = 8.8 Hz, 2H), 7.15 (d, *J* = 8.8 Hz, 2H), 7.11 (d, *J* = 8.3 Hz, 1H), 6.98 (app t, *J* = 7.6 Hz, 1H), 5.84 (dddd, *J* = 16.9, 10.5, 7.4, 6.5 Hz, 1H), 5.05 (d, *J* = 10.4 Hz, 1H), 5.04 (d, *J* = 17.2 Hz, 1H), 4.12-4.03 (m, 1H), 4.02-3.94 (m, 1H), 3.42 (app dt, *J* = 16.9, 5.4 Hz, 1H), 3.31 (app dt, *J* = 16.2, 5.0 Hz, 1H), 3.09 (dd, *J* = 14.7, 6.4 Hz, 1H), 2.88 (dd, *J* = 14.7, 7.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.6, 155.6, 149.3, 138.5, 133.1, 132.2, 131.5 (2C), 127.8 (2C), 124.9, 122.2, 121.9, 120.0, 118.9, 118.2, 85.2, 45.8, 44.5, 43.5. IR ν_{max} (film): 3073, 2942, 2836, 1608, 1593, 1577, 1479, 1461, 1330, 1217, 1118, 1009, 993, 918, 820, 777 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{20}H_{18}BrN_2O$ 381.0602 found 381.0605 (M+H).



38

(*S*)-5-Allyl-5-(4-nitrophenyl)-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (38):
Starting from the *p*-nitrophenyl-allyloxyflavone **20** (52 mg, 0.16 mmol) and following the general procedure described above using 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv) for the condensation step, dihydropyrazine **38** was obtained after purification on silica gel (petroleum ether : ethyl acetate = 70 : 30) as a bright yellow oil (51 mg, 0.15 mmol, 92 %). $[\alpha]_D^{25}$ (*c* 1.0, $CHCl_3$) = + 4.1°. er = 96:4 (ChiralPak AD 10% IPA in Hexane, retention time 6.29 : 8.01 min, major : minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 8.9 Hz, 2H), 7.86 (d, *J* = 7.8 Hz, 1H), 7.49 (d, *J* = 9.0 Hz, 2H), 7.43 (app t, *J* = 7.8 Hz, 1H), 7.15 (d, *J* = 8.1 Hz, 1H), 7.01 (app t, *J* = 7.5 Hz, 1H), 5.83 (dddd, *J* = 16.9, 10.3, 7.7, 6.4 Hz, 1H), 5.05 (d, *J* = 10.4 Hz, 1H), 5.02 (d, *J* = 17.1 Hz, 1H), 4.08 (ddd, *J* = 15.7, 5.1, 3.4 Hz, 1H), 3.99 (ddd, *J* = 16.7, 5.2, 3.3 Hz, 1H), 3.48 (app dt, *J* = 16.6, 5.6 Hz, 1H), 3.35 (app dt, *J* = 16.6, 5.3 Hz, 1H), 3.14 (dd, *J* = 14.6, 6.3 Hz, 1H), 2.92 (dd, *J* = 14.6, 7.7 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.3, 155.3, 148.9, 147.3, 146.8, 133.4, 131.5, 127.2 (2C), 125.0, 123.5 (2C), 122.6, 119.8, 119.5, 118.2, 85.3, 45.8, 44.5, 43.4. IR ν_{max} (film): 3076, 2948, 2845, 1609, 1593, 1521, 1461, 1347, 1218, 1118, 995, 853 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{20}H_{18}N_3O_3$ 348.1348 found 348.1361 (M+H).



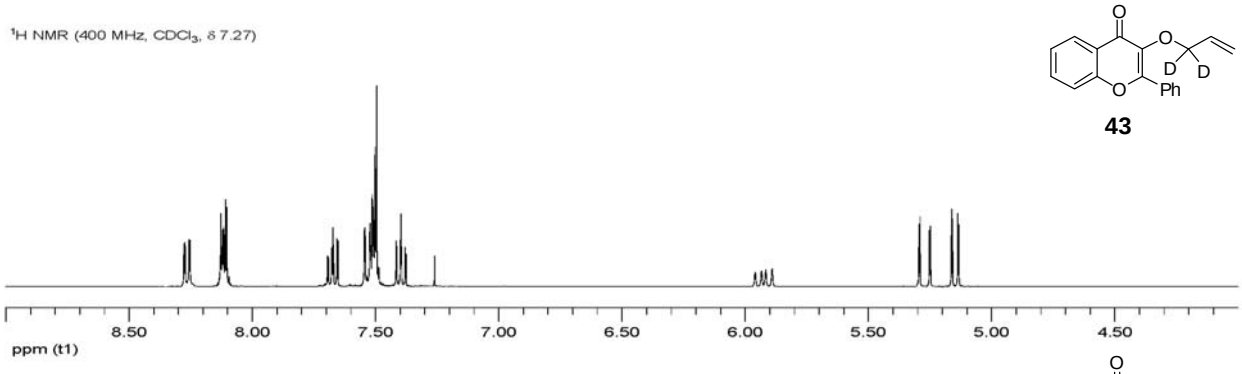
39

***(S)*-5-Allyl-5-(4-bromo-2-methoxyphenyl)-3,5-dihydro-2*H*-chromeno[4,3-*b*]pyrazine (39):**
Starting from allyloxyflavone **21** (62 mg, 0.16 mmol, 1.0 equiv) and using 1,2-ethylene diamine **24** (27 μL, 0.40 mmol, 2.5 equiv) for the condensation of the 3,4-chromanedione intermediate, the title dihydropyrazine **39** was obtained as a bright yellow oil (53 mg, 0.13 mmol, 80 %), after purification on silica gel (petroleum ether : ethyl acetate = 60 : 40). $[\alpha]_D^{25}$ (*c* 1.0, $CHCl_3$) = – 8.6°; er = 96:4 (ChiralPak AD 8% IPA in hexane, retention time 4.29 : 7.71 min, minor : major). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 7.8 Hz, 1H), 7.35 (app t, *J* = 7.8 Hz, 1H), 7.28 (d, *J* = 8.7 Hz, 1H), 7.03 (d, *J* = 8.4 Hz, 1H), 7.01-6.93 (m, 2H), 6.94 (s, 1H), 5.89-5.76 (m, 1H), 5.05 (d, *J* = 17.2 Hz, 1H), 5.01 (d, *J* = 12.5 Hz, 1H), 3.79 (app d, *J* = 12.2 Hz, 2H), 3.61 (s, 3H), 3.46-3.36 (m, 2H), 3.17 (dd, *J* = 14.1, 6.9 Hz, 1H), 3.09 (dd, *J* = 14.1, 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.4, 157.8, 156.2, 150.0, 132.9, 132.1, 129.1, 127.9, 124.8, 123.5, 123.0, 121.8, 119.9, 119.0, 117.8, 115.3,

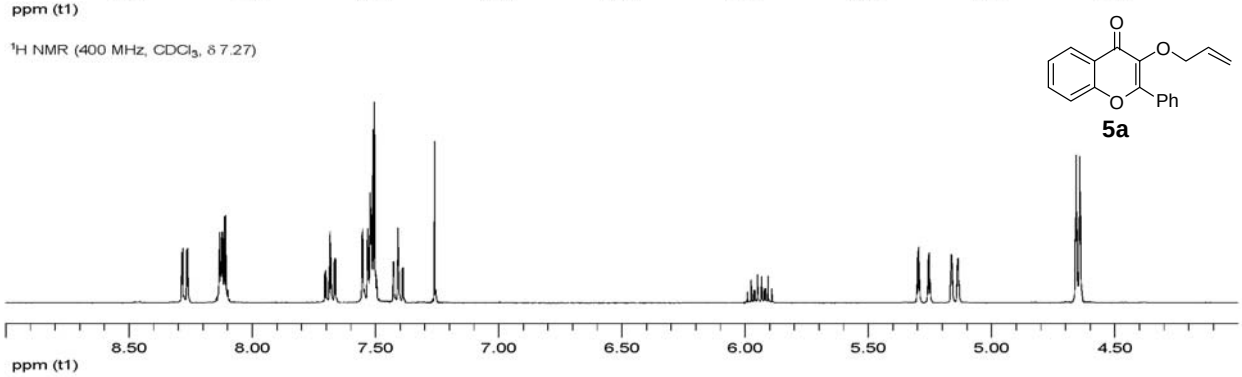
83.9, 55.4, 45.8, 44.6, 41.6. IR ν_{max} (film): 3075, 2940, 2841, 1593, 1487, 1460, 1393, 1330, 1247, 1116, 1028, 991, 917, 850 cm^{-1}. HRMS (ESI+) m/z calculated for $C_{21}H_{20}BrN_2O_2$ 411.0708 found 411.0725 (M+H).

VIII. Mechanistic Studies

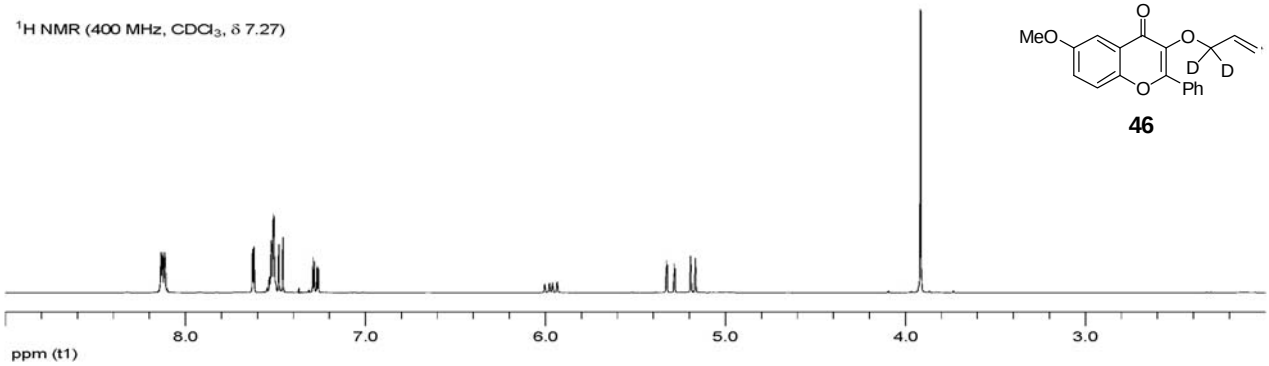
Experimental Procedures and Characterization Data for Rearrangement of Deuterium-labeled Substrates and Crossover Experiment.



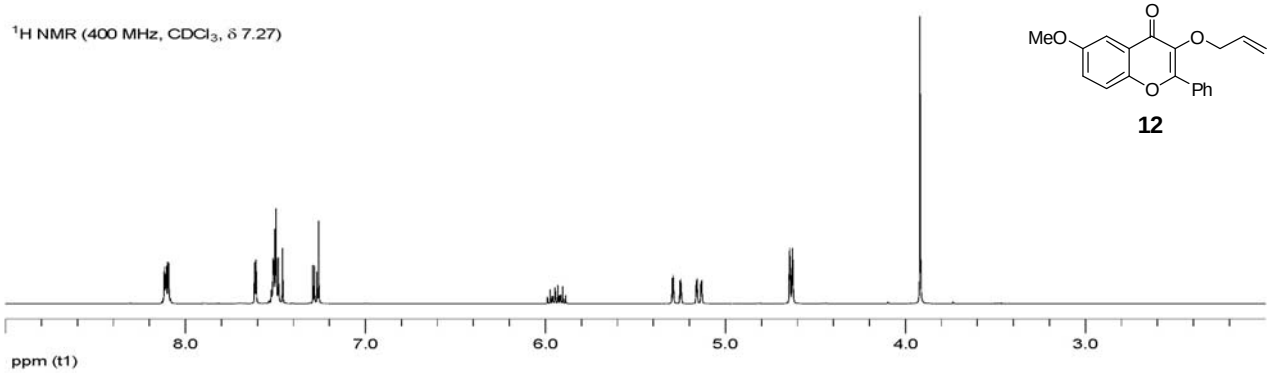
43



5a

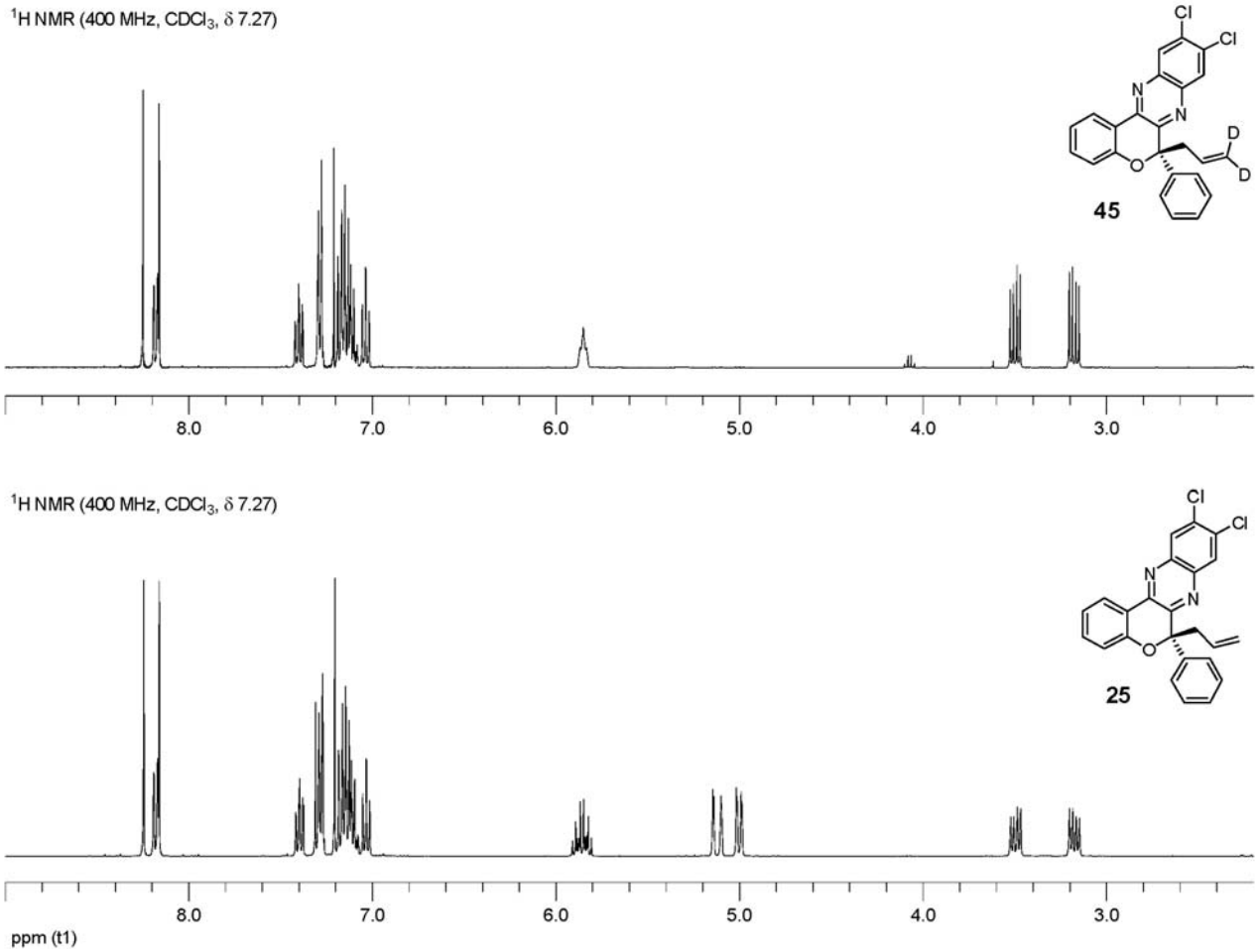


46

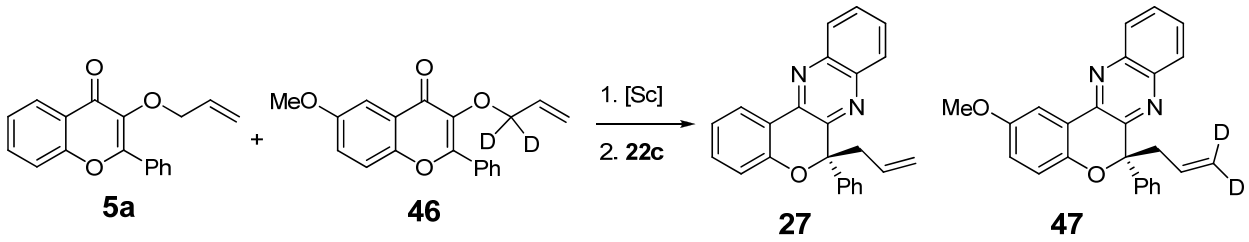


12

Equation (1) – Rearrangement of Allyloxy Flavone 43: Starting from d_2-allyloxyflavone **43** (40 mg, 0.14 mmoles, 1.0 equiv) and following the same procedure as described for the preparation of **25**, the *bis*-deuterated dichloropyrazine **45** was isolated after purification on silica gel (petroleum ether : dichloromethane = 98 : 2) as a yellow solid (59 mg, 0.14 mmol, 98 %). ^{1}H NMR spectrum shown on page S25 clearly shows complete transfer of the deuterium atoms to the terminal position of the double bond during the rearrangement process.

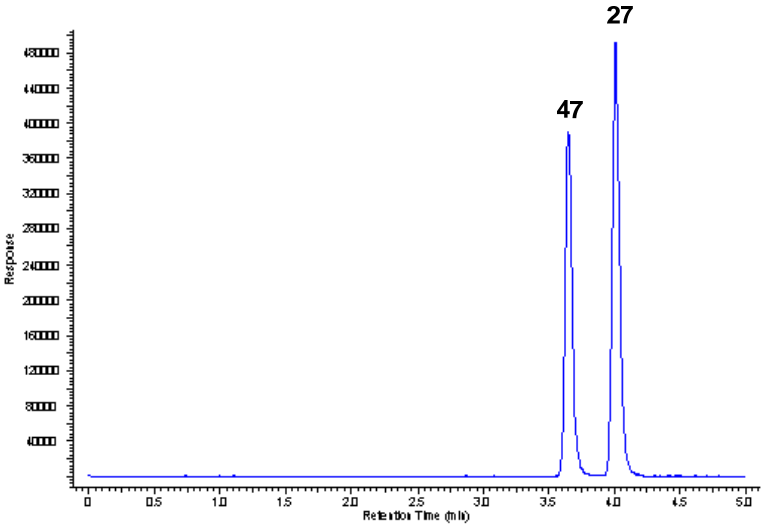


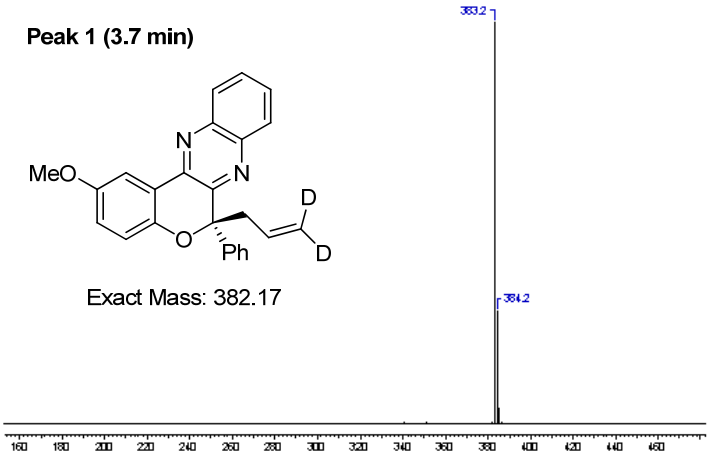
Equation (2) – Crossover Experiment

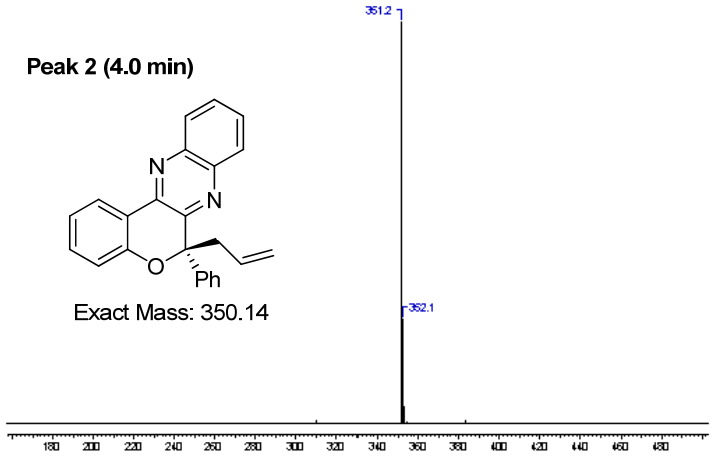


A mixture of non-labeled allyloxyflavone **5a** (22 mg, 0.08 mmol, 1.0 equiv) and deuterated methoxyallyloxyflavone **46** (25 mg, 0.08 mmol, 1.0 equiv) was subjected to the rearrangement conditions as described above (see **General Procedure § VII** (page S17). After quenching the intermediate

3,4-chromanediones with diamine **22c** (43 mg, 0.40 mmol, 2.5 equiv), the sieves were removed by filtration and the crude was concentrated. UPLC analysis performed on the crude mixture. LC separation was performed on a Waters Acquity UPLC using a BEH C18 column (2.1 x 100 mm/1.7 μM) and an isocratic method with 70:30 acetonitrile/water (0.01% formic acid).

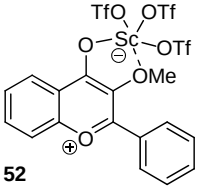






UV/Fluorescence Studies

- **Compound Synthesis**

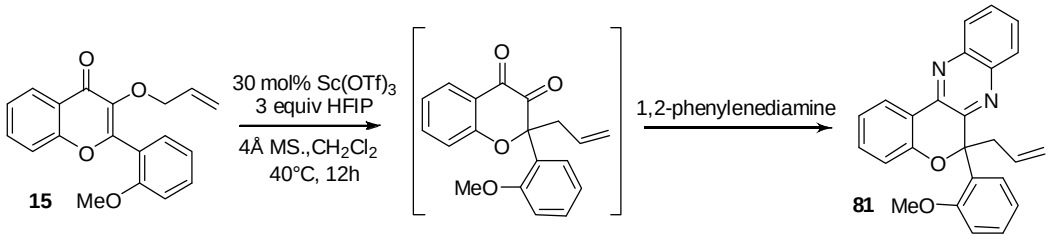


52

3-Methoxy-2-phenyl-4H-chromen-4-one, scandium triflate complex (52):

To a suspension of molecular sieves (4Å, 10.0 mg, flame-dried under high vacuum) was subsequently added CD_2Cl_2 (1.0 mL), 3-methoxy-2-phenyl-4H-chromen-4-one **53** (10.0 mg, 0.04 mmol) and scandium triflate (9.8 mg, 0.02 mmol). The mixture was stirred at room temperature for 0.5 h, and filtered though a pad of Celite to remove undissolved solid. The clear solution was used for NMR and UV/fluorescence studies without further purification. ^{1}H NMR (400 MHz, CD_2Cl_2) δ 8.58 (br, 1H), 8.19 (d, *J* = 6.4 Hz, 2H), 7.99 (dd, *J* = 7.7 Hz, 1H), 7.86 (d, *J* = 8.1 Hz, 1H), 7.69 (dd, *J* = 6.8 Hz, 1H), 7.61 (dd, *J* = 7.6Hz, 3H), 3.79 (s, 3H). ^{13}C NMR (400 MHz, CD_2Cl_2) δ 177.6, 165.0, 157.2, 142.2, 137.9, 134.3, 130.0, 129.3, 128.1, 124.0, 120.3, 119.2, 62.5, -4.5. IR_{max} (film): 3284(br), 1601, 1245, 1166, 1035, 757, 643 cm^{-1}.

6-Allyl-6-(2-methoxyphenyl)-6H-chromeno[3,4-b]quinoxaline (81):



15 **81**

To a suspension of molecular sieves (4Å, 20.0 mg, flame-dried under high vacuum) was subsequently added a solution of 3-(allyloxy)-2-(2-methoxyphenyl)-4H-chromen-4-one **15** (10.0 mg, 0.03 mmol) in CH_2Cl_2 (1 mL), 1,1,1,3,3,3-Hexafluoro-2-propanol (10 μL, 0.09 mmol) and scandium triflate (4.8 mg, 0.01 mmol). The mixture was stirred overnight at 40 °C. 1,2-Phenylene diamine (8.1 mg, 0.07 mmol) was added in one portion and the mixture was allowed to stir for 2 h at room temperature. After removal of molecular sieves by filtration through a pad of Celite, the solvent was evaporated *in vacuo* and the product **81** was isolated by flash column chromatography on silica gel.[S7] ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.40 (dd, *J* = 7.8, 1.7 Hz, 1H), 8.07 (dd, *J* = 8.4, 1.5 Hz, 1H), 7.91 (dd, *J* = 8.3, 1.6 Hz, 1H), 7.68 (ddd, *J* = 8.3, 6.9, 1.5 Hz, 1H), 7.60 (ddd, *J* = 8.4, 6.9, 1.6 Hz, 1H), 7.46 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.35 (ddd, *J* = 8.7, 7.2, 1.7 Hz, 1H), 7.29-7.25 (m, 1H), 7.09-7.04 (m, 1H), 6.97-6.93 (m, 2H), 6.80 (dd, *J* = 8.1, 0.9 Hz, 1H), 5.90 (dddd, *J* = 17.1, 10.2, 7.0, 7.0 Hz, 1H), 5.03 (dd, *J* = 17.1, 1.9 Hz, 1H), 4.93 (dd, *J* = 10.2, 1.9 Hz, 1H), 3.48 (m, 2H), 3.32 (m, 3H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 157.8, 156.6, 153.1, 143.8, 141.7, 141.7, 132.5, 132.5, 131.6, 129.7, 129.4, 129.1, 128.9, 128.5, 127.4, 125.1, 121.4, 120.0, 119.1, 117.2, 112.4, 84.4, 55.5, 43.9. IR_{max} (film): 3061, 2921, 2357, 1603, 1587, 1491, 1459, 1247, 1029, 752

[S7] For use of HFIP with $Sc(OTf)_3$-chiral ligand complexes, see: Kitajima, H.; lto, K.; Katsuki, T. *Tetrahedron,* **1997**, *33*, 17015-17028.

cm^{-1}. HRMS (ESI+) m/z calculated for $C_{25}H_{21}N_2O_2$ 381.1603 found 381.1618 (M+H).

- **Fluorescence Experiments**

Fluorescence spectra were recorded on a Fluorimeter. The spectra in CH_2Cl_2 solution were obtained at 25 °C using a quartz cuvette with a path length of 1 cm (excitation wavelength = 400 nm).

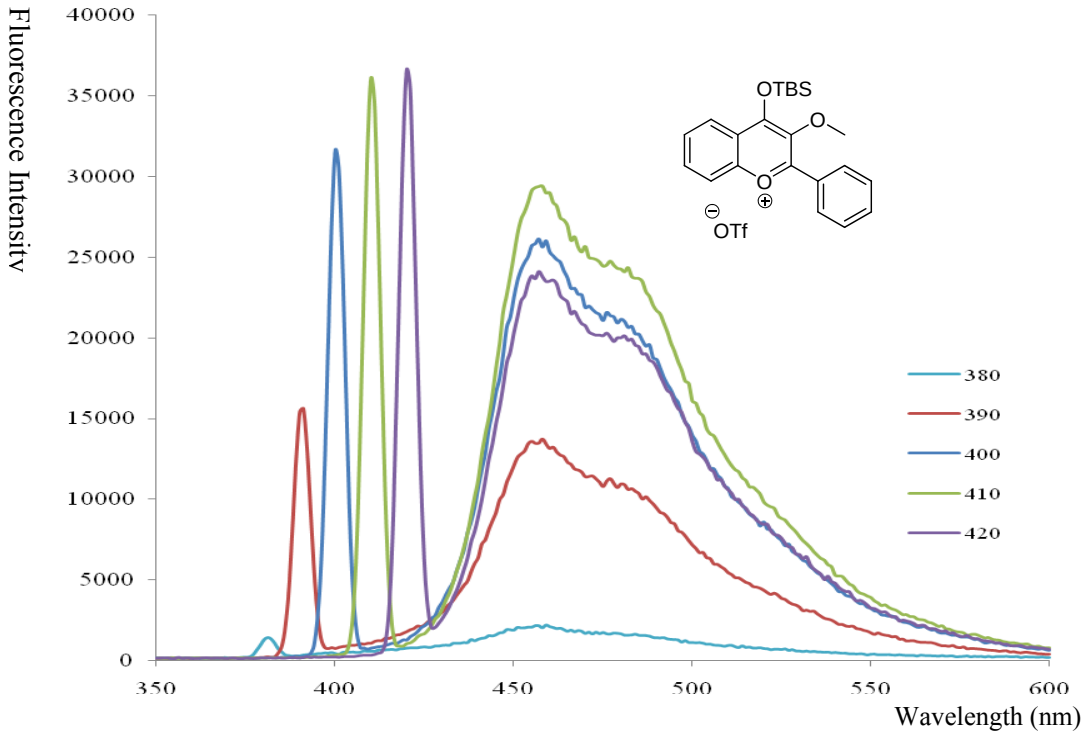


Figure 1. Fluorescence spectra of 4-(Tert-butyldimethylsilyloxy)-3-methoxy-2-phenylchromenylium triflate salt **51**, concentration of 3.0×10^{-4} M in CH_2Cl_2. (excitation wavelength stepwise scan)

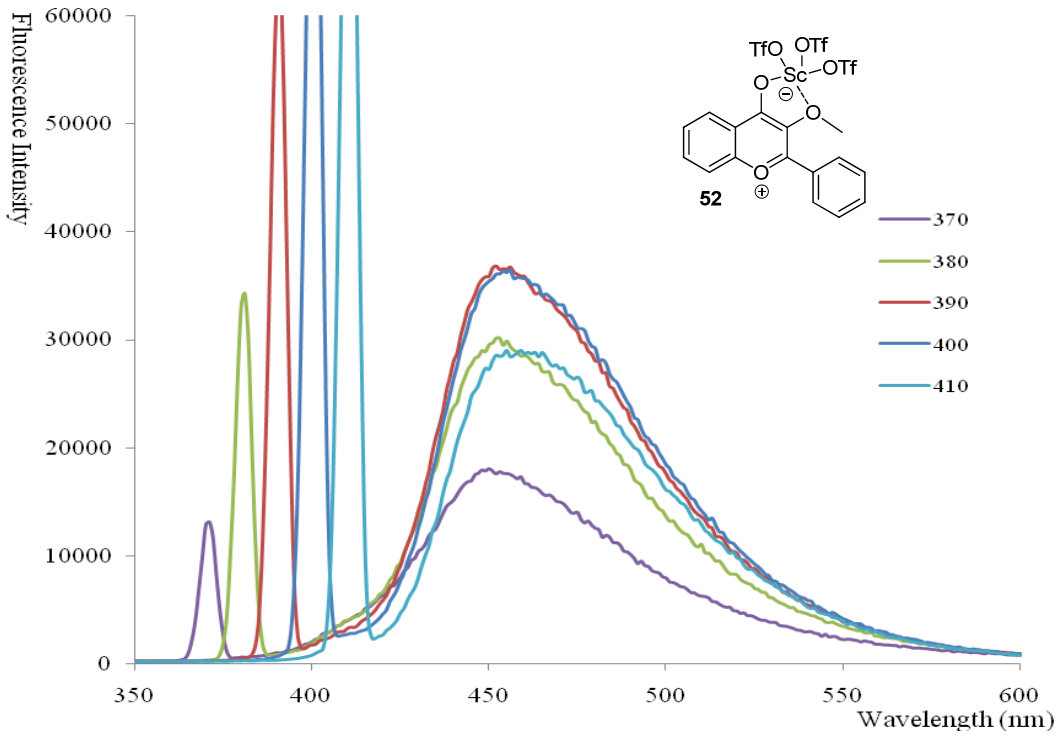


Figure 2. Fluorescence spectra of $Sc(OTf)_3$/3-methoxyflavone complex **52**, concentration of 3.0×10^{-4} M in CH_2Cl_2. (excitation wavelength stepwise scan)

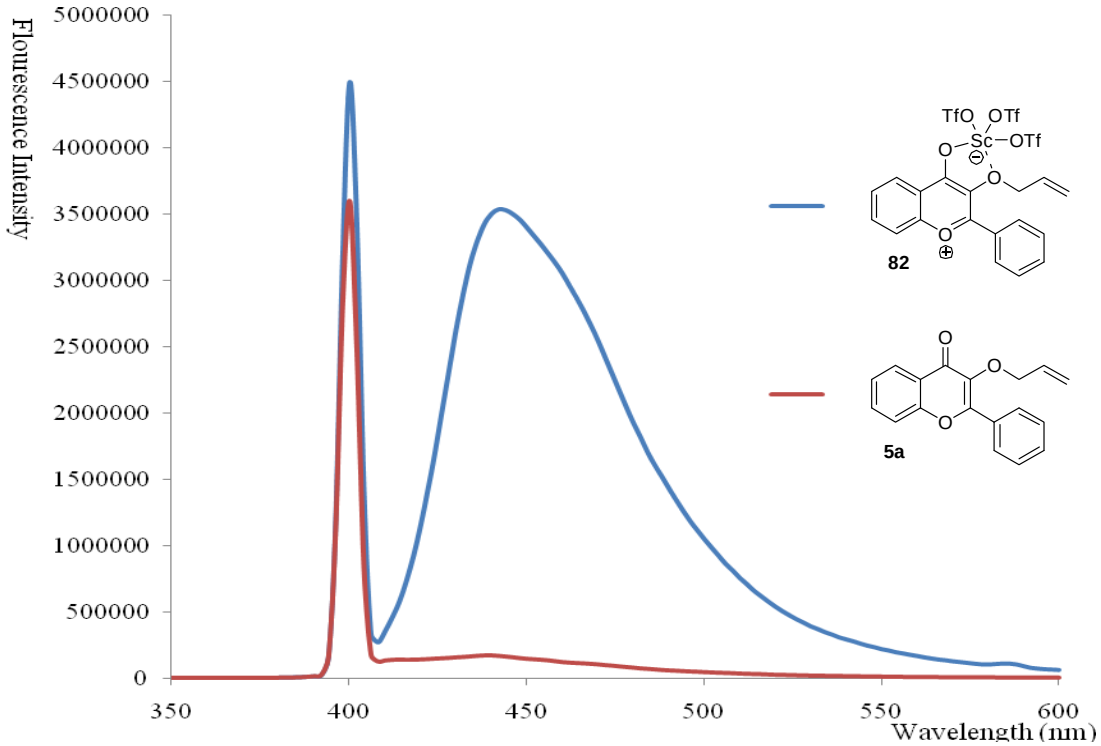


Figure 3. Overlay of fluorescence spectra of $Sc(OTf)_3$/3-allyloxyflavone complex **82** and 3-allyloxyflavone **5a**, concentration of 3.0×10^{-4} M in CH_2Cl_2.

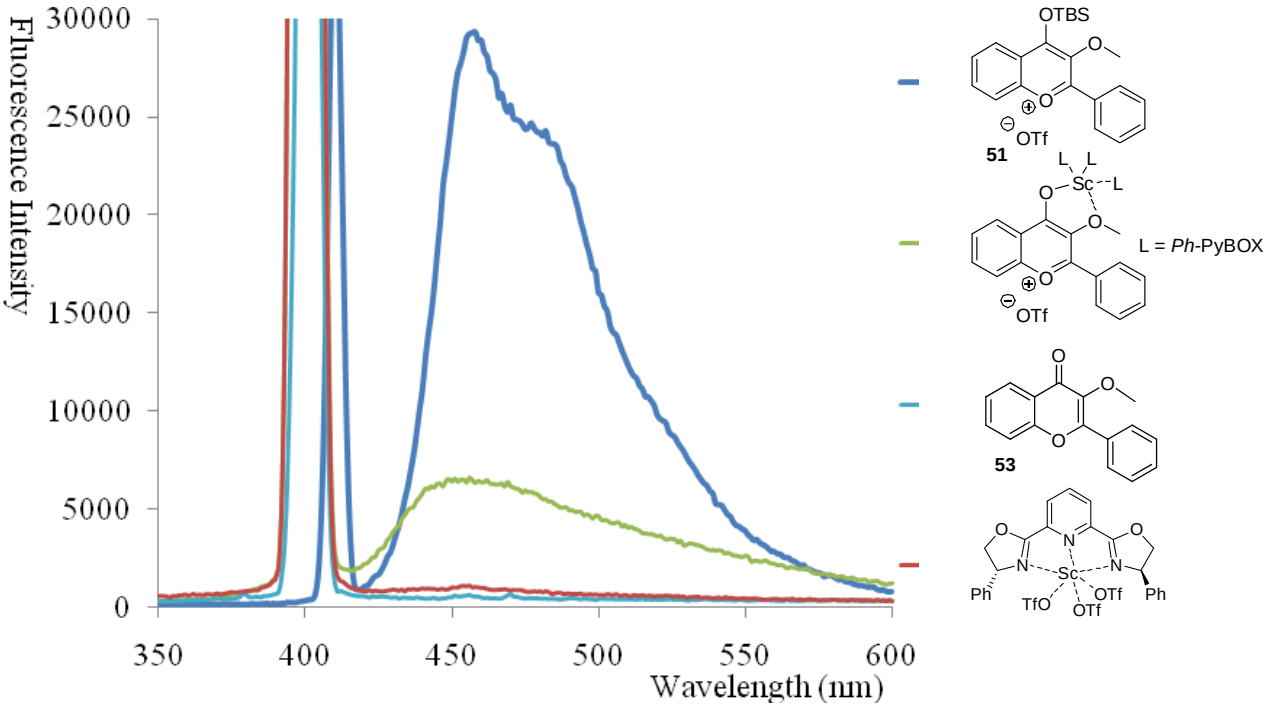
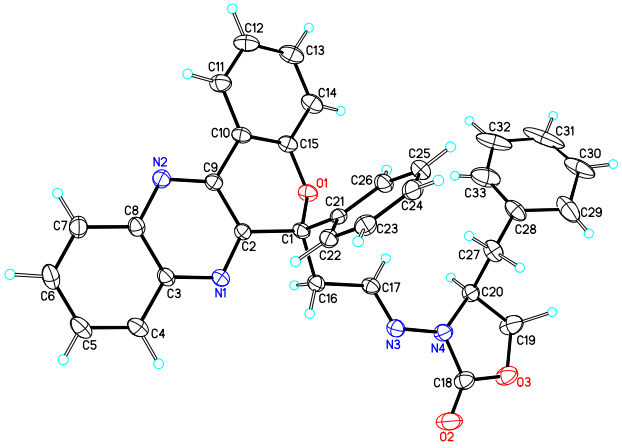


Figure 4. Overlay of fluorescence spectra of **51**, $Sc(OTf)_3$-PyBox-3-methoxyflavone complex, **53** and $Sc(OTf)_3$-PyBox complex, concentration of 3.0×10^{-4} M in CH_2Cl_2.

IX. X-ray Crystal Structure Data.



Crystals of compound **42** suitable for x-ray analysis were obtained by slow evaporation from $CDCl_3$. Crystallographic data have been deposited with the Cambridge Crystallographic Data Centre (CCDC 728510). Copies of the data can be obtained free of charge on application to the CCDC, 12 Union Road, Cambridge CB21EZ, UK (fax: (+44)-1223-336-033; e-mail: deposit@ccdc.cam.ac.uk.

Crystal Data and Structure Refinement for Pyrazine-hydrazone **42**.

Identification code	Pyrazine-hydrazone **42**	
Empirical formula	C_{33} H_{26} N_4 O_3	
Formula weight	526.58	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	P2(1)2(1)2(1)	
Unit cell dimensions	a = 10.009(4) Å	α= 90°.
	b = 15.153(6) Å	β= 90°.
	c = 17.540(6) Å	γ = 90°.
Volume	2660.2(17) $Å^3$	
Z	4	
Density (calculated)	1.315 Mg/m^3	
Absorption coefficient	0.086 mm^{-1}	
F(000)	1104	
Crystal size	0.60 x 0.40 x 0.40 mm^3	
Theta range for data collection	1.78 to 31.50°.	
Index ranges	-14<=h<=10, -21<=k<=22, -25<=l<=25	
Reflections collected	33418	
Independent reflections	4912 [R(int) = 0.0386]	
Completeness to theta = 31.50°	100.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9664 and 0.9502	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4912 / 0 / 481	
Goodness-of-fit on F^2	1.018	
Final R indices [I>2sigma(I)]	R1 = 0.0456, wR2 = 0.1160	
R indices (all data)	R1 = 0.0567, wR2 = 0.1232	
Absolute structure parameter	2.2(12)	
Largest diff. peak and hole	0.344 and -0.198 $e.Å^{-3}$	

Atomic coordinates (x 104) and equivalent isotropic displacement parameters ($Å^2$ x 10^3) for Pyrazine-hydrazone **42**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

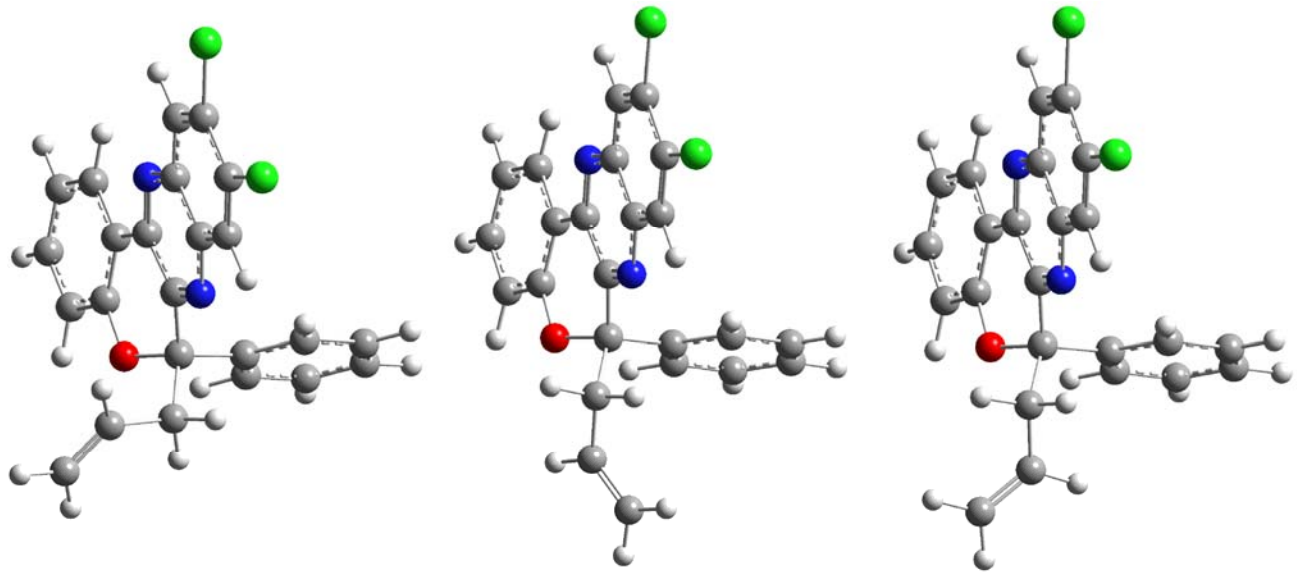
	x	y	z	U(eq)
O(1)	8260(1)	975(1)	7113(1)	26(1)
O(2)	2103(1)	904(1)	8896(1)	49(1)
O(3)	3184(1)	829(1)	10012(1)	42(1)
N(1)	6048(1)	1175(1)	5541(1)	26(1)
N(2)	8554(1)	1301(1)	4804(1)	27(1)
N(3)	4577(1)	1021(1)	8201(1)	27(1)
N(4)	4396(1)	1006(1)	8973(1)	30(1)
C(1)	7098(1)	1384(1)	6778(1)	23(1)
C(2)	7158(1)	1284(1)	5918(1)	21(1)
C(3)	6152(1)	1110(1)	4767(1)	26(1)
C(4)	4992(2)	953(1)	4328(1)	38(1)
C(5)	5088(2)	871(1)	3557(1)	42(1)
C(6)	6328(2)	957(1)	3189(1)	39(1)
C(7)	7465(2)	1116(1)	3596(1)	33(1)
C(8)	7404(1)	1186(1)	4399(1)	25(1)
C(9)	8430(1)	1343(1)	5554(1)	24(1)
C(10)	9617(1)	1411(1)	6037(1)	26(1)
C(11)	10887(2)	1606(1)	5751(1)	33(1)
C(12)	11984(2)	1592(1)	6229(1)	40(1)
C(13)	11826(2)	1379(1)	6992(1)	39(1)
C(14)	10580(2)	1191(1)	7289(1)	33(1)
C(15)	9474(1)	1210(1)	6808(1)	25(1)
C(16)	5908(1)	867(1)	7094(1)	27(1)
C(17)	5750(1)	921(1)	7938(1)	26(1)
C(18)	3123(2)	917(1)	9245(1)	33(1)
C(19)	4544(2)	782(2)	10261(1)	45(1)
C(20)	5420(2)	957(1)	9561(1)	26(1)
C(21)	7043(1)	2357(1)	7000(1)	22(1)
C(22)	6271(1)	2944(1)	6578(1)	26(1)
C(23)	6213(2)	3827(1)	6777(1)	31(1)
C(24)	6899(2)	4135(1)	7402(1)	33(1)

C(25)	7644(2)	3552(1)	7834(1)	34(1)
C(26)	7726(2)	2671(1)	7634(1)	29(1)
C(27)	6230(2)	1810(1)	9635(1)	33(1)
C(28)	7347(2)	1686(1)	10190(1)	35(1)
C(29)	7210(3)	2012(2)	10933(1)	57(1)
C(30)	8455(6)	1766(4)	11407(3)	63(2)
C(31)	9552(6)	1302(4)	11118(4)	83(2)
C(32)	9580(5)	1053(4)	10344(4)	64(2)
C(30')	8009(5)	1973(3)	11494(3)	50(1)
C(31')	9195(5)	1517(3)	11346(3)	50(1)
C(32')	9438(5)	1137(4)	10663(3)	52(1)
C(33)	8484(2)	1237(1)	9996(2)	55(1)

X. Circular Dichroism (CD) Data and Calculations.

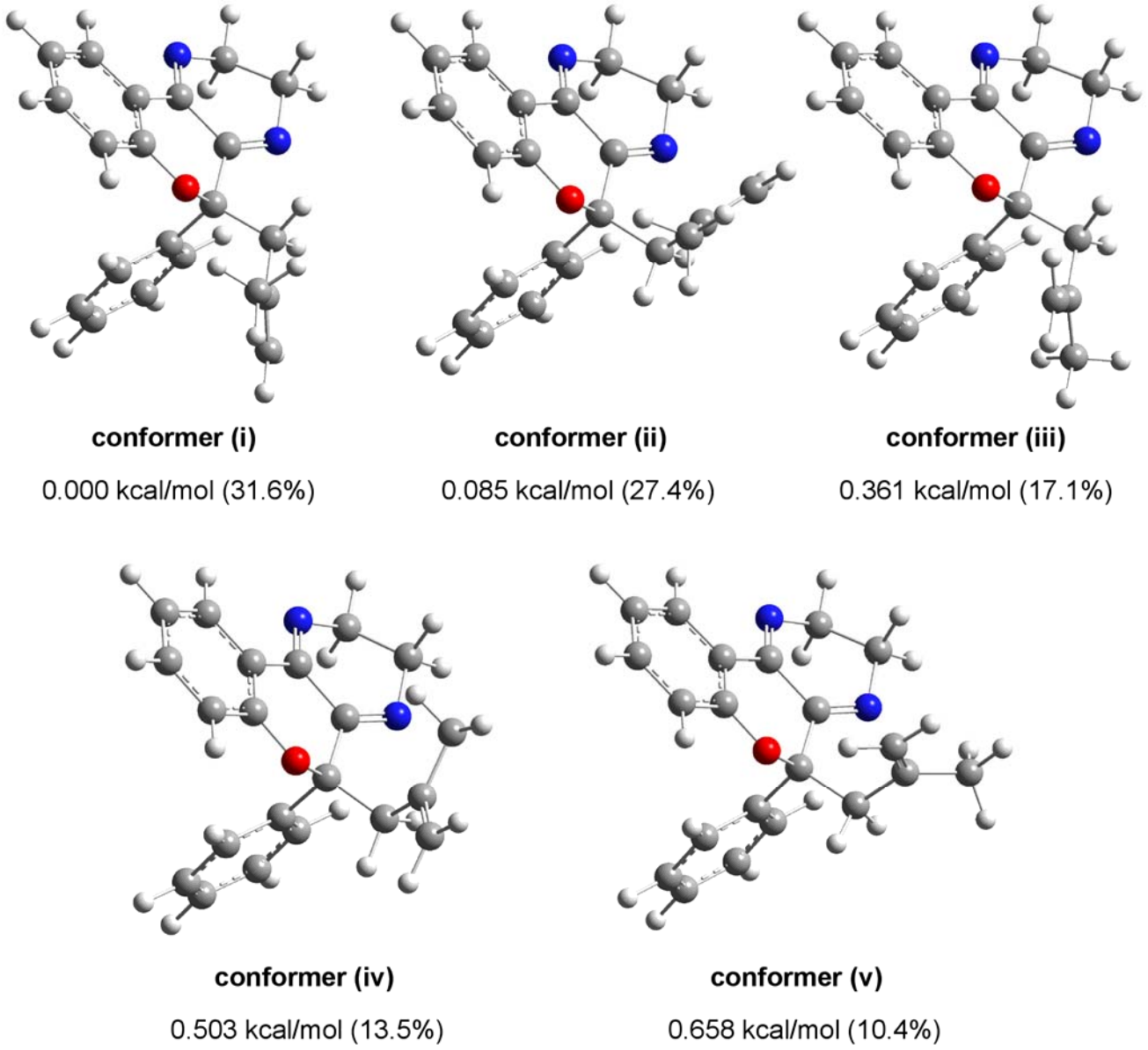
The conformational distribution of **7b** and **25** was calculated using MMFF94 systematic conformational searches using the Spartan02 program. For (*S*)-**7b**, two starting geometries that differ in the orientation of dihydropyrazine ring were submitted to MMFF94 search. The lower energy conformers differing from the most stable one by less than 10 kcal/mol were further fully optimized at the DFT/B3LYP/6-31G(d,p) level as implemented in Gaussian03 software. Conformers within1.5 kcal/mol from the most stable one were taken into account for CD calculations since contributions from conformers with more than 1.5 kcal/mol were found to be significantly smaller. The energies of conformers of (*S*)-**7b** that differ in the orientation of dihydropyrazine ring were all higher than 1.5 kcal/mol. CD spectra were calculated using Gaussian03 software by means of the TDDFT approach, the B3LYP functional, and the 6-31G(d) or aug-cc-pVDZ basis sets. The calculated CD spectra in Δε units were obtained based on velocity-representation rotational strengths by using Gaussian band shapes and 0.15 eV half-width at 1/e of peak height.

Figure 5. The three conformers of (*S*)-**25** taken into account for the CD calculation



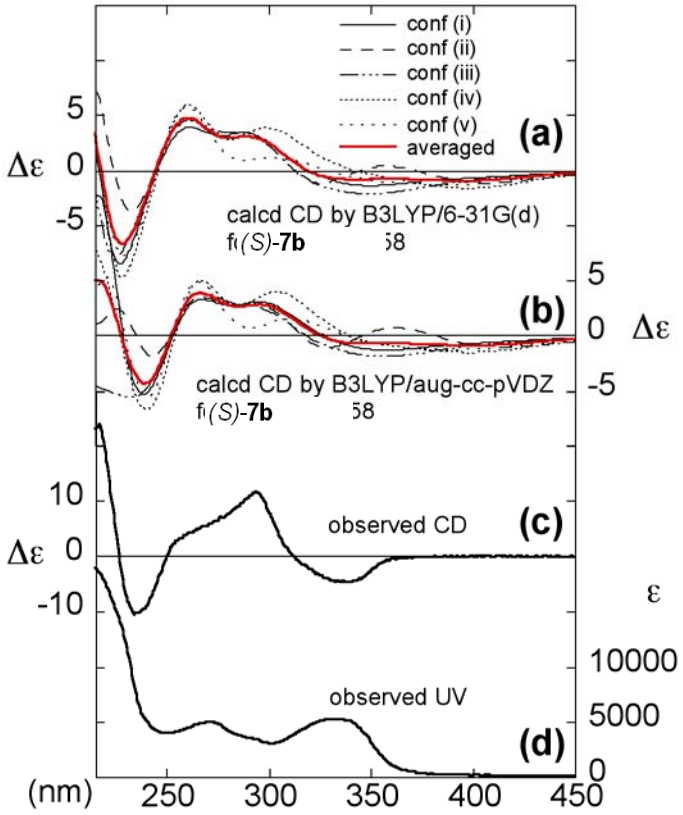
The stable conformers of (*S*)-**25** within 1.5 kcal/mol from the most stable were optimized using DFT/B3LYP/6-31G(d,p) level of theory. These conformers mainly differ mainly in the direction of the propenyl group. Their relative energy Δ*E* and Boltzmann population at 298.15K are shown under each structure. The fourth most stable conformer (not shown), whose relative energy is 1.561 kcal/mol, was not considered in the CD calculation.

Figure 6. The five conformers of (*S*)-**7b** taken into account for the CD calculation



The stable conformers of (*S*)-**7b** within 1.5 kcal/mol from the most stable one after optimization using DFT/B3LYP/6-31G(d,p) level of theory. Their relative energy Δ*E* and Boltzmann population at 298.15K are shown under each structure.

Figure 7. Comparison of the calculated CD spectra and the observed spectrum of **7b**.



(a) Calculated CD spectra at the TDDFT/B3LYP/6-31G(d) for (*S*)-**7b**. The averaged spectrum is a Boltzmann population weighted-average of the five conformers' spectra. (b) Calculated CD spectra at the TDDFT/B3LYP/aug-cc-pVDZ for (*S*)-**7b**. (c) The observed CD and (d) UV spectrum obtained as an acetonitrile solution (0.50 mM). The observed CD spectrum showed a good agreement with the calculated spectra: a negative band in the longer wavelength region, a positive peak at 294 nm, a positive shoulder at around 260 nm, and a negative sharp peak at 234 nm. The observed CD spectrum is normalized to 100 % ee. UV λ_{max} (ε): 218 (18200), 271 (5000), 334 (5300); CD λ_{ext} (Δε): 217 (+24.0), 234 (-10.6), 294 (+11.6), 333 (-4.7).

Optimized Cartesian Coordinates

(S)-**25**-(i)

B3LYP/6-31G(d,p) optimized geometry [E = -2029.32410499 hartrees]

Cartesian coodinates (Angstroms)

Center Number	Atomic Number	Coordinates (Angstroms) X	Y	Z
1	1	-0.794277	-3.625645	1.140359
2	6	-1.699721	-3.235119	0.689043
3	6	-3.988725	-2.183786	-0.528169
4	6	-1.652698	-1.953391	0.115729
5	6	-2.87087	-3.979348	0.66111
6	6	-4.012903	-3.452052	0.042345
7	6	-2.812759	-1.429034	-0.480902
8	1	-2.900067	-4.967051	1.109503
9	1	-4.929816	-4.033126	0.009924
10	1	-4.861629	-1.761226	-1.014158
11	6	-0.423323	-1.168111	0.036432
12	7	0.55357	0.934733	-0.619682
13	7	0.737109	-1.712612	0.359733
14	6	-0.510868	0.18921	-0.440368
15	8	-2.828801	-0.2068	-1.088172
16	6	-1.889756	0.807756	-0.665011
17	6	-2.392262	1.471878	0.634637
18	6	-3.343916	2.78185	2.932654
19	6	-3.726833	1.33045	1.03344
20	6	-1.542207	2.286558	1.394934
21	6	-2.015724	2.936817	2.534372
22	6	-4.196952	1.978487	2.176451
23	1	-4.398276	0.714903	0.447242
24	1	-0.507856	2.416357	1.094356

25	1	-1.342271	3.563062	3.112282
26	1	-5.234023	1.853016	2.474067
27	1	-3.710536	3.284043	3.823004
28	6	-1.894458	1.851523	-1.810381
29	1	-1.223512	2.660086	-1.503489
30	1	-2.907677	2.261795	-1.86205
31	6	-1.478507	1.315956	-3.152852
32	6	-2.276423	1.254781	-4.217931
33	1	-1.924158	0.877838	-5.173463
34	1	-3.312328	1.582349	-4.174824
35	1	-0.446359	0.980589	-3.237027
36	6	1.763922	0.382487	-0.306062
37	6	1.848428	-0.944007	0.207018
38	6	2.941864	1.141388	-0.479626
39	1	2.862641	2.147815	-0.873426
40	6	3.115963	-1.473506	0.546619
41	1	3.170882	-2.482304	0.937735
42	6	4.254803	-0.717145	0.374961
43	6	4.168284	0.606076	-0.147208
44	17	5.603754	1.572746	-0.373559
45	17	5.800291	-1.40635	0.803416

(S)-**25**-(ii)

B3LYP/6-31G(d,p) optimized geometry [E = -2029.32377347 hartrees]

Cartesian coodinates (Angstroms)

Center Number	Atomic Number	Coordinates (Angstroms) X	Y	Z
1	1	0.45048	-3.838253	-0.81574
2	6	1.378228	-3.484539	-0.379611

3	6	3.728254	-2.523001	0.795462
4	6	1.415767	-2.172616	0.120685
5	6	2.496584	-4.303142	-0.300483
6	6	3.668892	-3.820573	0.297144
7	6	2.606308	-1.695432	0.695262
8	1	2.46075	-5.314153	-0.692969
9	1	4.544185	-4.459344	0.36918
10	1	4.626341	-2.133189	1.262757
11	6	0.242192	-1.302101	0.148322
12	7	-0.590658	0.897807	0.668365
13	7	-0.952514	-1.787927	-0.140666
14	6	0.42141	0.074035	0.538072
15	8	2.699332	-0.4425	1.233001
16	6	1.840089	0.611355	0.733866
17	6	2.384832	1.154507	-0.601
18	6	3.388552	2.236139	-2.993706
19	6	1.612016	2.041712	-1.363153
20	6	3.668807	0.823783	-1.047319
21	6	4.164245	1.358488	-2.237742
22	6	2.111194	2.57953	-2.548622
23	1	0.616116	2.312722	-1.027937
24	1	4.284977	0.151757	-0.463226
25	1	5.161856	1.087281	-2.570988
26	1	1.497767	3.265031	-3.126177
27	1	3.775389	2.650632	-3.919958
28	6	1.872226	1.695504	1.841024
29	1	1.44074	1.237545	2.740727
30	1	1.204212	2.505016	1.540798
31	6	3.247558	2.220291	2.145842
32	6	3.593022	3.505629	2.083272
33	1	4.59489	3.839187	2.336678
34	1	2.886961	4.273827	1.777232
35	1	3.982723	1.47992	2.454616
36	6	-1.83556	0.408808	0.388579

37	6	-2.010169	-0.939213	-0.038397
38	6	-2.959625	1.254555	0.510147
39	1	-2.812329	2.276424	0.839038
40	6	-3.310987	-1.403519	-0.345863
41	1	-3.434448	-2.429309	-0.671827
42	6	-4.396078	-0.562792	-0.226027
43	6	-4.219768	0.782607	0.209858
44	17	-5.586549	1.856232	0.369753
45	17	-5.985274	-1.17237	-0.613504

(S)-**25**-(iii)

B3LYP/6-31G(d,p) optimized geometry [E = -2029.32359229 hartrees]

Cartesian coodinates (Angstroms)

Center Number	Atomic Number	Coordinates (Angstroms) X	Y	Z
1	1	0.488001	-3.789636	-0.864332
2	6	1.418417	-3.41899	-0.448379
3	6	3.775711	-2.41435	0.675825
4	6	1.443749	-2.105571	0.049289
5	6	2.5523	-4.21758	-0.391924
6	6	3.728394	-3.71333	0.180499
7	6	2.637509	-1.606131	0.597932
8	1	2.526042	-5.229742	-0.782228
9	1	4.615919	-4.336822	0.235152
10	1	4.675387	-2.00728	1.124879
11	6	0.256686	-1.255382	0.10052
12	7	-0.602802	0.931854	0.630349
13	7	-0.935333	-1.761161	-0.165006
14	6	0.420378	0.124344	0.485519

15	8	2.722595	-0.352204	1.131939
16	6	1.833814	0.684935	0.658292
17	6	2.341757	1.245022	-0.686124
18	6	3.284465	2.354098	-3.091756
19	6	3.624244	0.939292	-1.156283
20	6	1.539955	2.121683	-1.431184
21	6	2.008884	2.672357	-2.623306
22	6	4.089323	1.488051	-2.352784
23	1	4.26177	0.277634	-0.58341
24	1	0.545251	2.373066	-1.077732
25	1	1.373271	3.348723	-3.187422
26	1	5.085738	1.23634	-2.70435
27	1	3.647428	2.77916	-4.022832
28	6	1.862189	1.764281	1.770521
29	1	1.482234	1.304502	2.688736
30	1	1.144286	2.537048	1.477566
31	6	3.21563	2.369673	2.015664
32	6	3.860637	2.318179	3.18041
33	1	4.826207	2.795461	3.318448
34	1	3.445642	1.799019	4.040912
35	1	3.668098	2.896838	1.177502
36	6	-1.844619	0.422105	0.374962
37	6	-2.004865	-0.930135	-0.044058
38	6	-2.97991	1.249783	0.514884
39	1	-2.843448	2.275178	0.837508
40	6	-3.303487	-1.417084	-0.324594
41	1	-3.416094	-2.44598	-0.644607
42	6	-4.399929	-0.594038	-0.186588
43	6	-4.237644	0.7558	0.240841
44	17	-5.618815	1.807193	0.423504
45	17	-5.985955	-1.231476	-0.540904

(S)-**7b**-(i)

B3LYP/6-31G(d,p) optimized geometry [E = -996.99313848 hartrees]

Cartesian coodinates (Angstroms)

Center Number	Atomic Number	Coordinates (Angstroms) X	Y	Z
1	1	4.067204	0.087703	-0.944673
2	6	3.381247	0.86169	-0.61761
3	6	1.570802	2.795474	0.269898
4	6	2.152795	0.456182	-0.068635
5	6	3.704095	2.206743	-0.721284
6	6	2.795758	3.173523	-0.266903
7	6	1.244724	1.437002	0.363033
8	1	4.656283	2.508856	-1.145379
9	1	3.043537	4.22858	-0.338303
10	1	0.853837	3.530222	0.620853
11	6	1.811961	-0.959482	0.117566
12	7	0.219071	-2.366779	1.309968
13	6	2.158587	-3.260447	0.033495
14	6	1.304006	-3.356369	1.293602
15	7	2.621778	-1.897207	-0.225263
16	6	0.48434	-1.24931	0.751454
17	1	1.583741	-3.599717	-0.842769
18	1	1.922968	-3.187188	2.187396
19	1	3.031212	-3.917577	0.107334
20	1	0.865025	-4.353622	1.397396
21	8	0.033101	1.133634	0.920066
22	6	-0.581269	-0.153857	0.657
23	6	-1.199372	-0.171384	-0.752025
24	6	-2.41666	-0.237379	-3.284626
25	6	-1.634399	-1.384291	-1.304317
26	6	-1.387635	1.007611	-1.480777

27	6	-1.988746	0.972804	-2.739744
28	6	-2.240962	-1.416644	-2.559545
29	1	-1.497939	-2.30653	-0.748153
30	1	-1.066903	1.953925	-1.062971
31	1	-2.123918	1.897427	-3.293506
32	1	-2.571669	-2.365627	-2.97182
33	1	-2.883072	-0.262036	-4.265093
34	6	-1.656915	-0.339584	1.759316
35	1	-1.125872	-0.34296	2.718178
36	1	-2.063549	-1.343214	1.626231
37	6	-2.779564	0.679758	1.789978
38	6	-3.975831	0.395097	1.264585
39	1	-4.794431	1.109013	1.295129
40	1	-4.176036	-0.555069	0.778269
41	6	-2.510147	1.993433	2.482059
42	1	-1.697037	2.538502	1.993784
43	1	-3.401195	2.627116	2.495375
44	1	-2.193817	1.827616	3.520142

(S)-**7b**-(ii)

B3LYP/6-31G(d,p) optimized geometry [E = -996.99300345 hartrees]

Cartesian coodinates (Angstroms)

Center Number	Atomic Number	Coordinates (Angstroms) X	Y	Z
1	1	-3.406609	-0.522527	-2.088717
2	6	-3.190996	-0.668746	-1.03582
3	6	-2.567139	-0.994638	1.667114
4	6	-1.948198	-0.22019	-0.55632
5	6	-4.108982	-1.265393	-0.184374

6	6	-3.794112	-1.420716	1.17337
7	6	-1.6407	-0.39922	0.80181
8	1	-5.066701	-1.605264	-0.565221
9	1	-4.509156	-1.882175	1.848216
10	1	-2.303588	-1.111777	2.713056
11	6	-0.979725	0.460594	-1.424042
12	7	1.047831	1.808447	-1.316617
13	6	-0.163328	1.314598	-3.433942
14	6	0.586624	2.348814	-2.601269
15	7	-1.212005	0.633399	-2.676637
16	6	0.286523	0.93677	-0.776258
17	1	0.533633	0.54918	-3.810645
18	1	-0.064899	3.208001	-2.383104
19	1	-0.616002	1.782357	-4.314476
20	1	1.452877	2.738679	-3.145015
21	8	-0.464891	0.01475	1.360977
22	6	0.697124	0.263609	0.533646
23	6	1.398913	-1.073377	0.215648
24	6	2.778284	-3.471024	-0.284018
25	6	2.415456	-1.124382	-0.748133
26	6	1.087116	-2.235494	0.93086
27	6	1.770191	-3.426075	0.678801
28	6	3.101112	-2.313786	-0.993731
29	1	2.670205	-0.229075	-1.306013
30	1	0.311043	-2.207376	1.68617
31	1	1.511624	-4.320039	1.239077
32	1	3.886137	-2.335064	-1.74418
33	1	3.307939	-4.398757	-0.479435
34	6	1.641948	1.142212	1.398875
35	1	2.486686	1.40654	0.760674
36	1	2.022135	0.49099	2.194063
37	6	1.041675	2.395618	2.016891
38	6	1.183102	3.592206	1.437023
39	1	0.779755	4.491648	1.895043

40	1	1.69492	3.704978	0.48741
41	6	0.347895	2.236955	3.348012
42	1	1.034453	1.818388	4.096081
43	1	-0.01784	3.19643	3.72404
44	1	-0.494969	1.543918	3.273083

(S)-**7b**-(iii)

B3LYP/6-31G(d,p) optimized geometry [E = -996.99256304 hartrees]

Cartesian coodinates (Angstroms)

Center Number	Atomic Number	Coordinates (Angstroms) X	Y	Z
1	1	4.068223	0.1601	-0.992166
2	6	3.393139	0.906594	-0.587652
3	6	1.611393	2.767595	0.495211
4	6	2.176813	0.46118	-0.042443
5	6	3.717991	2.255203	-0.591679
6	6	2.824421	3.18456	-0.039579
7	6	1.282813	1.40662	0.48742
8	1	4.66048	2.588679	-1.014007
9	1	3.074636	4.241489	-0.033366
10	1	0.904172	3.471091	0.921686
11	6	1.833624	-0.963741	0.039998
12	7	0.250163	-2.455548	1.140994
13	6	2.166536	-3.252886	-0.230828
14	6	1.329903	-3.444805	1.03046
15	7	2.632159	-1.875265	-0.389647
16	6	0.514305	-1.297801	0.671182
17	1	1.577498	-3.520672	-1.122403
18	1	1.962903	-3.348537	1.925236

19	1	3.037144	-3.916805	-0.222114
20	1	0.887963	-4.445642	1.062147
21	8	0.085643	1.062145	1.048847
22	6	-0.543168	-0.191356	0.683165
23	6	-1.178795	-0.074233	-0.713146
24	6	-2.453343	0.120611	-3.210574
25	6	-1.435674	1.177798	-1.283906
26	6	-1.571691	-1.227834	-1.406193
27	6	-2.205843	-1.130857	-2.644796
28	6	-2.066933	1.272424	-2.524875
29	1	-1.150521	2.075906	-0.750402
30	1	-1.387049	-2.204731	-0.97068
31	1	-2.503687	-2.03507	-3.167791
32	1	-2.258051	2.251602	-2.954475
33	1	-2.942989	0.197077	-4.176924
34	6	-1.597604	-0.444066	1.791849
35	1	-1.049096	-0.449651	2.738422
36	1	-1.977129	-1.458119	1.645603
37	6	-2.740759	0.554379	1.855098
38	6	-2.618605	1.704744	2.525211
39	1	-3.439055	2.414639	2.586828
40	1	-1.6954	1.975651	3.027406
41	6	-4.028314	0.161948	1.172925
42	1	-4.791218	0.938028	1.279691
43	1	-3.875644	-0.025271	0.104608
44	1	-4.425821	-0.767703	1.601403

(S)-**7b**-(iv)

B3LYP/6-31G(d,p) optimized geometry [E = -996.99233700 hartrees]

Cartesian coodinates (Angstroms)

Center Number	Atomic Number	Coordinates (Angstroms) X	Y	Z
1	1	3.408017	1.183989	-1.753494
2	6	3.10482	1.188968	-0.712072
3	6	2.265885	1.14198	1.952553
4	6	1.912061	0.524958	-0.376432
5	6	3.868133	1.815623	0.261631
6	6	3.446901	1.782801	1.599187
7	6	1.493354	0.518571	0.964569
8	1	4.788478	2.323252	-0.008699
9	1	4.042481	2.265374	2.36866
10	1	1.921022	1.106962	2.980514
11	6	1.114886	-0.195249	-1.376811
12	7	-0.684774	-1.832618	-1.540629
13	7	0.569793	-0.966404	-3.50786
14	6	-0.062953	-2.175139	-2.825756
15	8	1.45317	-0.215164	-2.617093
16	6	-0.105298	-0.909292	-0.8743
17	6	-0.212262	-0.280198	-3.869449
18	6	0.69941	-2.94429	-2.630829
19	6	1.142534	-1.276298	-4.388113
20	6	-0.821048	-2.636774	-3.466155
21	6	0.356538	-0.108381	1.388394
22	6	-0.697443	-0.419349	0.448386
23	1	-1.540584	0.842655	0.169495
24	1	-3.176083	3.084562	-0.275379
25	1	-1.439786	1.970391	0.992591
26	1	-2.476807	0.847083	-0.873607
27	1	-3.289887	1.959191	-1.092135
28	6	-2.249344	3.084387	0.767217
29	1	-0.730293	1.97483	1.811093
30	1	-2.569094	-0.023264	-1.515149
31	6	-4.010161	1.94548	-1.905103

32	6	-2.154157	3.953656	1.411588
33	1	-3.804447	3.953075	-0.449288
34	1	-1.581985	-1.477271	1.162492
35	1	-2.209721	-1.926228	0.385202
36	6	-2.239798	-0.94011	1.85006
37	6	-0.852708	-2.560977	1.933525
38	6	-1.111817	-2.740907	3.232793
39	1	-0.639264	-3.536805	3.801749
40	6	-1.805086	-2.102089	3.772678
41	1	0.116054	-3.451042	1.197089
42	6	-0.346702	-3.892546	0.307833
43	6	0.987397	-2.884716	0.84737
44	17	0.478467	-4.255015	1.843381

(S)-**7b**-(v)

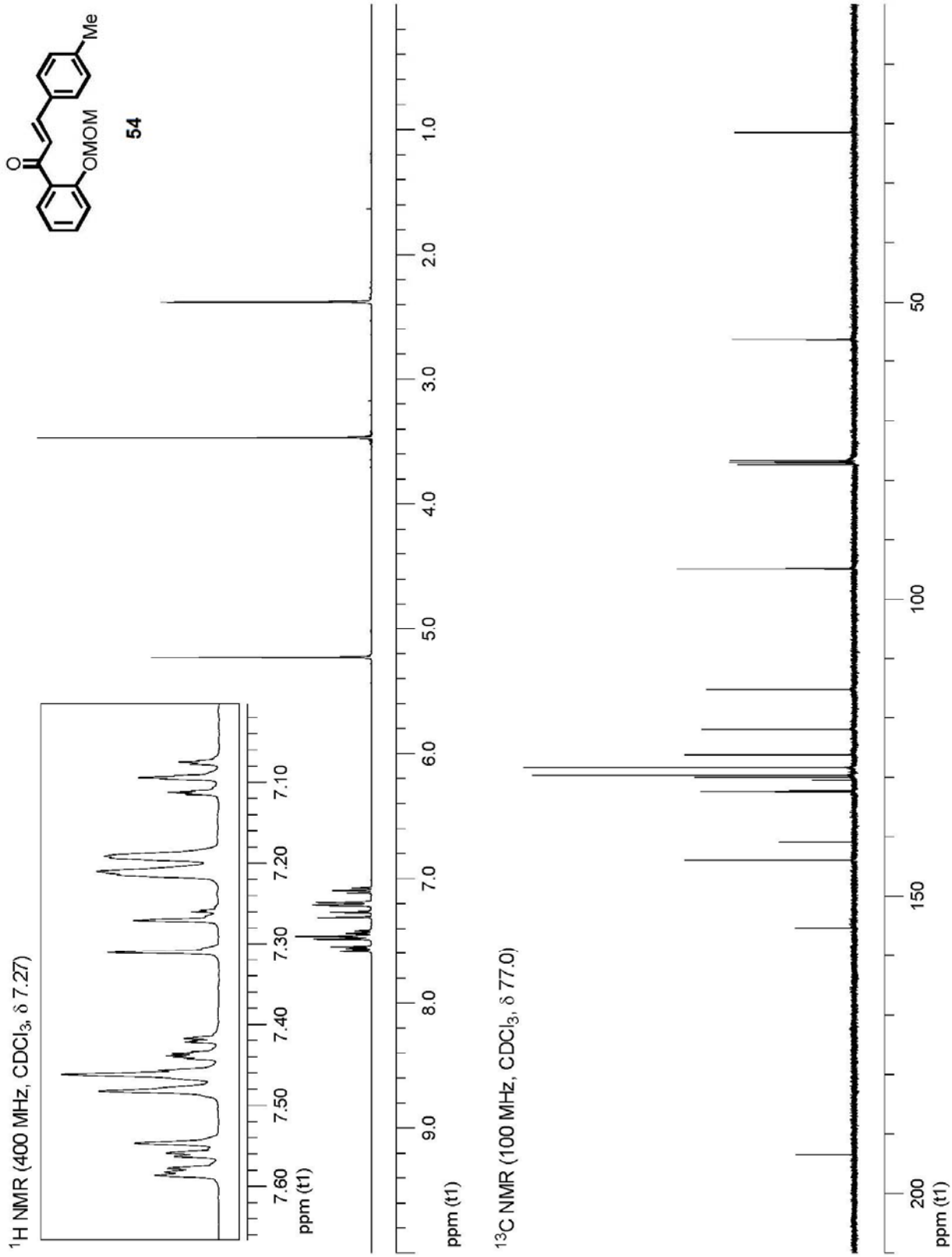
B3LYP/6-31G(d,p) optimized geometry [E = -996.99208920 hartrees]

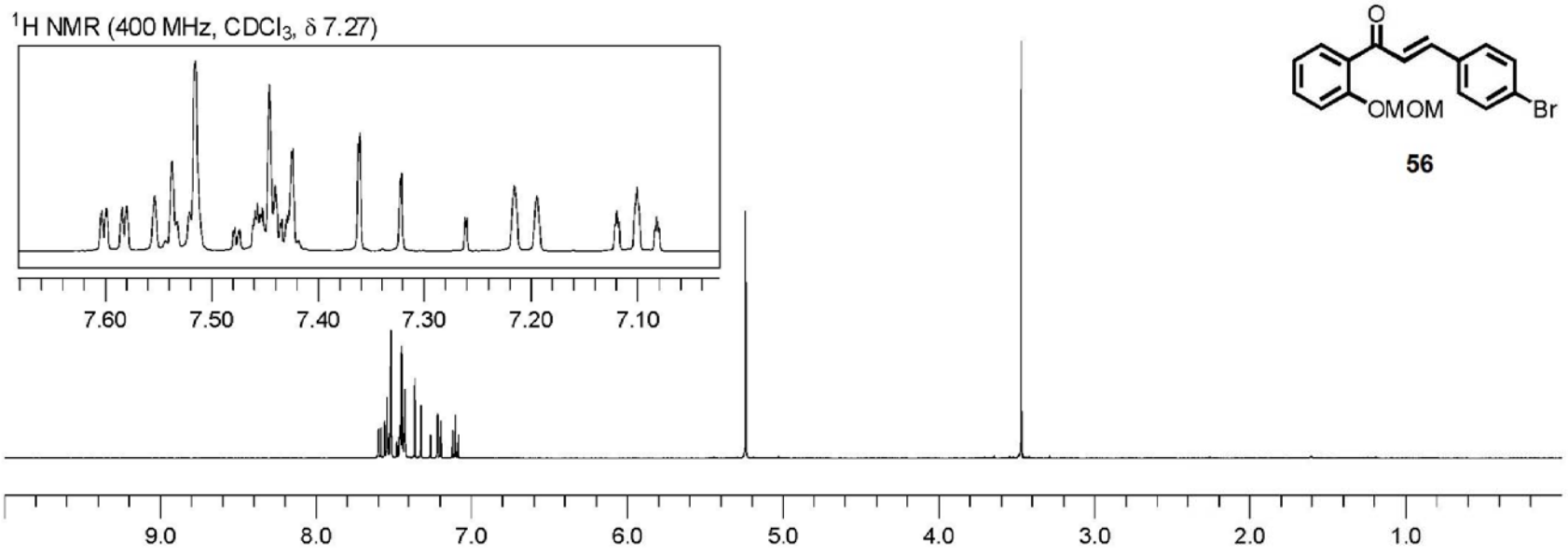
Cartesian coodinates (Angstroms)

Center Number	Atomic Number	Coordinates (Angstroms) X	Y	Z
1	1	-3.327356	1.089304	-1.99104
2	6	-3.203033	0.820402	-0.94759
3	6	-2.79929	0.147326	1.73334
4	6	-1.891881	0.661498	-0.466732
5	6	-4.294076	0.650473	-0.108366
6	6	-4.086204	0.320124	1.238708
7	6	-1.701023	0.31057	0.879793
8	1	-5.301951	0.778032	-0.490081
9	1	-4.934857	0.191283	1.904178
10	1	-2.618858	-0.11449	2.770665
11	6	-0.718163	0.892502	-1.317134

12	7	1.689647	1.237693	-1.158829
13	6	0.41153	1.415955	-3.286242
14	6	1.517261	1.991392	-2.407539
15	7	-0.839387	1.215292	-2.555743
16	6	0.622504	0.74179	-0.662132
17	1	0.722611	0.444855	-3.703018
18	1	1.286152	3.032608	-2.137677
19	1	0.216106	2.072647	-4.140301
20	1	2.474343	2.006635	-2.938333
21	8	-0.466267	0.138363	1.438154
22	6	0.685525	-0.116698	0.59844
23	6	0.703223	-1.607992	0.19827
24	6	0.841837	-4.337676	-0.459535
25	6	-0.07794	-2.545351	0.883761
26	6	1.561213	-2.055711	-0.815875
27	6	1.630682	-3.41002	-1.140957
28	6	-0.010135	-3.899862	0.554116
29	1	-0.737713	-2.215125	1.676929
30	1	2.178912	-1.340865	-1.350206
31	1	2.300571	-3.738603	-1.93036
32	1	-0.626456	-4.613123	1.093835
33	1	0.89172	-5.391816	-0.715854
34	6	1.914026	0.1816	1.492773
35	1	2.793908	-0.165711	0.947077
36	1	1.806215	-0.474036	2.364352
37	6	2.129512	1.622367	1.943861
38	6	1.253964	2.278076	2.712678
39	1	1.4486	3.298396	3.032502
40	1	0.324451	1.827707	3.040423
41	6	3.434977	2.246939	1.518123
42	1	4.286842	1.669704	1.902818
43	1	3.516889	2.245613	0.426211
44	1	3.531139	3.272975	1.884094

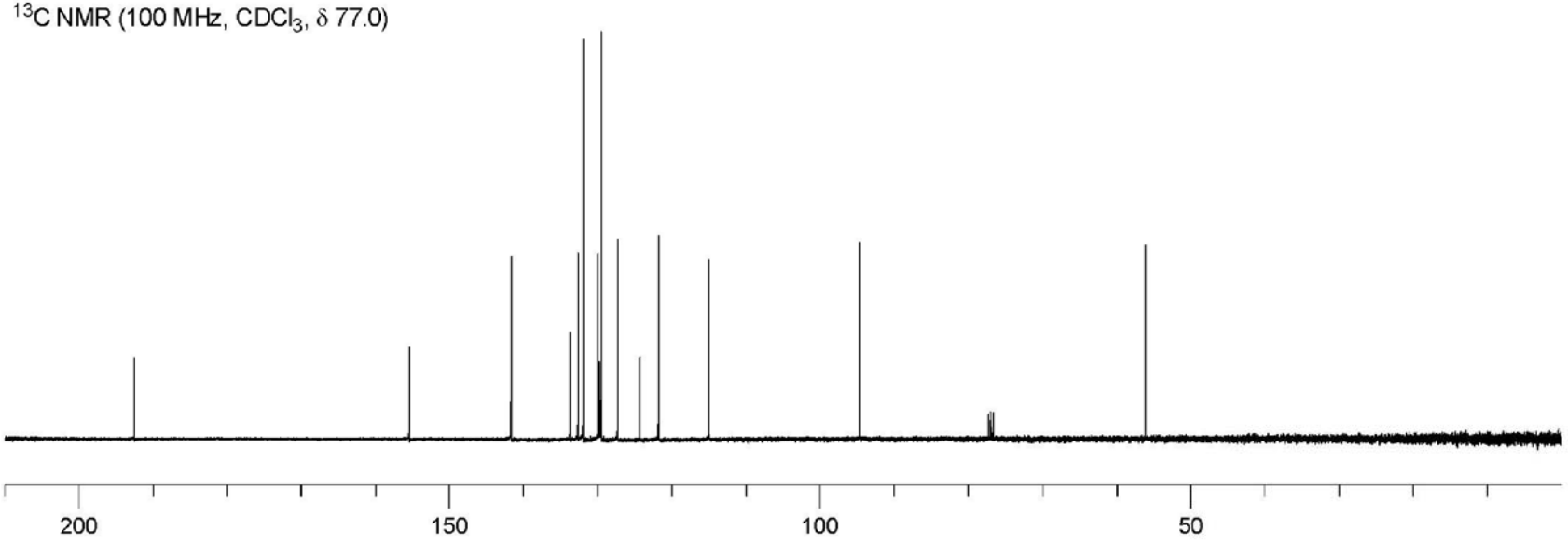
XI. Representative Spectral Data: ^{1}H and ^{13}C NMR of Select Compounds.



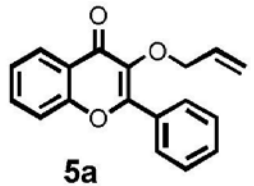

^{1}H NMR (400 MHz, $CDCl_3$, δ 7.27)
7.60
7.50
7.40
7.30
7.20
7.10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

O
OMOM
Br

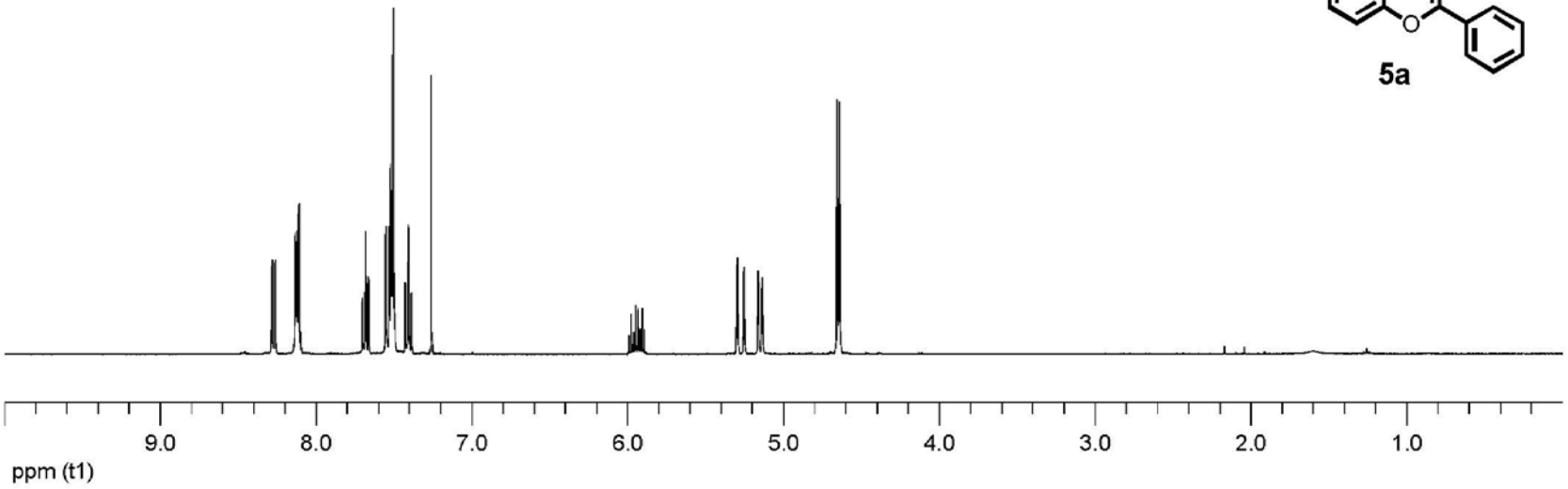
56


^{13}C NMR (100 MHz, $CDCl_3$, δ 77.0)
200
150
100
50

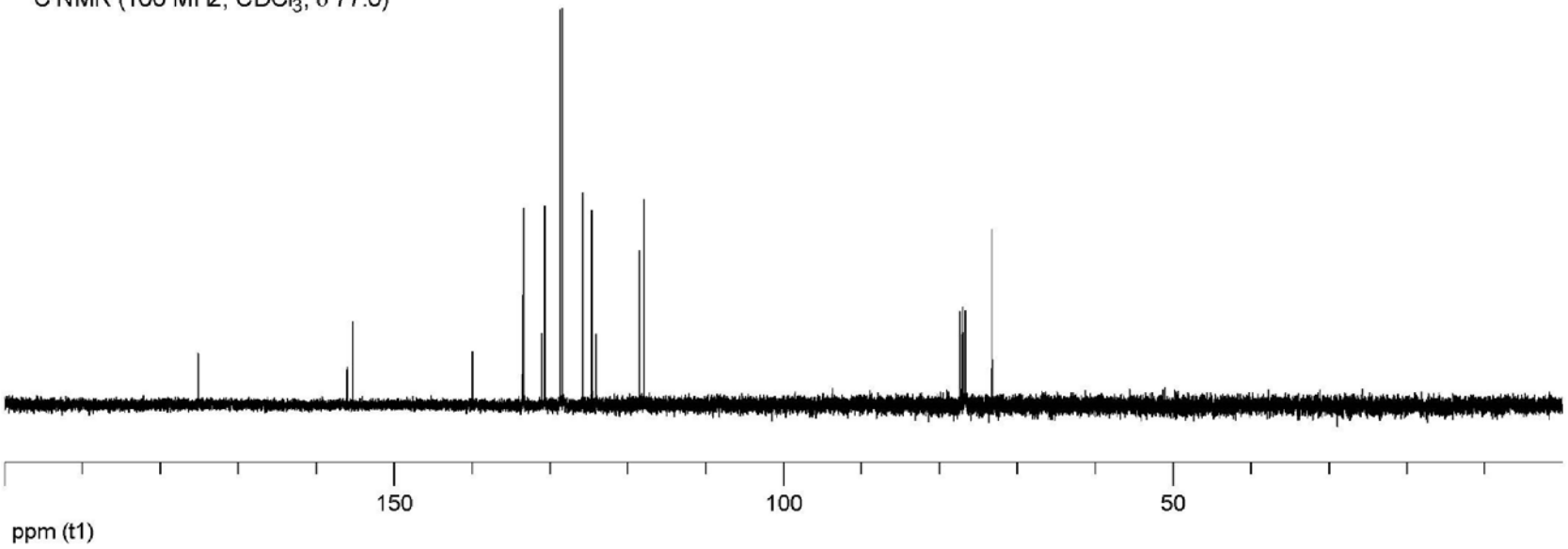
^{1}H NMR (400 MHz, $CDCl_3$, δ 7.27)



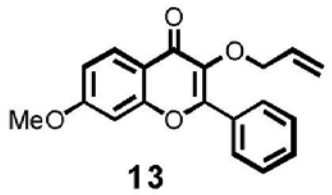
5a



^{13}C NMR (100 MHz, $CDCl_3$, δ 77.0)

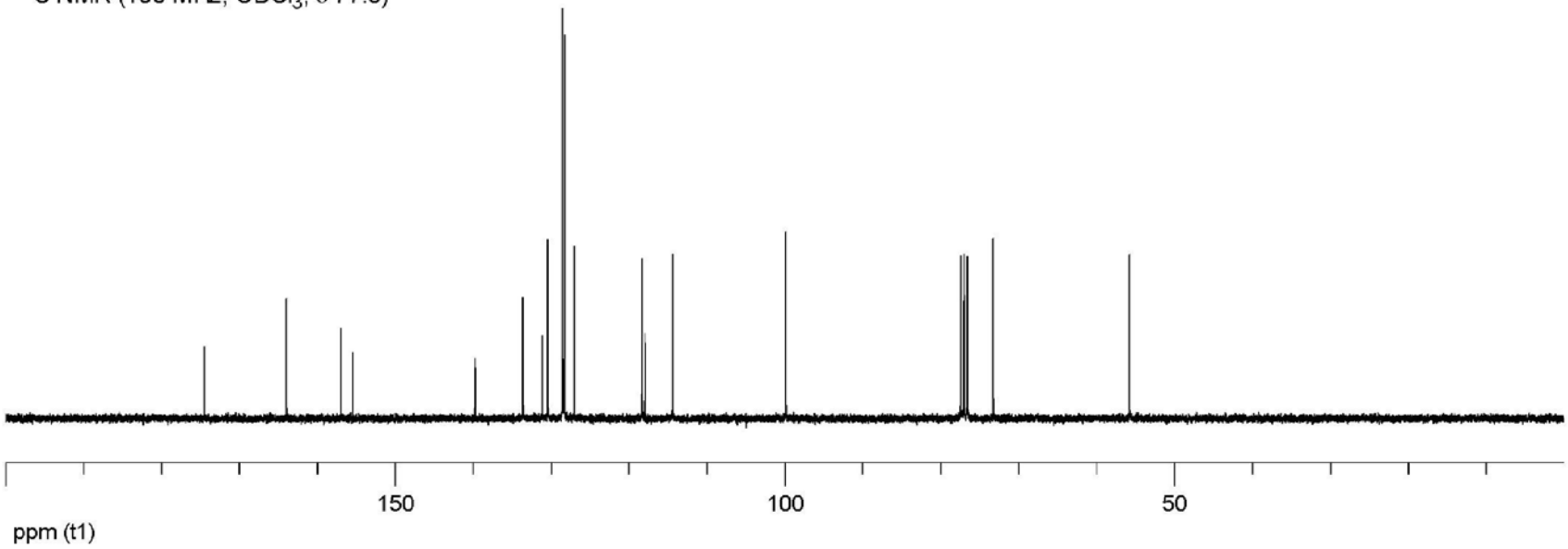


^{1}H NMR (400 MHz, $CDCl_3$, δ 7.27)

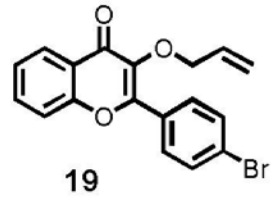


13

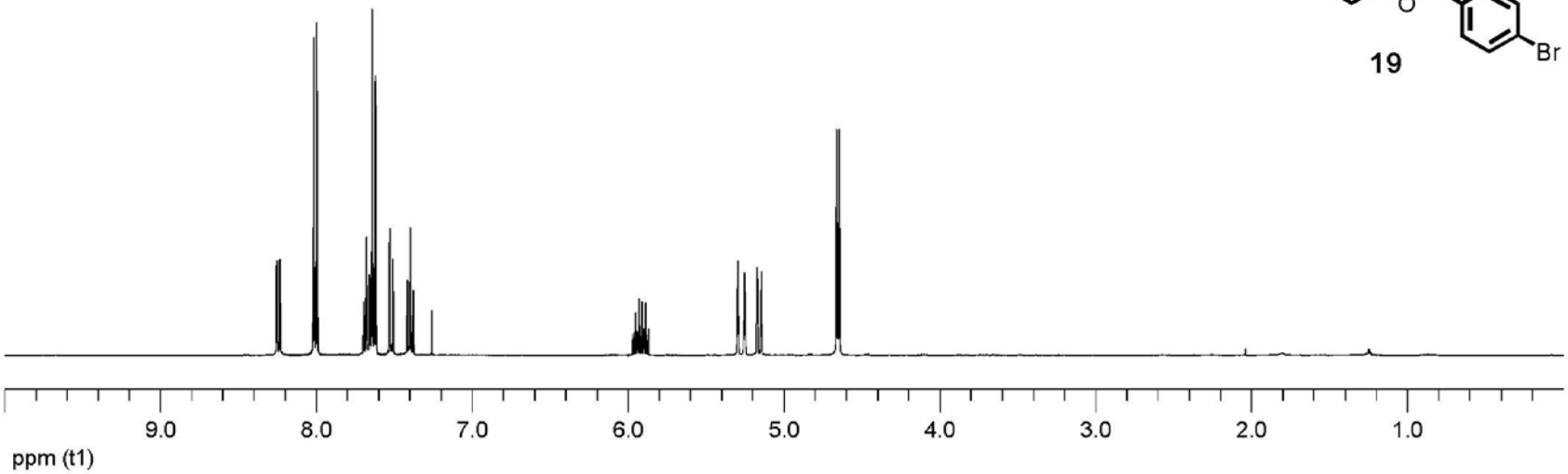
^{13}C NMR (100 MHz, $CDCl_3$, δ 77.0)



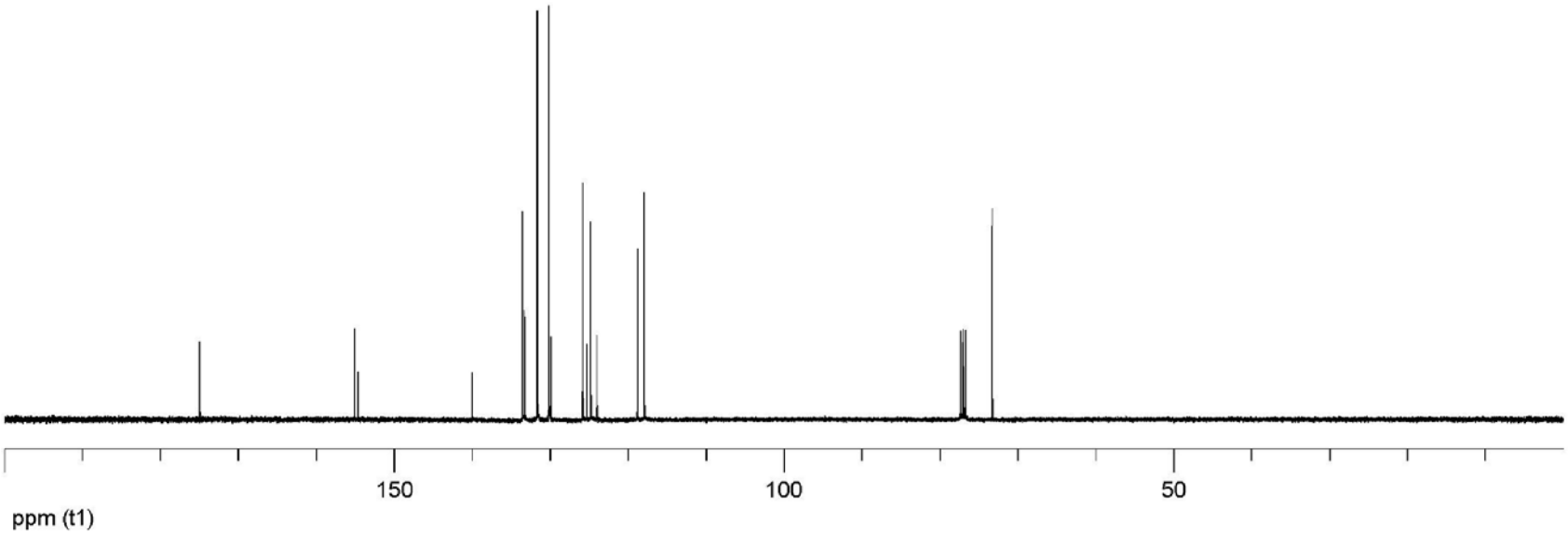
^{1}H NMR (400 MHz, $CDCl_3$, δ 7.27)

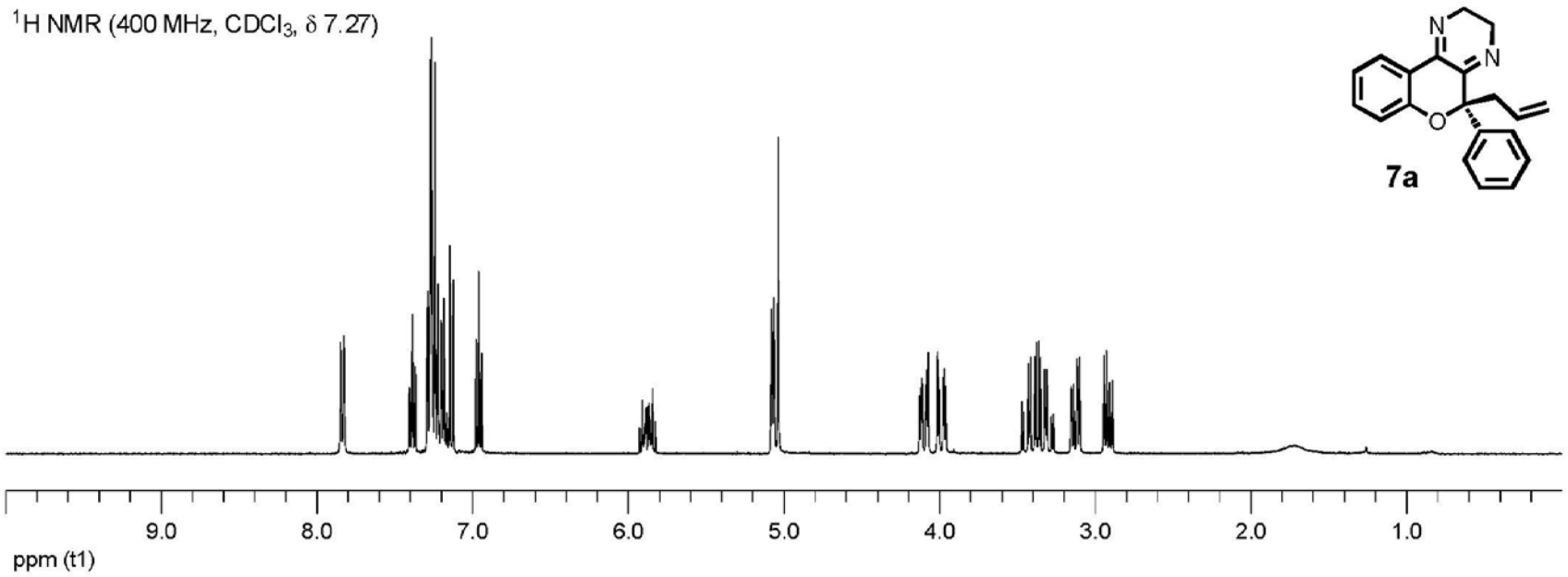


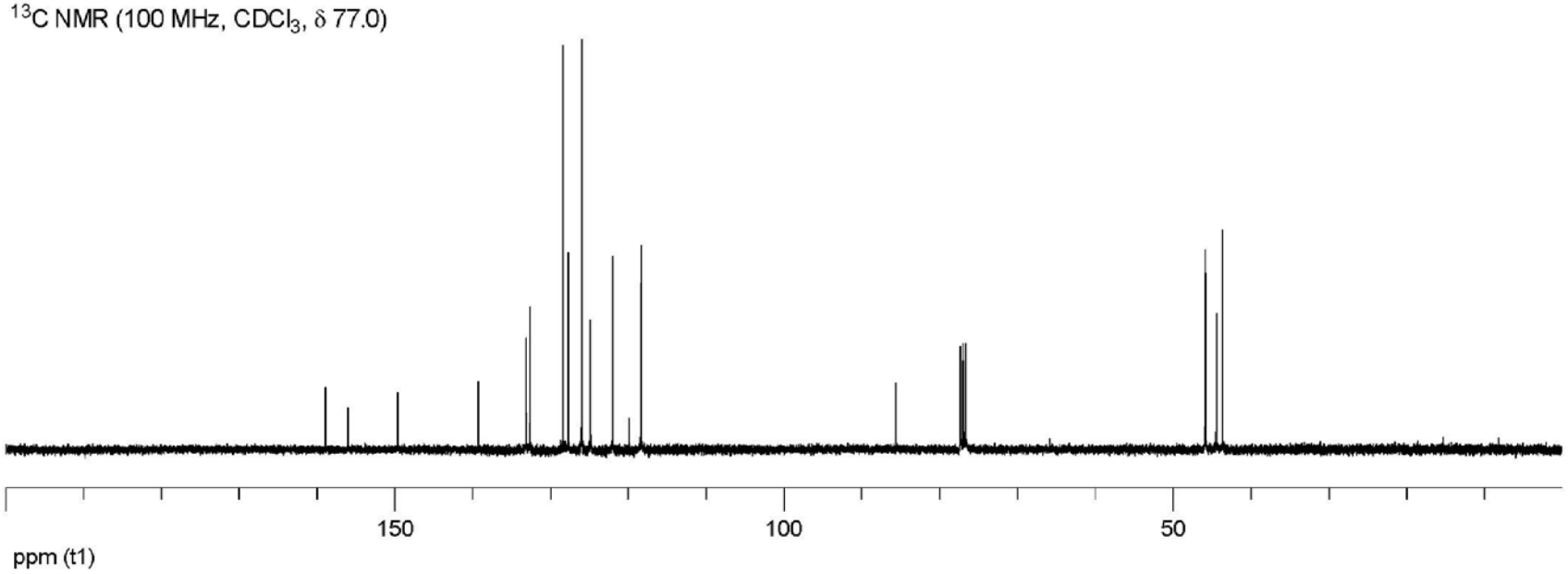
19



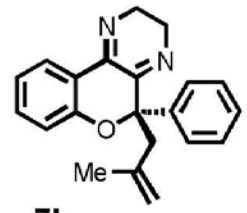
^{13}C NMR (100 MHz, $CDCl_3$, δ 77.0)




^{1}H NMR (400 MHz, $CDCl_3$, δ 7.27)
N
N
O
7a
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (t1)

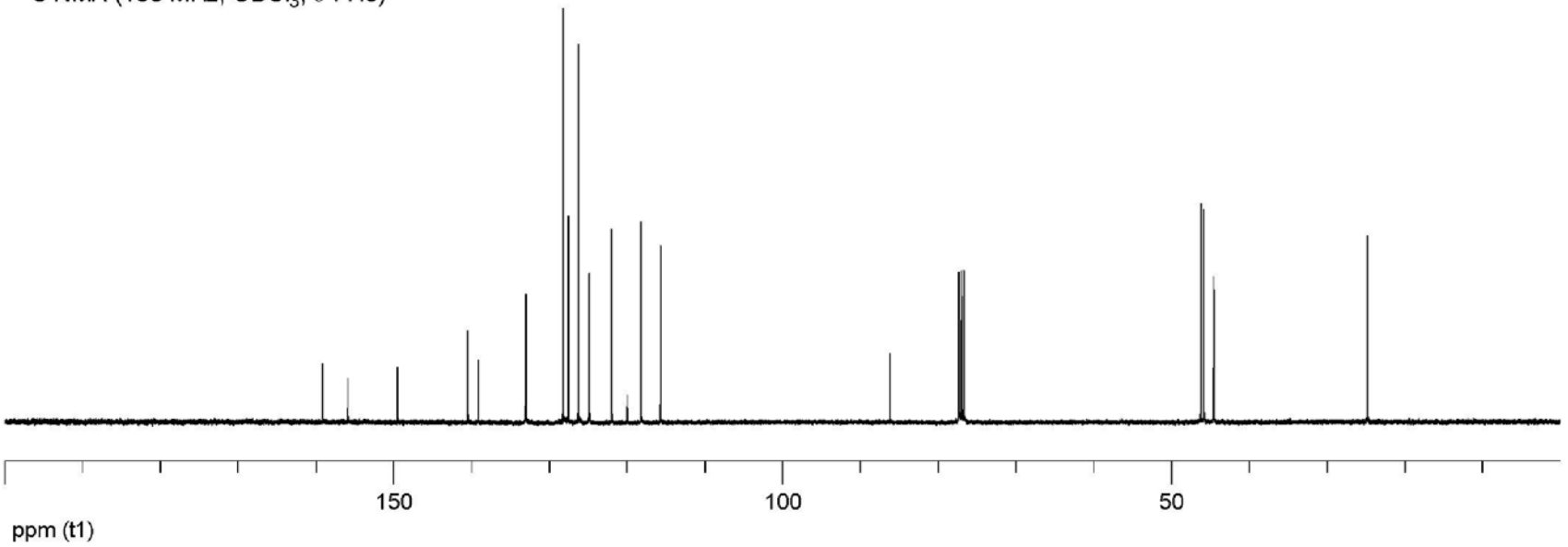

^{13}C NMR (100 MHz, $CDCl_3$, δ 77.0)
150
100
50
ppm (t1)

^{1}H NMR (400 MHz, $CDCl_3$, δ 7.27)

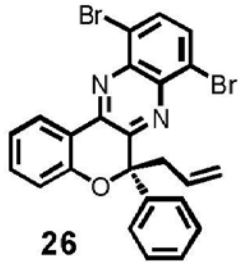


7b

^{13}C NMR (100 MHz, $CDCl_3$, δ 77.0)

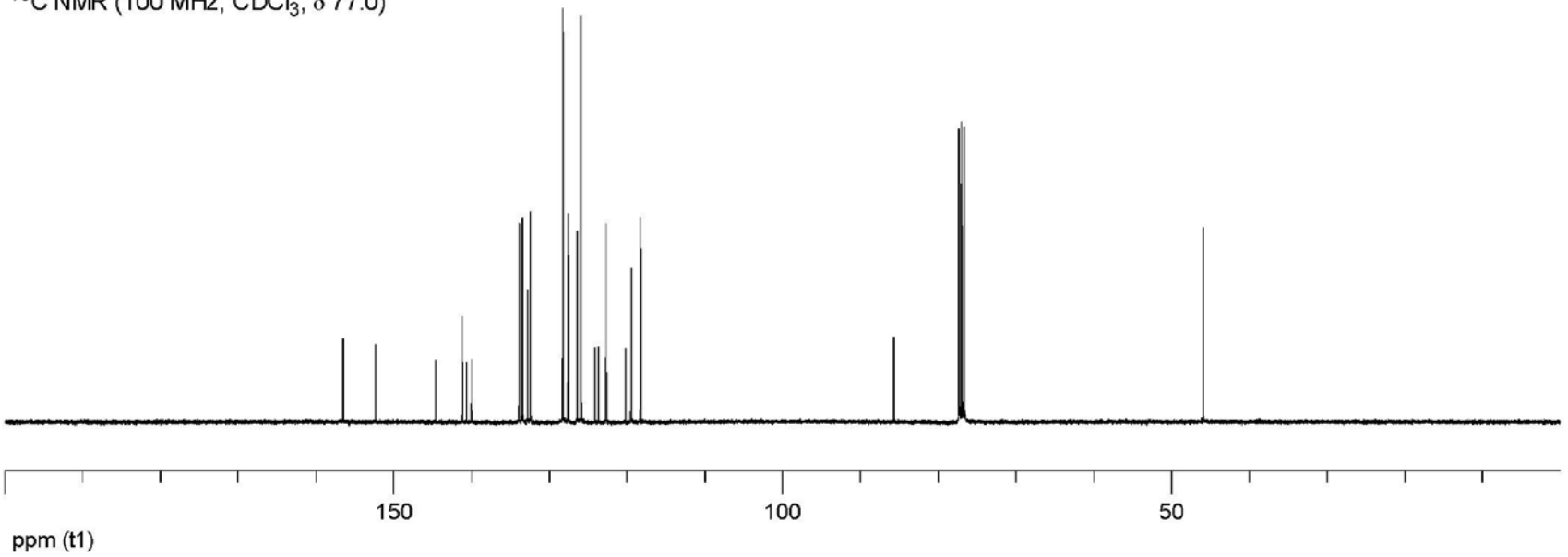


^{1}H NMR (400 MHz, $CDCl_3$, δ 7.27)

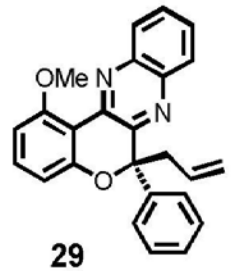


26

^{13}C NMR (100 MHz, $CDCl_3$, δ 77.0)



^{1}H NMR (400 MHz, $CDCl_3$, δ 7.27)



29

^{13}C NMR (100 MHz, $CDCl_3$, δ 77.0)

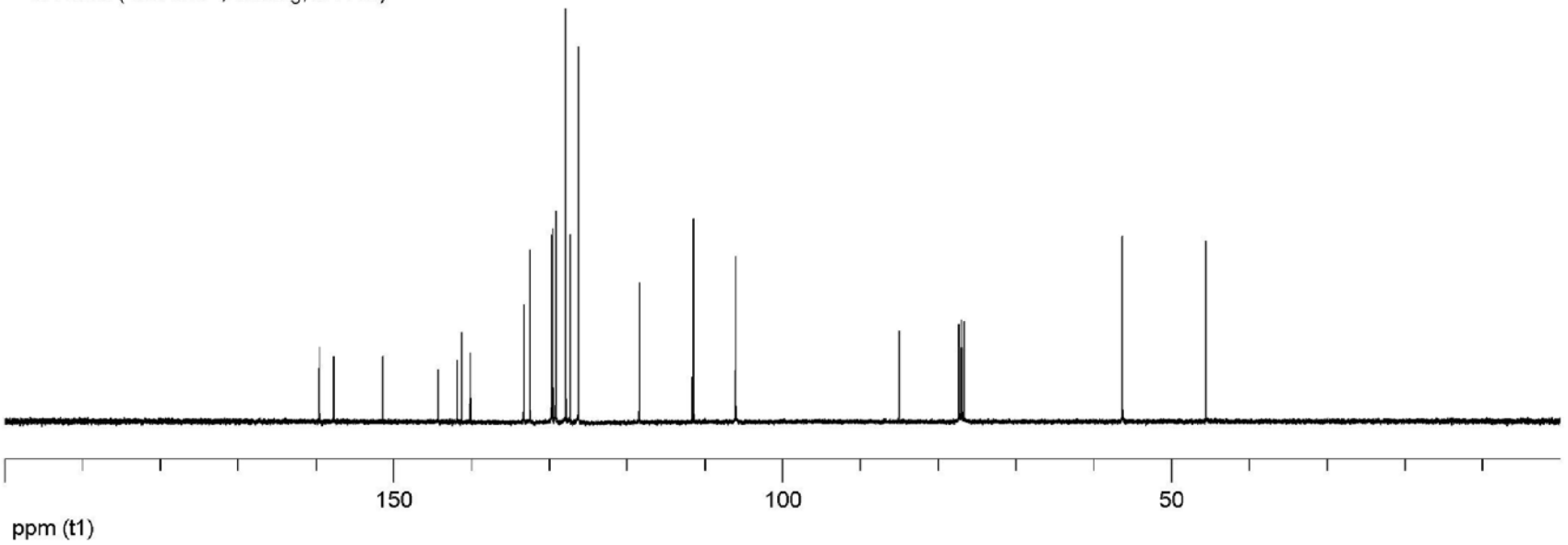


Figure 8. Proton NMR spectrum for **53** (400 MHz, CD_2Cl_2)

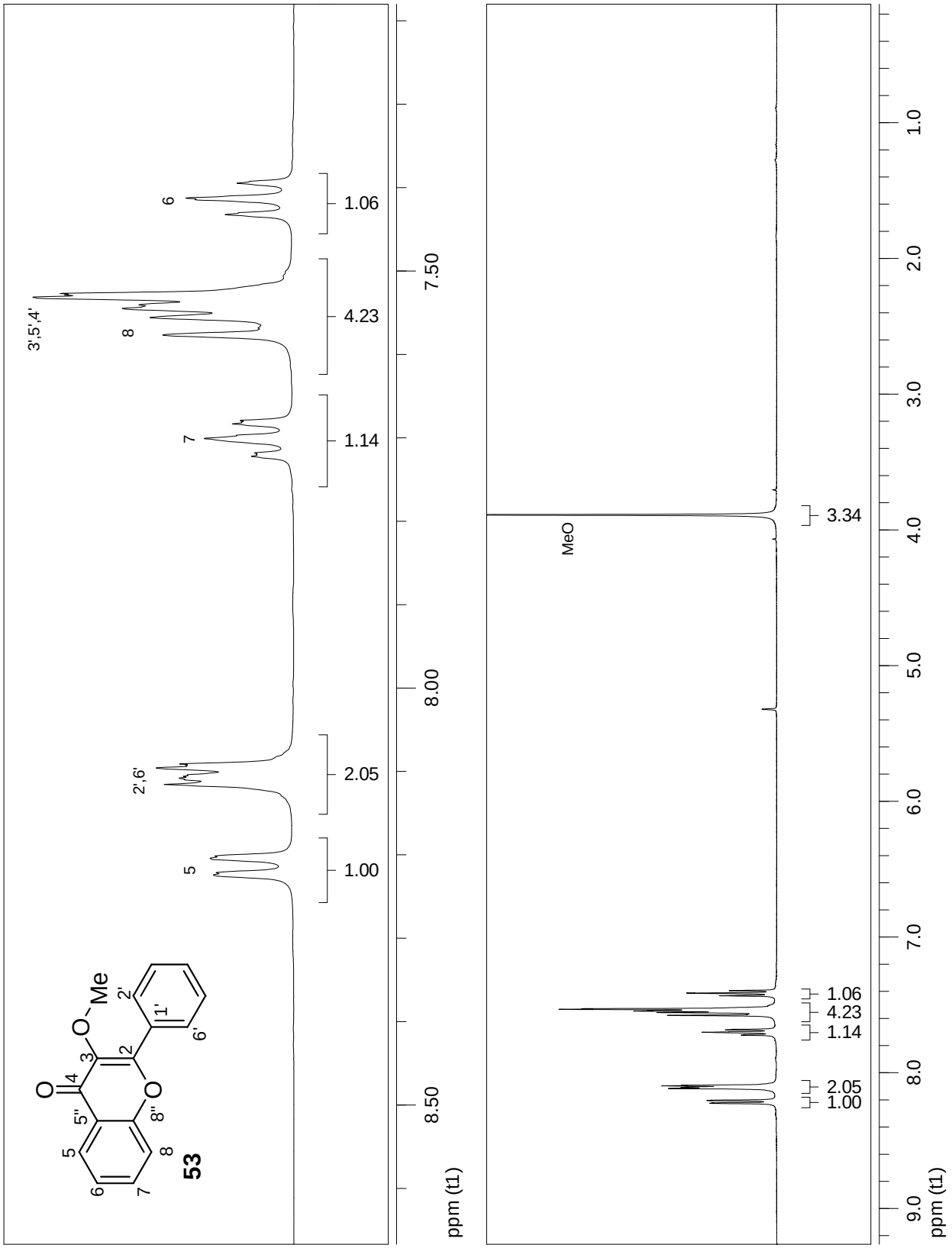


Figure 9. Carbon NMR spectrum for **53** (400 MHz, CD_2Cl_2)

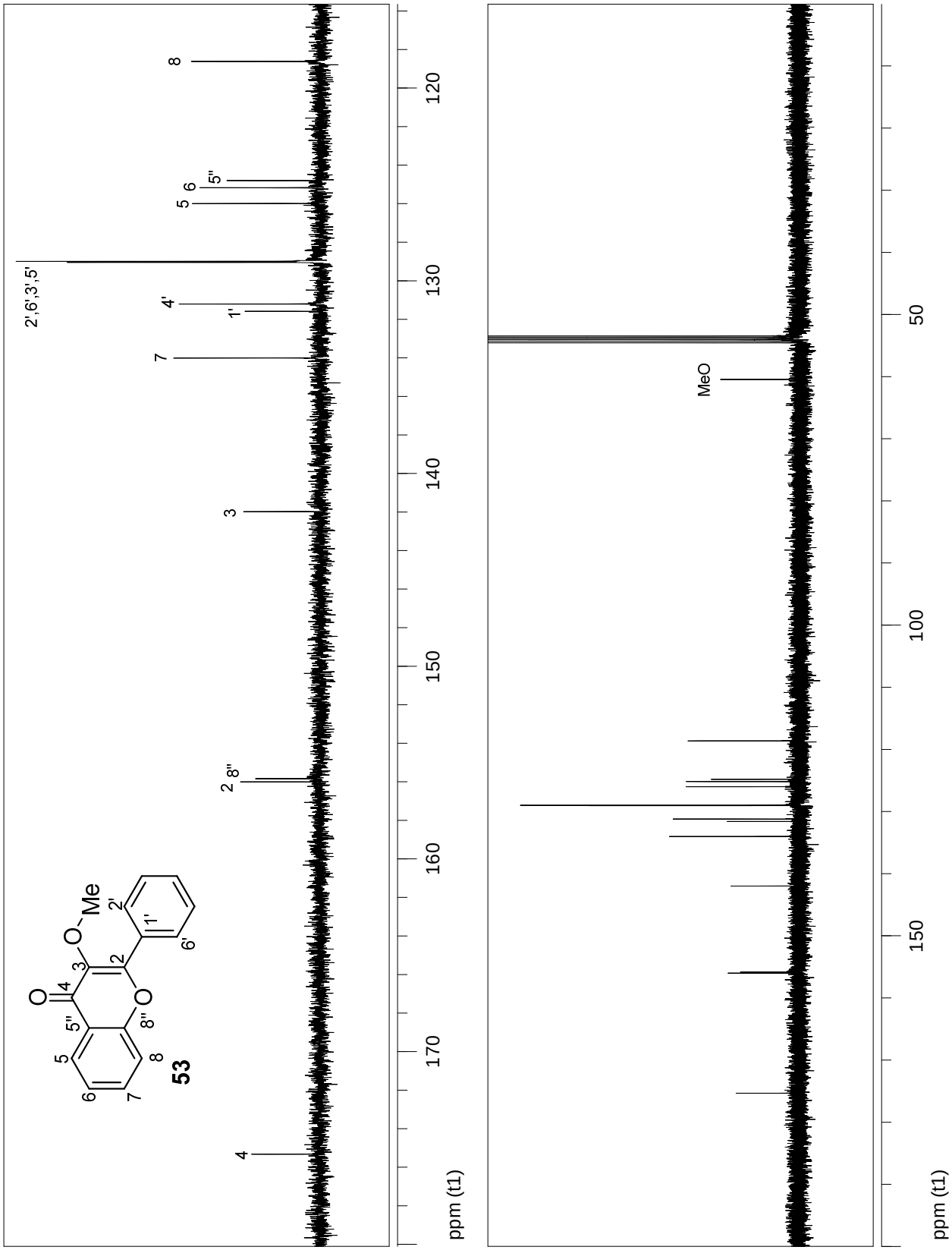


Figure 10. gCOSY NMR spectrum for **53** (400 MHz, CD_2Cl_2)

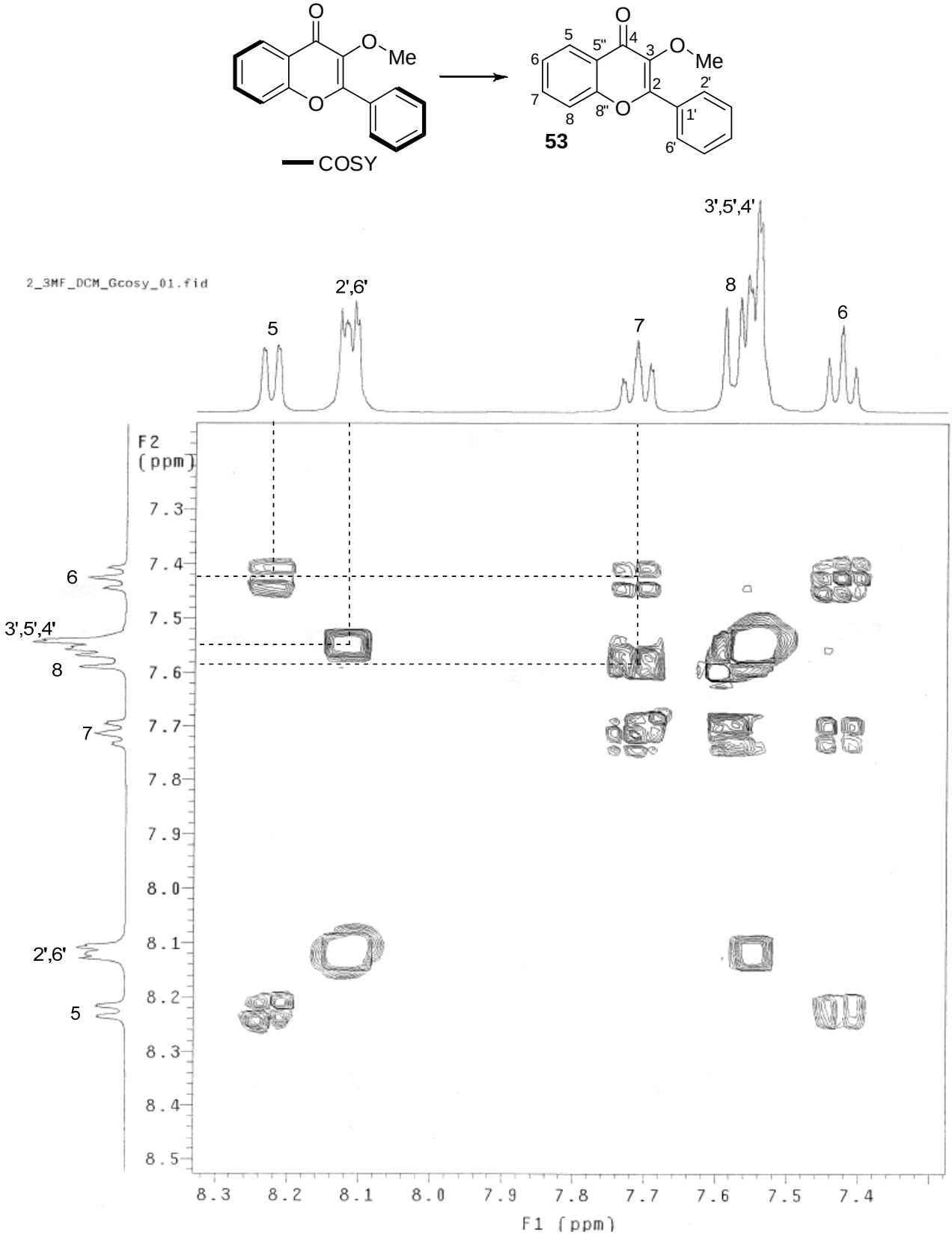
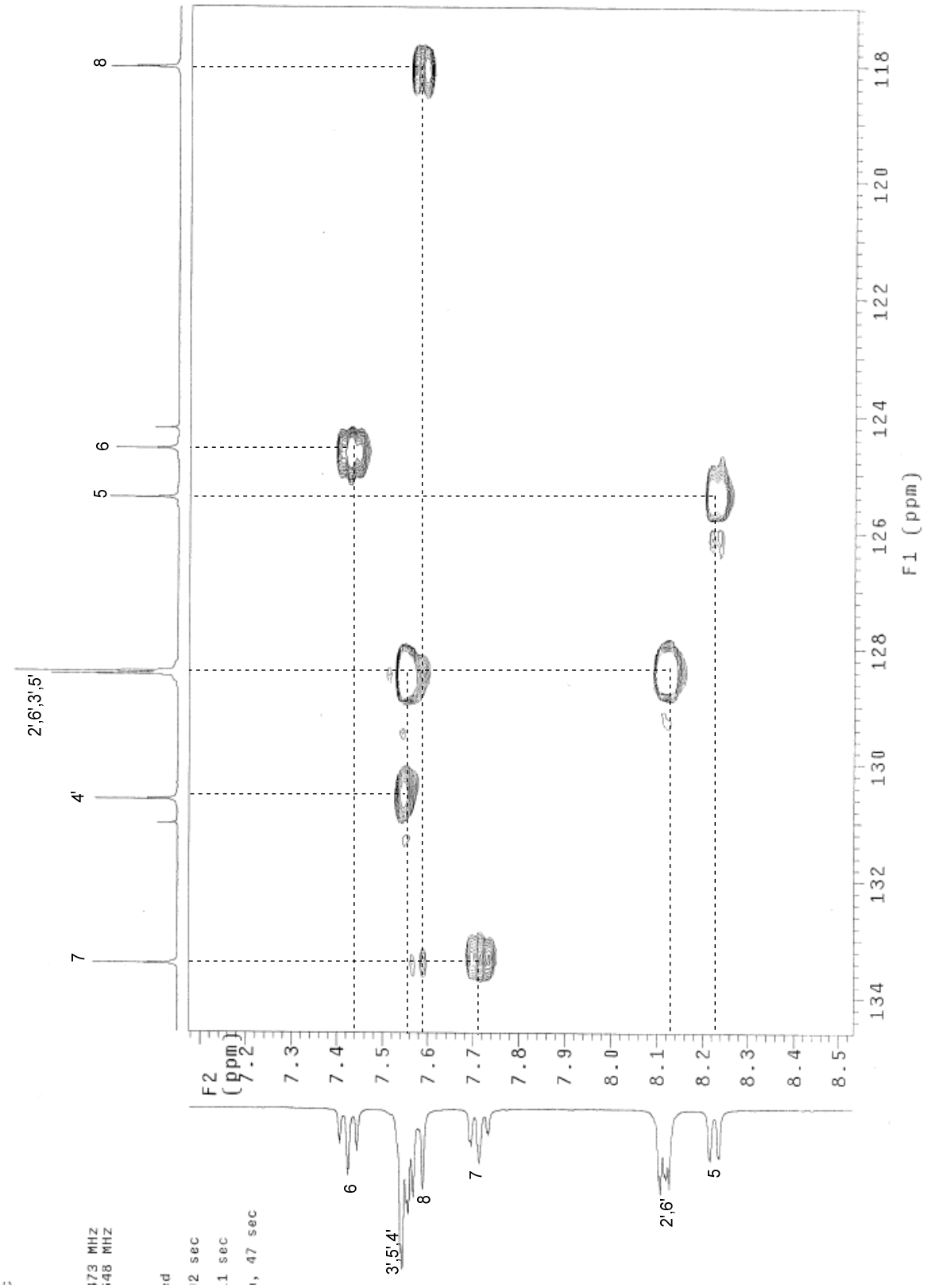


Figure 11. gHSQC NMR spectrum for **53** (400 MHz, CD_2Cl_2)



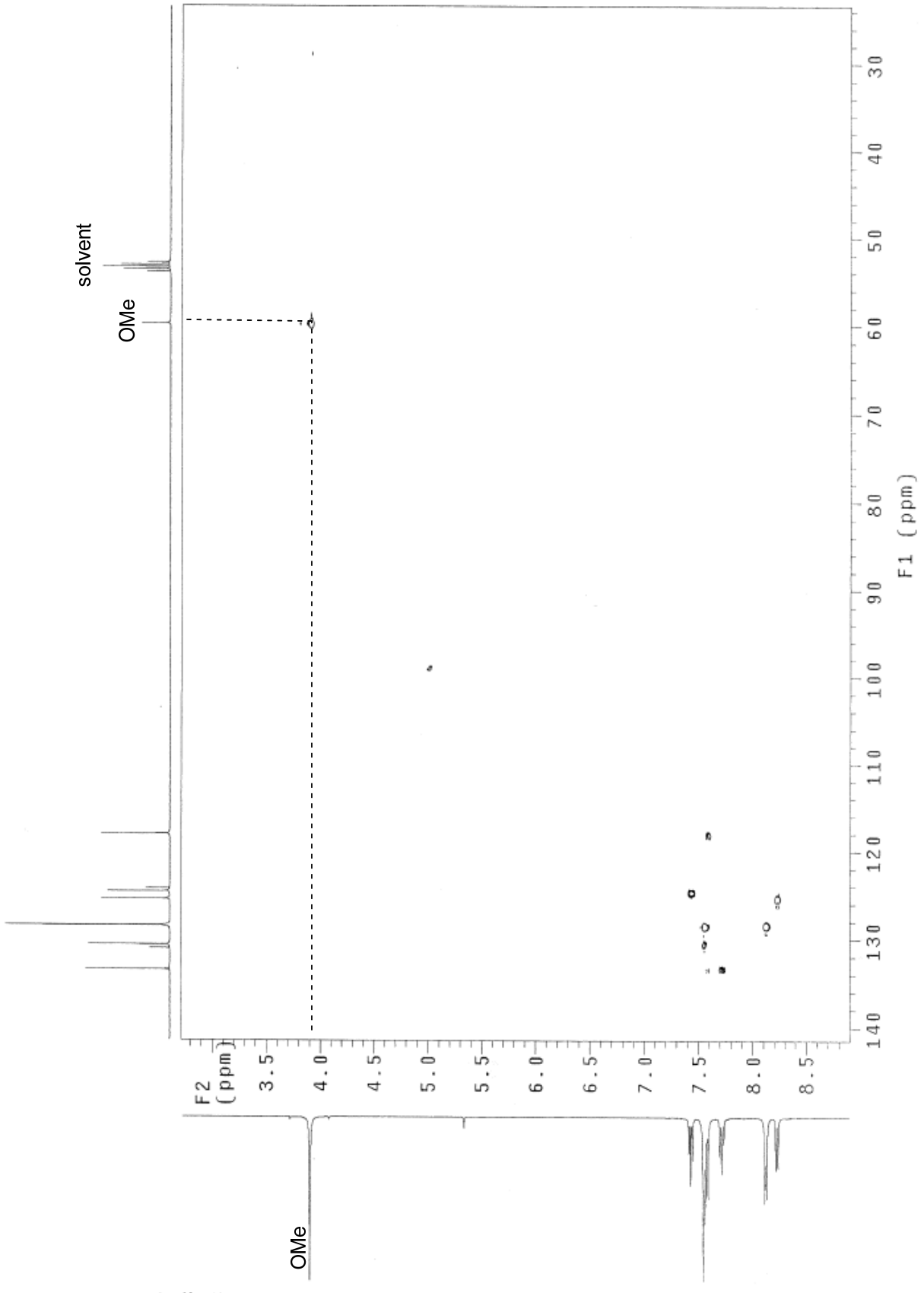
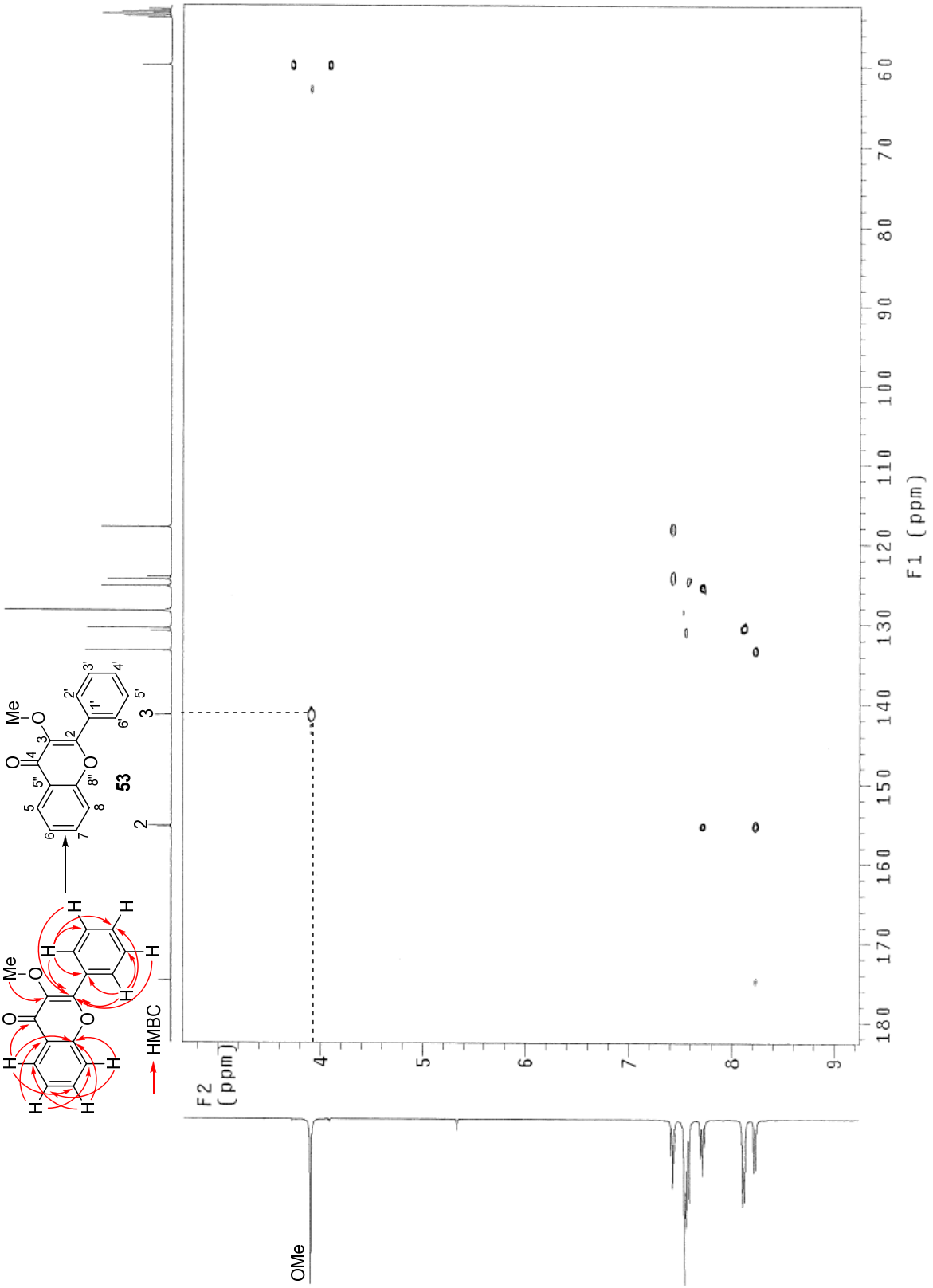

solvent
OMe
OMe
F2 (ppm)
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
F1 (ppm)
30
40
50
60
70
80
90
100
110
120
130
140

Figure 12. gHMBC NMR spectrum for **53**(400 MHz, CD_2Cl_2)



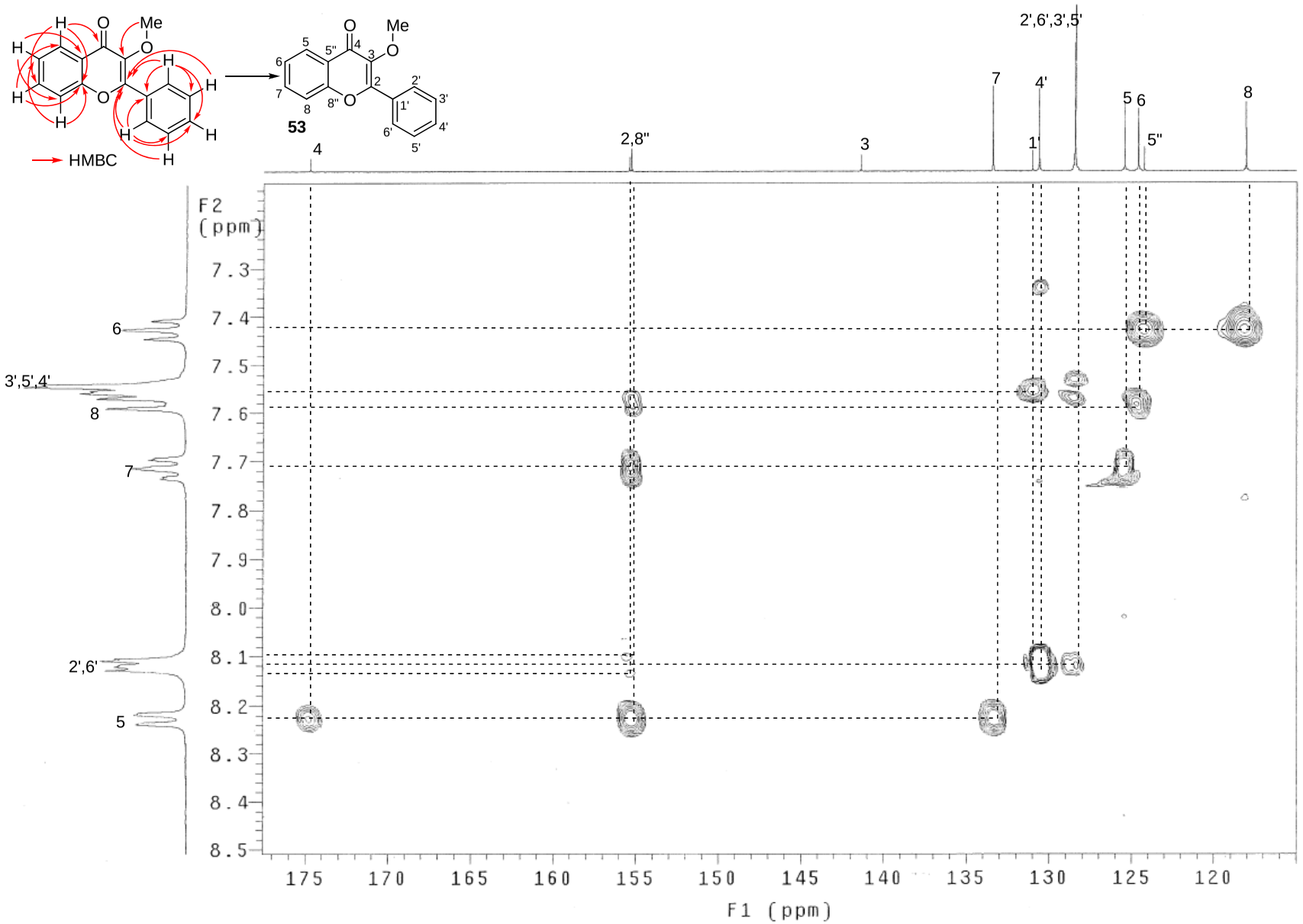
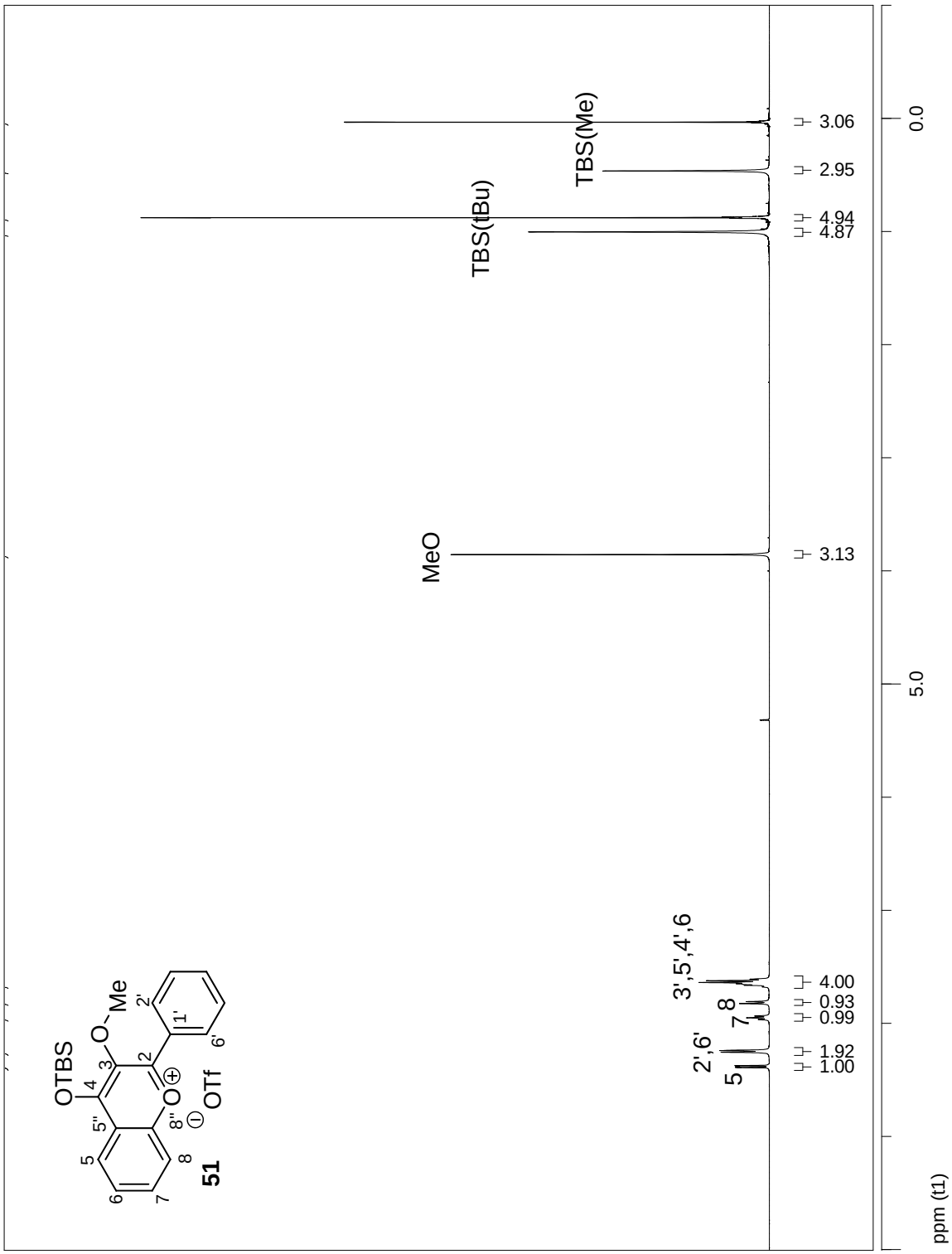

HMBC
53
2',6',3',5'
7
4'
5
6
8
4
2,8"
3
1'
5"
6
3',5',4'
8
7
2',6'
5
F2 (ppm)
7.3
7.4
7.5
7.6
7.7
7.8
7.9
8.0
8.1
8.2
8.3
8.4
8.5
175
170
165
160
155
150
145
140
135
130
125
120
F1 (ppm)

Figure 13. Proton NMR spectrum for **51** (400 MHz, CD_2Cl_2)[S8]



[S8] For example of diastereotopic TBS group, see Evans, D. A.; Allison, B. D.; Yang, M. G.; Masse, C. E. *J. Am. Chem. Soc.* **2001**, *123,* 10840-10852.

Figure 14. Carbon NMR spectrum for **51** (400 MHz, CD_2Cl_2)

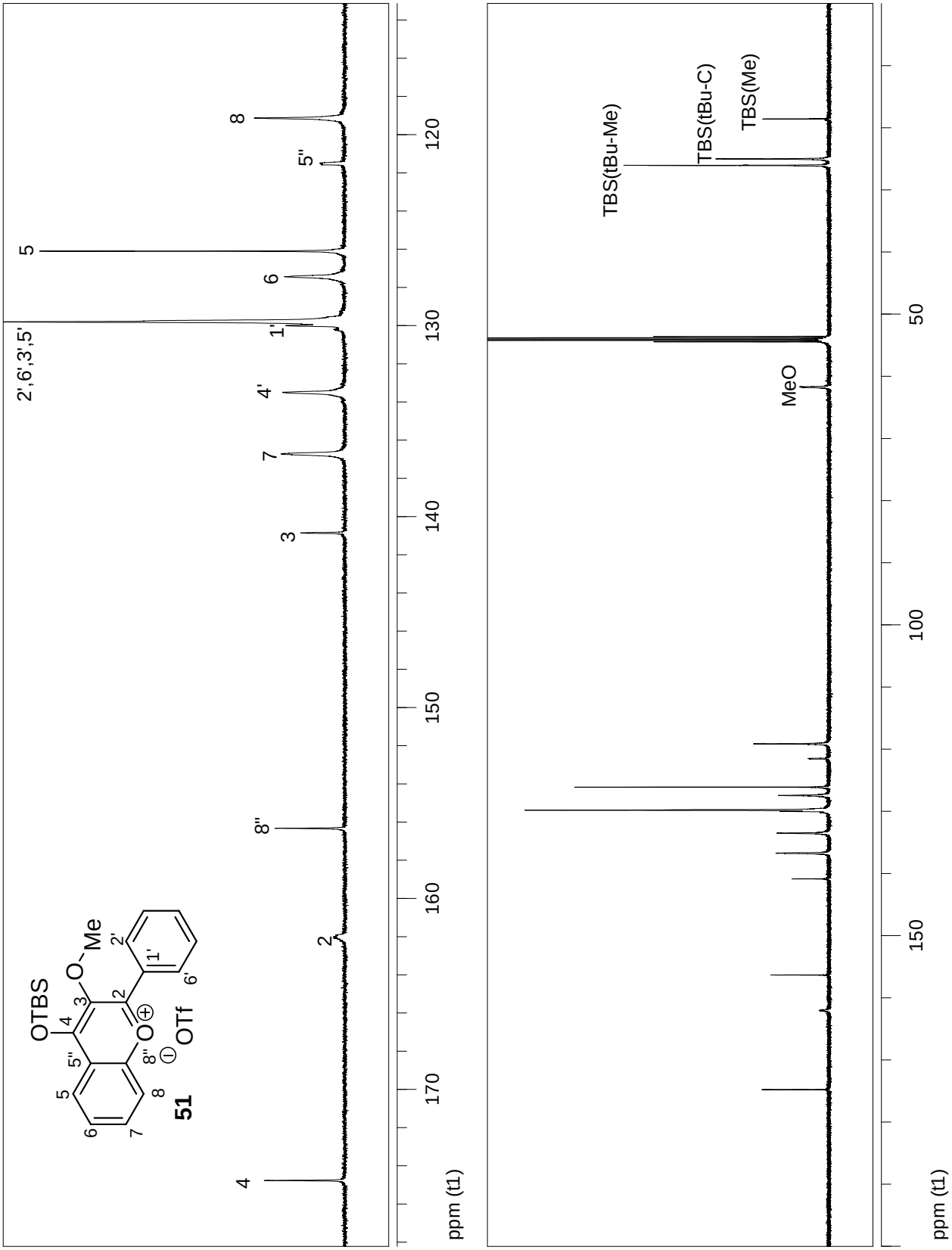


Figure 15. gCOSY NMR spectrum for **51** (500 MHz, CD_2Cl_2)

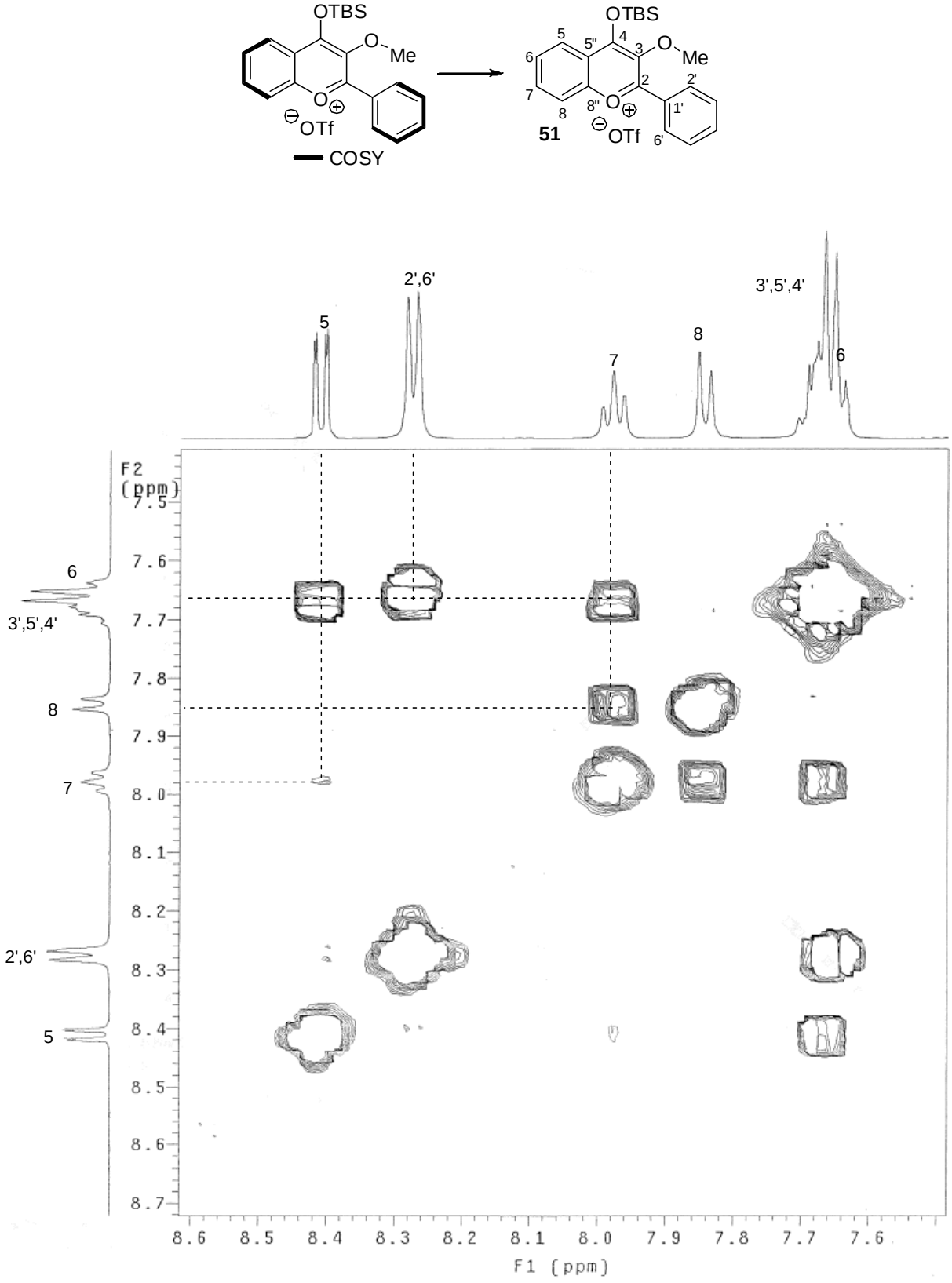
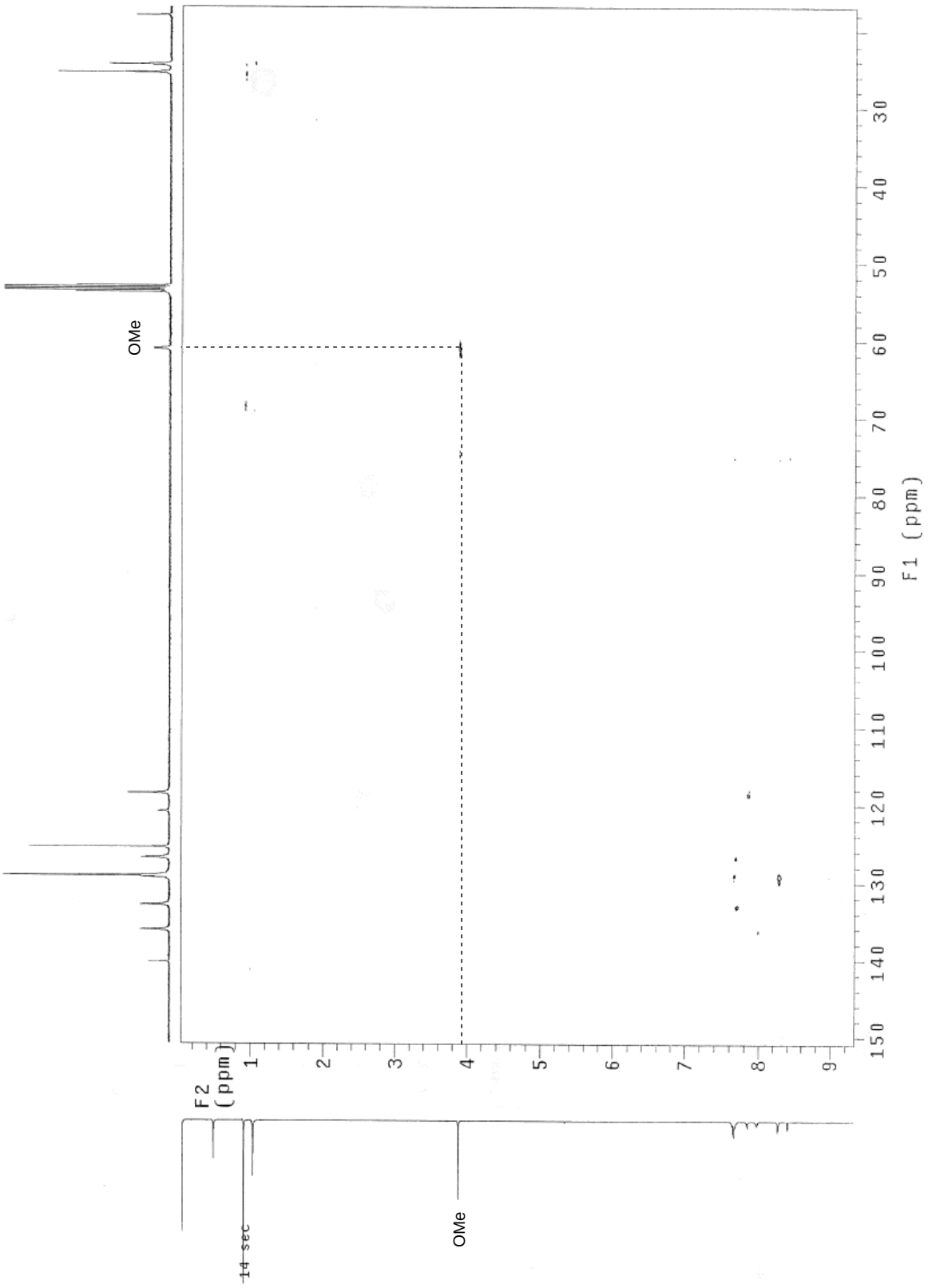


Figure 16. gHSQC NMR spectrum for **51** (500 MHz, CD_2Cl_2)



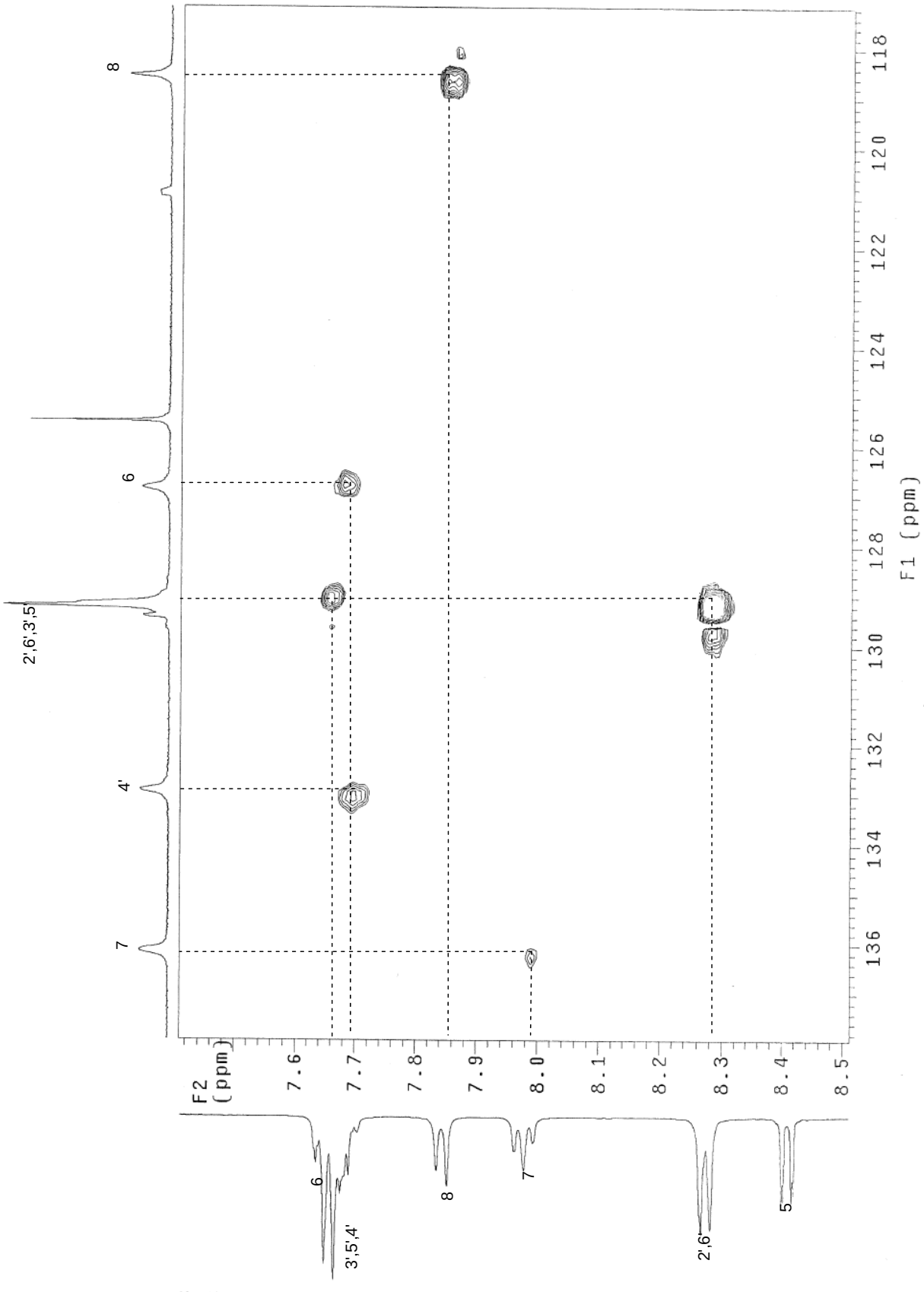
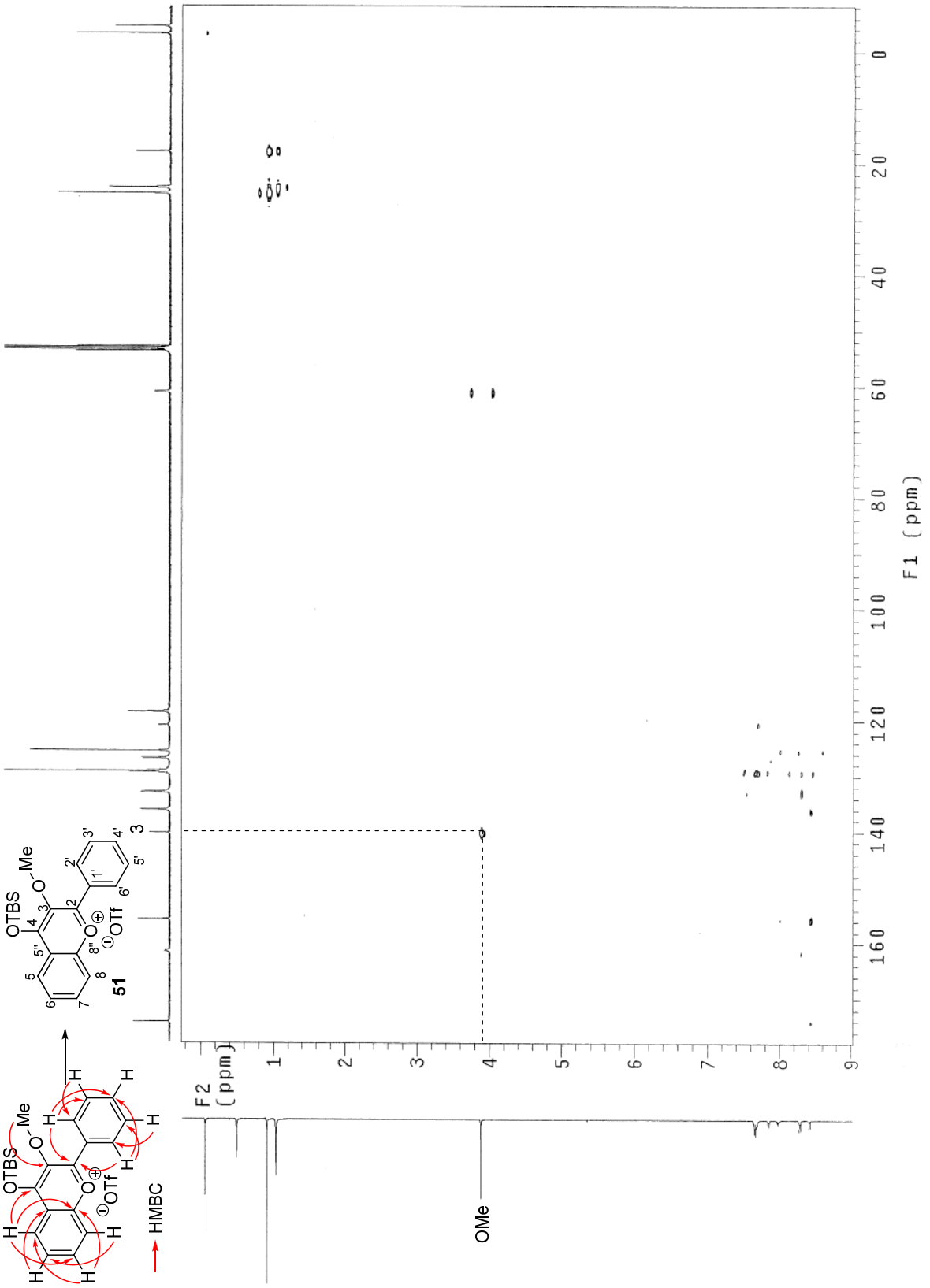

F2 (ppm)
F1 (ppm)
7.6
7.7
7.8
7.9
8.0
8.1
8.2
8.3
8.4
8.5
118
120
122
124
126
128
130
132
134
136
8
6
4'
7
2',6',3',5'
6
3',5',4'
8
7
2',6'
5

Figure 17. gHMBC NMR spectrum for **51** (500 MHz, CD_2Cl_2)



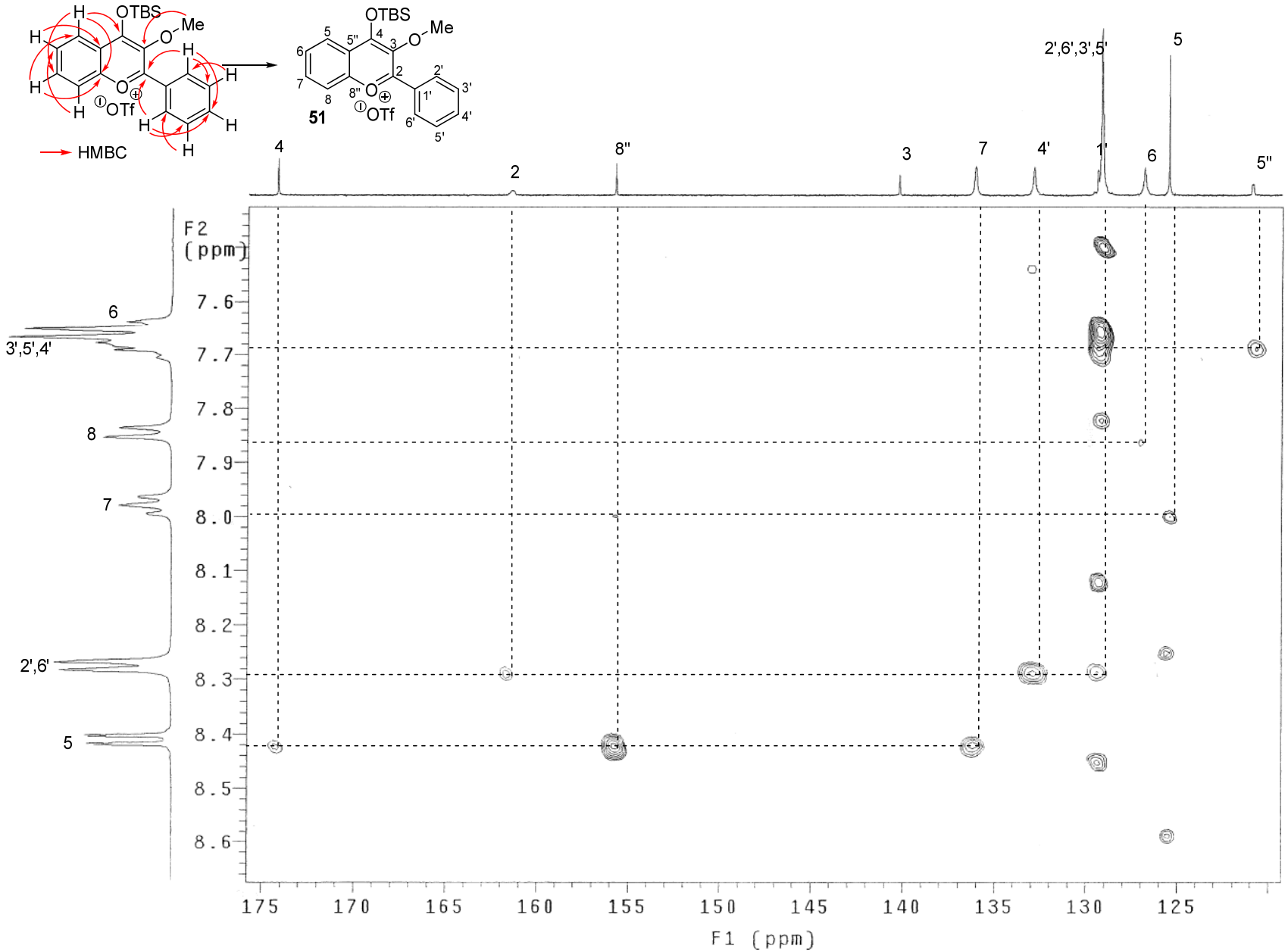

OTBS
Me
OTf
HMBC
51
4
2
8"
3
7
4'
1'
6
5
5"
2',6',3',5'
6
3',5',4'
8
7
2',6'
5
F2 (ppm)
F1 (ppm)

Figure 18. Proton NMR spectrum for **52** (400 MHz, CD_2Cl_2)

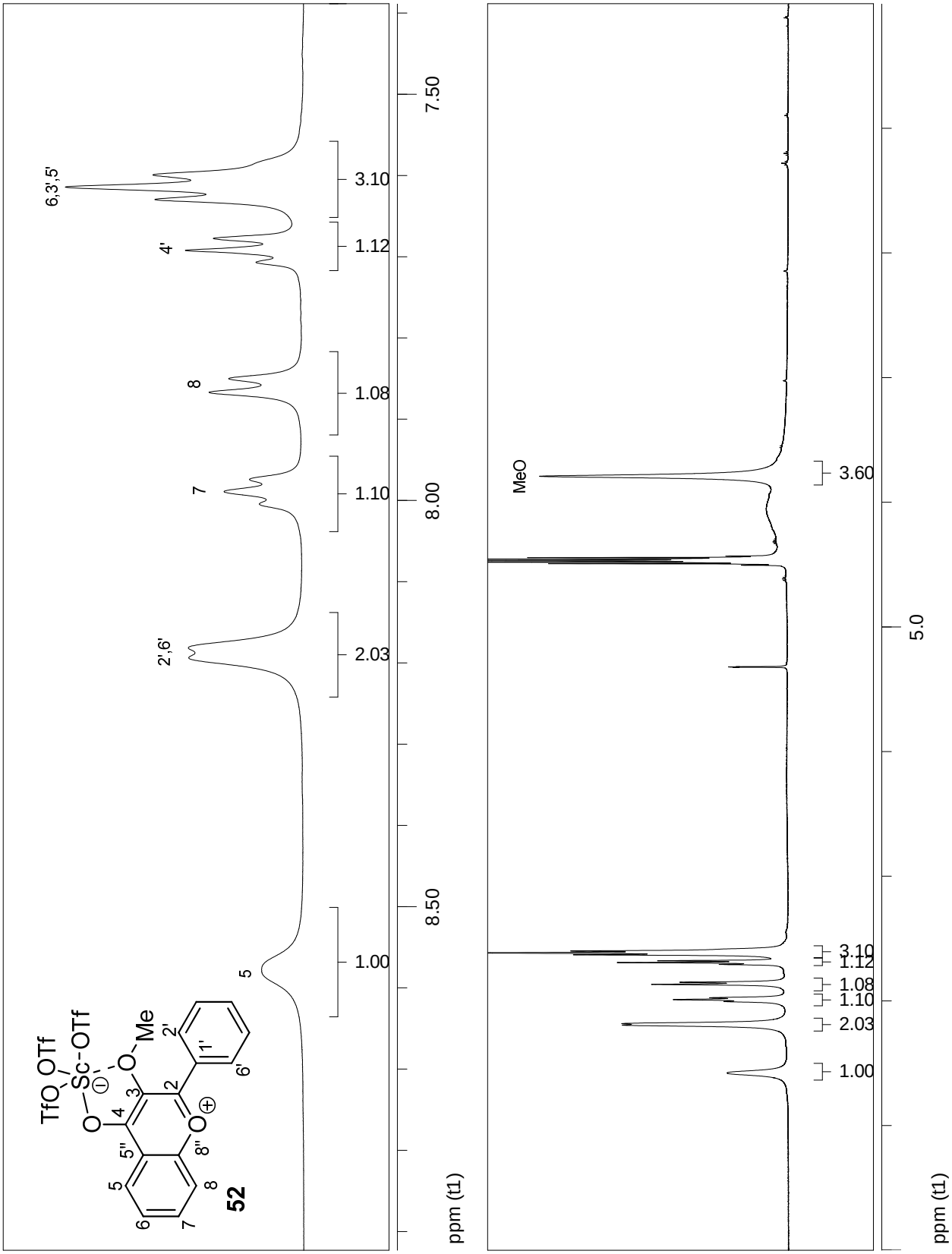


Figure 19. Carbon NMR spectrum for **52** (400 MHz, CD_2Cl_2)

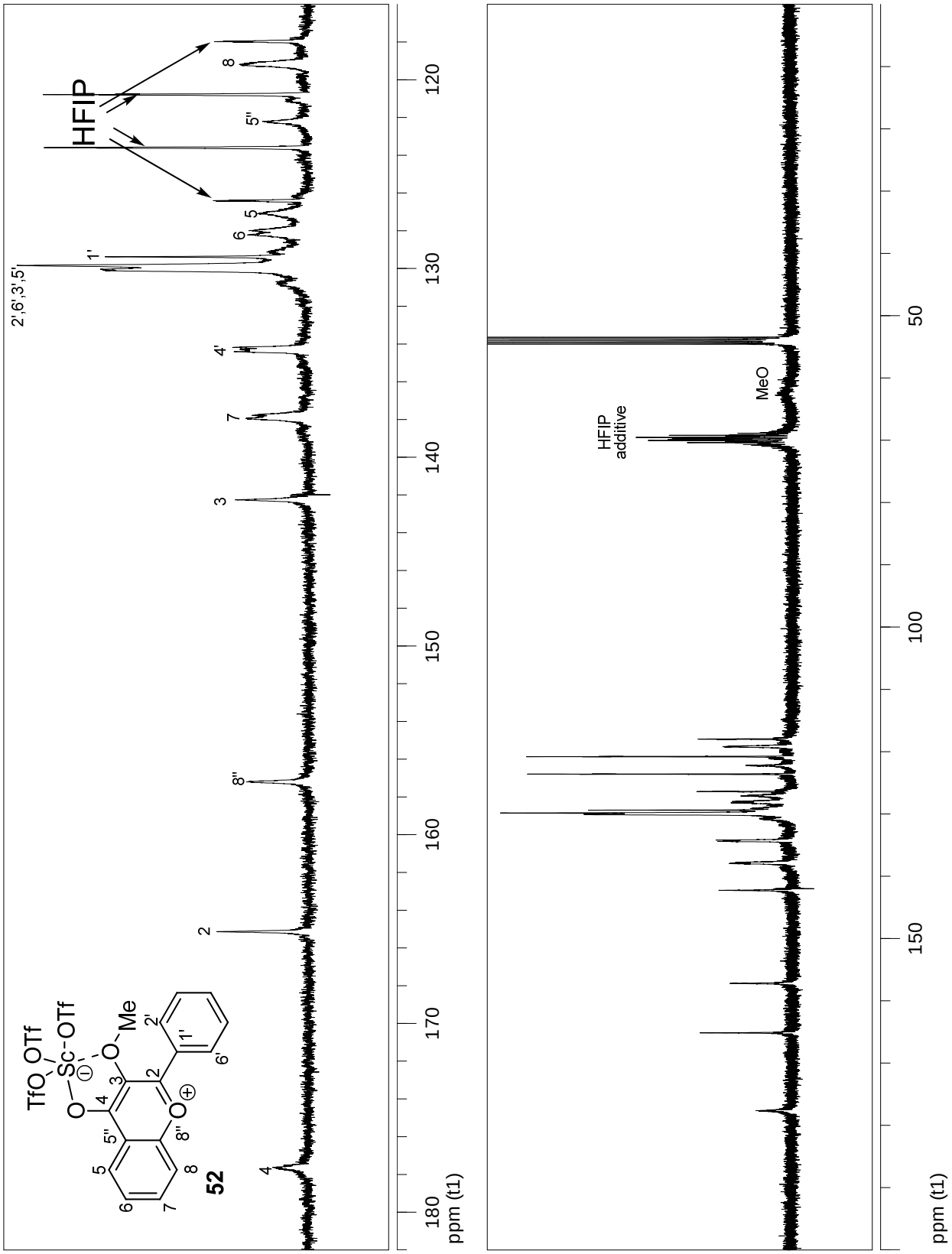


Figure 20. gCOSY NMR spectrum for **52** (400 MHz, CD_2Cl_2)

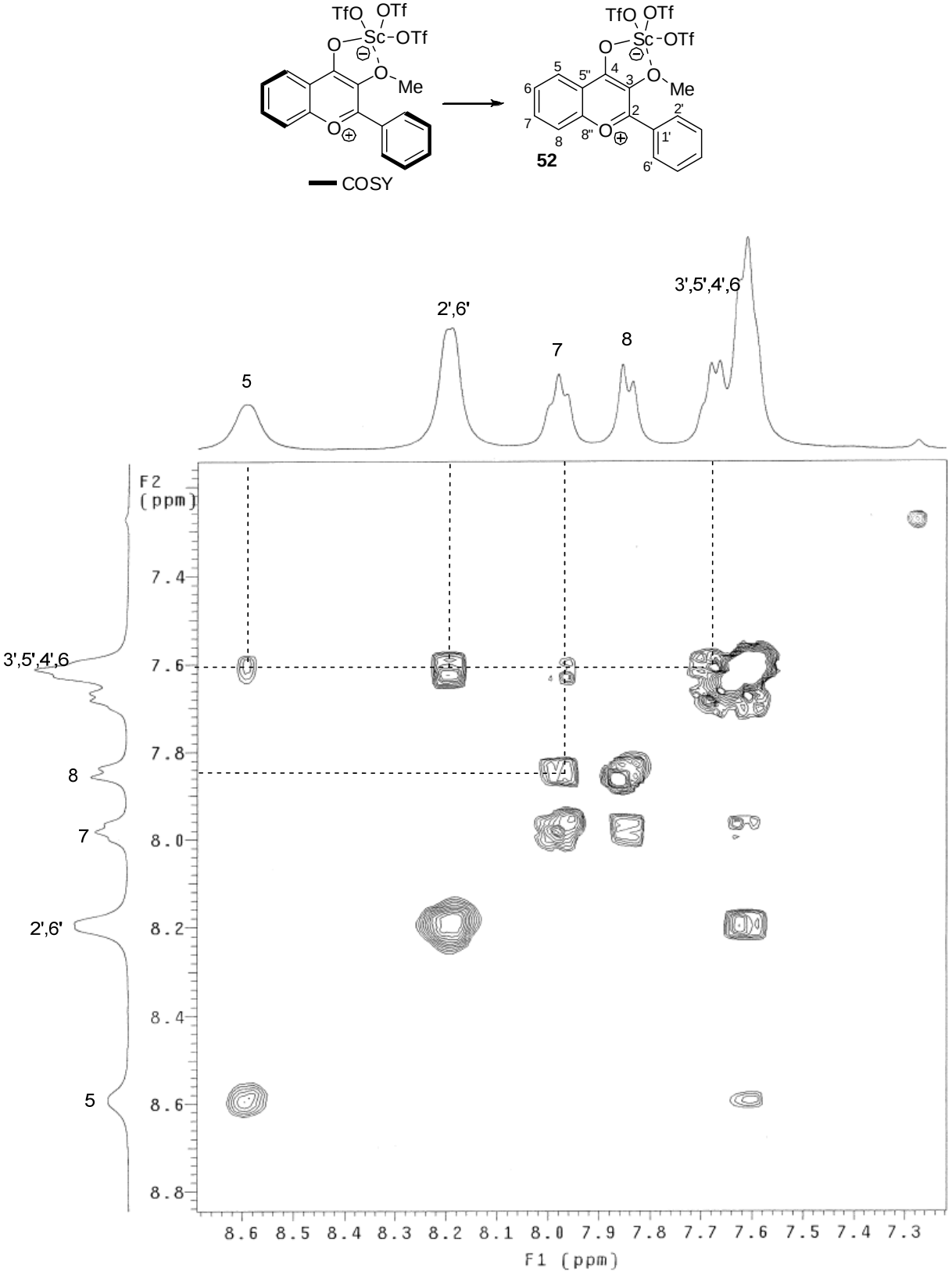
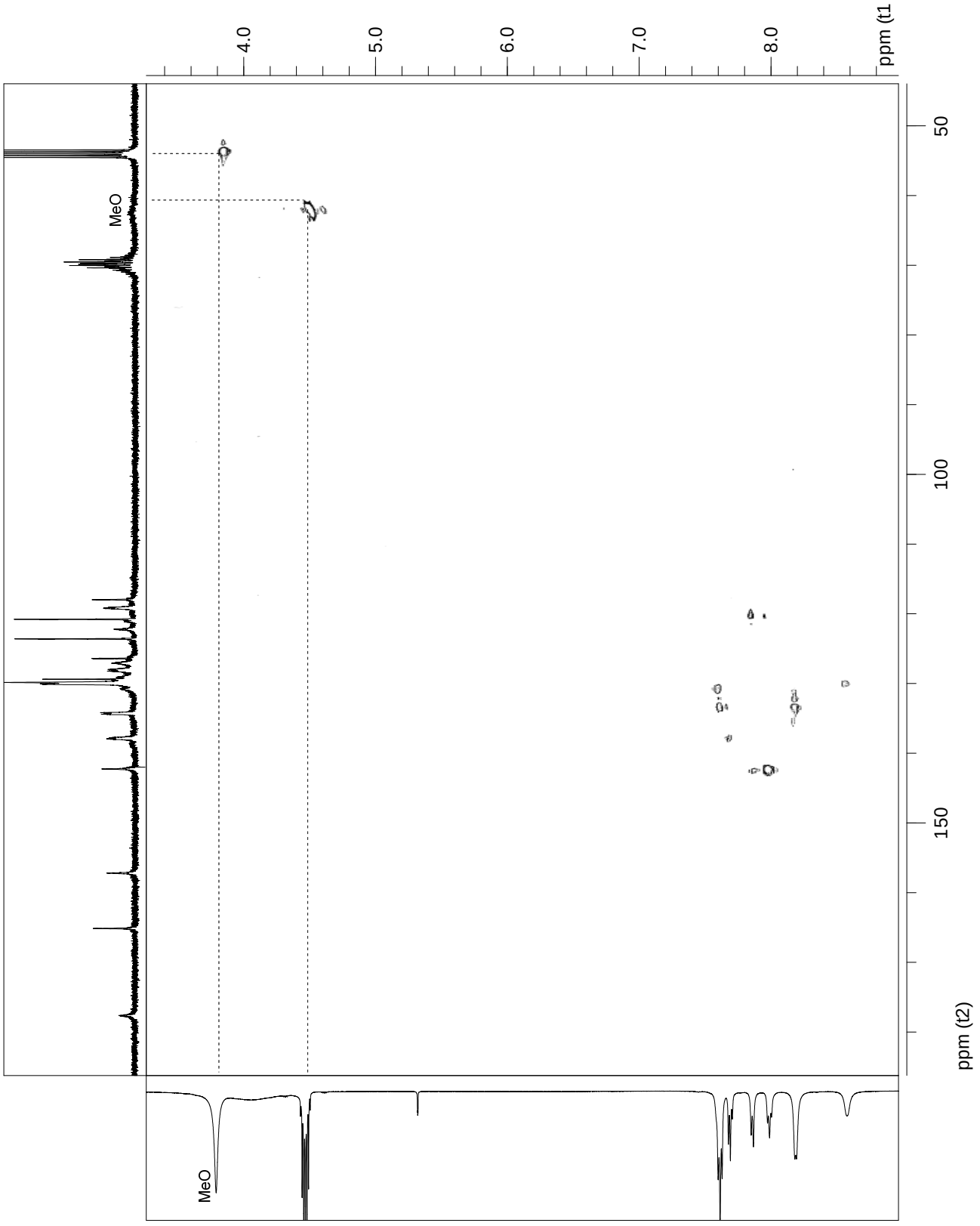


Figure 21. gHSQC NMR spectrum for **52** (400 MHz, CD_2Cl_2)



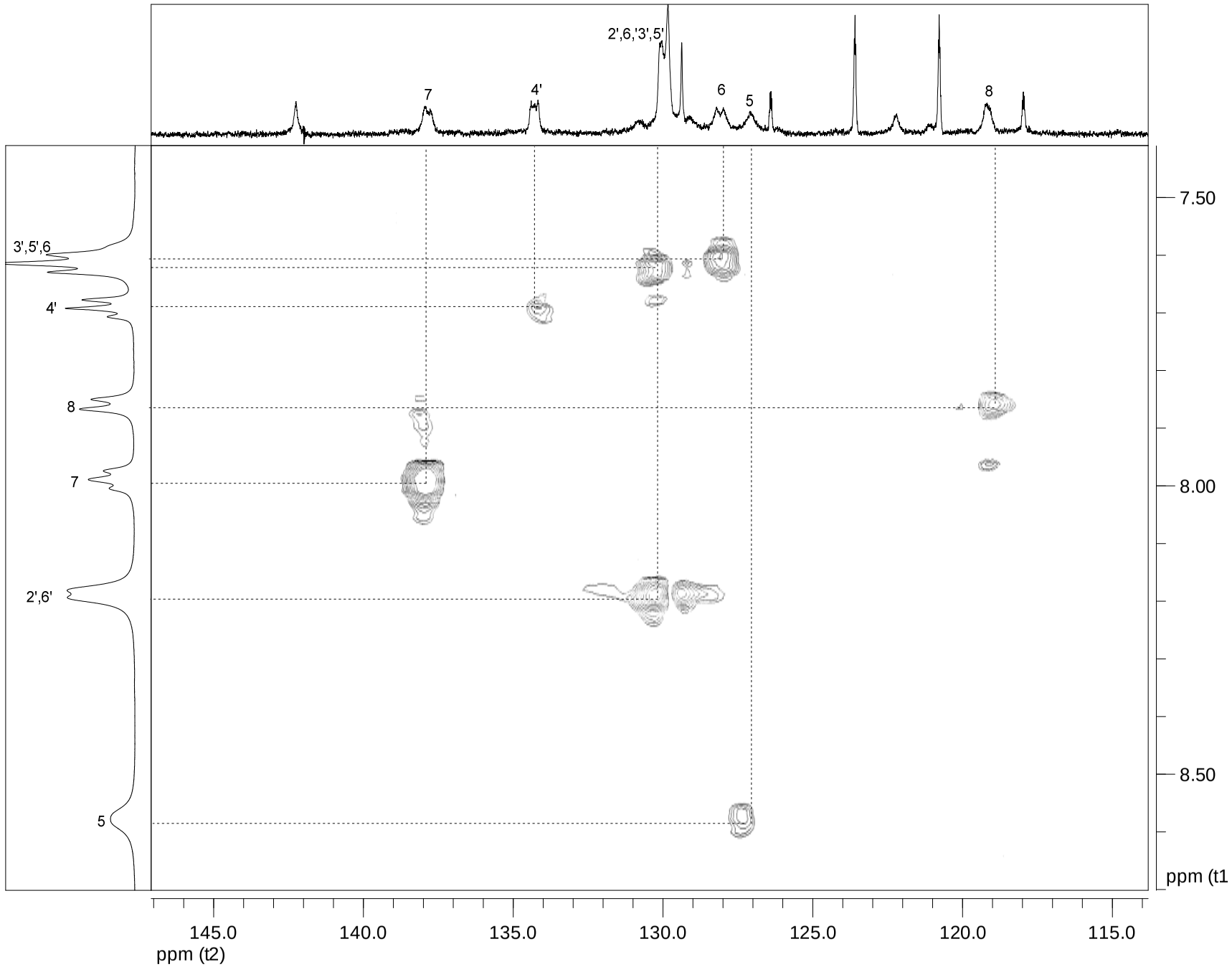
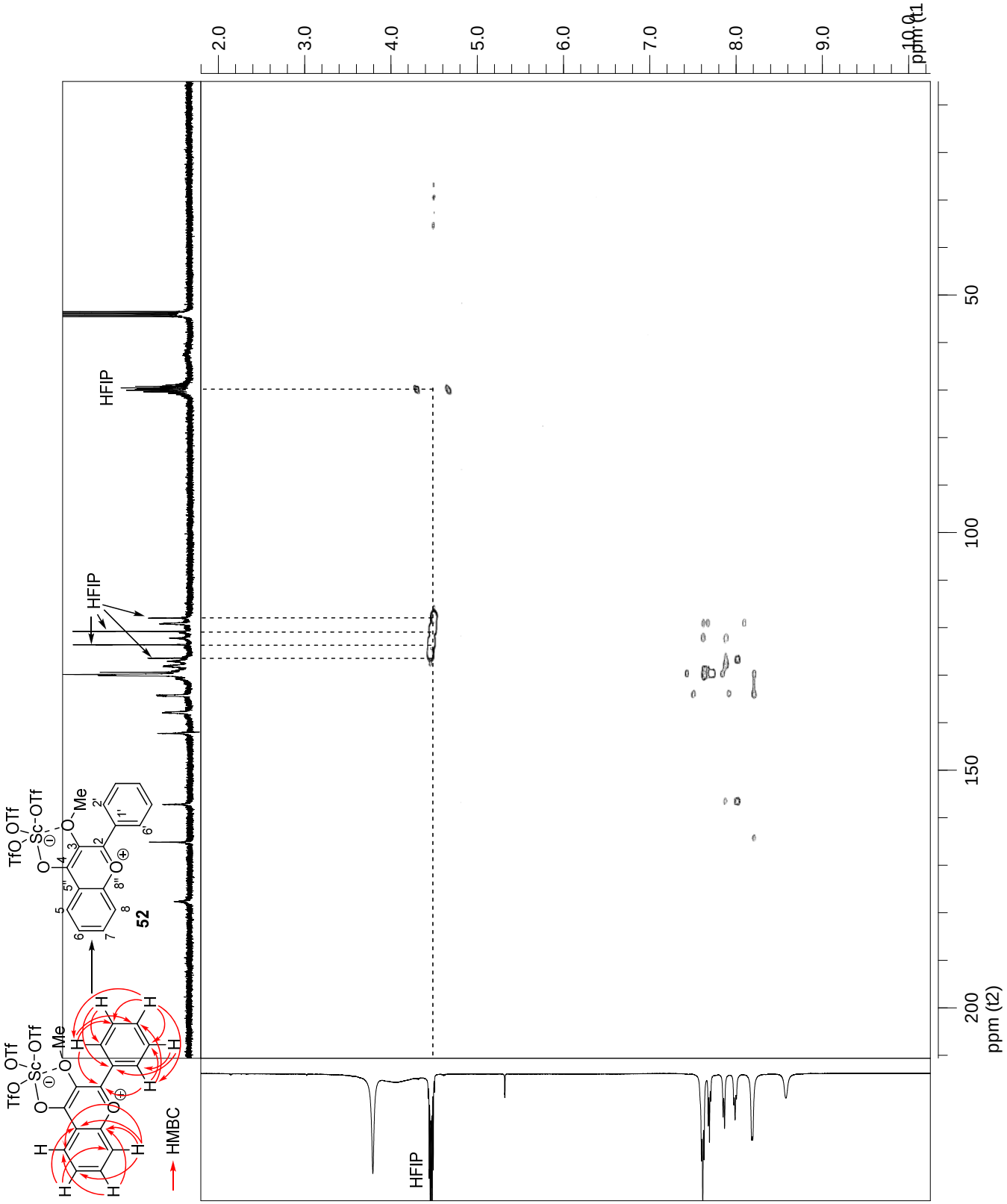
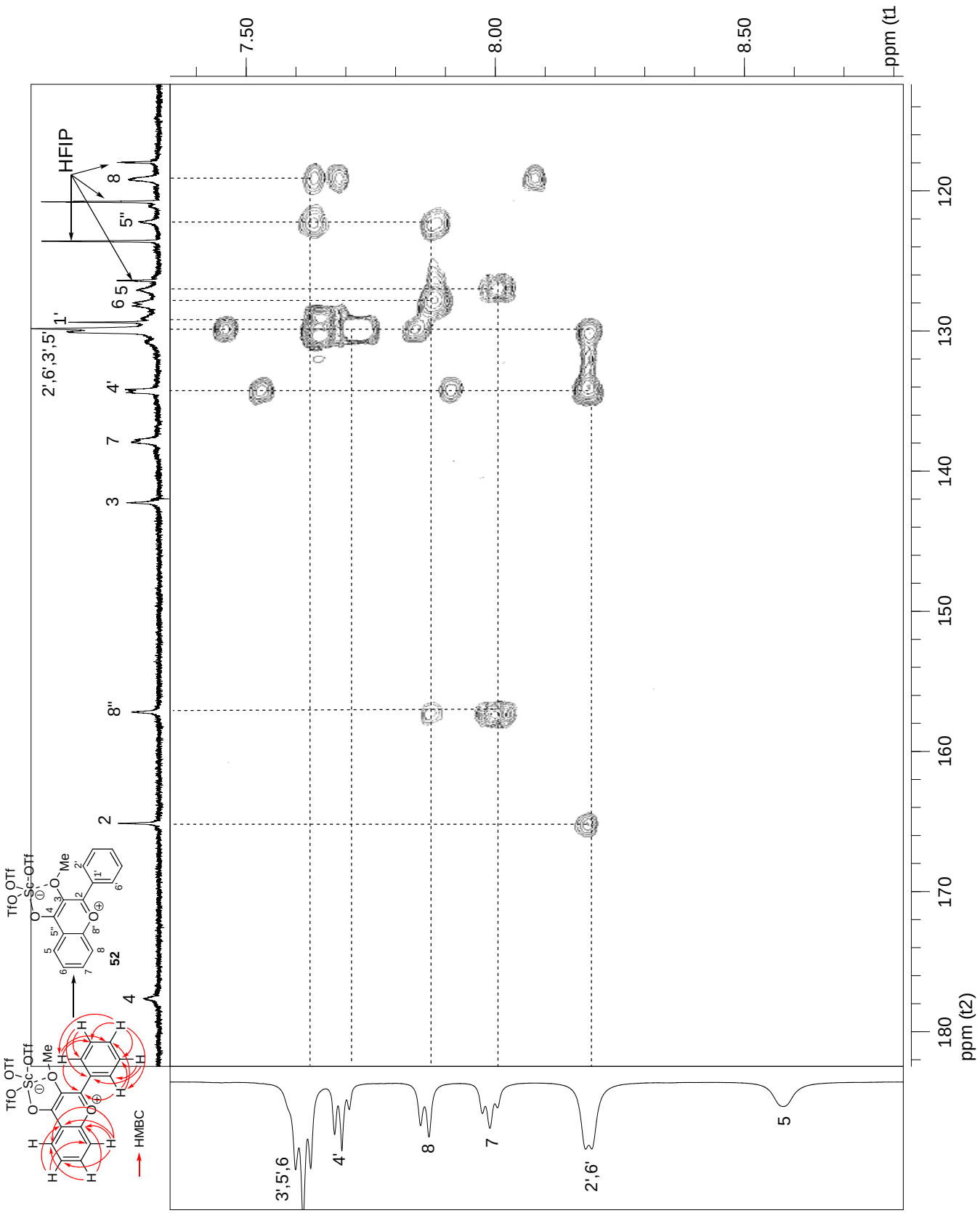
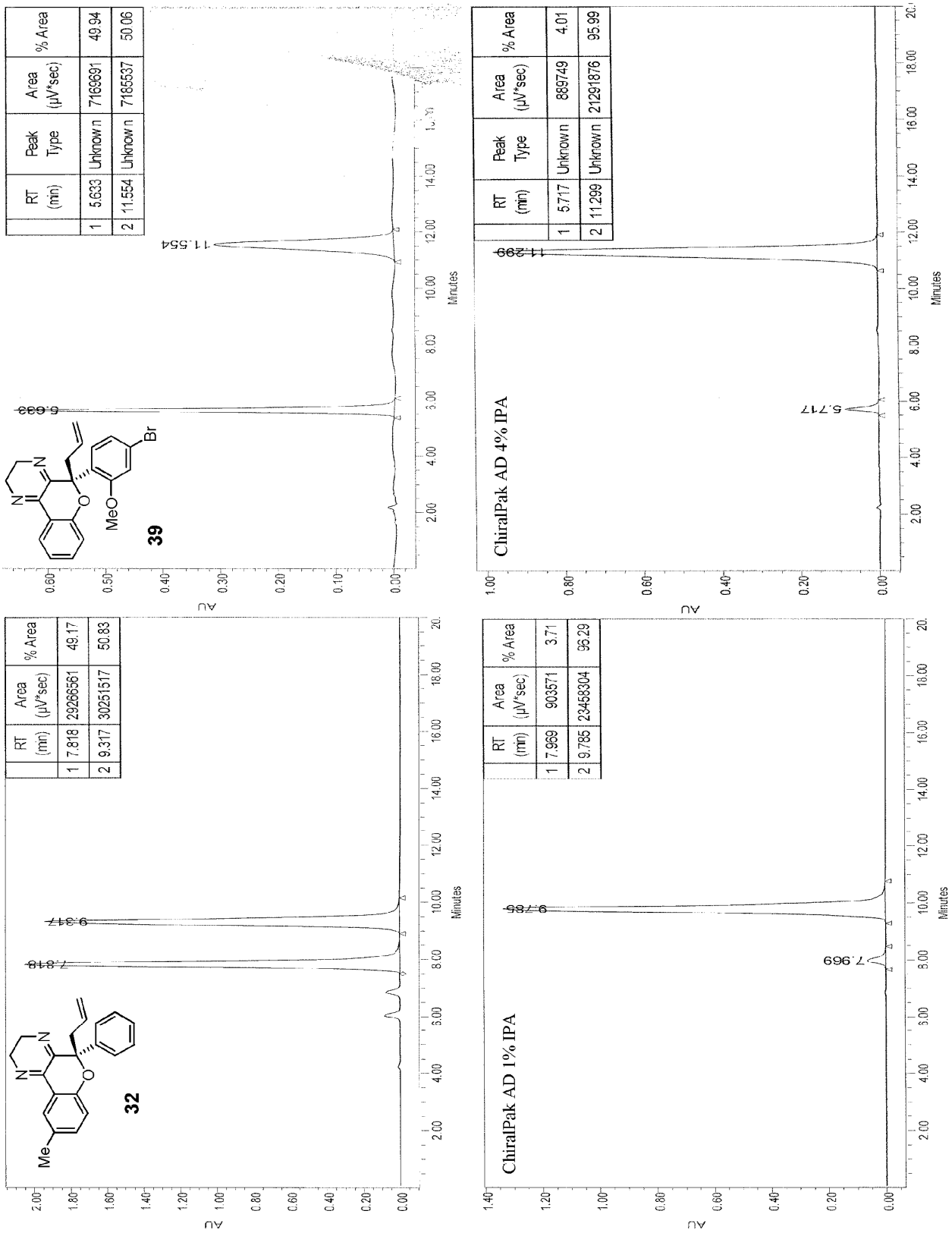

2',6,'3',5'
7
4'
6
5
8
3',5',6
4'
8
7
2',6'
5
7.50
8.00
8.50
ppm (t1
145.0
140.0
135.0
130.0
125.0
120.0
115.0
ppm (t2)

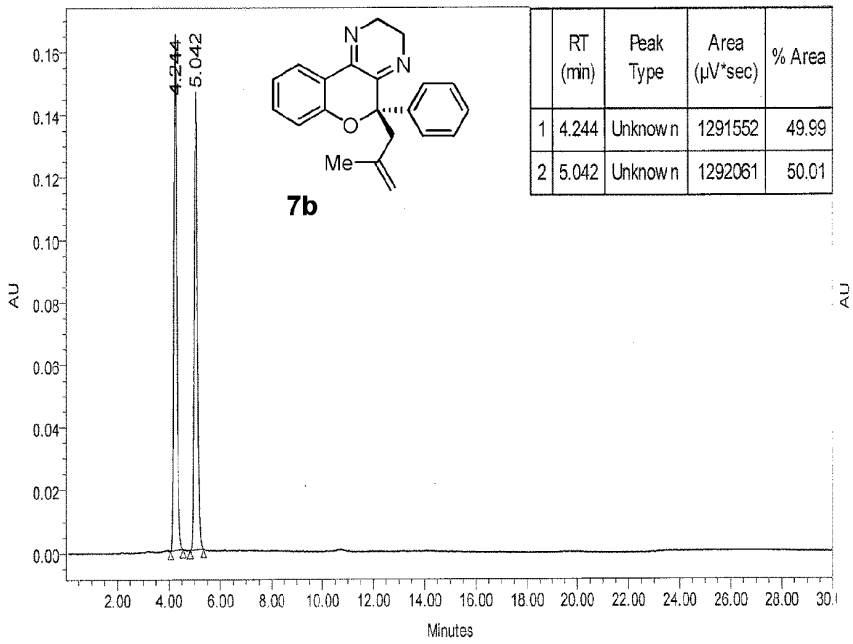
Figure 22. gHMBC NMR spectrum for **52** (400 MHz, CD_2Cl_2)



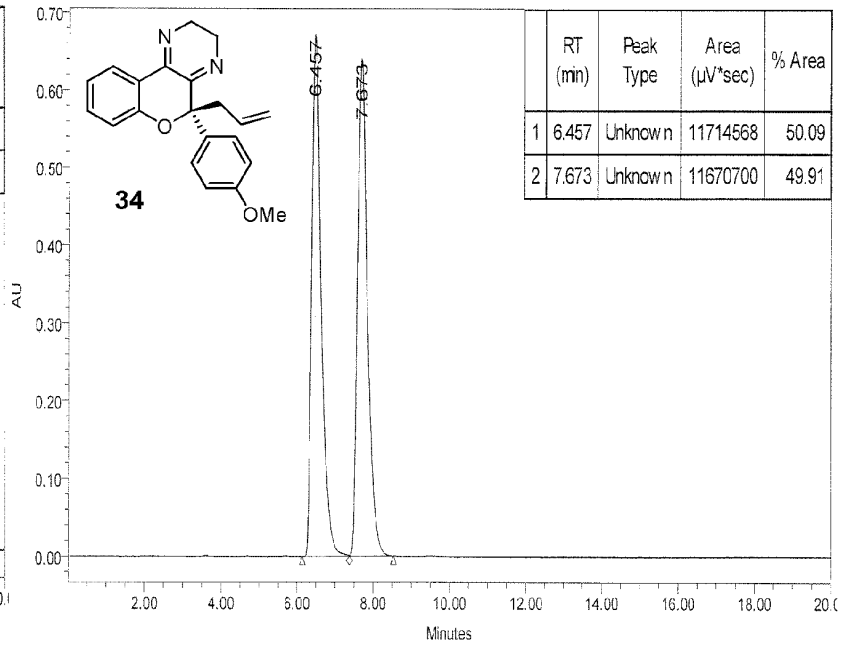

HFIP
2',6',3',5'
1'
4'
7
3
8"
2
4
5"
8
6
5
52
TfO OTf
Sc
OTf
Me
HMBC
3',5',6
4'
8
7
2',6'
5
7.50
8.00
8.50
ppm (t1)
120
130
140
150
160
170
180
ppm (t2)

XII. Representative Spectral Data: Chiral HPLC Traces of Select Compounds.

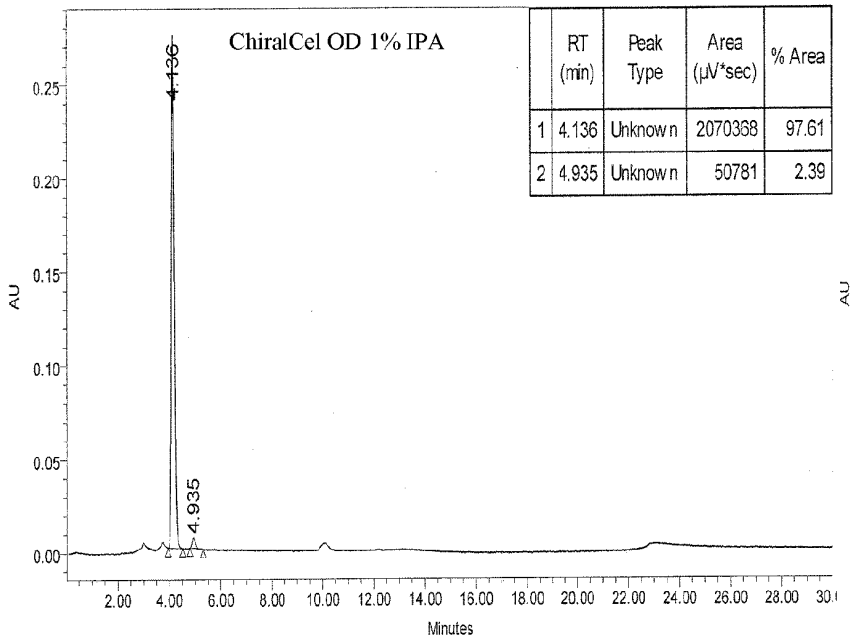




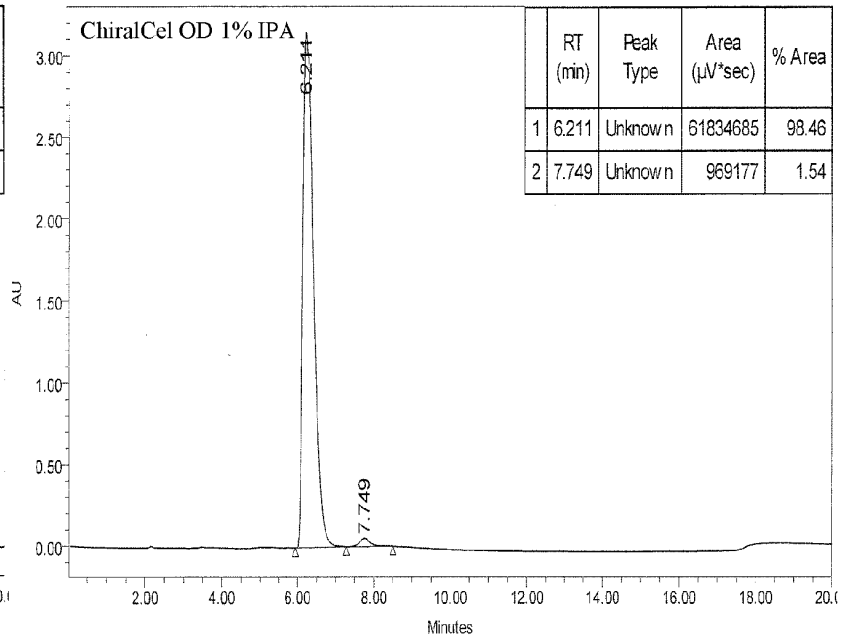
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	4.244	Unknown	1291552	49.99
2	5.042	Unknown	1292061	50.01



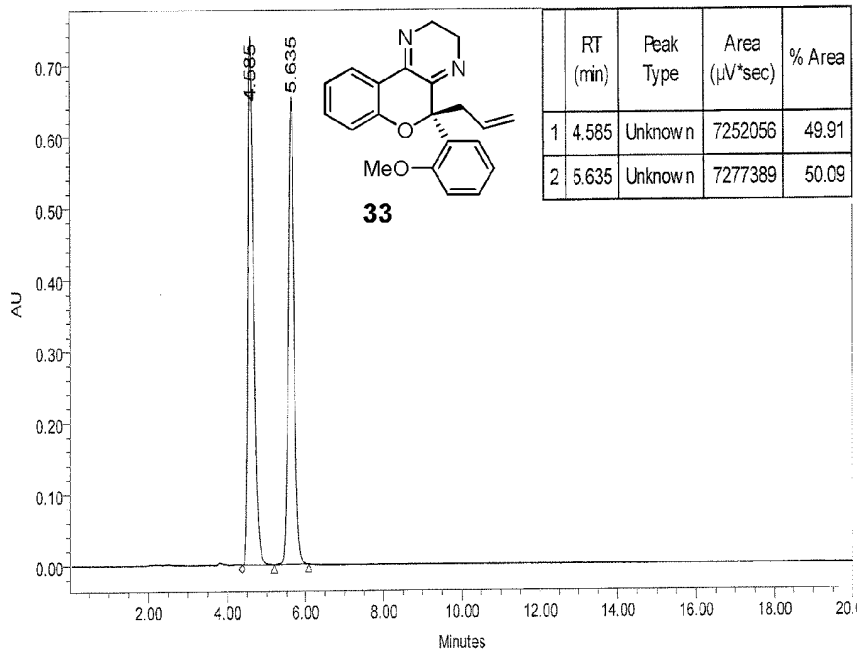
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	6.457	Unknown	11714568	50.09
2	7.673	Unknown	11670700	49.91



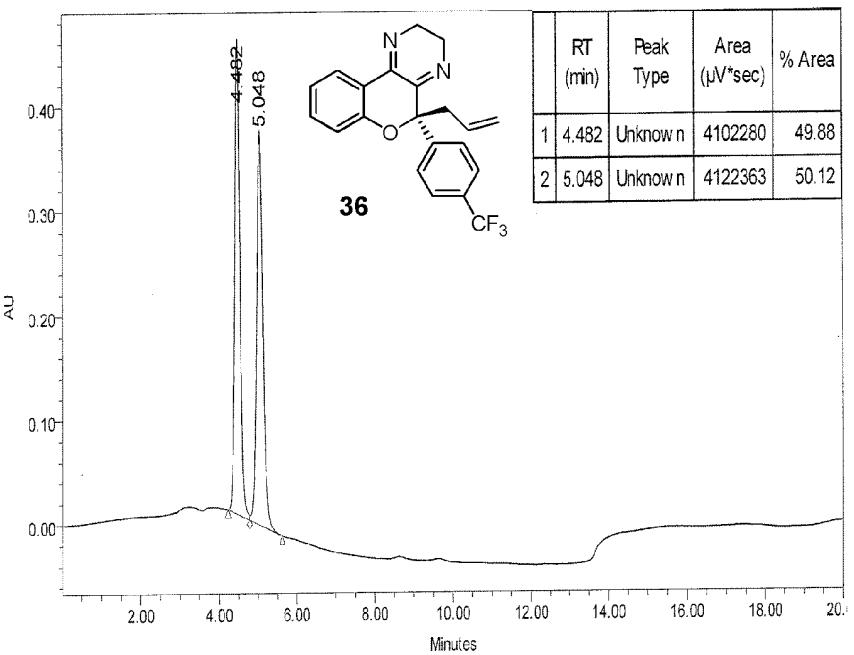
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	4.136	Unknown	2070368	97.61
2	4.935	Unknown	50781	2.39



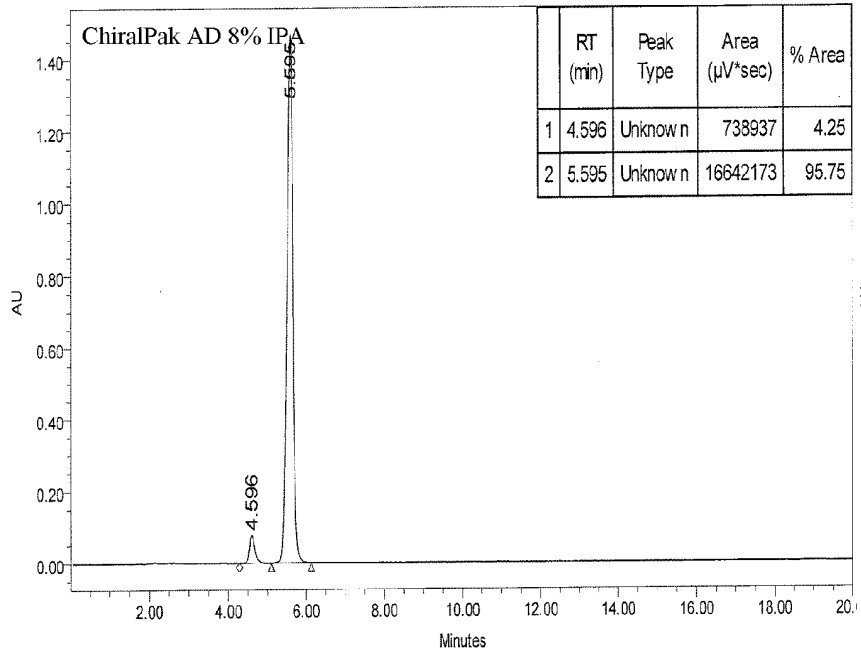
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	6.211	Unknown	61834685	98.46
2	7.749	Unknown	969177	1.54



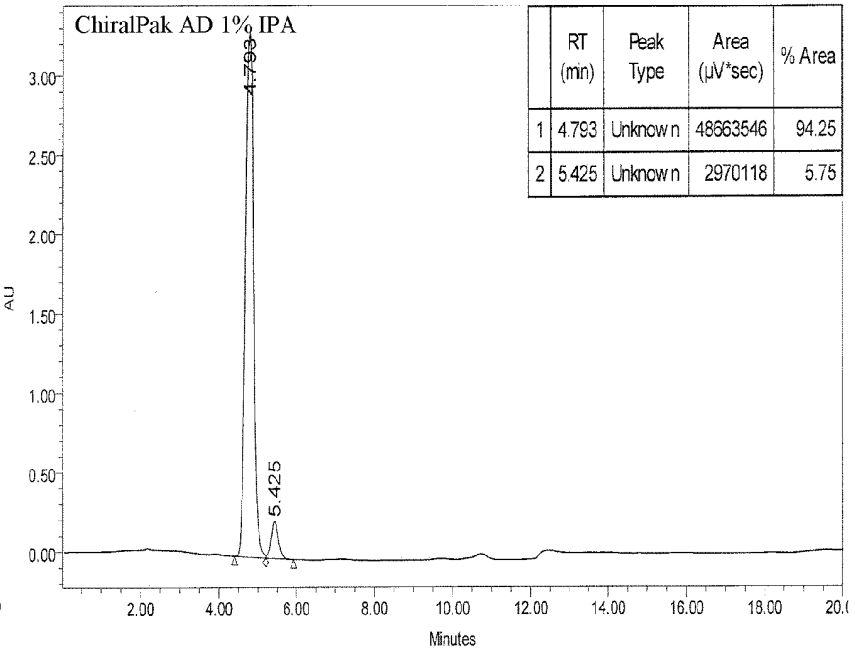
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	4.585	Unknown	7252056	49.91
2	5.635	Unknown	7277389	50.09



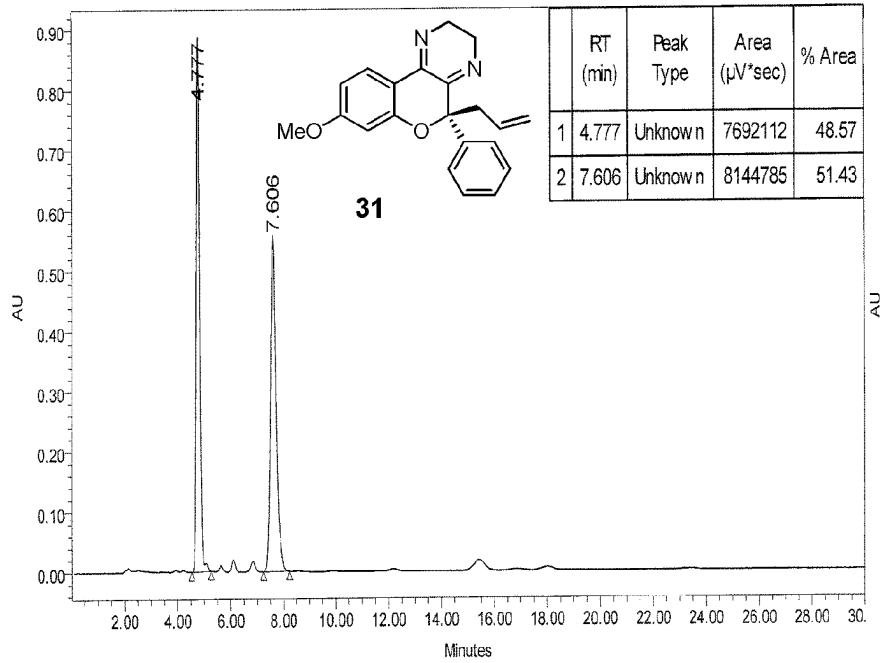
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	4.482	Unknown	4102280	49.88
2	5.048	Unknown	4122363	50.12



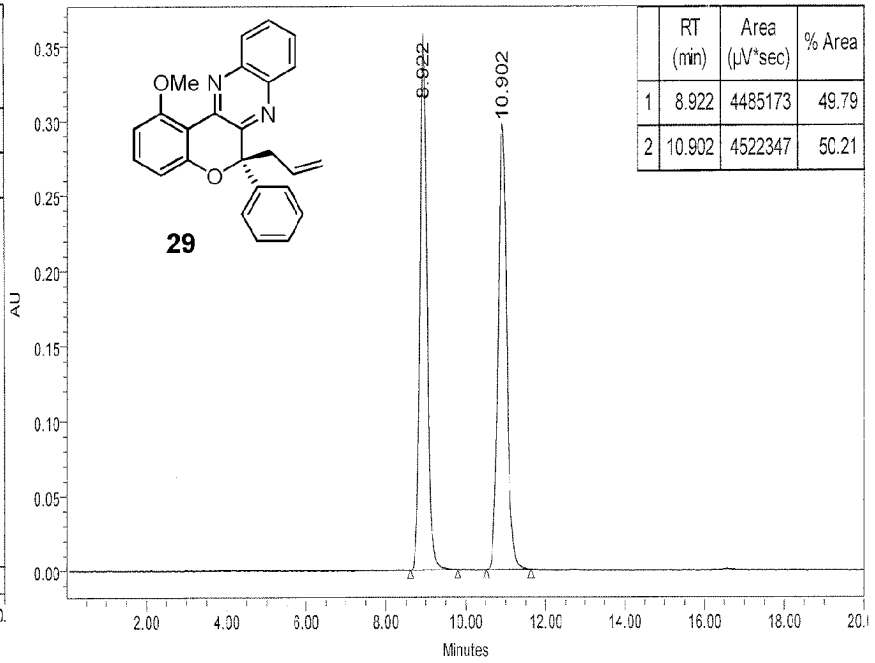
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	4.596	Unknown	738937	4.25
2	5.595	Unknown	16642173	95.75



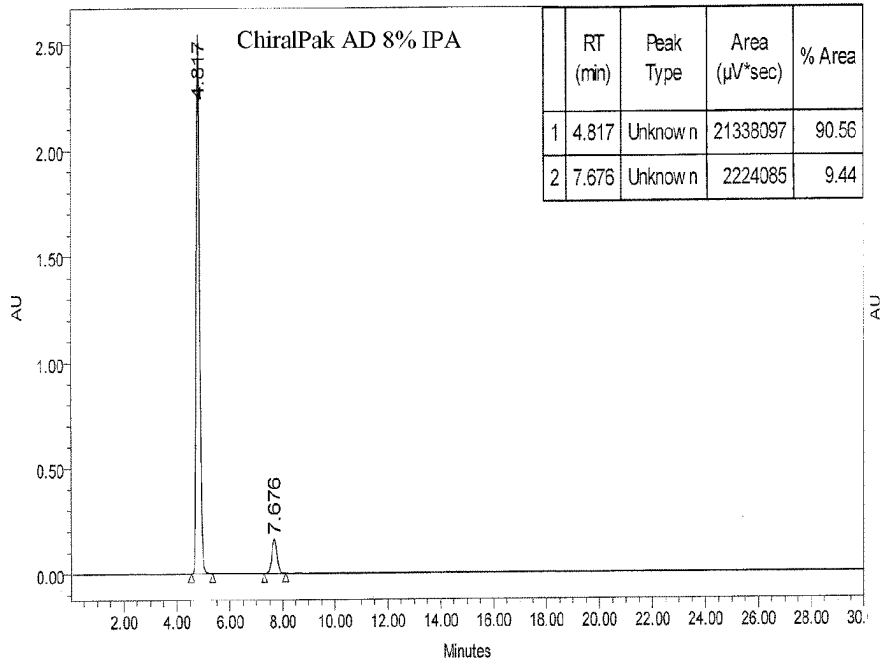
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	4.793	Unknown	48663546	94.25
2	5.425	Unknown	2970118	5.75



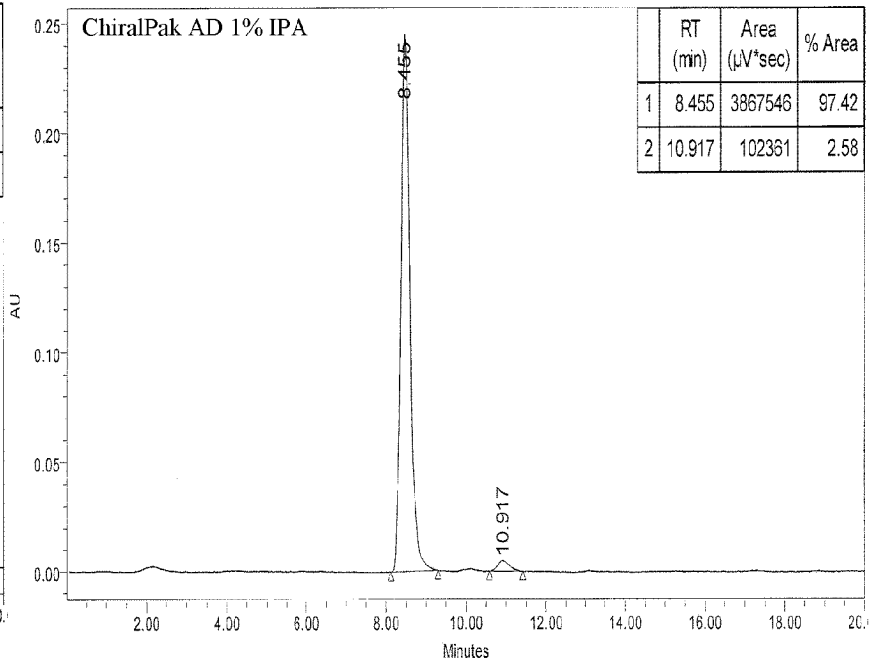
	RT (min)	Peak Type	Area (μV*sec)	% Area
1	4.777	Unknown	7692112	48.57
2	7.606	Unknown	8144785	51.43



	RT (min)	Area (μV*sec)	% Area
1	8.922	4485173	49.79
2	10.902	4522347	50.21



	RT (min)	Peak Type	Area (μV*sec)	% Area
1	4.817	Unknown	21338097	90.56
2	7.676	Unknown	2224085	9.44



	RT (min)	Area (μV*sec)	% Area
1	8.455	3867546	97.42
2	10.917	102361	2.58