Enantioselective vinylogous Michael addition of *γ*-butenolide to 2-iminochromenes

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Supporting Information

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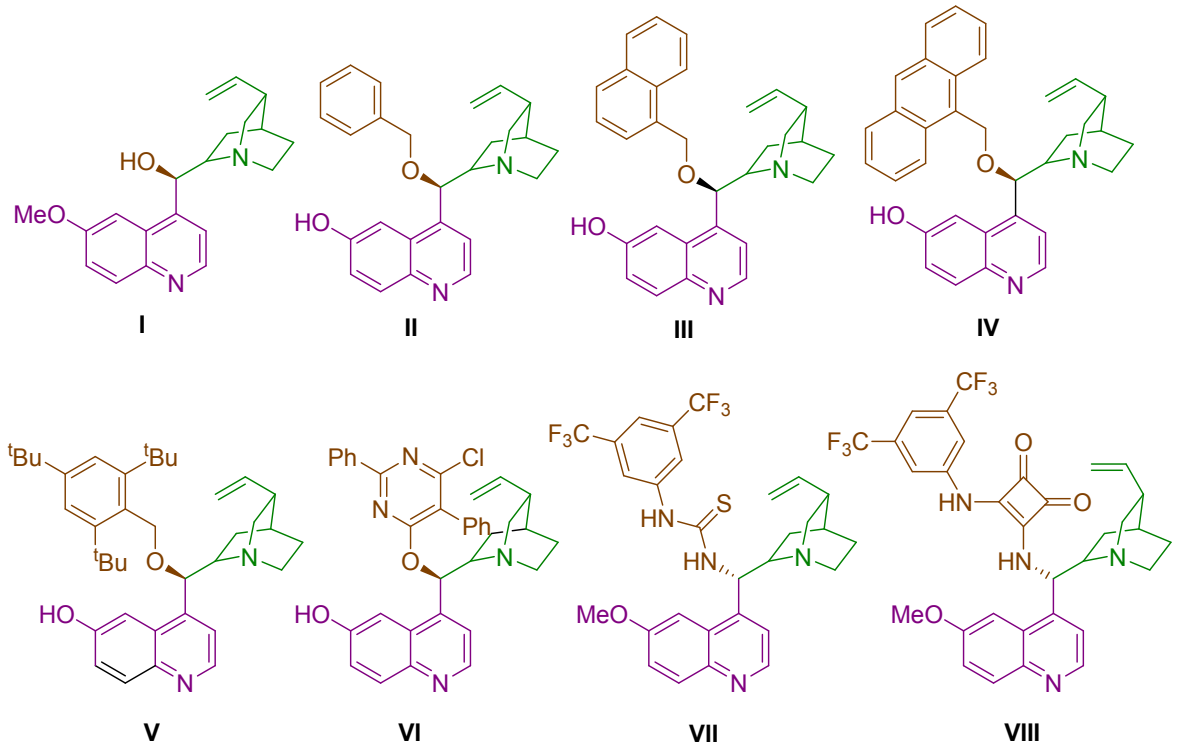
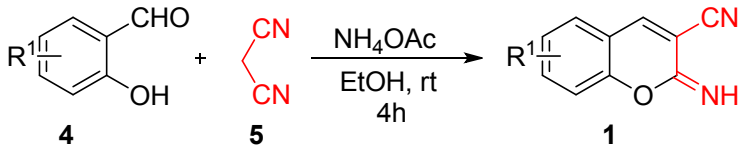
1. General Informations:

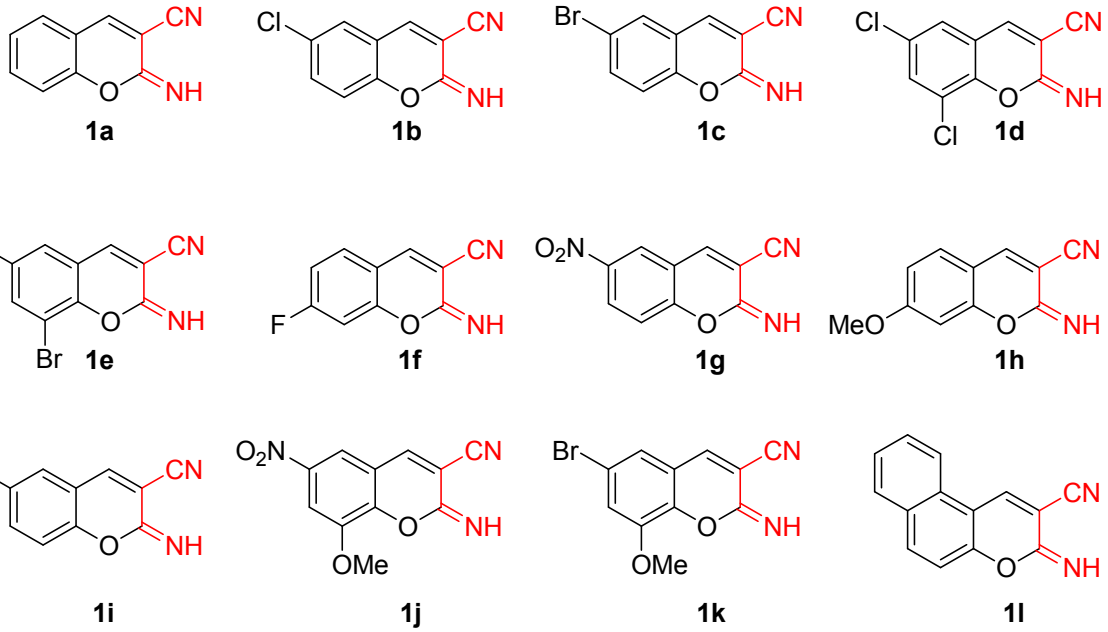
Bruker AV-300 (300 MHz and 75 MHz) and AV-400 (400 MHz and 100 MHz) instruments were used to record ^{1}H and ^{13}C spectra in deuterated solvents with residual solvent signals as internal references. ^{1}H NMR data were reported as follow: chemical shifts (δ, ppm), multiplicity (s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet), integration, coupling constant (Hz). ^{13}C NMR data is recorded in terms of chemical shifts (δ, ppm). Mass spectra recorded on a high-resolution mass spectrometer (ESI-TOF) in positive-ion mode. Specific rotations were recorded on an Autopol III Automatic Polarimeter. Column chromatography separations were performed on silica gel (100-200 mesh). High Performance Liquid Chromatography was performed on an Agilent 1200 series chromatographs using chiral column (ID, IC, IE, Lux 5u cellulose-4) (250 x 4.6 mm) as noted. UV absorption was monitored at 254 nm. All solvents and inorganic reagents were from commercial sources and used without further purification unless otherwise noted.

2. Preparation of the Catalysts: Catalysts **I** was purchased from Sigma Aldrich and used without further purification. Catalyst **II-VIII** was prepared according to known literature procedures.[1]



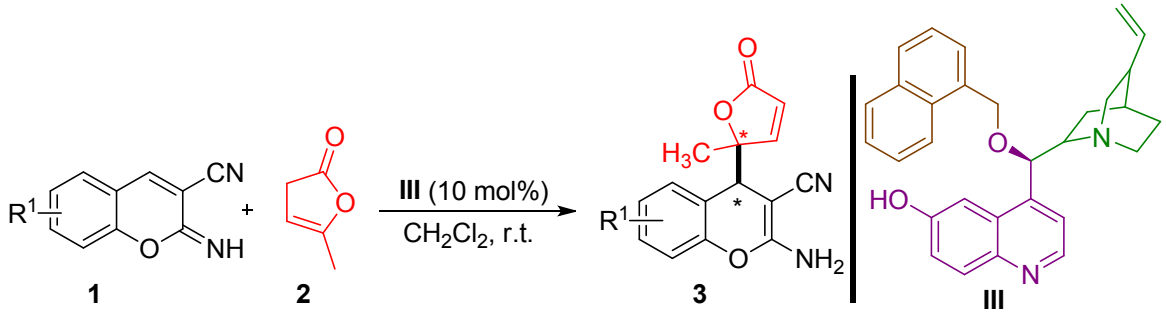
3. Preparation of 2-iminochromenes: α-Angelica lactone was purchased from Alfa Aesar and used without further purification. All salicylaldehyde derivatives were purchased from commercial sources and used without further purification. The electrophile iminochromenes (**1a-l**) were prepared according to the literature procedure.[2]





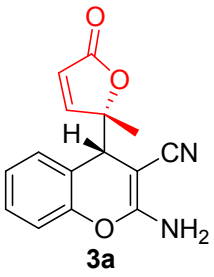
4. Preparation of Racemic Michael adducts: To the suspension of iminochromene **1** (0.1 mmol) in anhydrous dichloromethane (1 ml), β,γ-butenolide **2** (0.15 mmol) and then triethylamine (20 mol%) were added. The resulting reaction mixture was stirred at room temperature for 16 h. After that, the crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent yielded desire product. The purified product was subjected for HPLC analysis.

5. General Procedure for Asymmetric Vinylogous Michael Addition Reactions:



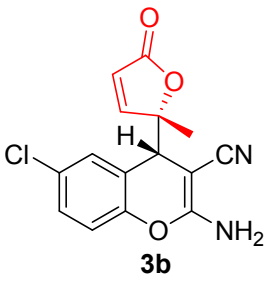
To the suspension of iminochromene **1** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. After that, the crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3**. The purified product was subjected for HPLC analysis.

6. Analytical Data for Products:



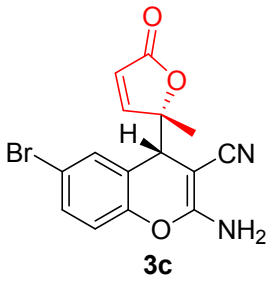
(*S*)-2-amino-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3a): To the suspension of iminochromene **1a** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/anti* (1.6:1) was determined by ^{1}H NMMR analysis of crude product (δ major: 3.68 ppm, δ minor: 3.84 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3a** as white solid (16 mg, 60% yield, R_f = 0.4, *syn/anti* = 1.6:1).The enantiomeric ratio of the *syn* diastereomer was determined to be 84:16 by HPLC, ID column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (major) = 19.9 min, t (minor) = 21.9 min, t (minor) = 24.4 min. $[\alpha]_{25}^{D}$ = -7.04 (c = 0.12, $CHCl_3$); **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 5.7 Hz, 1H), 7.31 (dd, *J* = 9.3, 5.8 Hz, 2H), 7.22 – 7.13 (m, 1H), 7.04 (d, *J* = 8.2 Hz, 1H), 6.09 (d, *J* = 5.7 Hz, 1H), 4.95 (s, 2H), 3.68 (s, 1H), 1.33 (s, 3H). **^{13}C-NMR** (75 MHz, $CDCl_3$) *δ* 171.62, 163.00, 158.59, 150.40, 130.47, 129.25, 125.08, 121.86, 120.29, 118.82, 116.33, 92.11, 53.99, 44.77, 19.39. **FTIR (KBr) cm^{-1}:** 3392, 3316, 2928, 2188, 1741, 1643, 1608, 1412, 1267, 1224, 1110, 1049, 822,

762. HRMS-ESI $[M+Na]^+$, calcd for $C_{15}H_{12}N_2NaO_3$ 291.0740, found 291.0740. **HRMS-ESI:** [M+Na]+, calcd for $C_{15}H_{12}N_2NaO_3$ 291.0740, found 291.0746.



3b

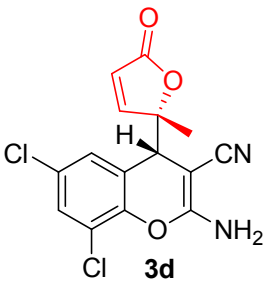
(*S*)-2-amino-6-chloro-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3b): To the suspension of iminochromene **1b** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 24 h. The *syn /anti* ratio (4:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.62 ppm, δ minor: 3.78 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3b** as white solid (21 mg, 70% yield, R_f = 0.4, *syn/anti* = 4:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 93:7 by HPLC, [ID column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (major) = 14.2 min, t (minor) = 14.9 min, t (minor) = 16.3 min, t (minor) =20.7 min]. $[\alpha]_{25}^{D}$ = -11.05 (*c* = 0.19, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) δ 7.73 (d, *J* = 5.2 Hz, 1H), 7.36 (d, *J* = 8.6 Hz, 1H), 7.30 –7.27 (m, 3H), 7.08 (d, *J* = 8.6 Hz, 1H), 6.09 (d, *J* = 5.3 Hz, 1H), 3.93 (s, 1H), 1.42 (s, 3H). **^{13}C-NMR** (100 MHz, DMSO-d_6) *δ* 171.34, 163.51, 159.66, 149.42, 129.39, 128.61, 127.43, 122.07, 120.95, 120.70, 117.75, 91.82, 49.28, 42.74, 20.51. **FTIR (KBr) cm^{-1}:** 3391, 3318, 3192, 2926, 2186, 1751, 1647, 1605, 1418, 1185, 1108. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{15}H_{11}ClN_2NaO_3$ 325.0350, found 325.0353.



3c

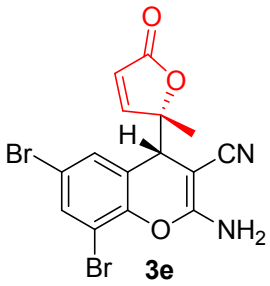
(*S*)-2-amino-6-bromo-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3c): To the suspension of iminochromene **1c** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/ anti* ratio (4.9:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.64 ppm, δ minor: 3.78 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3c** as light yellow solid (25 mg, 73% yield, R_f = 0.4, *syn/anti* = 4.9:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 90:10 by HPLC, [ID column,

λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (minor) = 27.7 min, t (major) = 40.2 min, t (minor) = 41.2, t (minor) = 53.3 min]. $[\alpha]_{25}^{D}$ = -5.62 (*c* = 0.16, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) δ 7.72 (d, *J* = 5.7 Hz, 1H), 7.47 (d, *J* = 8.7 Hz, 1H), 7.42 (d, *J* = 2.2 Hz, 1H), 7.32 (s, 2H), 7.01 (d, *J* = 8.7 Hz, 1H), 6.08 (d, *J* = 5.7 Hz, 1H), 3.92 (s, 1H), 1.41 (s, 3H). **^{13}C-NMR** (75 MHz, DMSO-d_6) δ 171.4, 163.5, 159.7, 149.9, 132.3, 131.5, 122.5, 121.0 120.7, 118.2, 115.4, 91.9, 49.3, 42.6, 20.6. **FTIR (KBr) cm^{-1}:** 3402, 3325, 3102, 2925, 2852, 2187, 1751, 1642, 1602, 1415, 1265, 1186, 1110. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{15}H_{11}BrN_2NaO_3$ 368.9845, found 368.9869.



3d

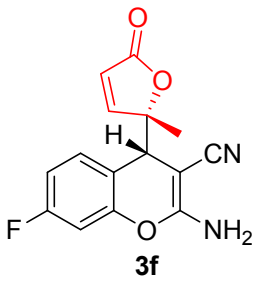
(*S*)-2-amino-6,8-dichloro-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3d): To the suspension of iminochromene **1d** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 24 h. The *syn/anti* ratio (8.6:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.63 ppm, δ minor: 3.81 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3d** as white solid (22 mg, 64% yield, R_f = 0.5, *syn/anti* = 8.6:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 87:13 by HPLC, [Lux cellulose-4 column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (minor) = 20.0 min, t (minor) = 28.7 min, t (minor) = 34.3 min, t (major) = 40.3 min]. $[\alpha]_{25}^{D}$ = +40.0 (*c* = 0.01, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) δ 7.72 (d, *J* = 5.5 Hz, 1H), 7.63 (s, 1H), 7.45 (s, 2H), 7.28 (s, 1H), 6.07 (d, *J* = 5.6 Hz, 1H), 3.99 (s, 1H), 1.42 (s, 3H). **^{13}C-NMR** (100 MHz, DMSO-d_6) δ 171.43, 163.20, 159.66, 145.57, 128.75, 128.45, 127.64, 123.69, 121.40, 120.88, 120.61, 91.83, 49.66, 43.01, 20.66. **FTIR (KBr) cm^{-1}**: 3422, 3348, 3199, 2927, 2855, 2187, 1745, 1645, 1608, 1418, 1245, 1115. **HRMS-ESI:** [M+Na]+, calcd for $C_{15}H_{10}Cl_2N_2NaO_3$ 358.9960, found 358.9966.



3e

(*S*)-2-amino-6,8-dibromo-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3e): To the suspension of iminochromene **1e** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas

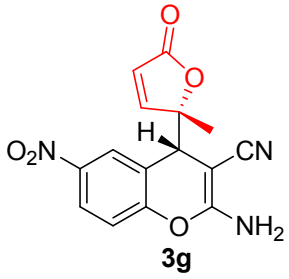
atmosphere. The resulting reaction mixture was stirred at room temperature for 20 h. The *syn/anti* ratio (4:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.56 ppm, δ minor: 3.73 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3e** as solid (21 mg, 52% yield, R_f = 0.5, *syn/anti* = 4:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 90:10 by HPLC, [Lux cellulose-4 column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (minor) = 23.0 min, t (minor) = 34.9 min, t (minor) = 39.5 min, t (major) = 45.2 min]. $[\alpha]_{25}^{D}$ = +3.33 (c = 0.15, $CHCl_3$); **^{1}H-NMR** (300 MHz, DMSO-d_6) δ 7.83 (d, J = 3 Hz, 1H), 7.72 (d, J = 5.7 Hz, 1H), 7.50-7.39 (m, 3H), 6.08 (d, J = 5.7 Hz, 1H), 3.99 (s, 1H), 1.41 (s, 3H). **^{13}C-NMR** (100 MHz, DMSO-d_6) δ 171.31, 163.17, 159.53, 147.00, 134.05, 131.83, 123.90, 120.81, 120.49, 115.58, 110.52, 91.76, 49.68, 42.99, 20.58. **FTIR (KBr) cm^{-1}**: 3448, 3342, 3205, 2925, 2854, 2186, 1743, 1648, 1522, 1414, 1252, 1178. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{15}H_{10}Br_2N_2NaO_3$ 446.8950, found 446.8946.



3f

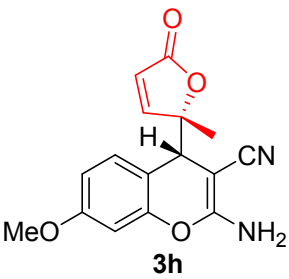
(*S*)-2-amino-7-fluoro-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4H-chromene-3-carbonitrile (3f): To the suspension of iminochromene **1f** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/anti* ratio (2.1:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.67 ppm, δ minor: 3.76 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3f** light yellow solid (17 mg, 58% yield, R_f = 0.5, *syn/anti* = 2.1:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 89:11 by HPLC, [Lux 5u cellulose-4 column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (minor) = 18.9 min, t (minor) = 24.9 min, t (minor) = 28.5 min, t (major) = 35.9 min]. $[\alpha]_{25}^{D}$ = -12.22 (c = 0.18, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) δ 7.67 (d, J = 5.7 Hz, 1H), 7.24 (s, 2H), 7.23 – 7.15 (m, 1H), 7.08 – 6.95 (m, 1H), 6.92 (dd, J = 9.4, 2.3 Hz, 1H), 6.02 (d, J = 5.7 Hz, 1H), 3.89 (s, 1H), 1.40 (s, 3H). **^{13}C-NMR** (100 MHz, DMSO-d_6) δ 171.93, 163.82, 160.21, 151.75, 151.62, 131.97, 131.87, 121.48, 121.17, 116.80 (d, J = 3.1 Hz), 111.53 (d, J = 21.7 Hz), 104.13 (d, J = 25.5 Hz), 92.47, 50.29, 42.92, 21.03. **FTIR** (KBr) cm^{-1}: 3475, 3312, 3195, 2924, 2192,

1745, 1648, 1501, 1409, 1148, 1111. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{15}H_{11}FN_2NaO_3$ 309.0646, found 309.0651.



3g

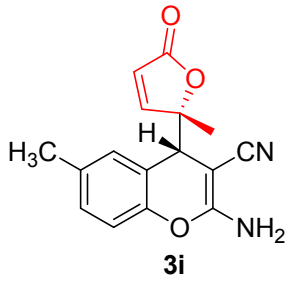
(*S*)-2-amino-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-6-nitro-4*H*-chromene-3-carbonitrile (3g): To the suspension of iminochromene **1g** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/anti* ratio (4:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.77 ppm, δ minor: 3.90 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3g** yellow solid (12 mg, 40% yield, R_f = 0.3, *syn/anti* = 4:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 87:13 by HPLC, [ID column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (major) = 20.7 min, t (minor) = 22.7 min, t (minor) = 24.8 min, t (minor) = 37.5min]. $[\alpha]_{25}^{D}$ = +20.0 (*c* = 0.06, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) *δ* 8.21 (s, 2H), 7.71 (d, *J* = 5.4 Hz, 1H), 7.43 (s, 2H), 7.30 (d, *J* = 9.3 Hz, 1H), 6.16 (d, *J* = 5.2 Hz, 1H), 4.17 (s, 1H), 1.46 (s, 3H). **^{13}C-NMR** (100 MHz, DMSO-d_6) *δ* 171.30, 162.66, 158.86, 154.90, 143.20, 125.66, 124.59, 121.82, 121.35, 120.26, 117.32, 91.16, 49.44, 42.27, 20.91. **FTIR (KBr) cm^{-1}:** 3421, 3328, 3202, 2928, 2195, 1742, 1649, 1525, 1415, 1258, 1092. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{15}H_{11}N_3NaO_5$ 336.0591, found 336.0596.



3h

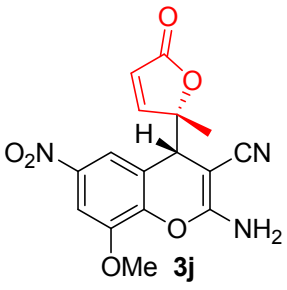
(*S*)-2-amino-7-methoxy-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3h): To the suspension of iminochromene **1h** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/anti* ratio (2.7:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.55 ppm, δ minor: 3.75 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3h** as white solid (19 mg, 63% yield, R_f = 0.5, *syn/anti* = 2.7:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 87:13 by HPLC, [IE

column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (minor) = 24.9 min, t (major) = 26.9 min, t (minor) = 30.8 min, t (minor) = 33.0 min]. $[\alpha]_{25}^{D}$ = -1.33 (*c* = 0.15, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) δ 7.64 (d, *J* = 5.4 Hz, 1H), 7.25 – 6.98 (m, 3H), 6.72 (d, *J* = 6.2 Hz, 1H), 6.55 (s, 1H), 6.03 (d, *J* = 5.4 Hz, 1H), 3.79 (s, 1H), 3.74 (s, 3H), 1.39 (s, 3H). **^{13}C-NMR** (100 MHz, DMSO-d_6) δ 171.65, 163.69, 159.90, 159.43, 151.38, 130.71, 121.36, 120.73, 111.95, 110.27, 101.15, 92.31, 55.46, 50.14, 42.68, 20.69. **FTIR (KBr) cm^{-1}:** 3448, 3332, 3203, 2924, 2852, 2185, 1748, 1652, 1510, 1408, 1251, 1111. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{15}H_{14}N_2NaO_4$ 321.0845, found 321.0851.



3i

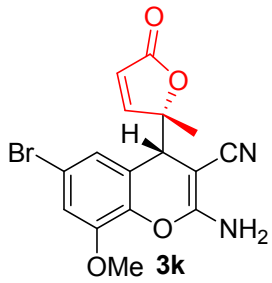
(*S*)-2-amino-6-methyl-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3i): To the suspension of iminochromene **1i** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/anti* ratio (2.3:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.75 ppm, δ minor: 3.81 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3i** as white solid (17 mg, 61% yield, R_f = 0.5, *syn/anti* = 2.3:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 86:14 by HPLC, [IC column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (major) = 25.1 min, t (minor) = 40.2 min, t (major) = 51.7 min, t (minor) = 71.1 min]. $[\alpha]_{25}^{D}$ = -6.67 (*c* = 0.03, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) δ 7.63 (dd, *J* = 5.7, 2.0 Hz, 1H), 7.17 (s, 2H), 7.09 (s, 1H), 7.00 (s, 1H), 6.92 (d, *J* = 8.2 Hz, 1H), 6.05 (dd, *J* = 5.7, 2.0 Hz, 1H), 3.81 (s, 1H), 2.26 (s, 3H), 1.40 (s, 3H). **^{3}C-NMR** (75 MHz, DMSO-d_6) δ 171.47, 163.80, 159.69, 148.55, 132.81, 130.09, 129.19, 121.29, 120.64, 119.72, 115.58, 92.01, 49.54, 43.21, 20.65, 20.31. **FTIR (KBr) cm^{-1}:** 3416, 3325, 3198, 2924, 2852, 2187, 1749, 1648, 1428, 1258, 1178, 1107. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{16}H_{14}N_2NaO_3$ 305.0897, found 305.0888.



3j

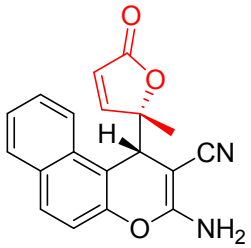
(*S*)-2-amino-8-methoxy-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-6-nitro-4*H*-chromene-3-carbonitrile (3j): To the suspension of iminochromene **1j** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting

reaction mixture was stirred at room temperature for 16 h. The *syn/anti* ratio (2.3:1) was determined by ^{1}H NMR analysis of the crude product (δ major: 3.74 ppm, δ minor: 3.87 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3j** as yellow solid (40% yield, R_f = 0.4, *syn/anti* = 2:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 89:11 by HPLC, [ID column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (minor) = 25.7 min, t (major) = 28.1 min, t (minor) = 31.8 min, t (minor) = 34.6 min]. $[\alpha]_{25}^{D}$ = +7.0 (*c* = 0.08, $CHCl_3$); **^{1}H-NMR** (300 MHz, DMSO-d_6) *δ* ^{1}H NMR (300 MHz, DMSO) δ 7.77 (m, 3H), 7.47 (s, 2H), 6.02 (d, *J* = 5.7 Hz, 1H), 4.09 (s, 1H), 3.93 (s, 3H), 1.42 (s, 3H). **^{13}C-NMR** (75 MHz, DMSO-d_6) *δ* δ 171.27, 162.88, 159.52, 147.45, 144.70, 142.83, 121.50, 120.77, 117.08, 106.55, 91.73, 56.51, 49.37, 42.56, 20.54. **FTIR** (KBr) cm^{-1}: 3381, 3329, 2924, 2854, 2194, 1746, 1655, 1529, 1416, 1344, 1227, 1104, 960, 825. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{16}H_{13}N_3NaO_6$ 366.0696, found 366.0704.



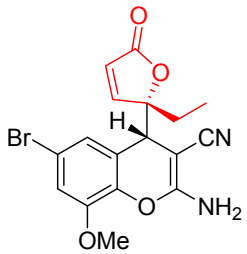
3k

(*S*)-2-amino-6-bromo-8-methoxy-4-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3k): To the suspension of iminochromene **1k** in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/anti* ratio (2.7:1) was determined by ^{1}H NMR analysis of crude product (δ major: 3.61 ppm, δ minor: 3.78 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3k** (27 mg, 67% yield, R_f =0.4, *syn/anti* = 2.7:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 93:7 by HPLC, [ID column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (major) = 21.0 min, t (minor) = 22.6 min, t (minor) = 27.6 min, t (minor) = 29.4 min]. $[\alpha]_{25}^{D}$ = +13.75 (*c* = 0.24, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) *δ* 7.69 (d, *J* = 5.5 Hz, 1H), 7.28 (s, 2H), 7.20 (s, 1H), 6.99 (s, 1H), 6.07 (d, *J* = 5.5 Hz, 1H), 3.88 (s, 1H), 3.83 (s, 3H), 1.40 (s, 3H). **^{13}C-NMR** (100 MHz, DMSO-d_6) *δ* 171.39, 163.46, 159.62, 147.93, 139.33, 123.38, 122.83, 120.91, 120.61, 115.21, 114.68, 91.82, 56.22, 49.37, 42.79, 20.63. **FTIR (KBr) cm^{-1}:** 3405, 3325, 2925, 2187, 1749, 1652, 1575, 1483, 1420, 1263, 1101. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{16}H_{13}BrN_2NaO_4$ 398.9950, found 398.9956.



3l

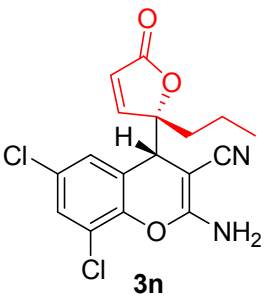
(*S*)-3-amino-1-((*S*)-2-methyl-5-oxo-2,5-dihydrofuran-2-yl)-1*H*-benzo[*f*]chromene-2-carbonitrile (3l): To the suspension of iminochromene **1l** (0.1 mmol) in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then *α*-Angelica lactone **2** (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 24 h. The *syn/anti* ratio (1:1) was determined by ^{1}H NMR analysis of crude product (δ major: 4.63 ppm, δ minor: 4.75 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3l** (13 mg, 40% yield, R_f =0.5, *syn/anti* = 1:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 83:17 by HPLC, [ID column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (major) = 19.8 min, t (minor) = 23.5 min, t (major) = 26.5 min, t (major) = 28.6 min]. $[\alpha]_{25}^{D}$ = +5.00 (*c* = 0.06, $CHCl_3$); **^{1}H-NMR** (400 MHz, DMSO-d_6) δ 8.23 (s, 1H), 7.91 (s, 2H), 7.61 (s, 2H), 7.49 (s, 1H), 7.28 (m, 3H), 5.62 (s, 1H), 4.63 (s, 1H), 1.55 (s, 3H). **^{13}C-NMR** (100 MHz, DMSO-d_6) *δ* 171.29, 163.98, 159.10, 148.91, 130.60, 130.25, 129.29, 128.28, 126.79, 124.77, 123.83, 121.35, 119.19, 116.46, 113.72, 92.92, 50.28, 38.86, 20.95. **FTIR (KBr) cm^{-1}:** 3448, 3322, 2925, 2185, 1748, 1645, 1587, 1412, 1243, 1105. **HRMS-ESI:** $[M+Na]^+$, calcd for $C_{19}H_{14}N_2NaO_3$ 341.0896 , found 341.0902.



3m

(*S*)-2-amino-6-bromo-4-((*S*)-2-ethyl-5-oxo-2,5-dihydrofuran-2-yl)-8-methoxy-4*H*-chromene-3-carbonitrile (3m): To the suspension of iminochromene **1k** in anhydrous dichloromethane (1 ml), catalyst **III** (10 mol%) and then 5-ethylfuran-2(3*H*)-one (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/anti* ratio (2.1:1) was determined by ^{1}H NMR analysis of crude product (δ major: 3.67 ppm, δ minor: 3.86 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3m** (28 mg, 71% yield, R_f =0.4, *syn/anti* = 2.1:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 95:5 by HPLC, [Lux cellulose-4 column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (minor) = 44.9 min, t (minor) = 52.5 min, t (minor) = 83.0 min, t

(major) = 117.4 min]. $[\alpha]_{25}^{D}$ = +0.12 (*c* = 0.27, $CHCl_3$); **^{1}H-NMR** (300 MHz, $CDCl_3$) δ 7.43 (d, *J* = 5.7 Hz, 1H), 6.99 (d, *J* = 2.9 Hz, 2H), 6.15 (d, *J* = 5.7 Hz, 1H), 5.08 (s, 2H), 3.87 (s, 3H), 3.67 (s, 1H), 1.83 – 1.73 (m, 2H), 0.71 (t, *J* = 7.3 Hz, 3H). **^{13}C-NMR** (75 MHz, $CDCl_3$) δ 171.80, 162.92, 156.71, 148.27, 139.44, 124.10, 123.45, 121.90, 117.35, 115.16, 94.74, 56.44, 54.12, 44.69, 29.81, 7.29. **FTIR** (KBr) cm^{-1}: 3402, 3319, 2922, 2185, 1748, 1651, 1573, 1481, 1416, 1260, 1104. **HRMS-ESI**: $[M+Na]^+$, calcd for $C_{17}H_{15}BrN_2NaO_4$ 413.0113, found 413.0119.

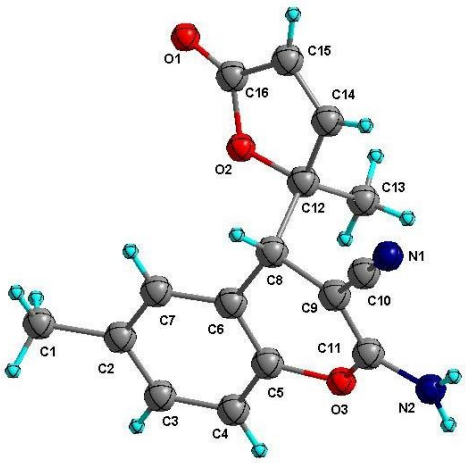


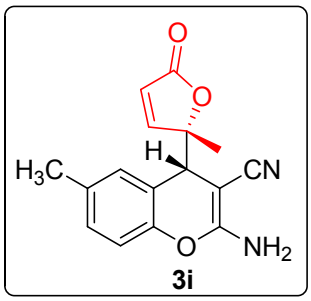
3n

(*S*)-2-amino-6,8-dichloro-4-((*S*)-5-oxo-2-propyl-2,5-dihydrofuran-2-yl)-4*H*-chromene-3-carbonitrile (3n): To the suspension of iminochromene **1d** in anhydrous dichloromethane (1 ml), catalyst III (10 mol%) and then 5-propylfuran-2(3H)-one (0.15 mmol) were added under the N_2 gas atmosphere. The resulting reaction mixture was stirred at room temperature for 16 h. The *syn/anti* ratio (9:1) was determined by ^{1}H NMR analysis of crude product (δ major: 3.67 ppm, δ minor: 3.87 ppm). The crude reaction mixture was purified by column chromatography on silica gel using ethylacetate/DCM (3:7) as eluent afforded the desire product **3n** (27 mg, 75% yield, R_f=0.4, *syn/anti* = 9:1). The enantiomeric ratio of the *syn* diastereomer was determined to be 89:11 by HPLC, [Lux cellulose-4 column, λ = 254 nm, hexanes:isopropanol = 8:2, 1.0 mL/min, t (minor) = 19.5 min, t (minor) = 22.8 min, t (minor) = 34.0 min, t (major) = 48.7 min]. $[\alpha]_{25}^{D}$ = -0.02 (*c* = 0.16, $CHCl_3$); **^{1}H-NMR** (300 MHz, $CDCl_3$) *δ* 7.51 (d, *J* = 5.7 Hz, 1H), 7.38 (d, *J* = 2.3 Hz, 1H), 7.18 (d, *J* = 2.3 Hz, 1H), 6.16 (d, *J* = 5.7 Hz, 1H), 5.21 (s, 2H), 3.67 (s, 1H), 1.77 – 1.72 (m, 2H), 1.25 – 1.03 (m, 3H), 0.84 (t, *J* = 7.1 Hz, 4H). **^{13}C-NMR** (75 MHz, $CDCl_3$) δ 171.54, 162.66, 156.91, 145.34, 130.17, 129.90, 128.60, 124.18, 123.26, 122.75, 122.26, 94.27, 54.16, 45.29, 33.43, 16.49, 14.11. **FTIR** (KBr) cm^{-1}: 3443, 3334, 3209, 2928, 2851, 2185, 1745, 1652, 1614, 1510, 1408, 1252, 1162, 961, 825. **HRMS-ESI**: $[M+Na]^+$, calcd for $C_{17}H_{14}N_2NaO_4$ 387.0279, found 387.0285.

7. Crystallographic data

Assignment of the absolute configuration of *syn*-3i by X-Ray Diffraction analysis:





Identification code		**3i**	
Empirical formula	$C_{16}H_{14}N_2O_3$	Density (calculated)	1.369 g/cm^3
Formula weight	282.29	Absorption coefficient	0.096 mm^{-1}
Temperature	305(2)	F(000)	296.0
Wavelength	0.71073 Å	Crystal size	0.21 x 0.19 x 0.17 mm^3
Crystal system	Triclinic	Theta range for data collection	2.622 to 28.458°
Space group	P -1	Index ranges	-8<=h<=8, -10<=k<=10, -19<=l<=19
Unit cell dimensions	a = 6.158(5)Å, α = 79.963(15)°	Reflections collected	21232
	b = 7.899(6) Å, β = 87.426(16)°	Completeness to theta = 25.00°	99.4%
	c = 14.325(10) Å, γ = 86.68(2)°	R indices (all data)	R1 = 0.1088, wR2 = 0.1934

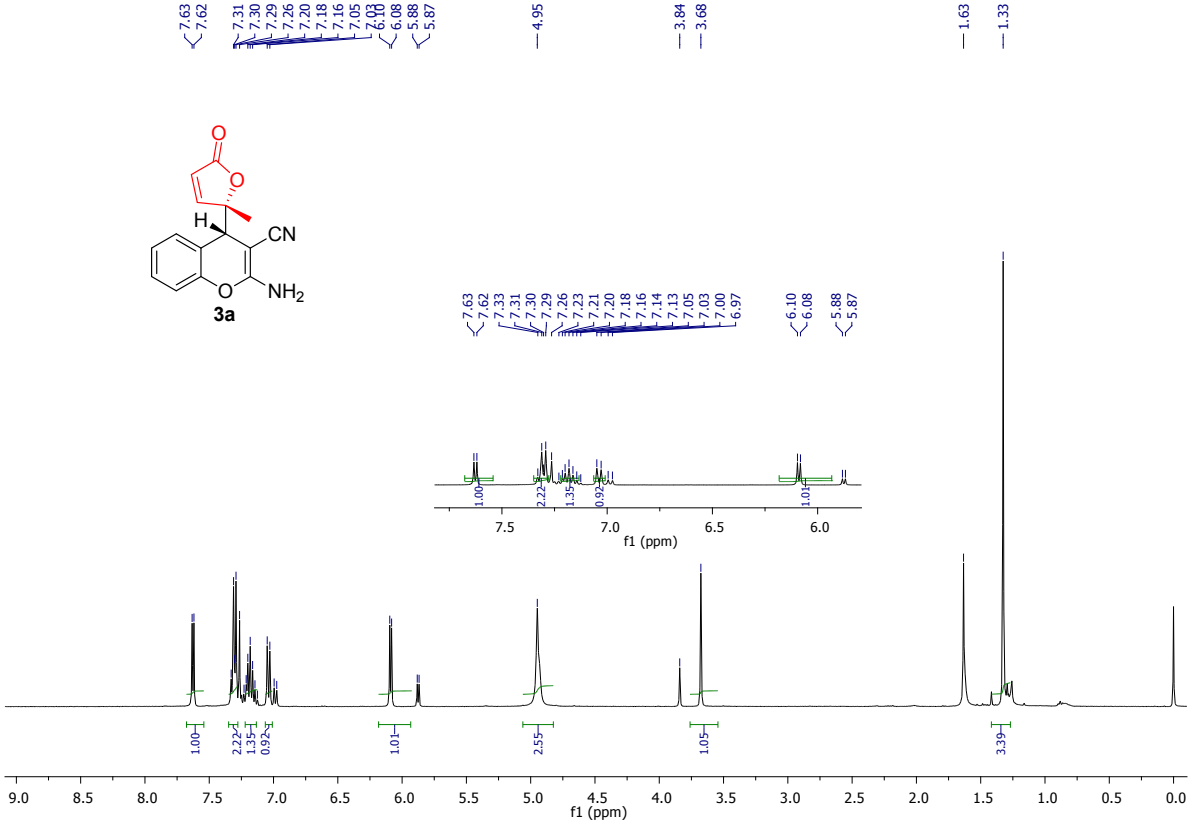
Volume	684.5(9) Å^3	**CCDC**	**1889051**
Z	2		

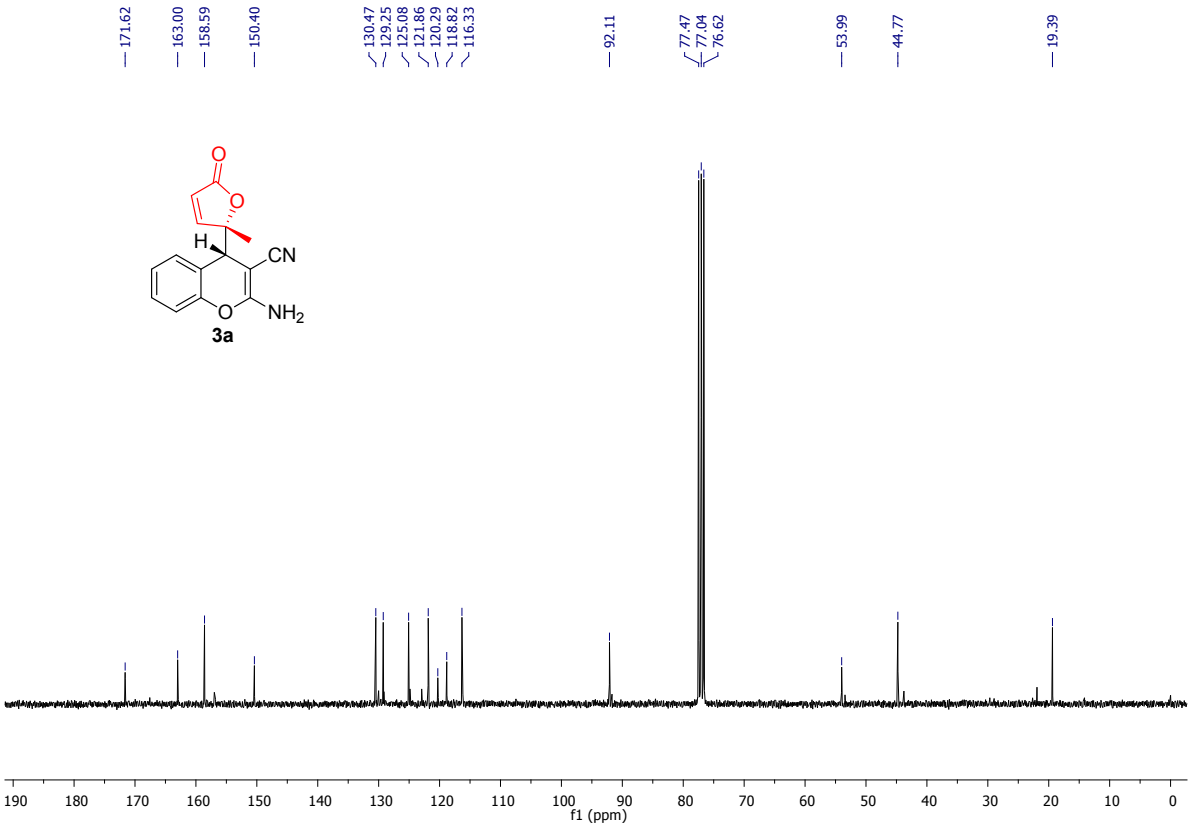
8. References

1. (a) Li, H.; Wang, Y.; Tang, L.; Deng. L. *J. Am. Chem. Soc.* **2004**, *126*, 9906. (b) Li, H.; Wang, Y.; Tang, L.; Wu, F.; Liu, X. Guo, C.; Foxman, B. M.; Deng, L. *Angew. Chem. Int. Ed.* **2005**, *44*, 105. (c) Song, J.; Wang, Y.; Deng, L. *J. Am. Chem. Soc.* **2006**, *128*, 6048. (d) Wang, Y.; Li, H.; Wang, Y.-Q.; Liu, Y.; Foxman, B. M.; Deng, L. *J. Am. Chem. Soc.* **2007**, *129*, 6364. (e) Singh, R. P.; Foxman, B. M.; Deng, L. *J. Am. Chem. Soc.* **2010**, *132*, 9558.

2. Li, W.; Liu, H.; Jiang, X.; Wang, J. *ACS Catal.* **2012**, *2*, 1535.

9. ^{1}H and ^{13}C Spectra of Compounds

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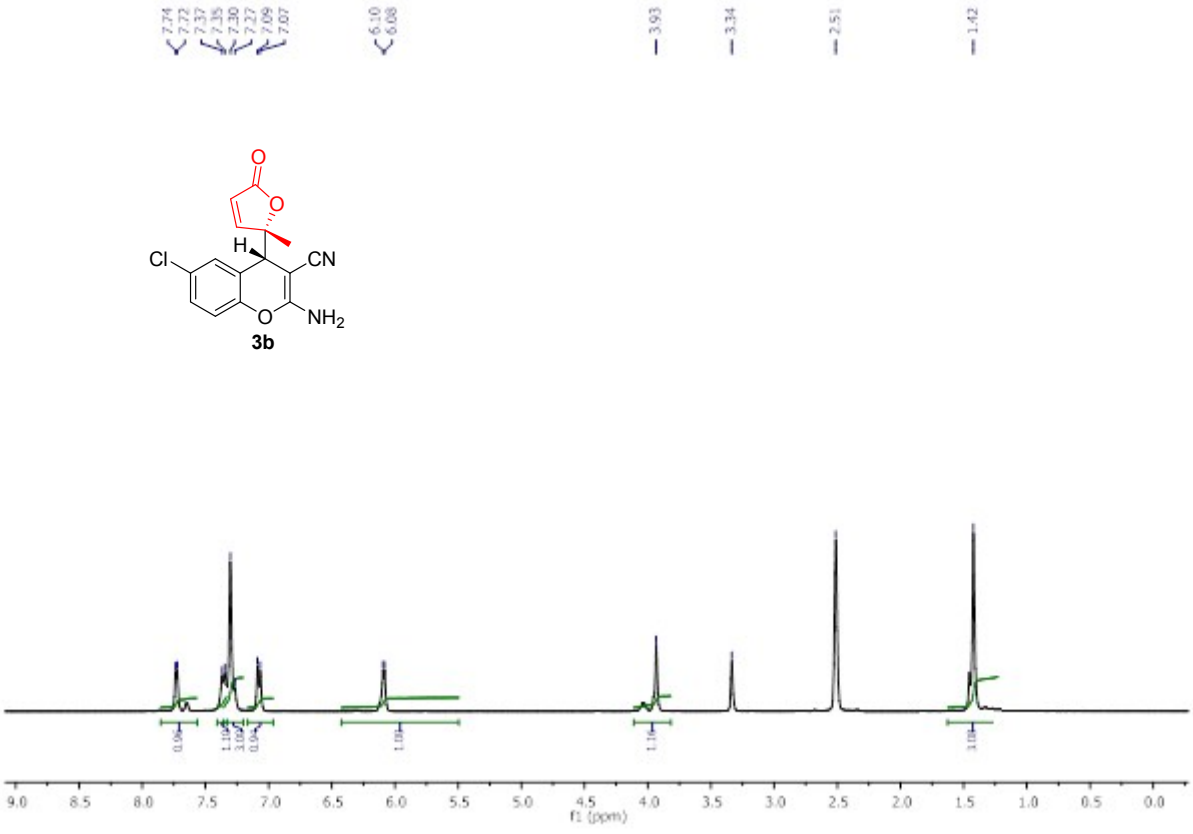
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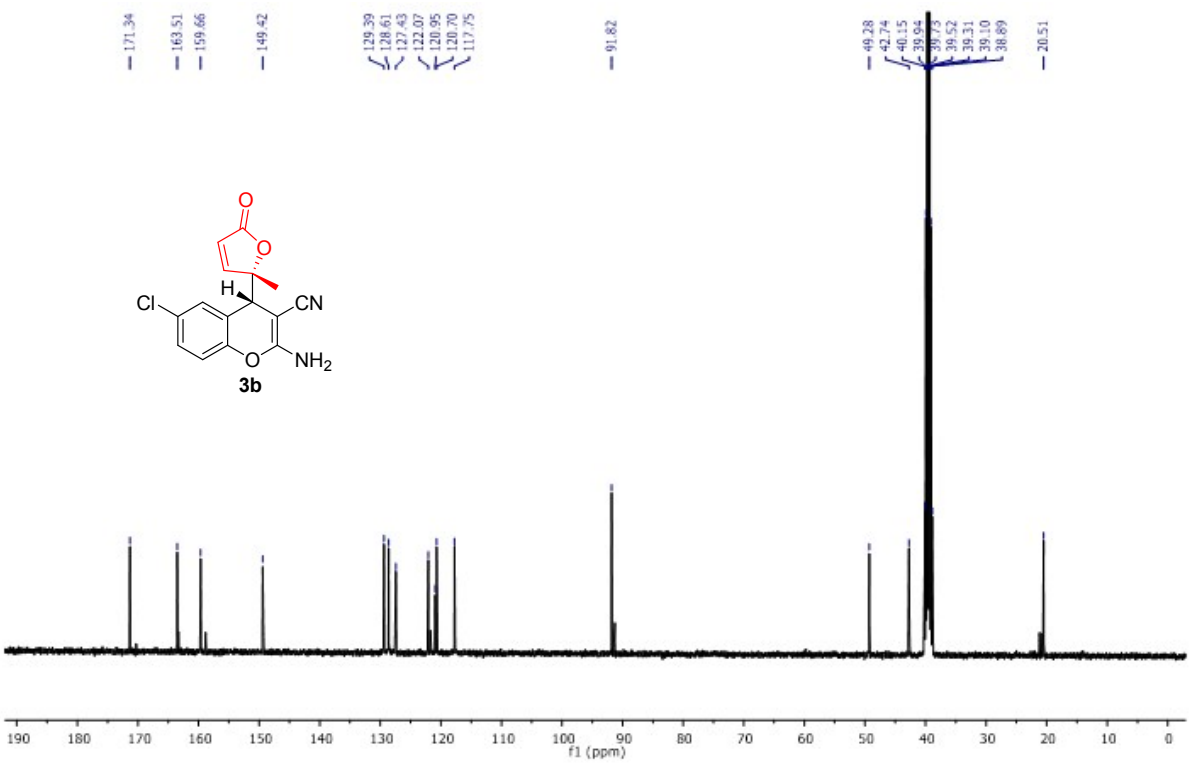
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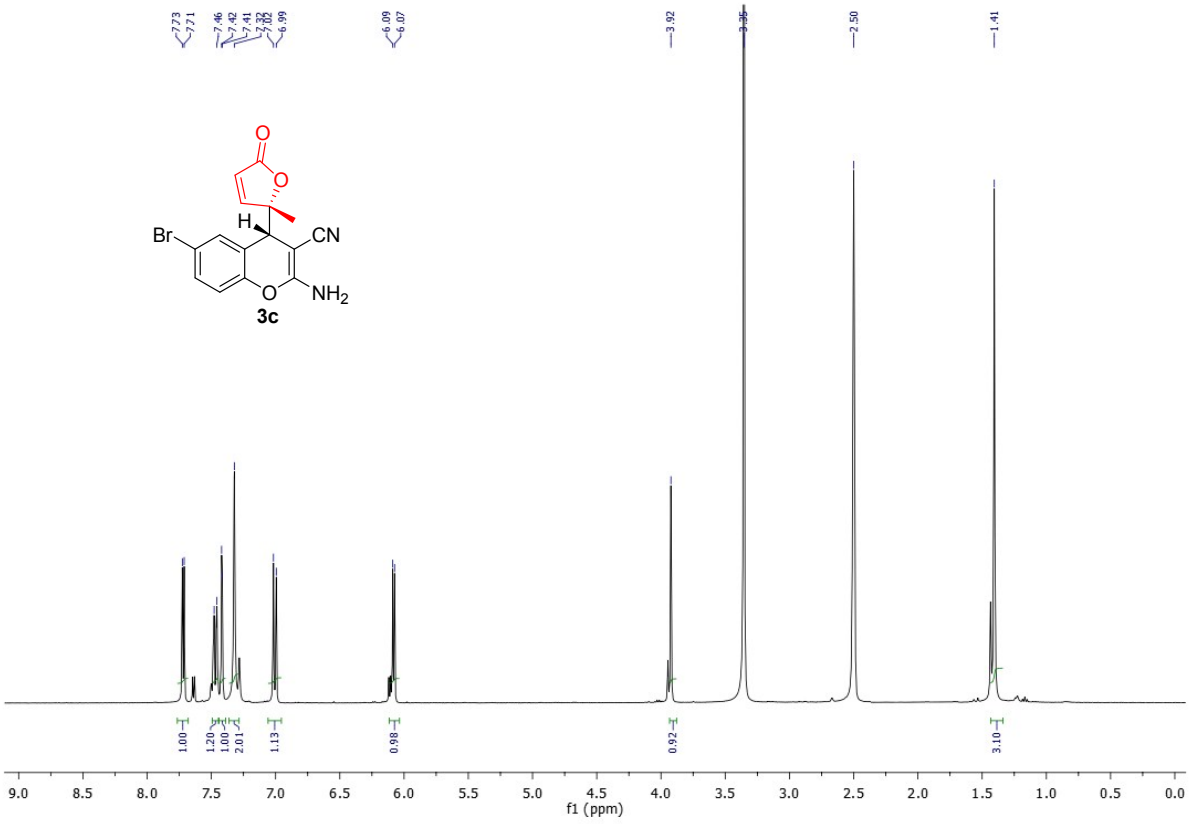
f1 (ppm)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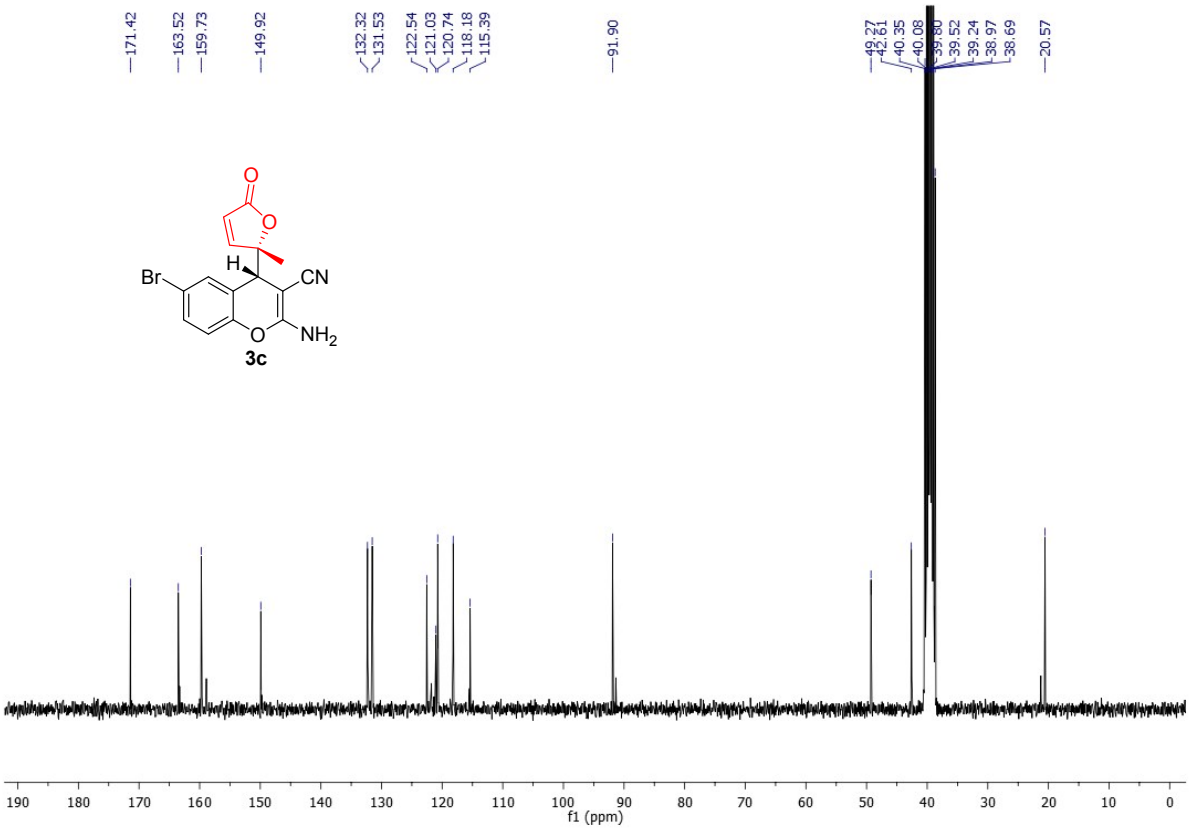
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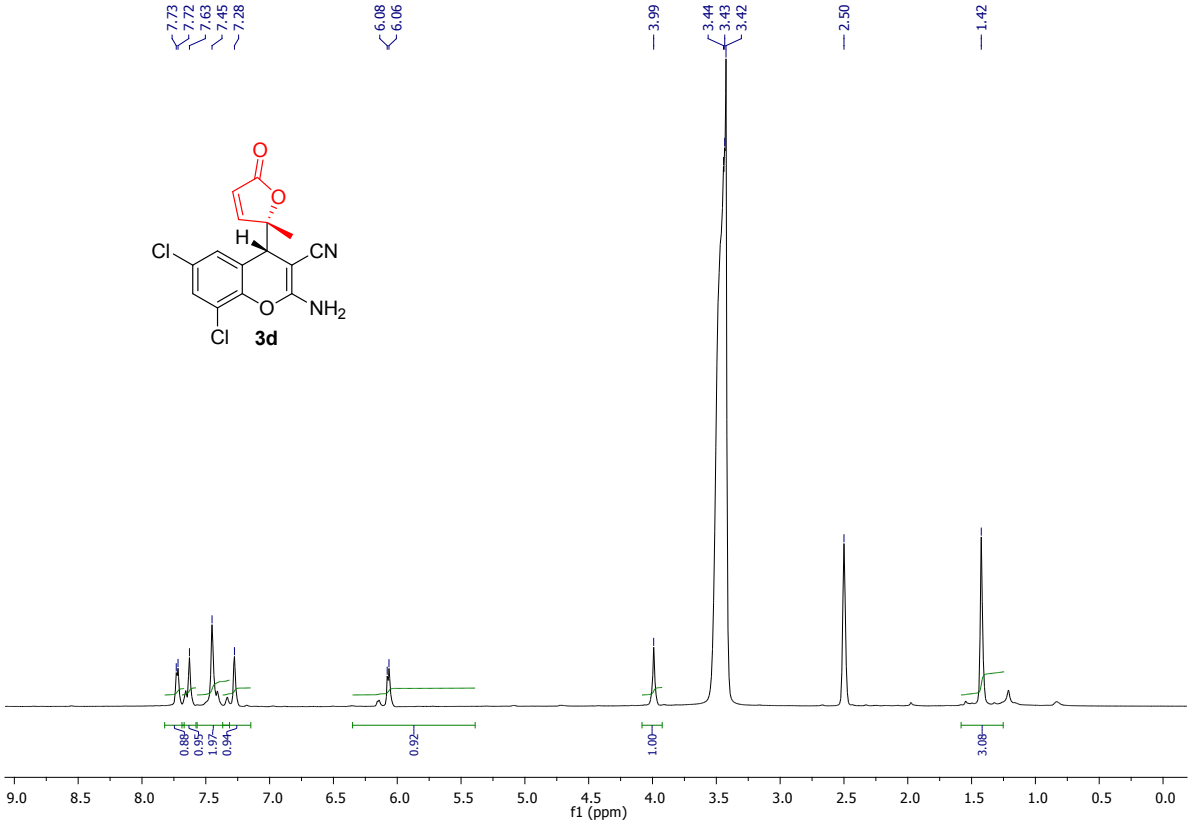
f1 (ppm)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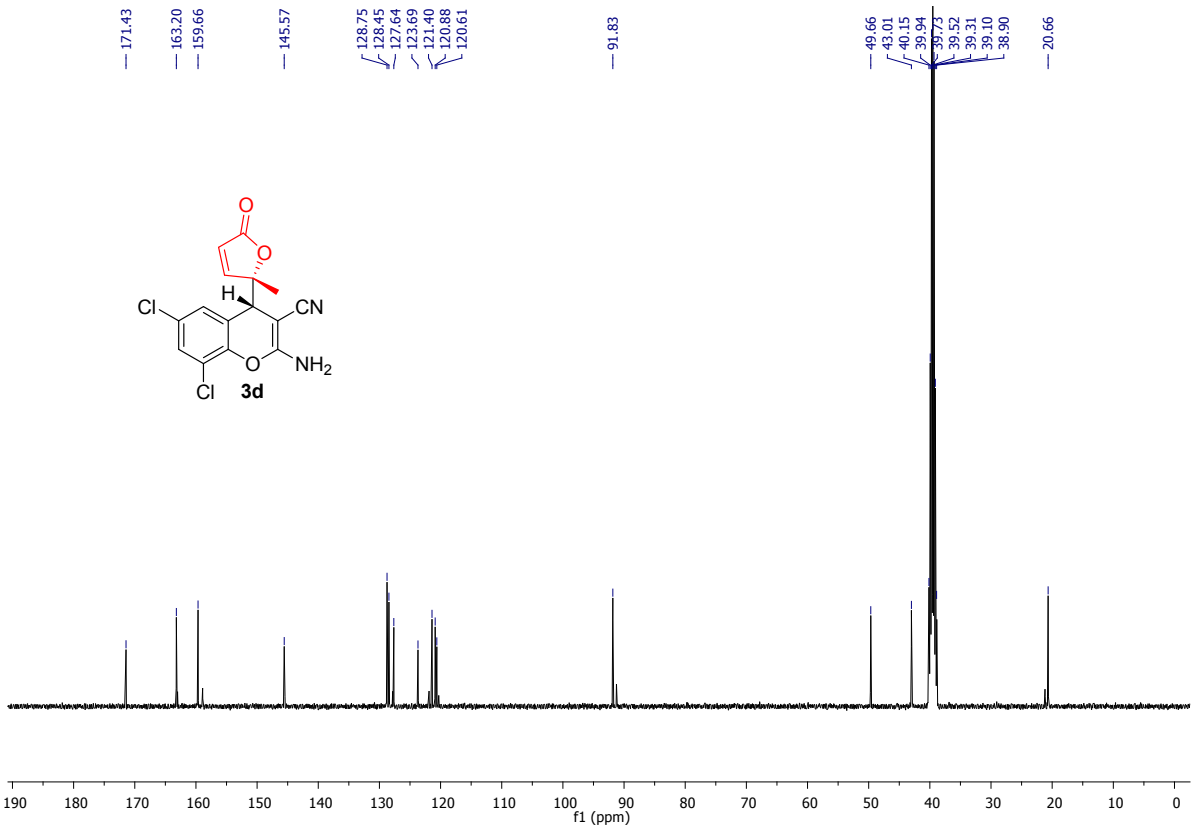
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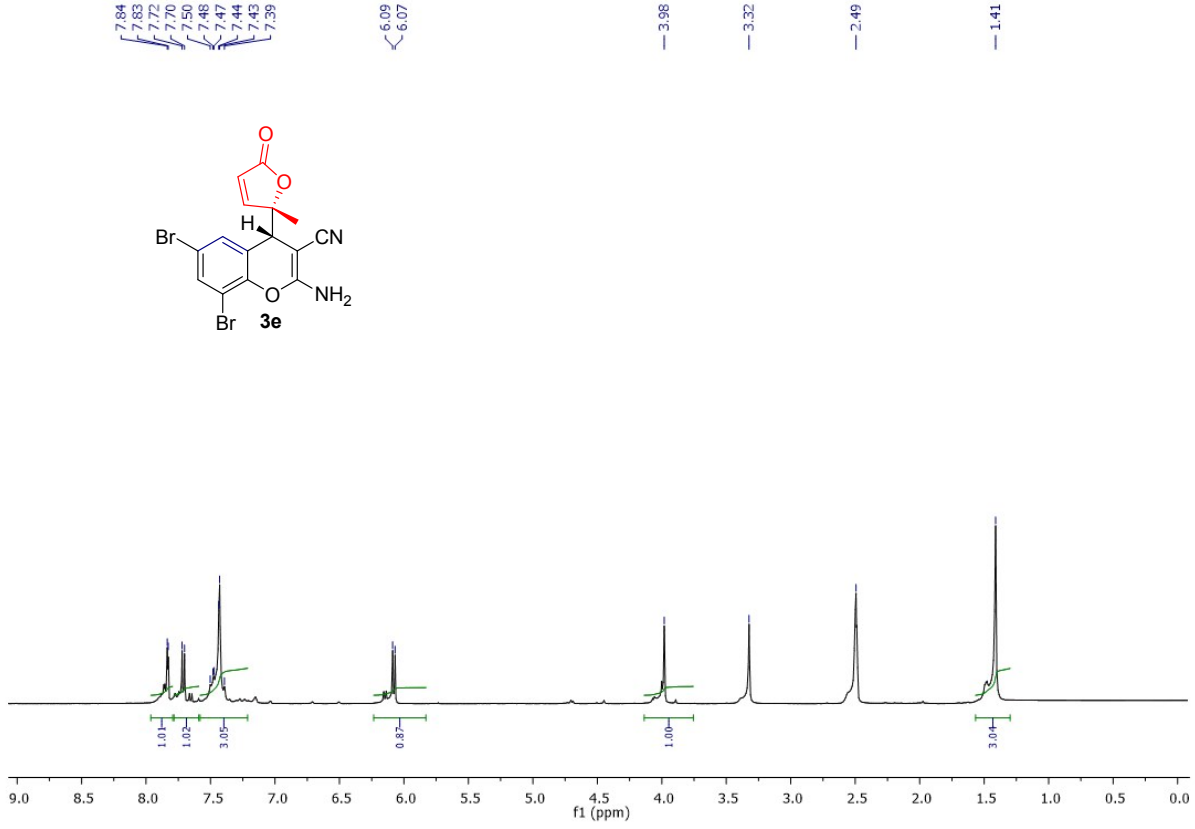
f1 (ppm)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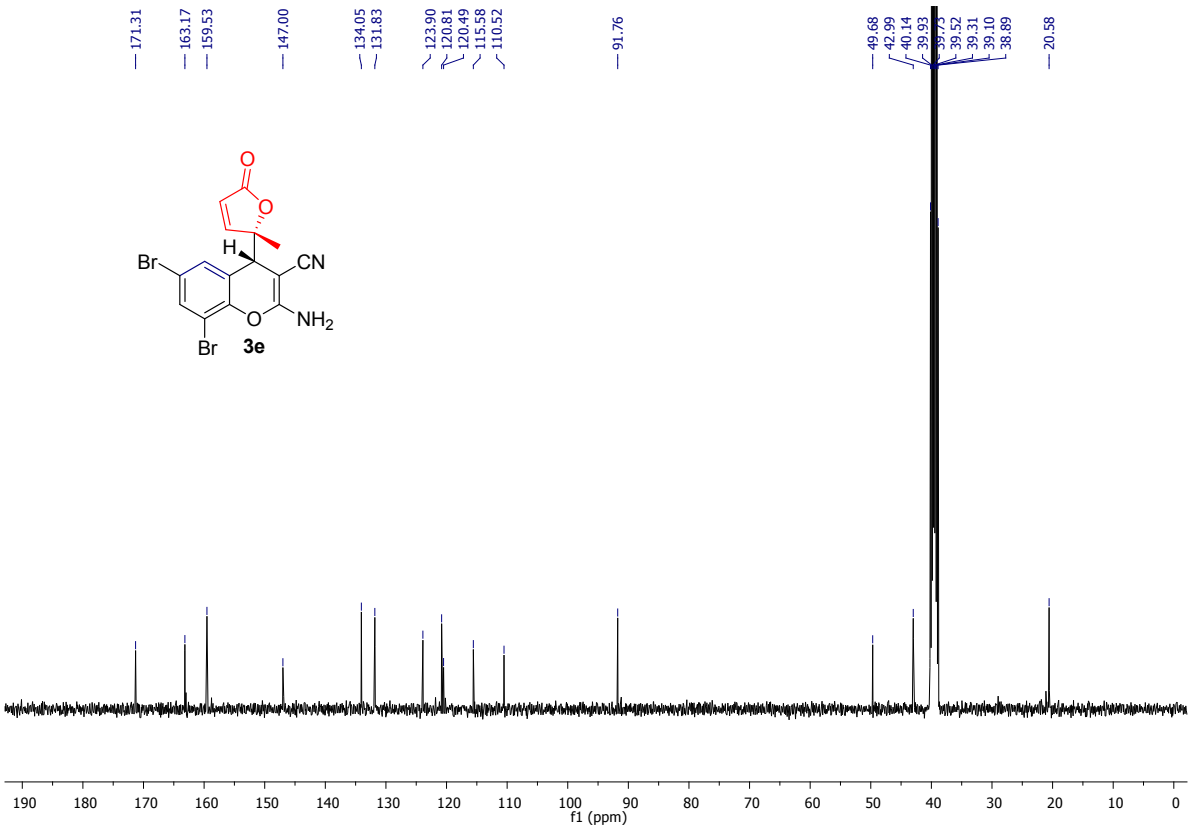
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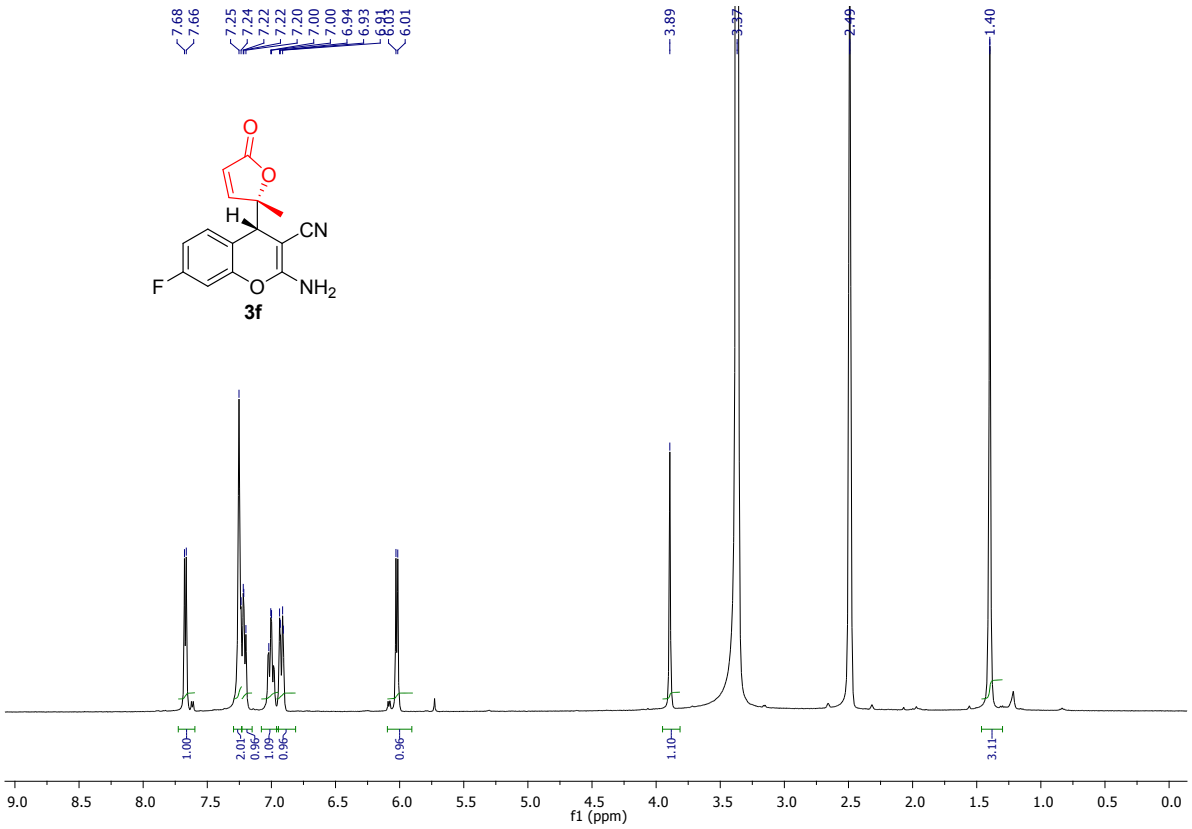
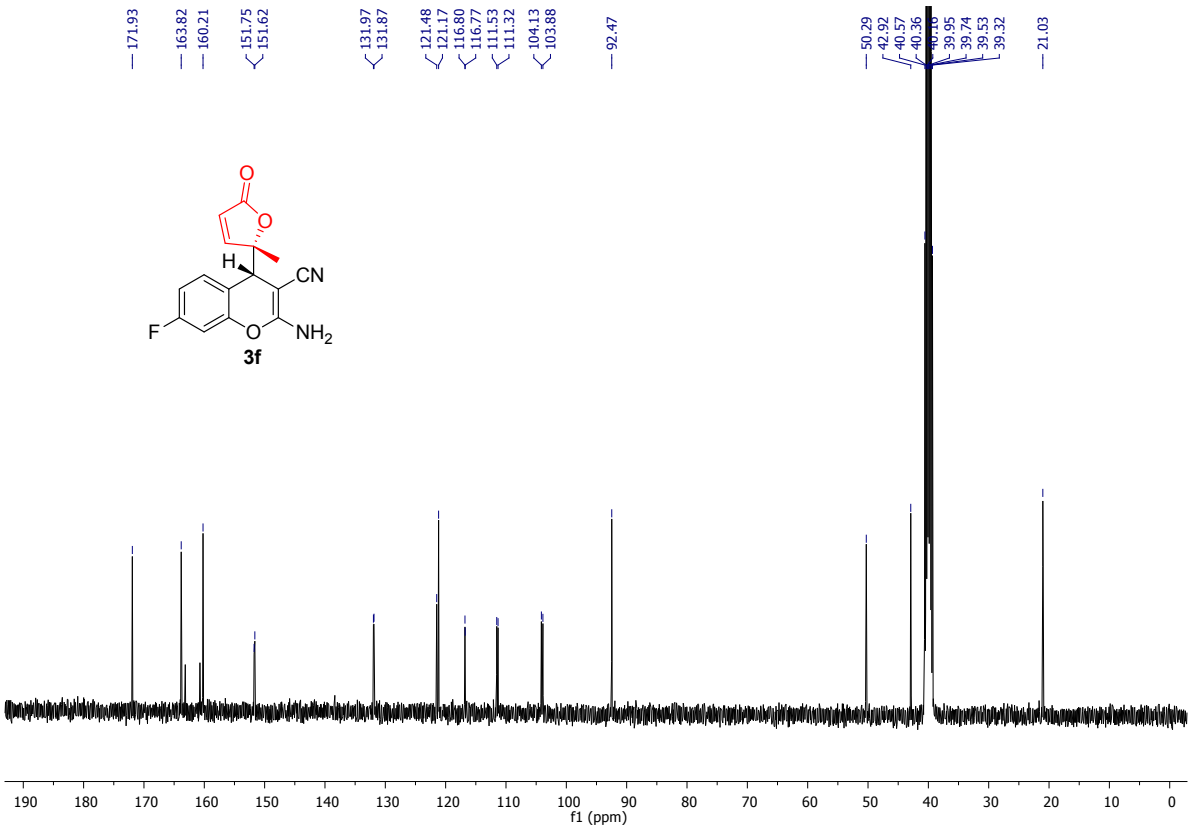
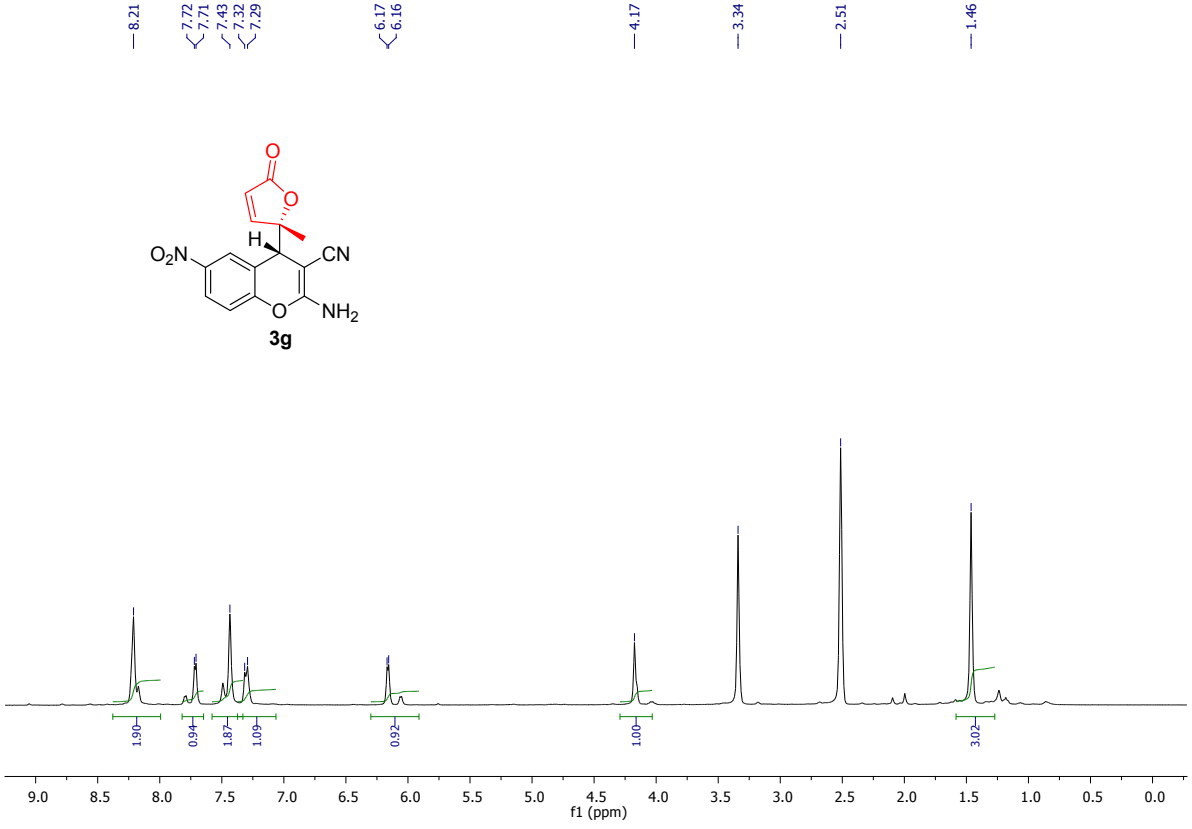
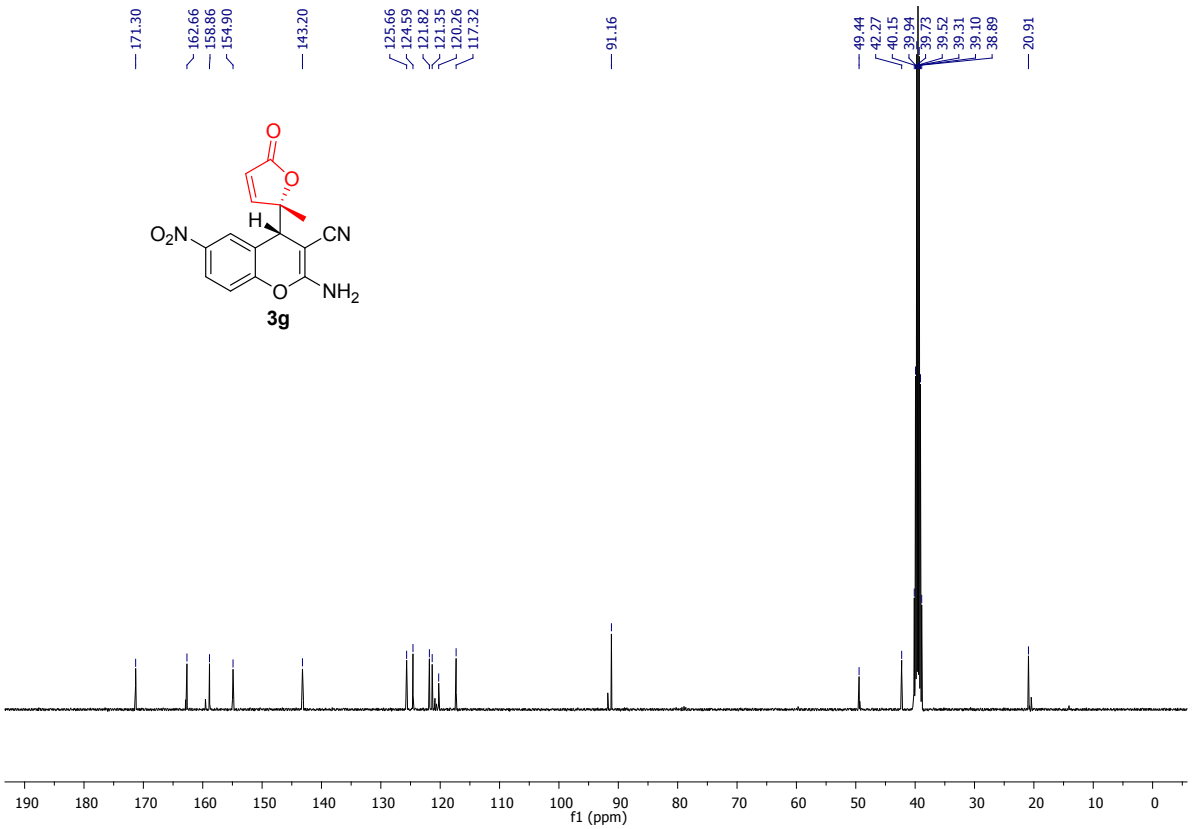
O
O
H
Br
CN
O
NH2
Br
3e
f1 (ppm)


7.68
7.66
7.25
7.24
7.22
7.22
7.20
7.00
7.00
6.94
6.93
6.01
6.01
3.89
3.37
2.49
1.40
O
O
H
CN
F
O
NH2
3f
1.00
2.01
0.96
1.09
0.96
0.96
1.10
3.11
f1 (ppm)


171.93
163.82
160.21
151.75
151.62
131.97
131.87
121.48
121.17
116.80
116.77
111.53
111.32
104.13
103.88
92.47
50.29
42.92
40.57
40.36
39.95
39.74
39.53
39.32
21.03
O
O
H
CN
F
O
NH2
3f
f1 (ppm)


8.21
7.72
7.71
7.43
7.32
7.29
6.17
6.16
4.17
3.34
2.51
1.46
O
O
H
CN
O2N
O
NH2
3g
1.90
0.94
1.87
1.09
0.92
1.00
3.02
f1 (ppm)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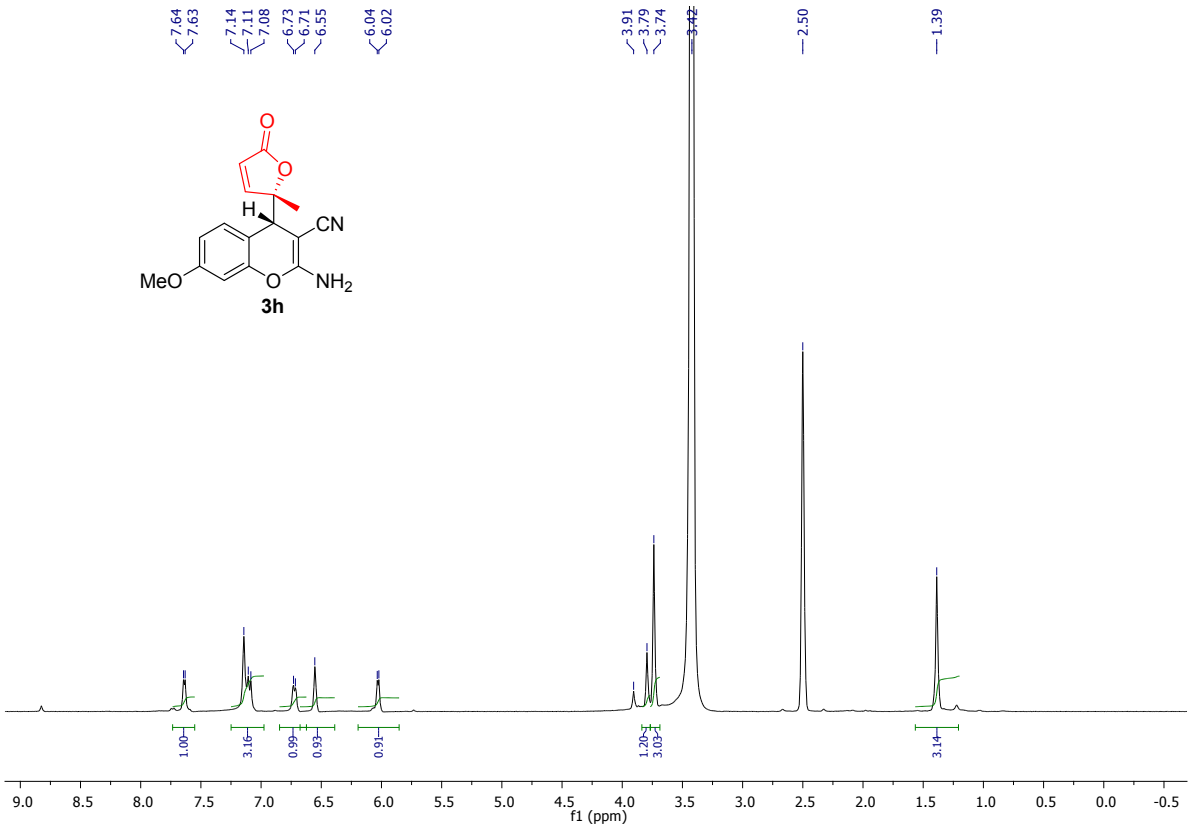
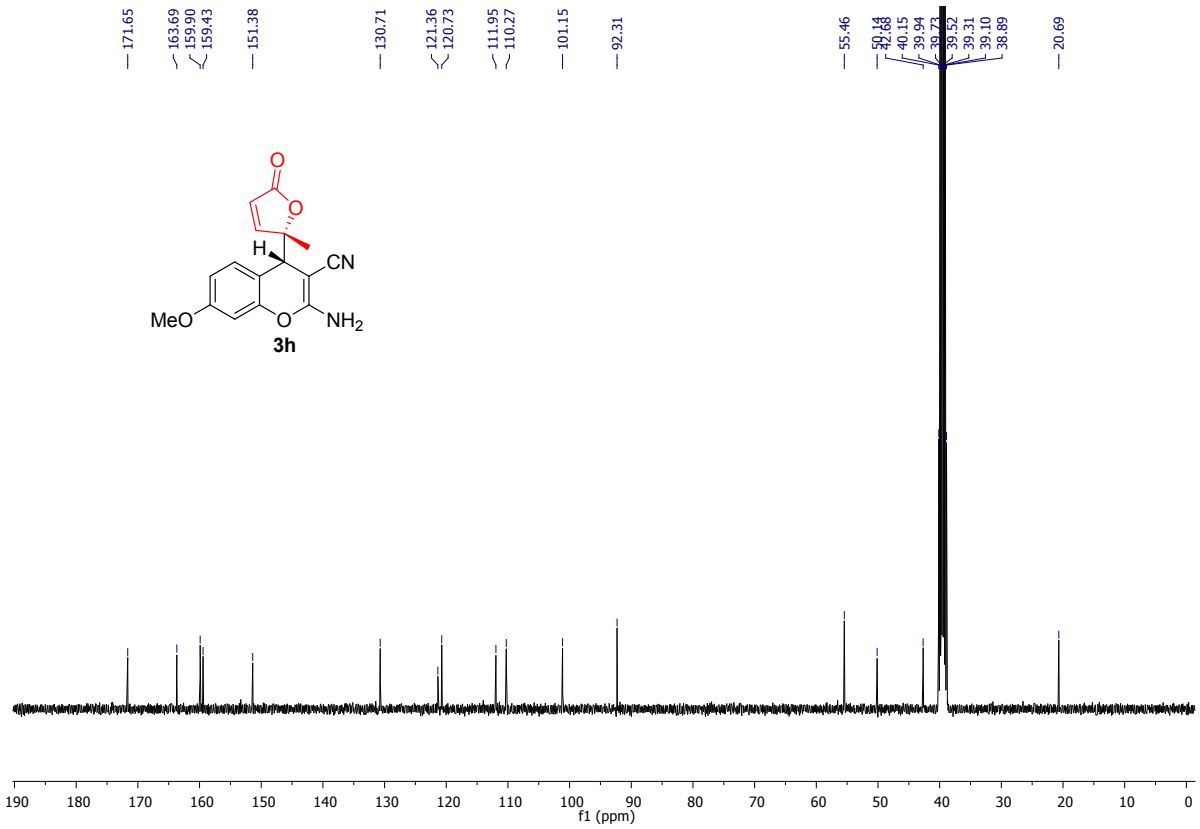
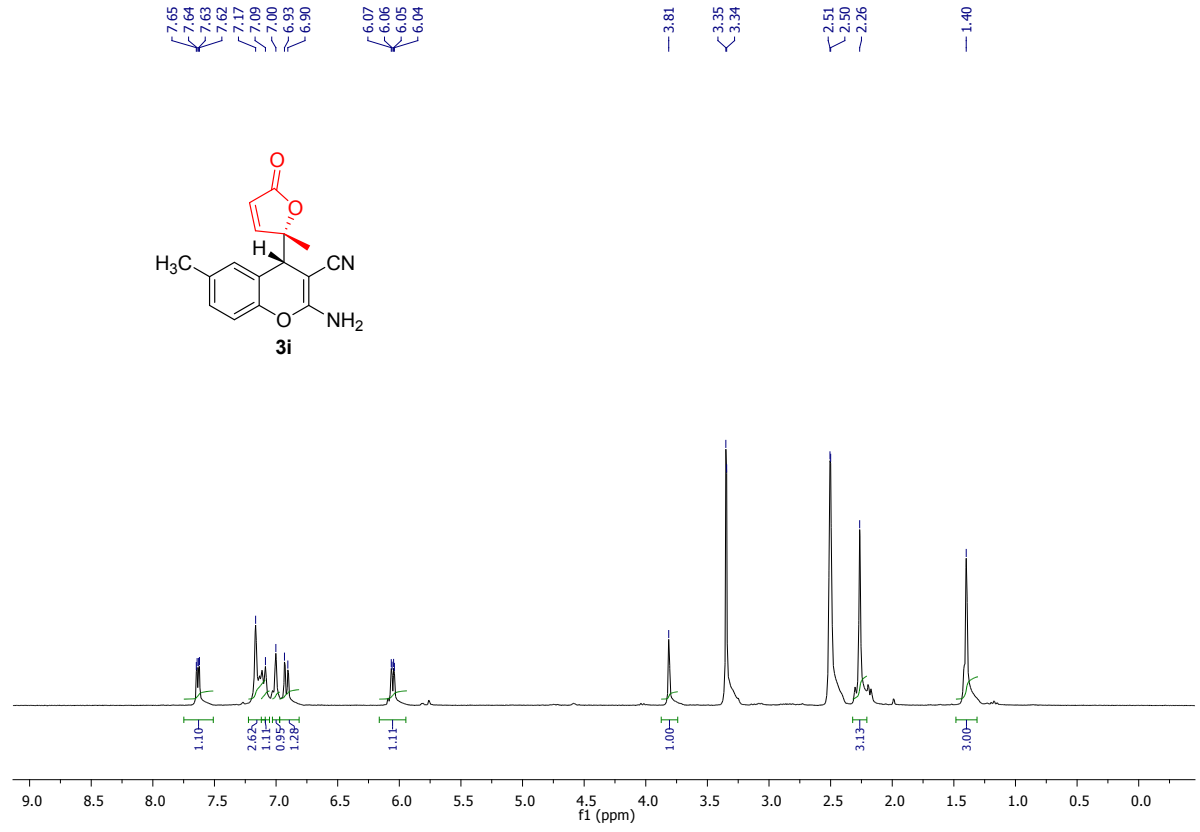
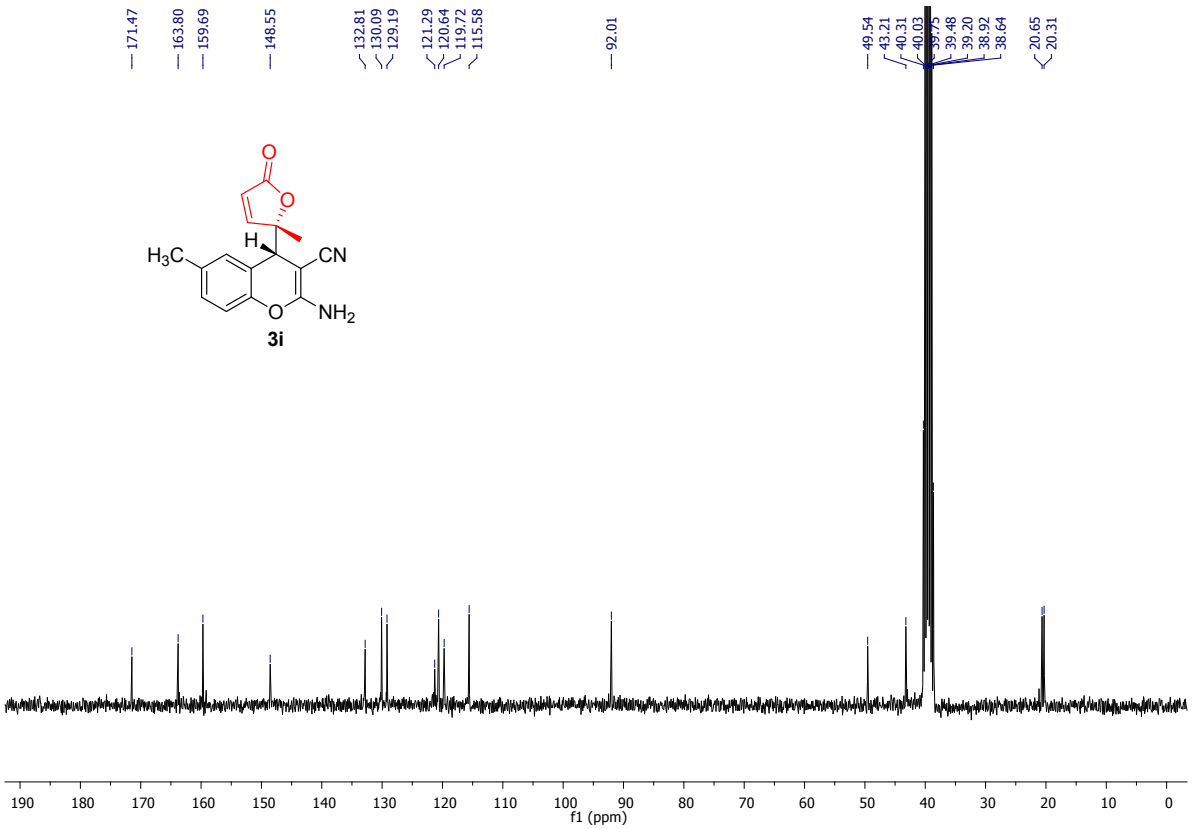
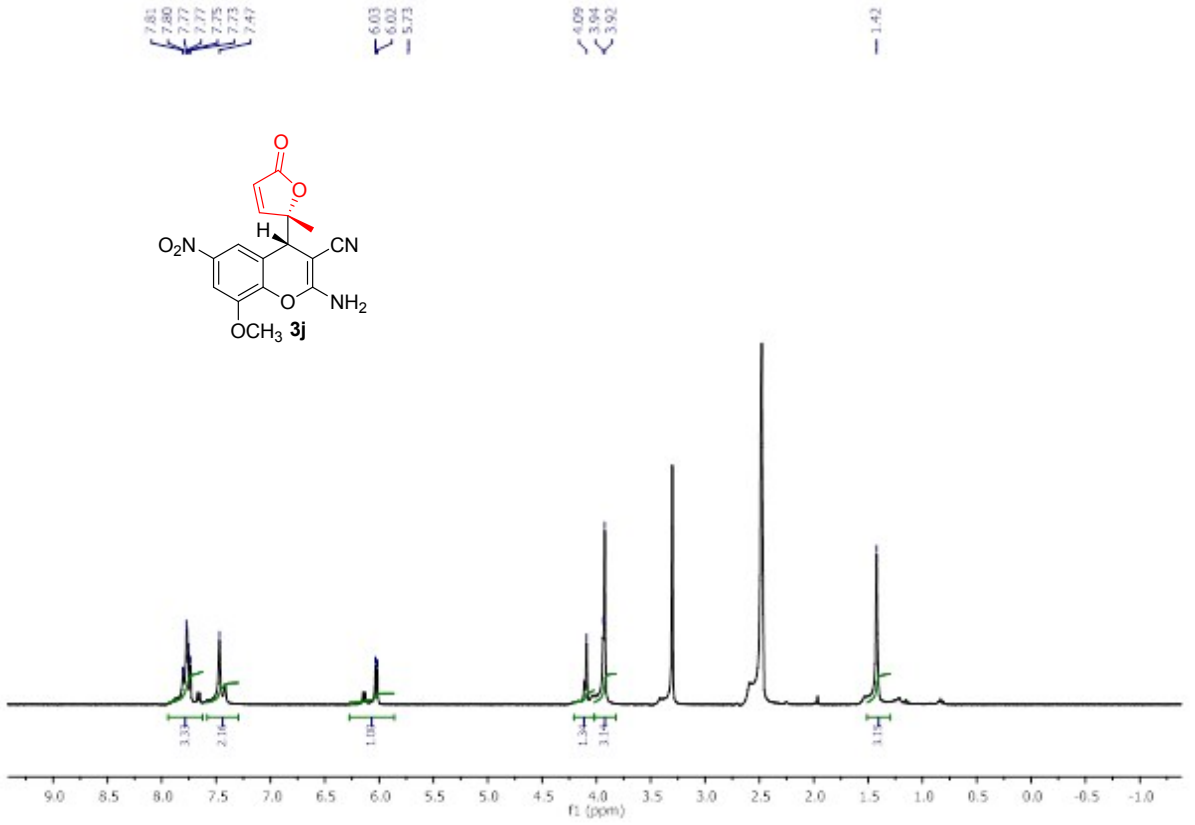
158.86
154.90
143.20
125.66
124.59
121.82
121.35
120.26
117.32
91.16
49.44
42.27
40.15
39.94
39.73
39.52
39.31
39.10
38.89
20.91
O
O
H
O2N
CN
O
NH2
3g
f1 (ppm)

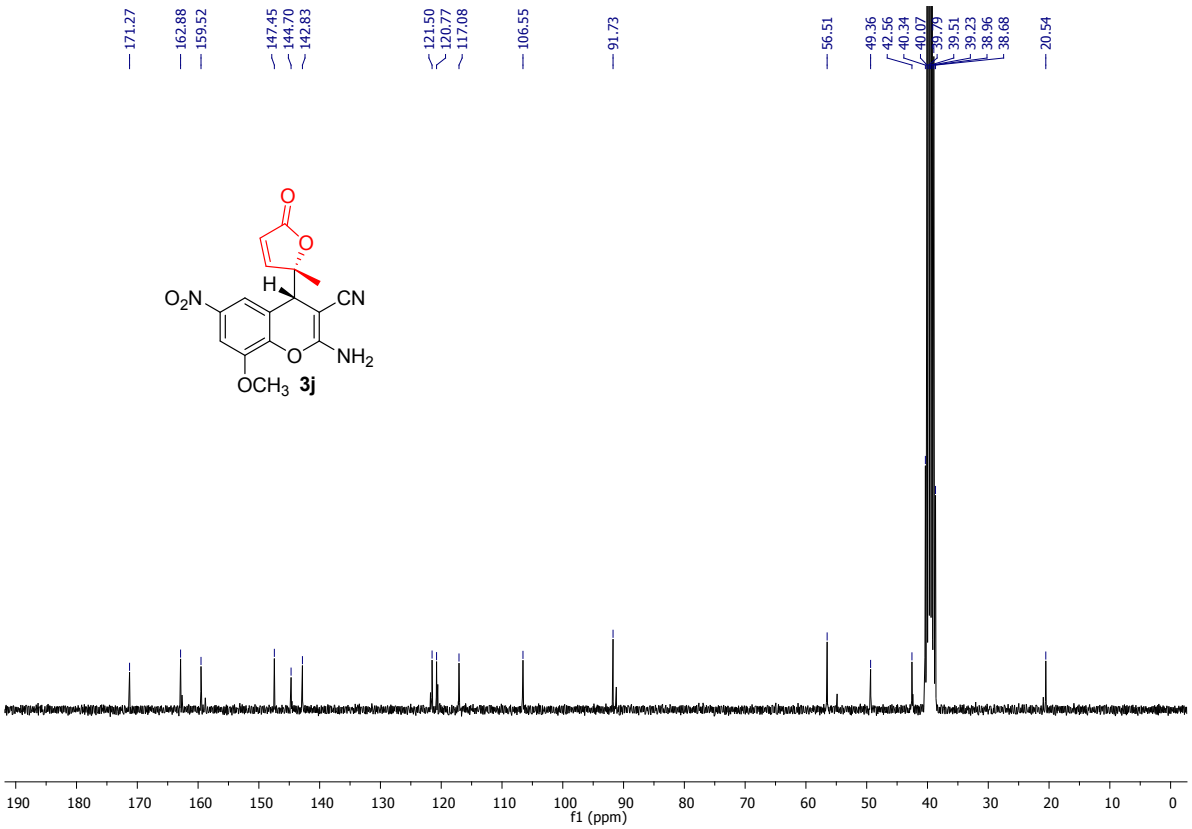

7.64
7.63
7.14
7.11
7.08
6.73
6.71
6.55
6.04
6.02
3.91
3.79
3.74
3.42
2.50
1.39
O
O
H
CN
MeO
O
NH2
3h
1.00
3.16
0.99
0.93
0.91
1.20
3.03
3.14
f1 (ppm)

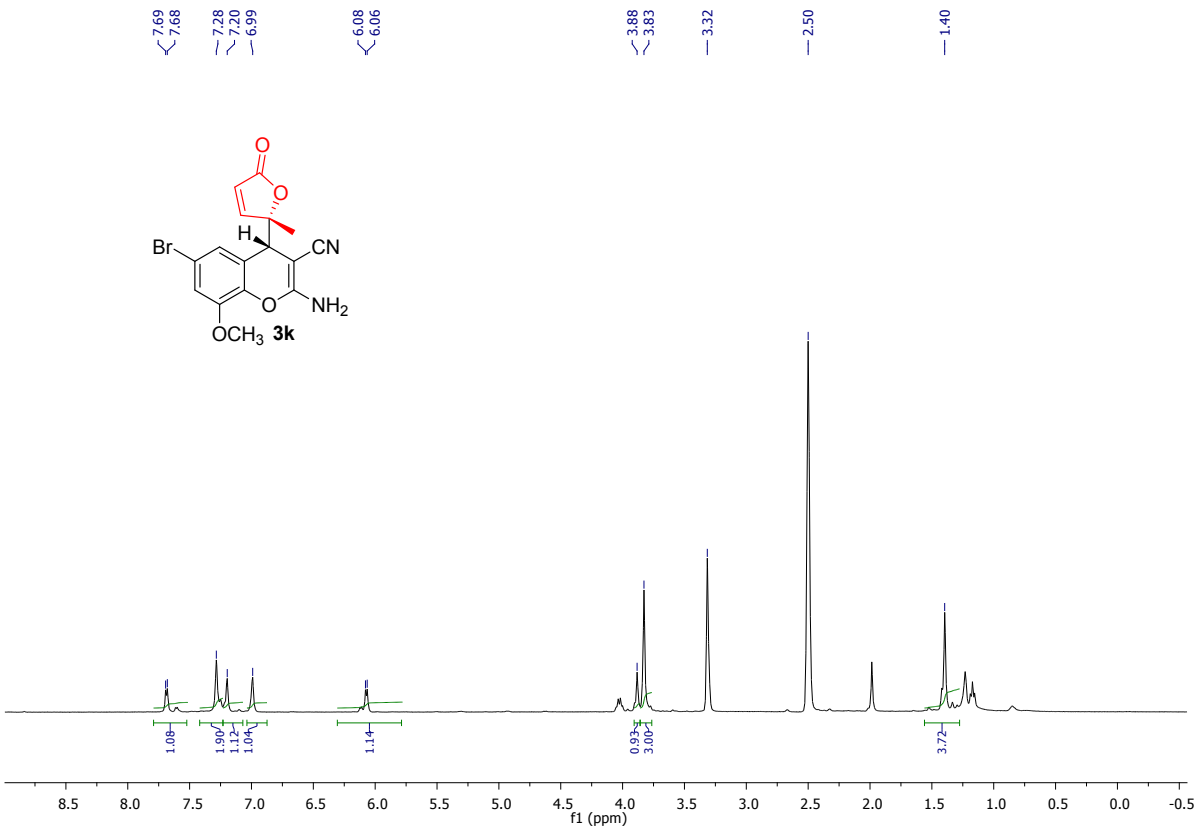

171.65
163.69
159.90
159.43
151.38
130.71
121.36
120.73
111.95
110.27
101.15
92.31
55.46
50.14
40.15
39.94
39.73
39.52
39.31
39.10
38.89
20.69
O
O
H
CN
MeO
O
NH2
3h
f1 (ppm)

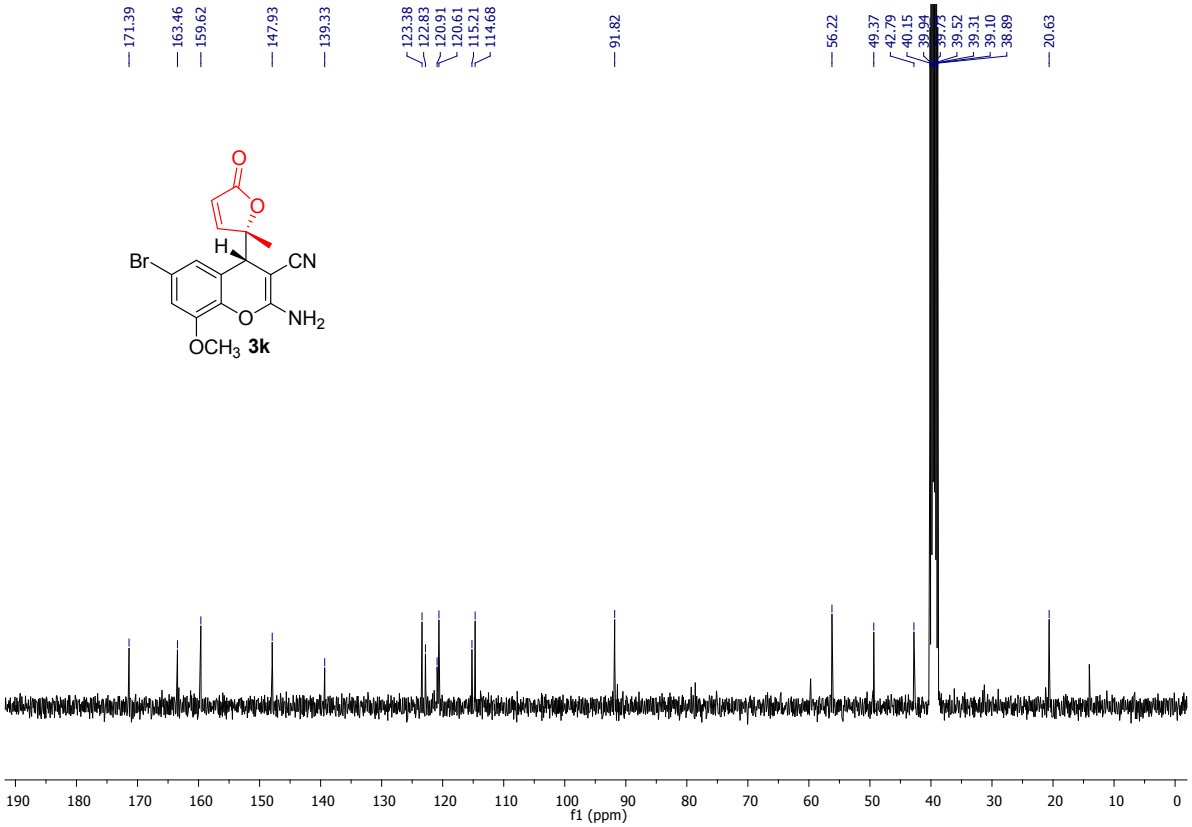

7.65
7.64
7.63
7.62
7.17
7.09
7.00
6.93
6.90
6.07
6.06
6.05
6.04
3.81
3.35
3.34
2.51
2.50
2.26
1.40
O
O
H
H3C
CN
O
NH2
3i
1.10
2.62
1.11
0.95
1.28
1.11
1.00
3.13
3.00
f1 (ppm)

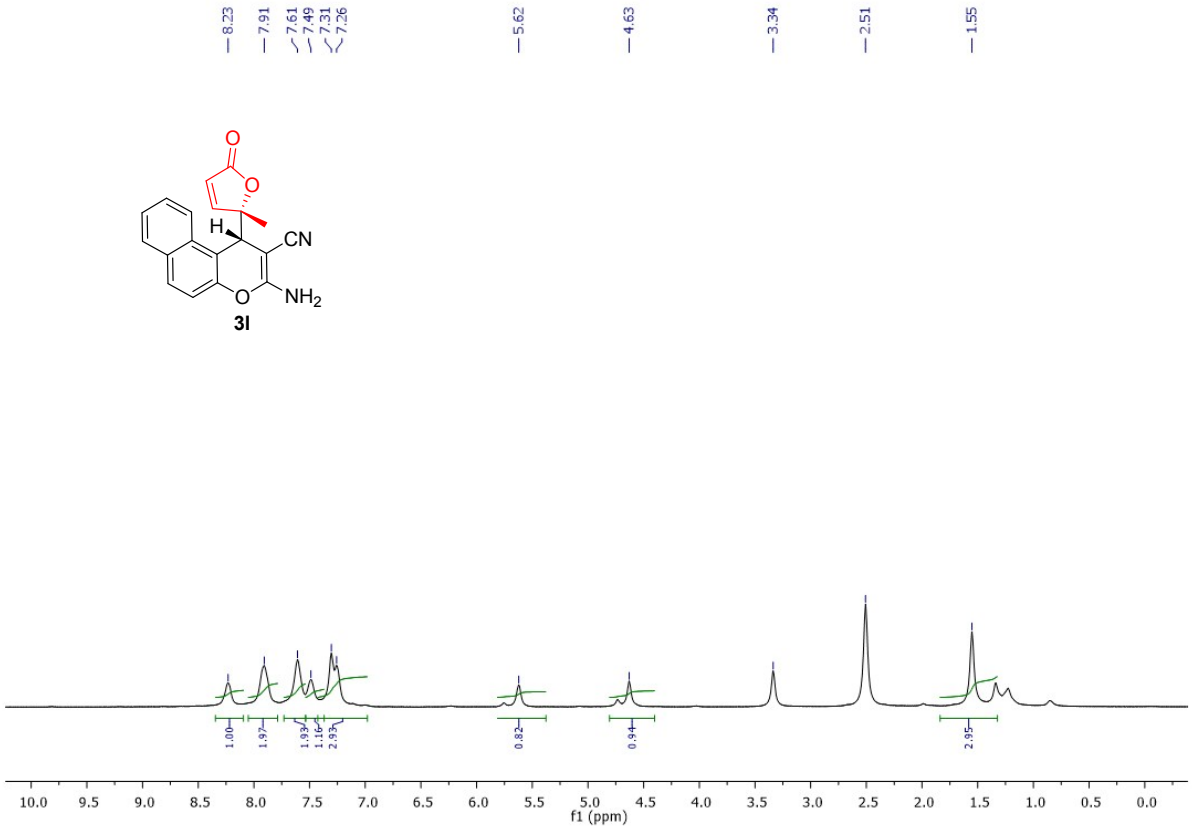

171.47
163.80
159.69
148.55
132.81
130.09
129.19
121.29
120.64
119.72
115.58
92.01
49.54
43.21
40.31
40.03
39.48
39.20
38.92
38.64
20.65
20.31
O
O
H
H3C
CN
O
NH2
3i
f1 (ppm)

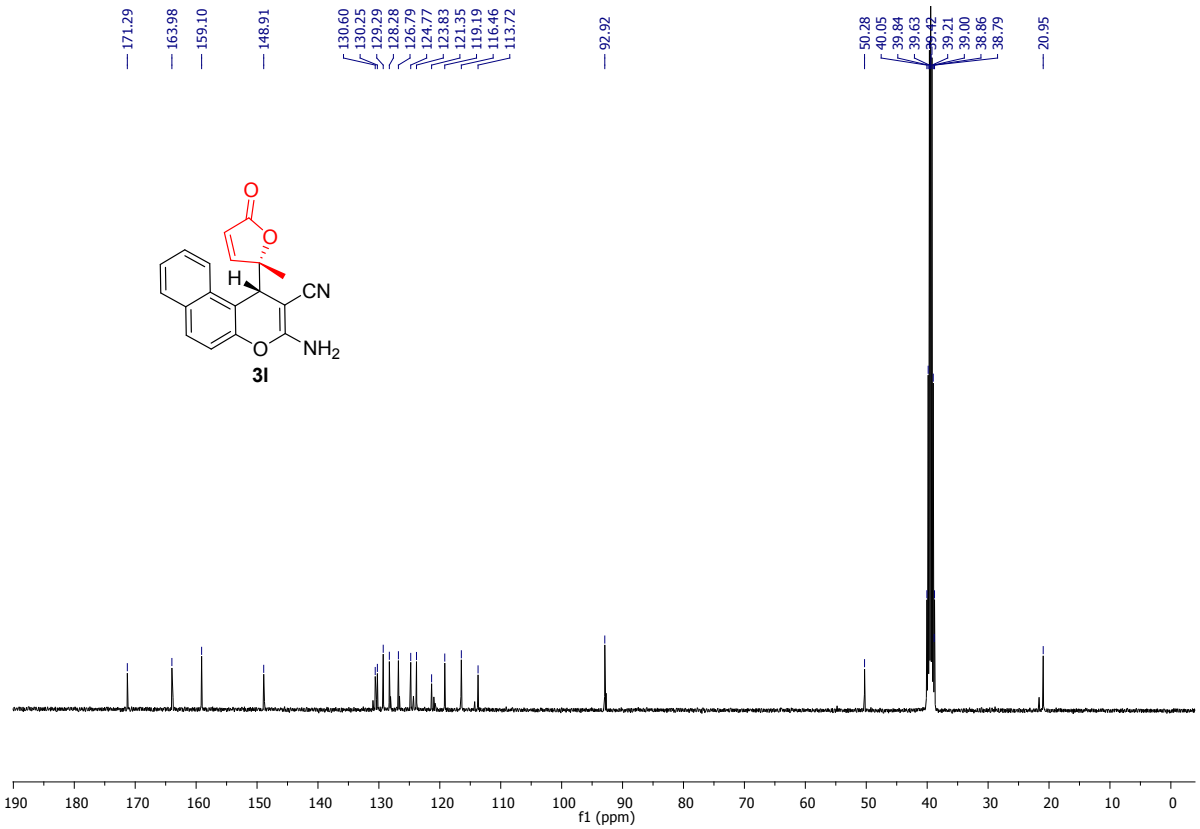

7.81
7.80
7.77
7.77
7.77
7.75
7.73
7.47
6.03
6.02
5.73
4.09
3.94
3.92
1.42
O
O
H
O2N
CN
O
NH2
OCH3 3j
f1 (ppm)

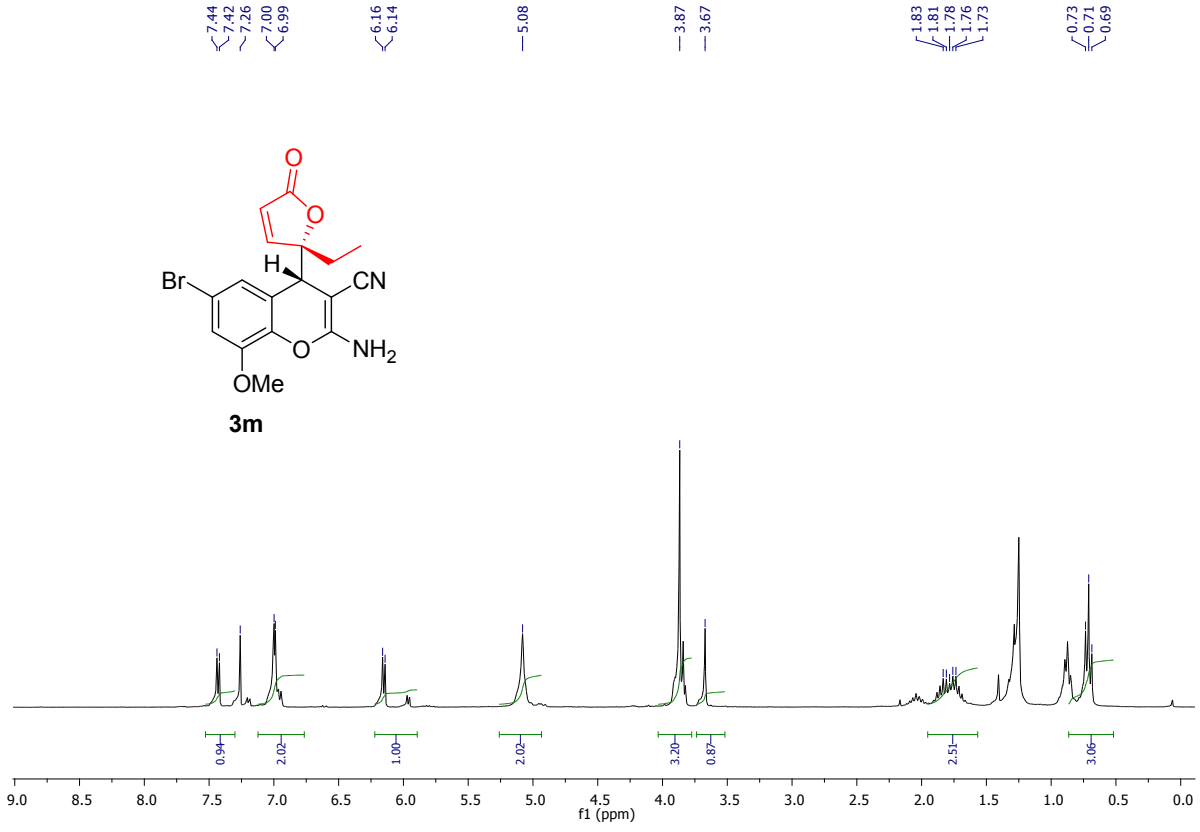

171.27
162.88
159.52
147.45
144.70
142.83
121.50
120.77
117.08
106.55
91.73
56.51
49.36
42.56
40.34
40.07
39.79
39.51
39.23
38.96
38.68
20.54
O
O
H
O2N
CN
O
NH2
OCH3 3j
f1 (ppm)

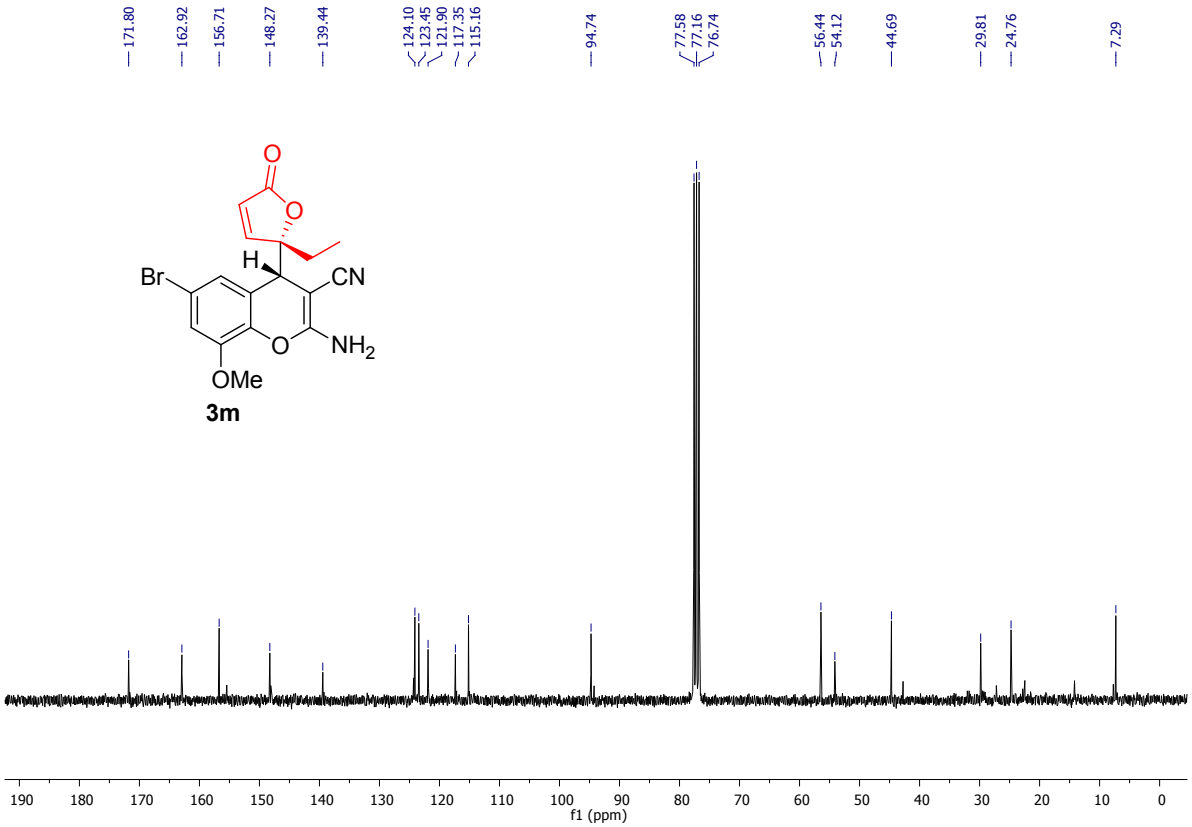

7.69
7.68
7.28
7.20
6.99
6.08
6.06
3.88
3.83
3.32
2.50
1.40
O
O
H
Br
CN
O
NH2
OCH3 3k
1.08
1.90
1.12
1.04
1.14
0.93
3.00
3.72
f1 (ppm)

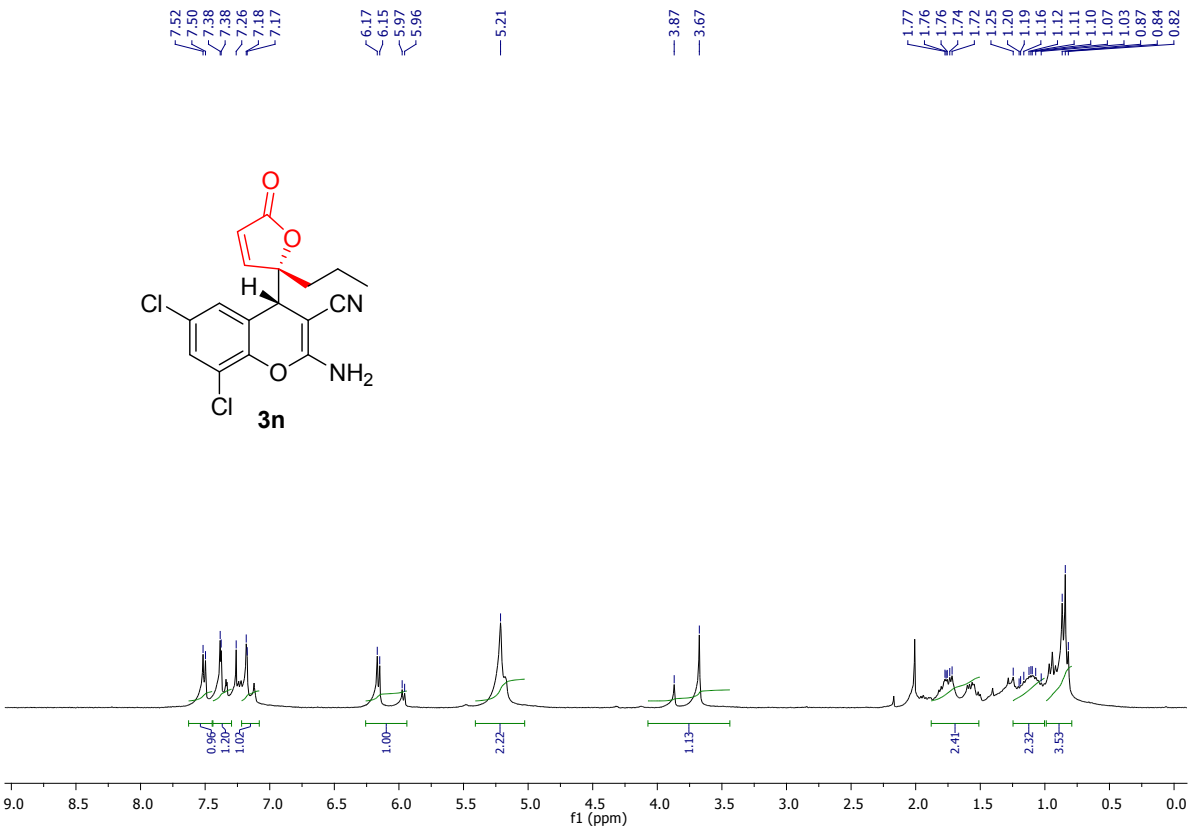

171.39
163.46
159.62
147.93
139.33
123.38
122.83
120.91
120.61
115.21
114.68
91.82
56.22
49.37
42.79
40.15
39.94
39.73
39.52
39.31
39.10
38.89
20.63
O
O
H
Br
CN
O
NH2
OCH3 3k
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

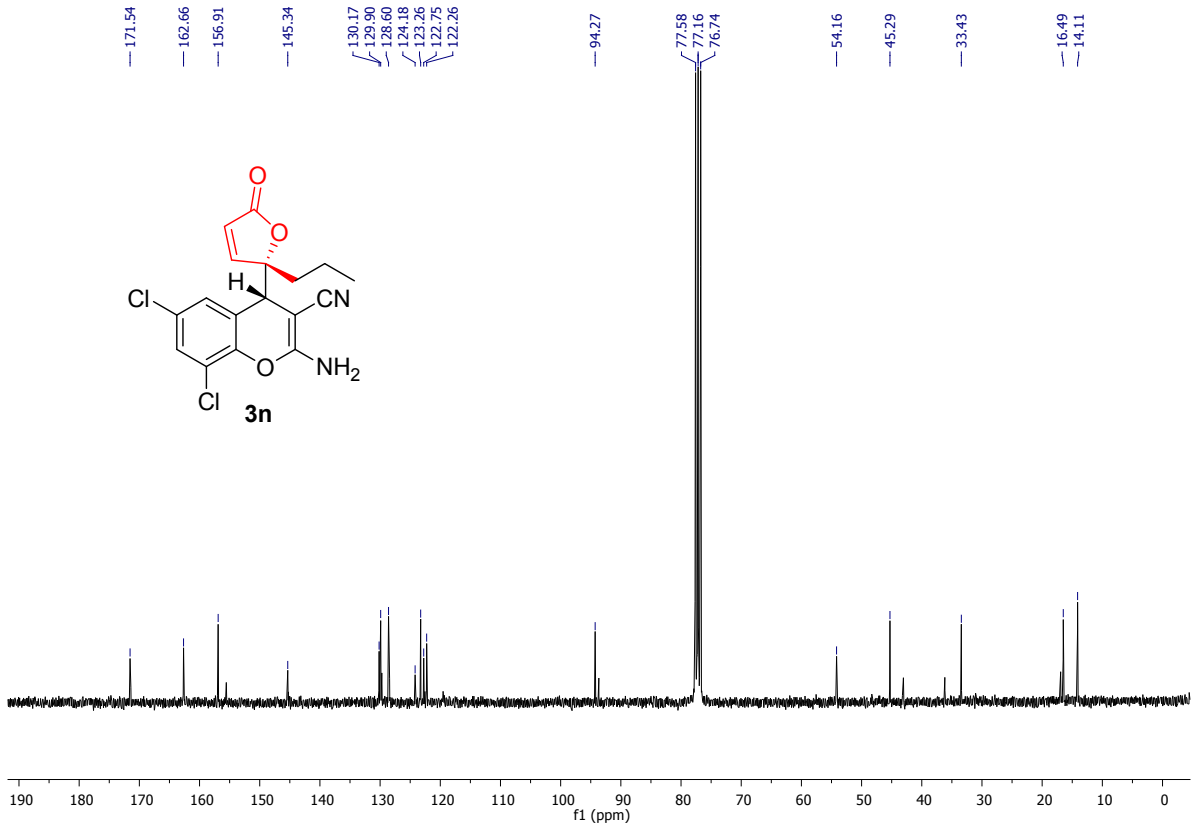

8.23
7.91
7.61
7.49
7.31
7.26
5.62
4.63
3.34
2.51
1.55
O
O
H
CN
O
NH2
3l
1.00
1.97
1.93
1.16
2.93
0.82
0.94
2.95
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


171.29
163.98
159.10
148.91
130.60
130.25
129.29
128.28
126.79
124.77
123.83
121.35
119.19
116.46
113.72
92.92
50.28
40.05
39.84
39.63
39.42
39.21
39.00
38.86
38.79
20.95
O
O
H
CN
O
NH2
3l
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.44
7.42
7.26
7.00
6.99
6.16
6.14
5.08
3.87
3.67
1.83
1.81
1.78
1.76
1.73
0.73
0.71
0.69
O
O
H
Br
CN
O
NH2
OMe
3m
0.94
2.02
1.00
2.02
3.20
0.87
2.51
3.06
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

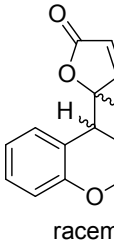

171.80
162.92
156.71
148.27
139.44
124.10
123.45
121.90
117.35
115.16
94.74
77.58
77.16
76.74
56.44
54.12
44.69
29.81
24.76
7.29
O
O
H
Br
CN
O
NH2
OMe
3m
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.52
7.50
7.38
7.38
7.26
7.18
7.17
6.17
6.15
5.97
5.96
5.21
3.87
3.67
1.77
1.76
1.76
1.74
1.72
1.25
1.20
1.19
1.16
1.12
1.11
1.10
1.07
1.03
0.87
0.84
0.82
O
O
H
Cl
CN
O
NH2
Cl
3n
0.96
1.20
1.02
1.00
2.22
1.13
2.41
2.32
3.53
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

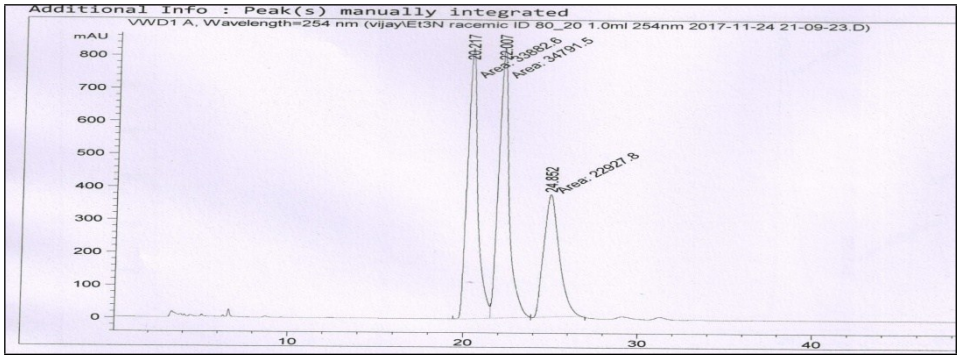


10. HPLC Spectra of Compounds

HPLC, Chiralpak ID, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

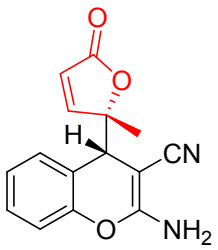


racemic

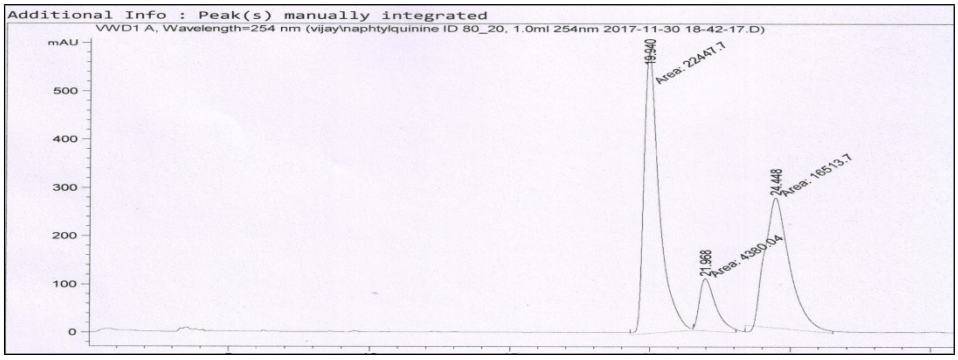


Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.217	MF	0.6859	3.38826e4	823.25360	36.9890
2	22.007	MF	0.7051	3.47915e4	822.32928	37.9812
3	24.852	FM	1.0235	2.29278e4	373.34723	25.0298
Totals :				9.16019e4	2018.93011	



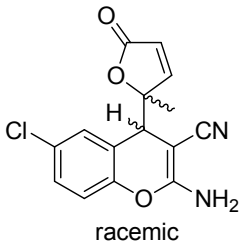
3a, 84:16 er (*syn*)



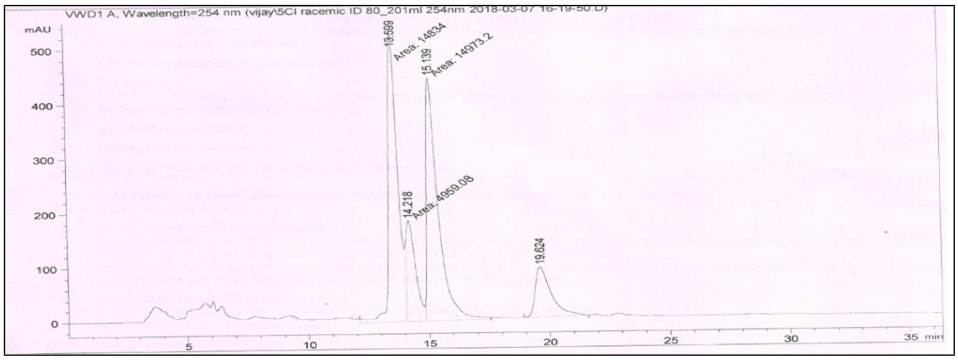
Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.940	MM	0.6428	2.24477e4	582.03992	51.7928
2	21.968	MM	0.6716	4380.04248	108.69023	10.1059
3	24.448	MM	1.0186	1.65137e4	270.20474	38.1014
Totals :				4.33415e4	960.93489	

HPLC, Chiralpak ID, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

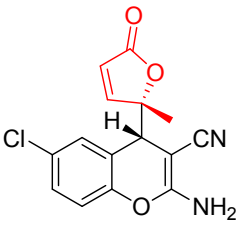


racemic

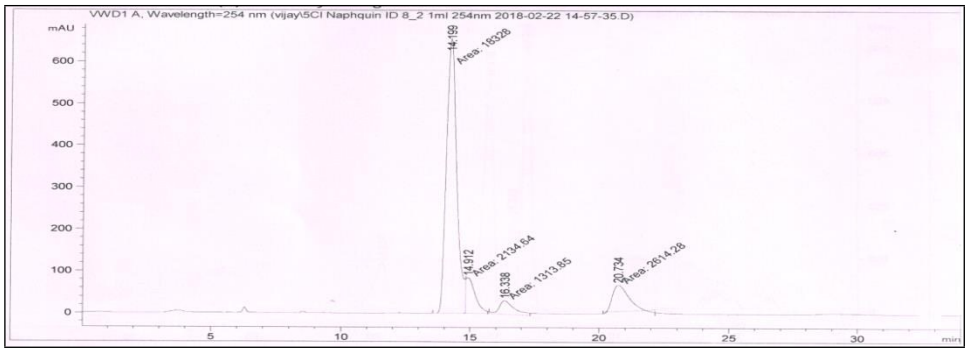


Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.599	MF	0.4682	1.48340e4	528.09656	38.0662
2	14.218	FM	0.4452	4959.07568	185.64545	12.7257
3	15.139	FM	0.5594	1.49732e4	446.12991	38.4234
4	19.624	BB	0.6666	4202.70264	91.88905	10.7847



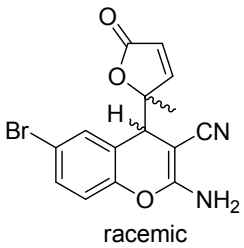
3b, 93:7 er (*syn*)



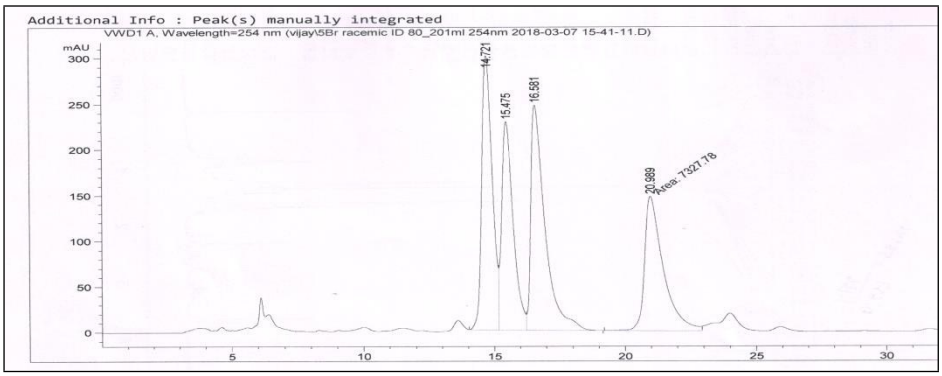
Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.199	MF	0.4662	1.83280e4	655.27032	75.1432
2	14.912	FM	0.4215	2134.63794	84.41354	8.7518
3	16.338	MM	0.6834	1313.85315	32.04145	5.3867
4	20.734	MM	0.7032	2614.28003	61.96589	10.7183

HPLC, Chiralpak ID, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

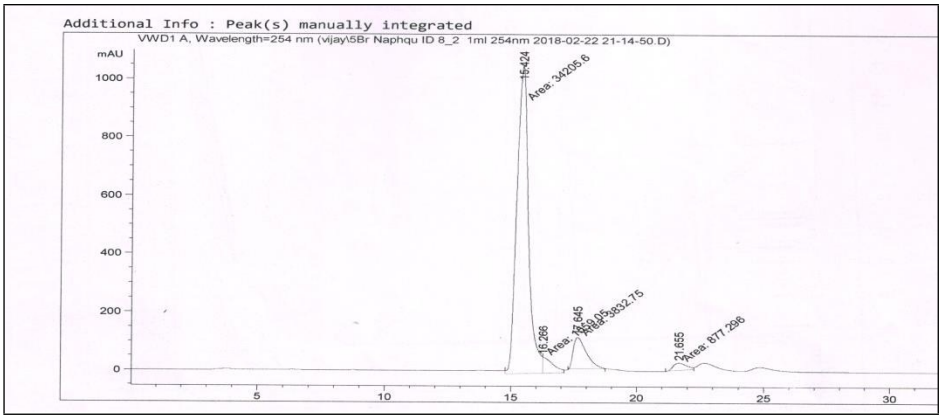


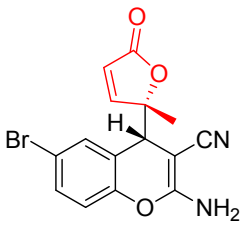
racemic



Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.721	BV	0.4329	8402.93652	299.90372	26.1806
2	15.475	VV	0.4636	7077.09961	228.33879	22.0498
3	16.581	VB	0.5514	9288.18066	246.61469	28.9387
4	20.989	MF	0.8279	7327.78418	147.51198	22.8308
Totals :				3.20960e4	922.36917	

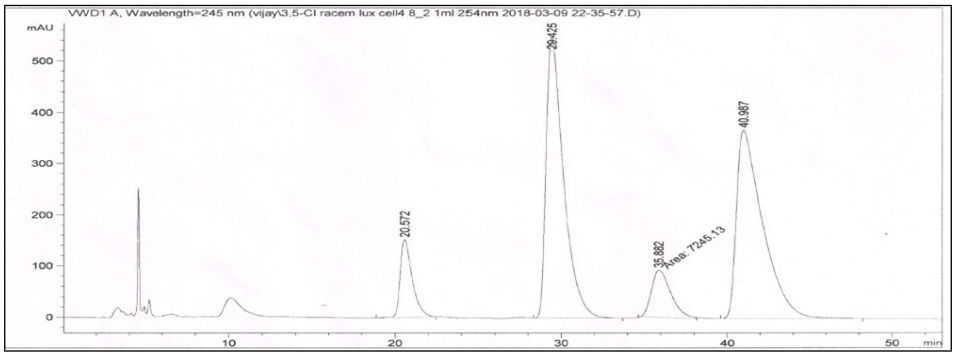


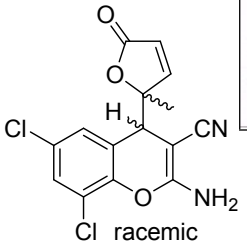


3c, 90:10 er (syn)

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.424	MF	0.5402	3.42056e4	1055.24438	84.5111
2	16.266	FM	0.4613	1559.04700	56.33274	3.8519
3	17.645	MM	0.5954	3832.75146	107.29118	9.4695
4	21.655	MM	0.6000	877.29645	24.37019	2.1675
Totals :				4.04747e4	1243.23850	

HPLC, Lux cellulose-4 column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

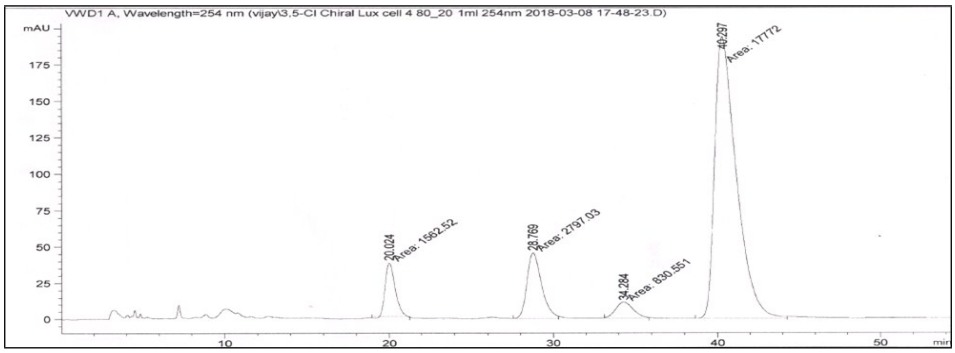


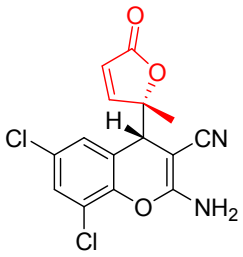


racemic

Signal 1: VWD1 A, Wavelength=245 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.572	BB	0.7485	7548.50537	151.18475	7.9170
2	29.425	BB	1.0716	4.01268e4	547.80701	42.0857
3	35.882	MM	1.3326	7245.13281	90.61201	7.5988
4	40.987	BB	1.5464	4.04251e4	368.06082	42.3985



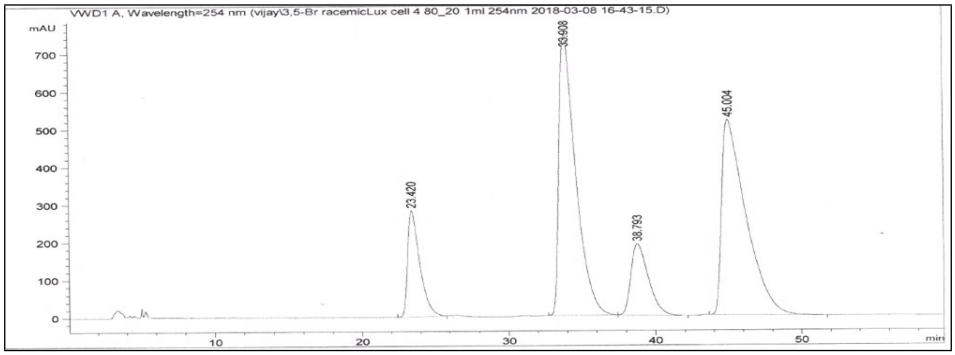


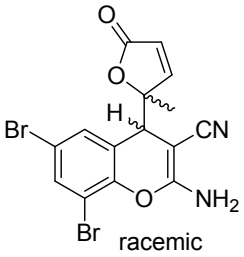
3d, 87:13 er (*syn*)

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.024	MM	0.7039	1562.51636	36.99631	6.8048
2	28.769	MM	1.0276	2797.03027	45.36296	12.1811
3	34.284	MM	1.2522	830.55060	11.05422	3.6170
4	40.297	MM	1.5283	1.77720e4	193.81644	77.3972

HPLC, Lux cellulose-4 column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

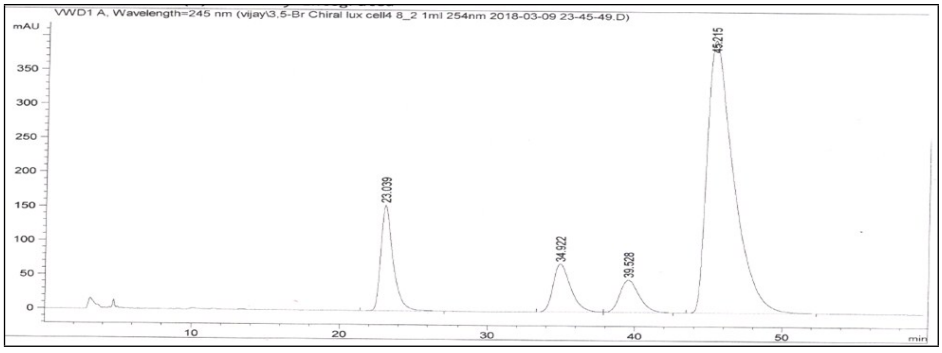


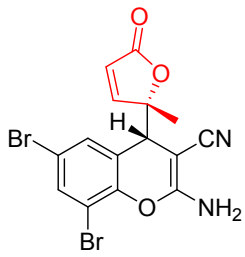


racemic

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.420	BB	0.8644	1.61819e4	282.03174	10.7160
2	33.908	BB	1.0983	5.94764e4	745.05573	39.3866
3	38.793	BB	1.2726	1.56680e4	189.50336	10.3757
4	45.004	BB	1.5716	5.96802e4	519.00012	39.5216



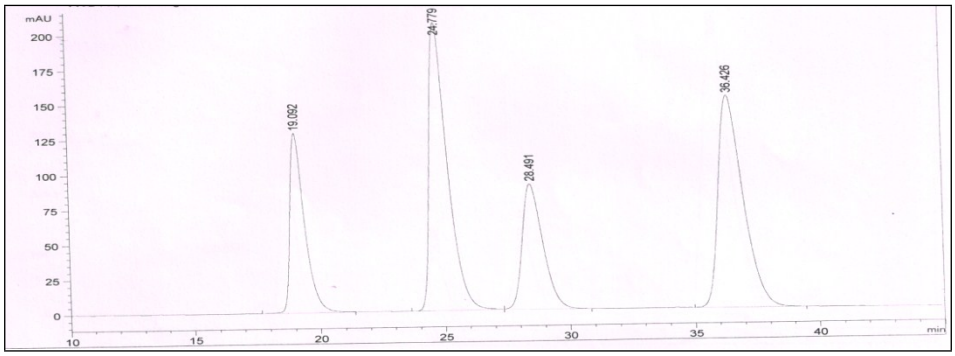


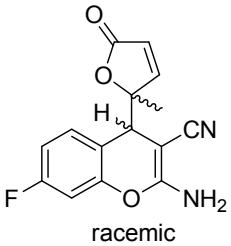
3e, 90:10 er (*syn*)

Signal 1: VWD1 A, Wavelength=245 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.039	BB	0.8607	8905.87207	154.67427	12.9641
2	34.922	BB	1.2409	5739.71777	69.90378	8.3552
3	39.528	BB	1.3399	4224.68408	47.12553	6.1498
4	45.215	BB	1.7173	4.98260e4	398.89474	72.5308

HPLC, Lux cellulose-4 column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

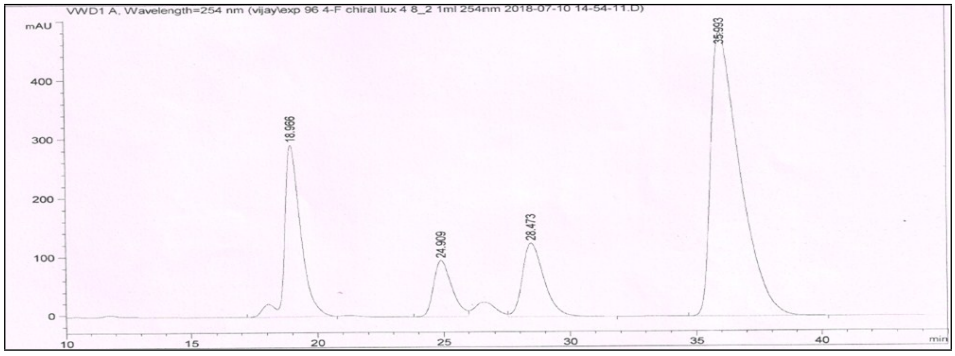


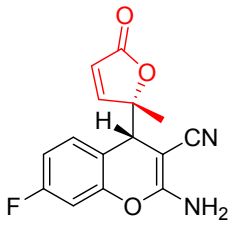


racemic

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.092	BB	0.6046	5154.63721	128.32356	16.5378
2	24.779	BB	0.7684	1.04534e4	206.20622	33.5380
3	28.491	BB	0.8704	5105.89111	89.65244	16.3814
4	36.426	BB	1.0576	1.04549e4	151.98244	33.5429



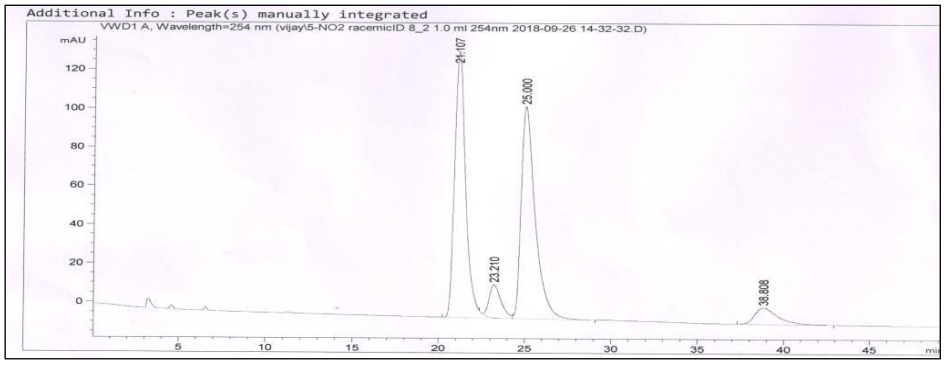


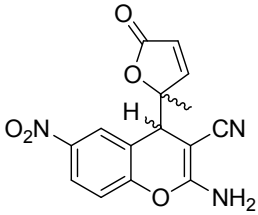
3f, 89:11 er (*syn*)

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	18.966	VB R	0.6367	1.30661e4	292.07690	20.2790
2	24.909	BV	0.7872	4961.70068	96.44021	7.7007
3	28.473	VB	0.9139	7499.20459	125.71819	11.6390
4	35.993	BB	1.1984	3.89046e4	483.15979	60.3813

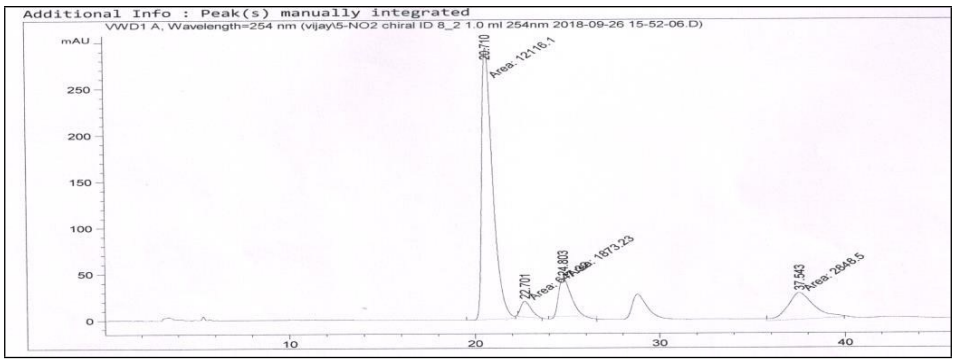
HPLC, Chiralpak ID, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

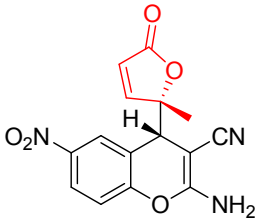




Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.107	BV R	0.6728	6118.74072	137.33020	44.0105
2	23.210	VV E	0.7322	814.91644	16.91070	5.8615
3	25.000	VB	0.8356	6159.41650	109.44867	44.3031
4	38.808	BB	1.2101	809.83032	8.54940	5.8249
Totals :				1.39029e4	272.23897	



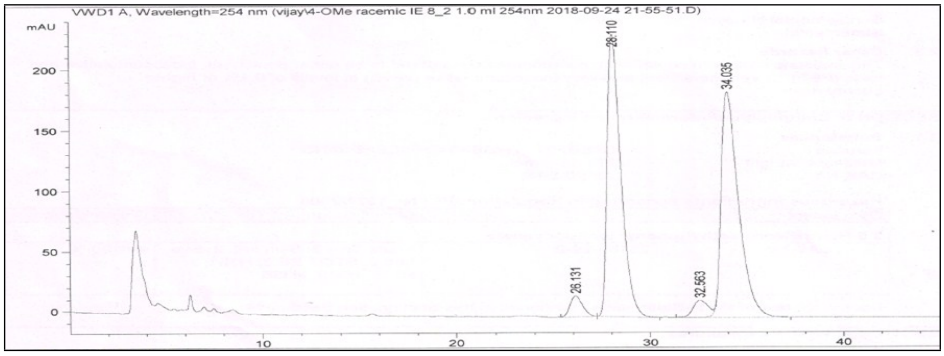


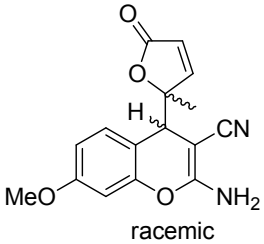
3g, 87:13 er (*syn*)

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.710	MM	0.6890	1.21161e4	293.07172	69.2937
2	22.701	MM	0.6482	647.32019	16.64503	3.7021
3	24.803	MM	0.7662	1873.23022	40.74587	10.7132
4	37.543	MM	1.6579	2848.49756	28.63550	16.2909
Totals :				1.74852e4	379.09811	

HPLC, Chiralpak IE column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

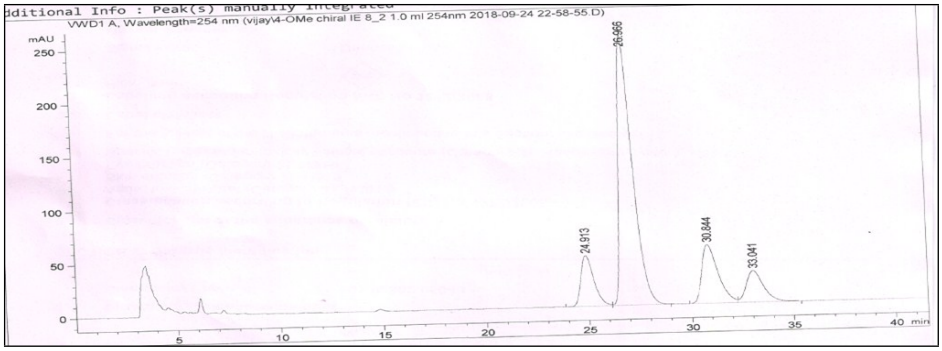


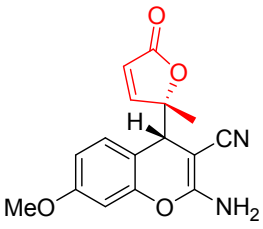


racemic

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	26.131	BB	0.6917	788.41724	17.80034	3.1772
2	28.110	BB	0.7549	1.15592e4	233.75085	46.5816
3	32.563	BV E	0.7589	750.13708	14.53911	3.0229
4	34.035	VB R	0.9480	1.17172e4	187.00363	47.2183



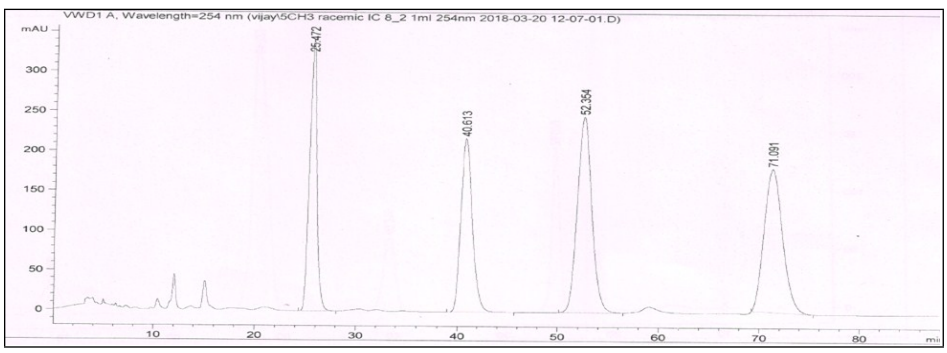


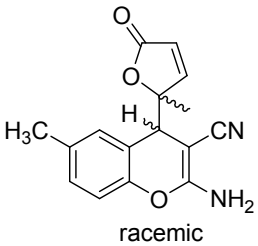
3h, 87:13 er (syn)

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.913	BV	0.6798	2100.95581	47.89386	11.1362
2	26.966	VB	0.7227	1.19733e4	254.09586	63.4645
3	30.844	BV	0.8286	3037.93750	55.32360	16.1027
4	33.041	VB	0.8820	1753.90503	29.82700	9.2966

HPLC, Chiralpak IC column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

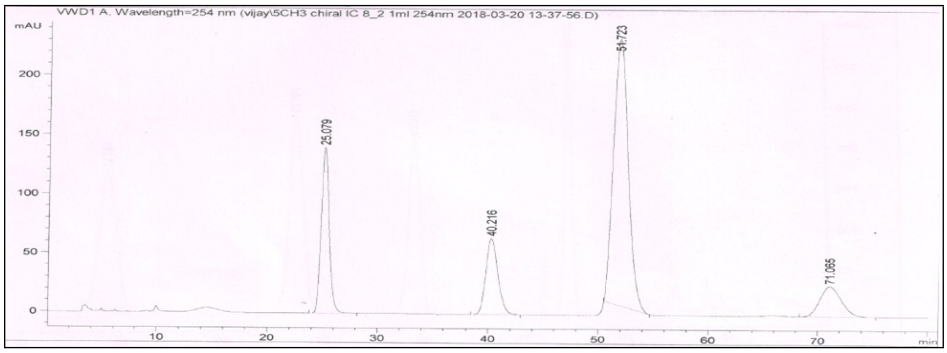


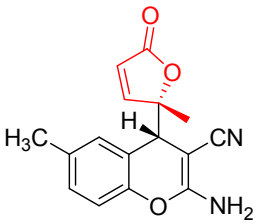


racemic

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	25.472	BB	0.7770	1.72534e4	340.61041	20.9633
2	40.613	BB	1.2291	1.74665e4	218.39073	21.2223
3	52.354	BB	1.4043	2.45017e4	246.13969	29.7703
4	71.091	BB	1.7584	2.30810e4	179.71390	28.0441





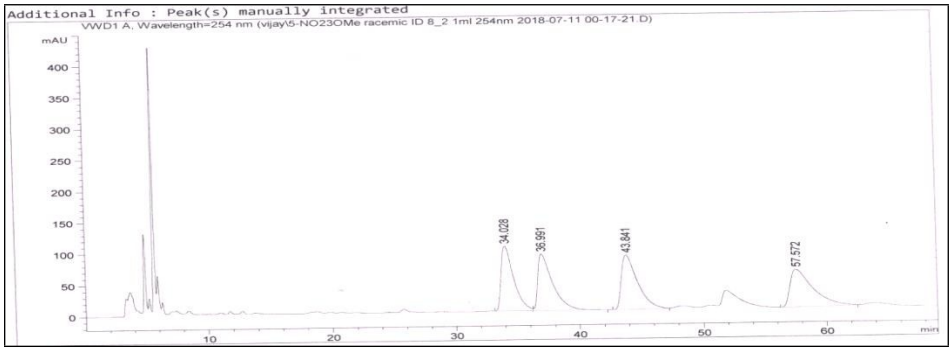
3i, 86:14 er (*syn*)

Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	25.079	BB	0.7593	6981.23828	140.34831	19.0595
2	40.216	BB	1.1817	4959.40771	64.96187	13.5397
3	51.723	BB	1.3767	2.11328e4	225.01875	57.6948
4	71.065	BB	1.8485	3555.17993	26.17641	9.7060

HPLC, Chiralpak ID column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

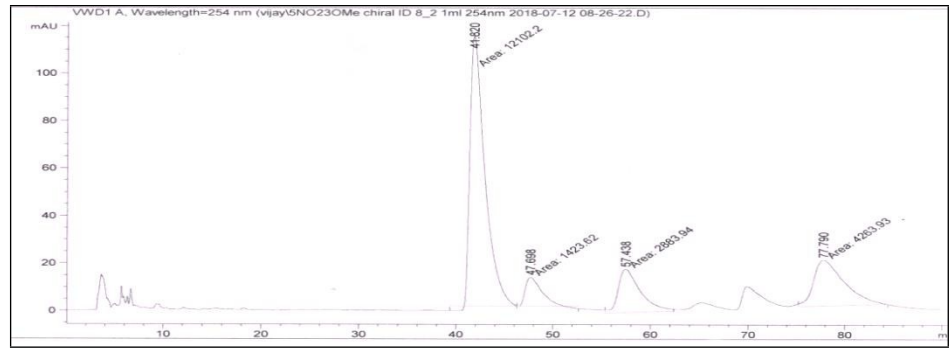
racemic



Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	34.028	BV	1.0388	7297.29590	103.09281	24.1431
2	36.991	VB	1.1978	7470.90576	89.87405	24.7175
3	43.841	BB	1.2966	7781.48633	86.65832	25.7450
4	57.572	BB	1.7323	7675.52881	60.00613	25.3945

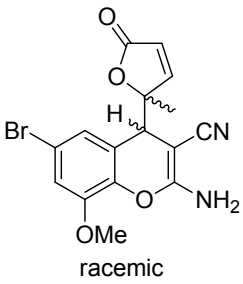
3j, 89:11 er (*syn*)



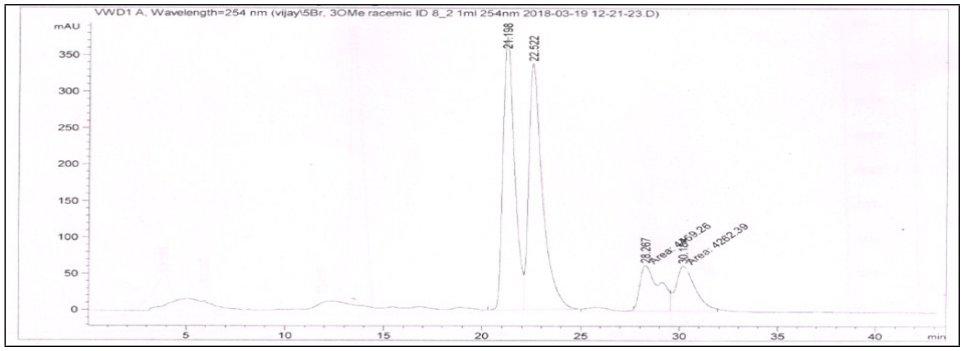
Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	41.820	MF	1.7724	1.21022e4	113.80166	58.5392
2	47.698	FM	1.9502	1423.62219	12.16616	6.8861
3	57.438	MM	2.6360	2883.94189	18.23438	13.9498
4	77.790	MM	3.7035	4263.92676	19.18888	20.6249

HPLC, Chiralpak ID column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

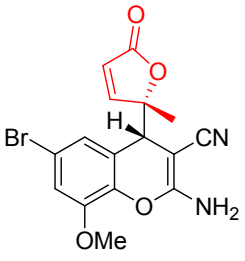


racemic

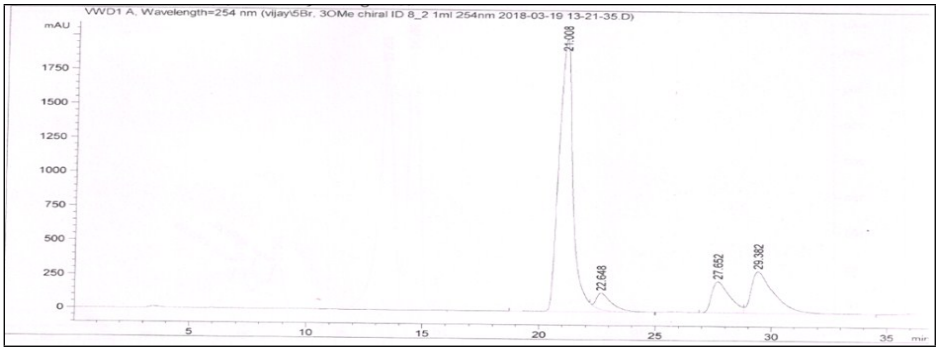


Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.198	BV	0.6173	1.52857e4	375.16977	37.7451
2	22.522	VB	0.7118	1.64898e4	337.63852	40.7184
3	28.267	MF	1.1716	4459.26172	63.43809	11.0113
4	30.184	FM	1.1359	4262.38525	62.54182	10.5252



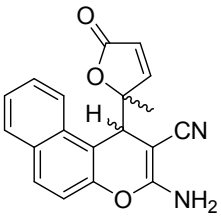
3k, 93:7 er (*syn*)



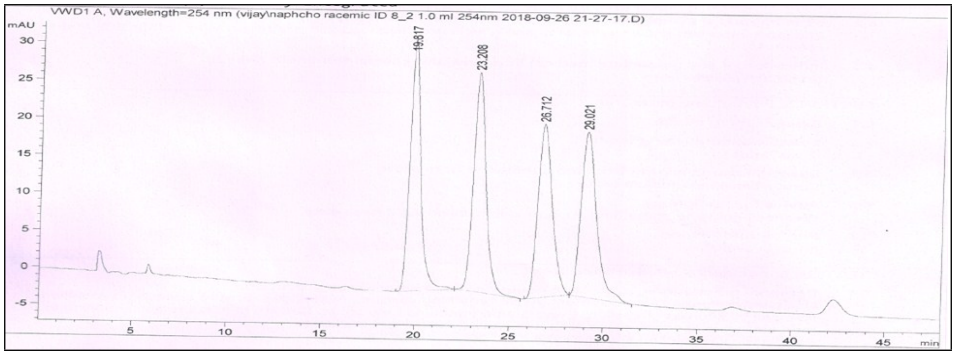
Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.008	BV R	0.6649	8.43477e4	1996.36902	68.2538
2	22.648	VB E	0.6826	5590.73486	119.32601	4.5240
3	27.652	BV	0.8007	1.24662e4	230.97147	10.0876
4	29.382	VB	0.9868	2.11748e4	307.32919	17.1346

HPLC, Chiralpak ID column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

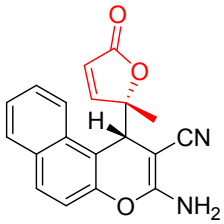


racemic

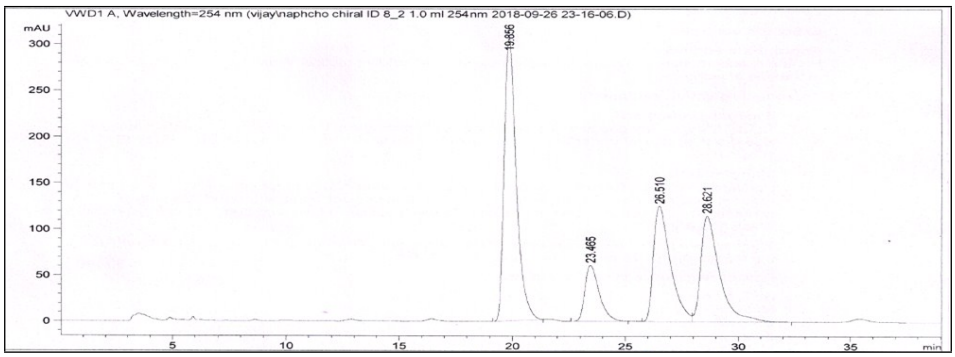


Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.817	BB	0.6204	1358.59607	33.47892	26.1042
2	23.208	BB	0.7069	1352.45410	29.16927	25.9862
3	26.712	BB	0.8204	1224.39270	23.06222	23.5256
4	29.021	BB	0.8686	1269.06860	21.98074	24.3840



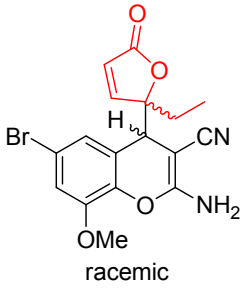
3l, 83:17 er (*syn*)



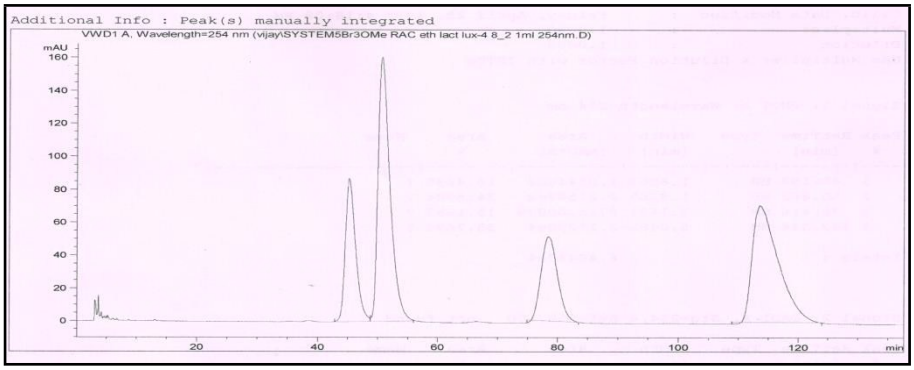
Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.856	BB	0.5784	1.14950e4	305.87585	42.0872
2	23.465	BB	0.6715	2652.16602	60.85109	9.7105
3	26.510	BV	0.7774	6531.15332	125.23237	23.9127
4	28.621	VB	0.8512	6634.08594	114.97156	24.2896

HPLC, Lux cellulose-4 column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

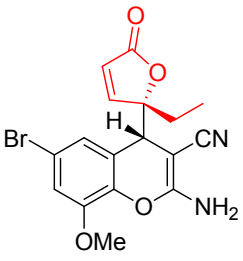


racemic

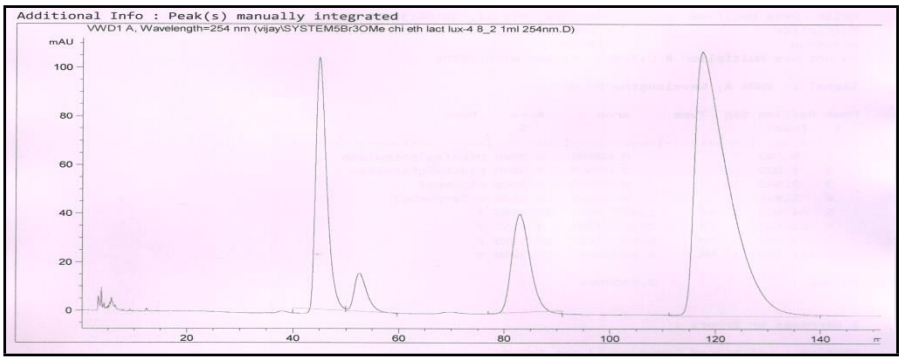


Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Area %
1	45.193	BB	1.8063	1.05446e4	16.4635
2	50.662	BB	1.9365	2.21597e4	34.5984
3	78.416	MM	3.1691	9715.00879	15.1683
4	113.544	MM	5.0482	2.16290e4	33.7698
Totals :				6.40483e4	

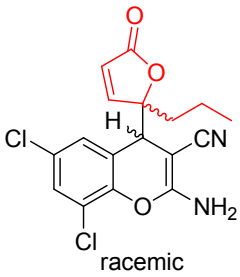


3m, 95:5 er (*syn*)

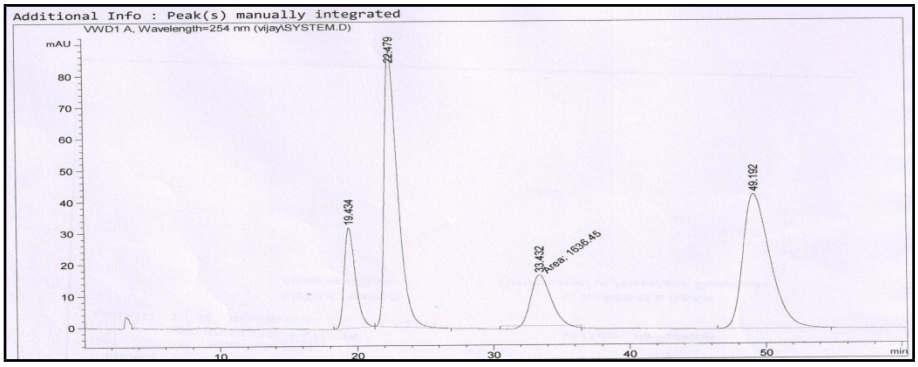


Peak #	RetTime [min]	Sig	Type	Area	Area %
5	44.926	1	MF	1.47454e4	19.5903
6	52.566	1	FM	2570.97290	3.4157
7	83.000	1	MM	9480.77637	12.5959
8	117.409	1	MM	4.84716e4	64.3980
Totals :				7.52688e4	

HPLC, Lux cellulose-4 column, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.

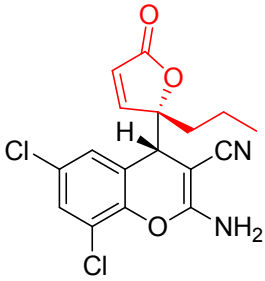


racemic

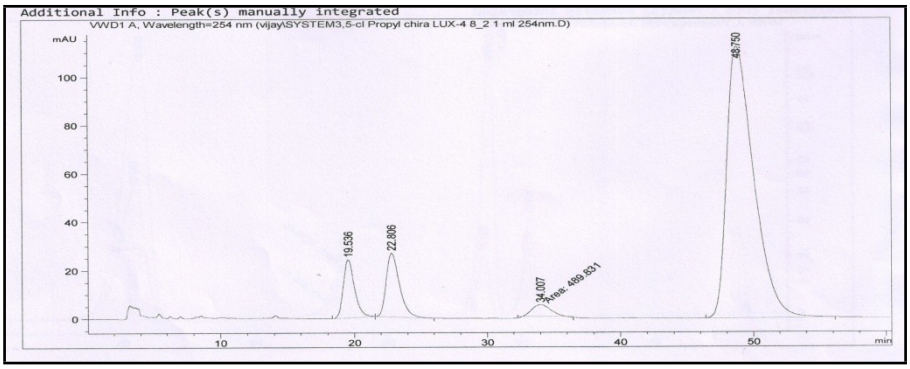


Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.434	BB	0.8656	1817.30139	32.00016	11.8023
2	22.479	BB	1.0292	5954.14648	87.79508	38.6687
3	33.432	MM	1.6832	1636.44971	16.20422	10.6278
4	49.192	BB	1.9764	5989.93701	42.96889	38.9012
Totals :				1.53978e4	178.96835	



3n, 89:11 er (*syn*)

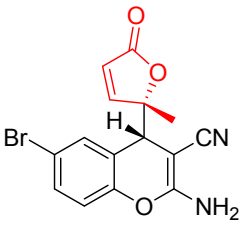


Signal 1: VWD1 A, Wavelength=254 nm

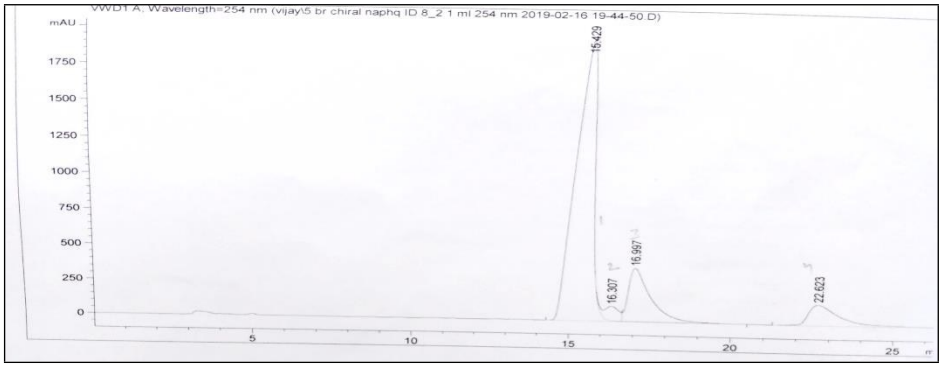
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.536	BB	0.8879	1415.04419	24.10355	7.1609
2	22.806	BB	1.0329	1833.51721	26.44561	9.2786
3	34.007	MM	1.6454	489.83096	4.96157	2.4788
4	48.750	BB	1.9960	1.60223e4	112.33318	81.0816

HPLC data for Reaction performed at 5 mmol scale:

HPLC, Chiralpak ID, hexanes: isopropanol = 8:2, 1.0 mL/min, λ= 254 nm.



3c, 82:18 er (*syn*)



Signal 1: VWD1 A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.429	BV R	0.7157	8.03014e4	1948.75574	71.7581
2	16.307	VV E	0.4856	3401.24023	103.97865	3.0394
3	16.997	VB E	0.6783	1.83462e4	382.70660	16.3943
4	22.623	BBA	0.9797	9856.80566	146.53960	8.8081
Totals :				1.11906e5	2581.98059	