Concise and Diversity-Oriented Synthesis of Novel Scaffolds Embedded with Privileged Benzopyran Motif

SUPPLEMENTARY INFORMATION

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Ⅰ. General Experimental Information

All reactions were performed under dry nitrogen atmosphere. In experiment that required anhydrous solvents, dichloromethane(DCM), tetrahydrofuran(THF), and toluene were dried by distillation in the presence of CaH_2 or Sodium metal. Other solvent and organic reagent were purchased from commercial sources and used without further purification unless otherwise mentioned. Tin reagent, (E)-tributyl(3-methoxyprop-1-enyl)tin (entry 2, Table 1), was synthesized from propargyl methyl ether using AIBN and tributyltin hydride in dry benzene. Azide reagents were prepared by the nucleophilic substitution reaction of NaN_3 with benzyl bromide (entry 1 in pathway A2) or 2-(bromomethyl)pyridine (entry 2 in pathway A2) in DMF.

^{1}H NMR spectra were obtained on Bruker 300 MHz FT-NMR, Varian 500 MHz FT-NMR and Bruker 600 MHz FT-NMR spectrometers. ^{13}C NMR spectra were recorded at Bruker 300 MHz FT-NMR and Varian 500 MHz FT-NMR. Chemical shifts are reported in ppm relative to solvent signal. Multiplicity is indicated as follows: s (singlet); d (doublet); t (triplet); q (quartet); m (multiplet); dd (doublet of doublet); ddd (doublet of doublet of doublet); dt (triplet of doublet); td (doublet of triplet); etc.; br s (broad singlet). Coupling constants are reported in Hz. Mass analysis (LRMS) was performed with a Water Alliance LC/MS system consisting of a Micromass Quattromicro mass spectrometer and Surveyor MSQ Plus LC/MS system by direct injection for electron spray ionization (ESI) or atmosphere pressure chemical ionization (APCI), and GC Double focusing mass spectrometer by direct injection for electron ionization (EI) or fast atomic bombardment (FAB). The products were purified by flash column chromatography on silica gel (Merck Silica gel 60 230-400 mesh). The eluent used for purification is reported in parentheses. Thin-layer chromatography (TLC) was performed on pre-coated glass-backed plates (silica gel 60 F_{254} 0.25mm), and components were visualized by observation under UV light (254 and 365 nm) or by treating the plates with anisaldehyde, $KMnO_4$, and phosphomolybdic acid followed by heating.

Ⅱ. Biological Assay Procedures and Data

1. Biological Experiment Procedure

Cell culture

The human cancer cell line (A549 lung carcinoma cell) was obtained from American Type Culture Collection [Manassas, VA, USA] and maintained in complete medium; RPMI 1640 [USP, Austin, TX, USA], supplemented with heat-inactivated 10% FBS [USP, Austin, TX, USA] and with 1% Antibiotic-Antimycotic solution [USP, Austin, TX, USA]. Cells were maintained in a humidified atmosphere of 5% CO_2 and 95% air at 37℃, and cultured in T75 Flask [Nalge Nunc International, Naperville, IN, USA].

Assessment of in vitro cytotoxicity assay

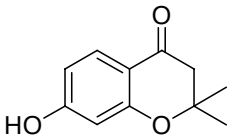
Cell viability was measured by the Cell Counting Kit (CCK)-8 assay [Dojindo, Tokyo, Japan][1], and the experimental procedure is based on the manufacturer's manual. Cells were cultured into 96-well plates at a density of 2×10^4 cells/well for 24 h, followed by the treatment of representative compounds with benzopyran substructure in various concentrations. After 24 h incubation with compounds, 10μL of WST-8 solution (2-(2-methoxy-4-nitrophenyl)-3-(4-nitrophenyl)-5-(2,4-disulfophenyl)-2*H*-tetrazolium, monosodium salt, [Sigma-Aldrich Chemical Co., St. Louis, MO, USA]) was added to each well, and plates were incubated for additional 2 h at 37℃. The absorbance of each well at 450nm was measured with a reference at 630 nm using a Bio-Tek model ELx800^{TM} microplate reader [Bio-Tek Instruments, Inc., Winooski, VT, USA]. The percentage of cell viability was calculated by following formula: %cell viability = (mean absorbance in test wells) / (mean absorbance in control well) × 100. Results were plotted as cell viability versus concentration of tested compound using Origin pro 7.0 [OriginLab Co., North Hampton, MA, USA]. IC_{50} value was calculated using non-linear regression analysis (exponential function of following equation was used for obtain IC_{50} value: $Y= Ae^{-t/x}$, Y = cell viability, A=100, X = concentration of tested compound, and Levenberg-Marquardts alteration was used for regression.) Then t value was acquired and x value for 50% cell viability was calculated. Each experiment was performed in quadruplicate experiments.

Reference:
1. (a) M. Ishiyama, Y. Miyazono, K, Sasamoto, Y. Ohkura and K. Ueno, *Talanta*, **1997**, *44*, 1299; (b) H. Tominaga, M. Ishiyama, F. Ohseto, K. Sasamoto, T. Hamamoto, K. Suzuki and M. Watanabe, *Anal. Commun.*, **1999**, *36*, 47.

Ⅲ. Experimental Procedures

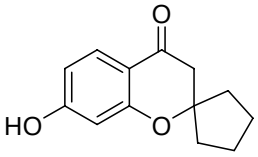
1. Pathway A

7-hydroxy-2,2-dimethyl-2,3-dihydrochromen-4-one(2a)



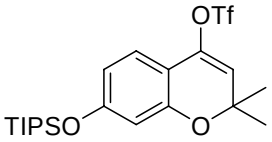
To a solution of **1a** (3.0 g, 19.72 mmol) and pyrrolidine (3.506 g, 49.29 mmol) in distilled Toluene (100 ml) was added acetone (14.48 ml, 197.18 mmol) in one portion. Then, the mixture was heated to reflux for 14 h with a Dean-Stark apparatus. After reaction completion, the solvent was removed under reduced pressure. The resultant was dissolved with EA and washed with 1N HCl, aqueous NH_4Cl (2 times) solution and brine. The organic layer was dried over anhydrous $MgSO_4$ and filtered. Then, the filtrate was condensed under reduced pressure and the resulting mixture was purified with silica gel flash column chromatograph (EA:Hexane = 1:4) to provide a desired product **2a** (3.29 g, 86.7 %) as a yellow solid; ^{1}H NMR (CD_3OD, 300 MHz) 7.66(d, *J* = 8.7, 1H), 6.43(dd, *J* = 8.6, 2.2, 1H), 6.27(d, *J* = 2.2, 1H), 2.67 (s, 2H), 1.43(s, 6H); ^{13}C NMR (CD_3OD, 300 MHz) 192.1, 165.5, 162.4, 127.9, 112.9, 109.6, 102.7, 79.0, 47.7, 25.4; MS (ESI+) Calcd for $C_{11}H_{13}O_3$ $[M + H]^+$ 193.08. Found 193.11.

7-hydroxy-2-spiropentyl-2,3-dihydrochromen-4-one(2b)



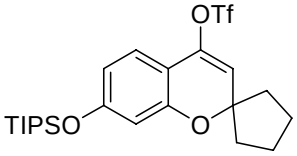
To a solution of **1b** (5.0 g, 30.1 mmol) and pyrrolidine (6.42 g, 90.3 mmol) in EtOH (150 ml) was added cyclopentanone (3.8 g, 45.1 mmol) in one portion. Then, the mixture was heated to reflux for 12 h with a Dean-Stark apparatus. After reaction completion, the reaction mixture was condensed under reduced pressure. The resultant was dissolved with EA and washed with 1N HCl, aqueous NH_4Cl (2 times) solution and brine. The organic layer was dried over anhydrous $MgSO_4$ and filtered. Then, the filtrate was condensed under reduced pressure and the resulting mixture was purified with silica gel flash column chromatograph (EA:Hexane = 1:5) to provide a desired product, 7-methoxy-2-spiropentyl-2,3-dihydrochromen-4-one, (6.1 g, 87.2 %) as a pale yellow solid. Then, demethylation was directly proceed. The previous prepared compound (3.0 g, 12.9 mmol) was dissolved in pyridine hydrochloride (20.2 g, 174.2 mmol). Then, the mixture was heated for 14 h at 190℃. The resulting solid was removed with filtration through Celite® and the filtrate was condensed under reduced pressure. The resultant was dissolved in EA and washed with 1N HCl and brine. The organic layer was dried over anhydrous $MgSO_4$ and filtered. Then, the filtrate was condensed under reduced pressure and the resulting mixture was purified with silica gel flash column chromatograph (EA:Hexane = 1:3) to provide a product **2b** (2.73 g, 97.1 %) as a yellow solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.79(d, *J* = 8.7, 1H), 7.57(bs, 1H), 6.52(dd, *J* = 8.6, 2.3, 1H), 6.39(d, *J* = 2.3, 1H) 2.80(s, 2H), 2.07(m, 2H), 1.85(m, 2H), 1.66(m, 4H); ^{13}C NMR (CD_3OD, 300 MHz) 192.3, 165.4, 162.7, 128.1, 113.6, 109.7, 103.0, 90.0, 46.0, 36.9, 23.4; MS (ESI+) Calcd for $C_{13}H_{15}O_3$ $[M + H]^+$ 219.09. Found 218.83.

2,2-dimethyl-7-(triisopropylsilyloxy)-2H-chromen-4-yl trifluoromethanesulfonate(3a)



The mixture of **2a** (1.4 g, 7.28 mmol) and imidazole (0.595 g, 8.78 mmol) was stirred in anhydrous CH_2Cl_2 (40 ml) under N_2. Then, TIPSCl (1.685 g, 6.24 mmol) was added dropwise at 0 ℃ via syringe and the mixture was stirred for 3 h at room temperature. Deionized water (30 ml) was poured and the reaction mixture was stirred for additional 10 min. Then the solution was extracted with EA and washed with aqueous NH_4Cl, saturated $NaHCO_3$ solution, and brine. The organic layer was dried over anhydrous $MgSO_4$ and filtered. Then, the filtrate was condensed under reduced pressure. The following enol-triflation was directly carried out after the purification with flash column chromatography (EA:Hexane = 1:10). To a solution of resulting compound (1.3 g, 3.73 mmol) and DTBMP (0.842 g, 4.10 mmol) in anhydrous CH_2Cl_2 (40 ml) at 0 ℃ with ice bath under N_2 was added triflic anhydride (1.26 g, 0.753 ml, 4.476 mmol) via syringe. The mixture was continuously stirred for 10 min at 0 ℃. The resulting solid was removed by the filtration through Celite® and the filtrate was condensed under reduced pressure. Then, the mixture was dissolved with EA (50 ml) and washed with saturated $NaHCO_3$ solution and brine. The organic layer was dried over anhydrous $MgSO_4$ and filtered. Then, the filtrate was condensed under reduced pressure and the resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:50) to give a product (1.56 g, 87 %) as colorless oil; ^{1}H NMR ($CDCl_3$, 300 MHz) 6.87(d, *J* = 8.4, 1H), 6.28(dd, *J* = 8.3, 2.3, 1H), 6.15(d, *J* = 2.2, 1H), 5.25 (s, 1H), 1.28(s, 6H), 1.05(m, 3H), 0.87(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 159.2, 155.0, 142.7, 122.4, 115.3, 113.0, 109.7, 108.6, 78.0, 27.8, 17.9, 12.6; MS (ESI+) Calcd for $C_{21}H_{32}F_3O_5SSi$ $[M + H]^+$ 481.16. Found 481.08.

2-spiropentyl-7-(triisopropylsilyloxy)-2H-chromen-4-yl trifluoromethanesulfonate(3b)



Compound **3b** was synthesized using identical procedure for **3a**. Silica gel column chromatography (Hexane only) afforded a product **3b** (78.9 %) as a colorless oil; ^{1}H NMR ($CDCl_3$, 300 MHz) 6.87(d, *J* = 8.4, 1H), 6.27(dd, *J* = 8.3, 2.3, 1H), 6.15(d, *J* = 2.2, 1H), 5.35(s, 1H), 2.14(m, 2H), 1.84(m, 2H), 1.63(m, 4H), 1.22(m, 3H), 1.06(d, *J* = 6.8, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 158.9, 154.9, 142.7, 122.2, 114.5, 112.9, 110.4, 108.7, 88.4, 39.1, 23.3, 17.9, 12.6; MS (ESI+) Calcd for $C_{23}H_{34}F_3O_5SSi$ $[M + H]^+$ 507.18. Found 507.46.

1-1. Pathway A1

General Procedure A1-A: Stille coupling reaction and *in situ* Diels–Alder reaction, 4a~b

To a solution of **3a~b** compound (0.729 mmol) and $Pd(PPh_3)_4$ (42.1 mg, 0.0365 mmol) in THF (7 ml) under N_2 was added tin reagent (0.875 mmol) via syringe in one portion. The mixture was heated at 70 ℃. After 20 h, the reaction mixture was diluted with diethyl ether (7 ml) and the resulting solid was removed by filtration through Celite®. The filtrate was condensed under reduced pressure and dissolved in toluene (4 ml). Then, a solution of maleimide reagent (0.875 mmol) in toluene (3 ml) was added to a resulting diene solution in one portion at room temperature. After stirring for 10 h at 40℃, the mixture was filtered through Celite® and condensed under reduced pressure. The resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:5).

General Procedure A1-B: Hydrogenation, 6a~b

A solution of **4a~b** compound (0.188 mmol) and 10% Pd/C (10 mol%) in MeOH/THF(1:1, 3 ml) was treated with H_2 gas at atmospheric pressure. Then, the reaction mixture was stirred for 3 h at room temperature. After reaction completion, the reaction mixture was filtered through Celite® and the solvent was evaporated under reduced pressure to provide a desired product in quantitative yield.

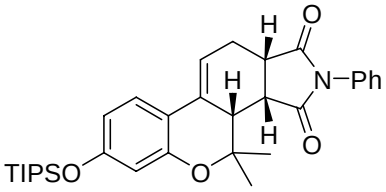
General Procedure A1-C: Aromatization, 7a~b

A solution of **4a~b** compound (0.188 mmol) and DDQ (93.9 mg, 0.414 mmol) in benzene (3 ml) was stirred overnight at 80 ℃. The mixture was diluted with diethyl ether and the resulting yellow solid was removed by filtration through Celite®. Then, the filtrate was condensed under reduced pressure. Finally the resultant was purified with flash column chromatography (EA:Hexane = 1:10)

General Procedure A1-D: Epoxidation, 8a~b

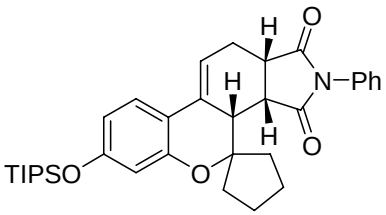
A solution of **4a~b** compound (0.1881 mmol) and DTBMP (96.6 mg, 0.470 mmol) in anhydrous DCM (7 ml) was stirred at 0 ℃. m-CPBA (64.9 mg, 0.3762 mmol) was added to the previous solution. Then, the mixture was stirred for 3 h at 0 ℃. The reaction was terminated by dilution with DCM. The resulting reaction mixture was washed with saturated aqueous solution of ammonium chloride and sodium bicarbonate. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated under reduced pressure. The resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:5)

4a-1



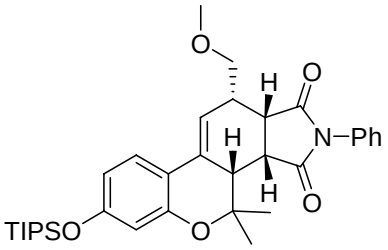
General Procedure A1-A; yield 84.1% as a white solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.34(d, *J* = 9.2, 1H), 7.27(m, 3H), 6.90(m, 2H), 6.45(m, 2H), 6.25(m, 1H), 3.60(dd, *J* = 8.5, 5.1, 1H), 3.37(m, 1H), 3.03(ddd, *J* = 14.9, 7.5, 1.6, 1H), 2.55(d, *J* = 3.7, 1H), 2.29(td, *J* = 14.9, 5.5, 1H), 1.88(s, 3H), 1.33(s, 3H), 1.23(m, 3H), 1.07(d, *J* = 6.2, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 178.4, 175.5, 157.3, 153.3, 132.9, 131.8, 128.8, 128.2, 126.3, 123.1, 116.2, 114.4, 114.0, 109.8, 75.4, 45.3, 42.4, 41.5, 28.8, 26.0, 25.5, 17.9, 12.6; MS (ESI+) Calcd for $C_{32}H_{42}NO_4Si$ $[M + H]^+$ 555.27. Found 555.16.

4b-1



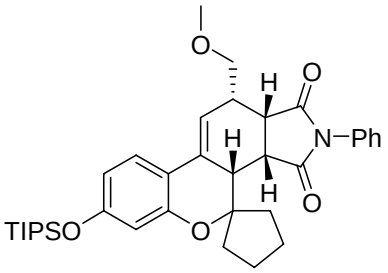
General Procedure A1-A; yield 82.2% as a white solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.31(m, 1H), 7.24(m, 3H), 6.90(m, 2H), 6.48(m, 1H), 6.45(m, 1H), 6.24(br s, 1H), 3.52(dd, ; *J* = 8.4, 5.7, 1H), 3.36(t, *J* = 6.3, 1H), 3.06(ddd, *J* = 14.7, 7.6, 1.3, 1H), 2.83(m, 1H), 2.61(d, *J* = 4.6, 1H), 2.27(td, *J* = 14.6, 5.0, 1H), 1.72(m, 8H), 1.23(m, 3H), 1.08(d, *J* = 7.0, 1H); ^{13}C NMR ($CDCl_3$, 300 MHz) 178.3, 175.7, 157.1, 153.6, 133.2, 131.9, 128.8, 128.2, 126.3, 123.3, 116.7, 115.6, 114.3, 110.1, 87.3, 77.2, 44.9, 42.4, 39.5, 35.8, 25.2, 23.5, 23.2, 17.9, 12.6; MS (APCI+) Calcd for $C_{34}H_{44}NO_4Si$ $[M + H]^+$ 558.30. Found 558.18.

4a-2



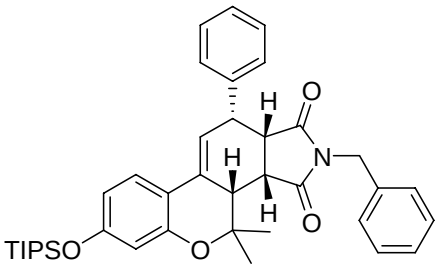
General Procedure A1-A; reaction at 60℃ (Diels–Alder reaction); yield 81.3% as a pale brown solid; eluent (EA:Hexane = 1:4); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.36(d, *J* = 9.2, 1H), 7.24(m, 3H), 6.83(m, 2H), 6.27(m, 2H), 6.07(br s, 1H), 4.07(dd, *J* = 9.2, 7.0, 1H), 3.91(t, *J* = 8.1, 1H), 3.60(dd, *J* = 8.3, 5.3, 1H), 3.46(s, 3H), 3.44(s, 1H), 2.76(m, 1H), 2.59(br s, 1H), 1.89(s, 3H), 1.30(s, 3H), 1.22(m, 3H), 1.08(d, *J* = 6.2, 18H); ^{13}C NMR ($CDCl_3$, 500 MHz) 176.2, 175.5, 157.4, 153.5, 131.7, 129.3, 129.1, 128.6, 126.3, 125.3, 124.0, 118.5, 113.2, 108.6, 78.1, 73.6, 59.0, 43.6, 41.6, 34.5, 26.0, 25.3, 24.6, 17.9, 12.6; MS (APCI+) Calcd for $C_{34}H_{46}NO_5Si$ $[M + H]^+$ 576.31. Found 576.13.

4b-2



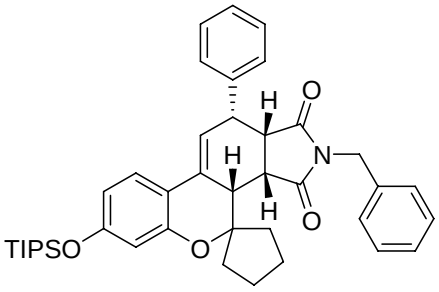
General Procedure A1-A; reaction at 60℃(Diels–Alder reaction); yield 80.4% as a pale brown solid; eluent (EA:Hexane = 1:4); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.35(m, 1H), 7.24(m, 3H), 6.83(m, 2H), 6.46(m, 2H), 6.06(dd, *J* = 4.4, 2.1, 1H), 4.10(m, 1H), 3.96(m, 1H), 3.51(m, 5H), 2.90(br s, 1H), 2.76(m, 1H), 2.67(m, 1H), 1.79(m, 6H), 1.38(m, 1H), 1.25(m, 3H), 1.08(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 176.2, 175.4, 157.3, 153.7, 132.7, 131.7, 128.8, 128.2, 126.3, 123.6, 119.3, 115.2, 114.3, 109.9, 87.2, 72.8, 59.2, 45.5, 44.0, 42.6, 39.6, 38.2, 35.7, 23.5, 23.3, 17.9, 12.6; MS (APCI+) Calcd for $C_{36}H_{48}NO_5Si$ $[M + H]^+$ 602.32. Found 602.04.

4a-3



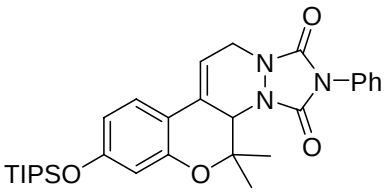
To a solution of **3a** (0.350 g, 0.729 mmol), trans-2-phenylvinylboronic acid (0.129 g, 0.875 mmol), $Pd(PPh_3)_4$ (42.1 mg, 0.0365 mmol) in solvent mixture (7 ml) of EtOH:Toluene (1:1) under N_2 was added 10% $NaCO_3$ solution (1.8 ml) via syringe at room temperature. Then, the mixture was heated for 6 h at 60 ℃. After completion, the resulting solid was filtered to remove through Celite® and the filtrate was condensed under reduced pressure. The resultant was dissolved in EtOAc (7 ml) and washed with distilled H_2O (2 Times). The organic layer was dried over $MgSO_4$ and filtered. Then, the filtrate was condensed under reduced pressure and dissolved in toluene (4 ml). Then, a solution of N-benzyl maleimide (0.164 g, 0.875 mmol) in toluene (3 ml) was added to a previous solution in one portion at room temperature. After stirring for 12 h at 80℃, the mixture was filtered through Celite® and condensed. The resultant was purified with column chromatography(EA: Hexane=1:5) to give a product (1.56 g, 0.377 mmol, 83.2%) as a pale orange solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.30(m, 5H), 7.08(m, 6H), 6.50(m, 2H), 6.32(br s, 1H), 4.54(d, *J* = 14.0, 1H), 4.29(d, *J* = 14.0, 1H), 3.72(t, *J* = 5.8, 1H), 3.56(dd, *J* = 8.0, 4.6, 1H), 3.37(t, *J* = 7.4, 1H), 2.68(br s, 1H), 1.87(s, 3H), 1.40(s, 3H), 1.31(m, 3H), 1.10(d, *J* = 6.9, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 175.2, 175.0, 157.5, 153.6, 138.8, 135.9, 132.8, 128.9, 128.4, 128.25, 128.21, 127.4, 127.1, 123.3, 118.6, 114.4, 114.0, 109.8, 75.2, 48.4, 45.5, 42.9, 42.5, 42.0, 29.1, 26.2, 17.9, 12.7; MS (APCI+) Calcd for $C_{39}H_{48}NO_4Si$ $[M + H]^+$ 622.33. Found 622.21.

4b-3



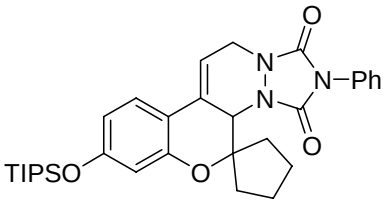
Compound **4b-3** was synthesized with identical procedure for **4a-3**. Silica gel flash column chromatography (EA: Hexane=1:5) afforded a product (82.1%) as a pale orange solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.31(m, 8H), 7.07(m, 3H), 6.52(m, 1H), 6.48(m, 1H), 6.37(br s, 1H), 4.54(d, *J* = 14.2, 1H), 4.31(d, *J* = 14.1, 1H), 3.73(t, *J* = 5.4, 1H), 3.50(dd, *J* = 8.0, 5.1, 1H), 3.41(t, *J* = 6.4, 1H), 2.74(br s, 1H), 1.91(m, 8H), 1.25(m, 3H), 1.10(d, *J* = 6.8, 18H); ^{13}C NMR ($CDCl_3$, 500 MHz) 175.4, 175.2, 157.4, 153.9, 138.9, 135.8, 134.2, 133.2, 128.8, 128.4, 128.2, 127.4, 127.1, 123.5, 118.7, 115.5, 114.2, 110.1, 87.1, 48.2, 45.1, 43.3, 42.7, 42.1, 39.8, 36.1, 23.5, 23.1, 18.0, 12.7; MS (APCI+) Calcd for $C_{41}H_{50}NO_4Si$ $[M + H]^+$ 648.34. Found 648.14.

4a-4



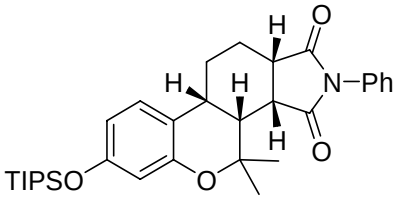
General Procedure A1-A; yield 85.1% as a pale brown solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.52(m, 4H), 7.40(m, 1H), 7.26(s, 1H), 6.50(dd, *J* = 8.5, 2.4, 1H), 6.39(d, *J* = 2.3, 1H), 6.17(dd, *J* = 3.5, 2.1, 1H), 4.87(s, 1H), 4.55(ddd, *J* = 16.4, 5.7, 0.8, 1H), 4.08(td, *J* = 16.4, 2.5, 1H), 1.64(s, 3H), 1.26(m, 3H), 1.18(s, 3H), 1.10(d, *J* = 6.9, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 158.1, 155.4, 152.9, 149.7, 131.1, 129.2, 128.3, 128.0, 125.4, 124.3, 113.5, 113.4, 110.4, 108.2, 80.7, 56.3, 46.0, 27.8, 21.0, 17.9, 12.6; MS (APCI+) Calcd for $C_{30}H_{40}N_3O_4Si$ $[M + H]^+$ 534.27. Found 534.10.

4b-4



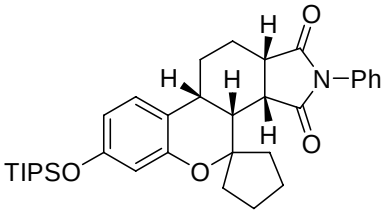
General Procedure A1-A; yield 84.3% as a pale brown solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.51(m, 4H), 7.38(m, 1H), 7.23(m, 1H), 6.49(dd, *J* = 8.5, 2.4, 1H), 6.38(d, *J* = 2.3, 1H), 6.11(m, 1H), 5.03(s, 1H), 4.53(dd, *J* = 16.7, 5.5, 1H), 4.12(td, *J* = 16.4, 2.4, 1H), 2.31(m, 1H), 2.02(m, 2H), 1.66(m, 5H), 1.25(m, 3H), 1.10(d, *J* = 6.7, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 158.0, 154.9, 153.2, 150.1, 129.2, 128.7, 128.2, 126.0, 125.4, 124.2, 114.0, 113.5, 109.5, 108.5, 91.4, 53.6, 45.5, 36.4, 24.6, 23.8, 22.7, 17.9, 12.7; MS (APCI+) Calcd for $C_{32}H_{42}N_3O_4Si$ $[M + H]^+$ 560.29. Found 560.07.

6a-1



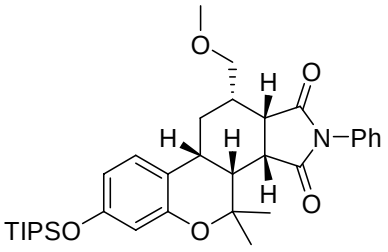
General Procedure A1-B; yield 97.8% as a pale brown solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.25(m, 3H), 6.90(d, *J* = 8.4, 1H), 6.75(m, 2H), 6.38(dd, *J* = 8.4, 2.4, 1H), 6.34(d, *J* = 2.3, 1H), 3.44(m, 2H), 3.24(br s, 1H), 2.46(m, 1H), 2.16(m, 2H), 1.92(m, 1H), 1.73(s, 3H), 1.51(m, 1H), 1.42(s, 3H), 1.19(m, 3H), 1.06(d, *J* = 7.1, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 178.7, 175.2, 155.8, 154.2, 132.0, 128.7, 128.1, 127.1, 126.2, 115.6, 112.2, 107.9, 74.8, 41.4, 38.7, 38.5, 28.4, 27.7, 27.3, 25.4, 21.6, 17.9, 12.6; MS (APCI+) Calcd for $C_{32}H_{44}NO_4Si$ $[M + H]^+$ 534.30. Found 534.16.

6b-1



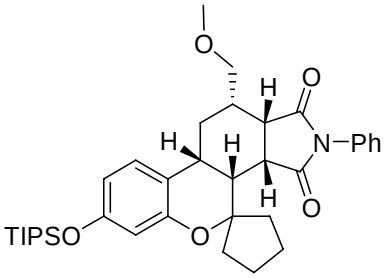
General Procedure A1-B; yield 97.2% as a pale brown solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.25(m, 3H), 6.88(d, *J* = 8.3, 1H), 6.74(m, 2H), 6.38(dd, *J* = 8.4, 2.3, 1H), 6.34(d, *J* = 2.3, 1H), 3.35(dd, *J* = 9.2, 4.8, 2H), 3.22(br s, 1H), 2.59(m, 1H), 2.42(m, 1H), 2.15(m, 3H), 1.94(m, 3H), 1.75(m, 3H), 1.51(m, 2H), 1.21(m, 3H), 1.05(d, *J* = 7.1, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 178.6, 175.3, 155.7, 153.9, 132.0, 128.7, 128.0, 127.2, 126.2, 116.6, 112.3, 108.1, 86.5, 41.3, 39.9, 39.3, 38.7, 37.4, 28.9, 25.3, 23.8, 23.7, 21.5, 17.9, 12.6; MS (APCI+) Calcd for $C_{34}H_{46}NO_4Si$ $[M + H]^+$ 560.31. Found 560.00.

6a-2



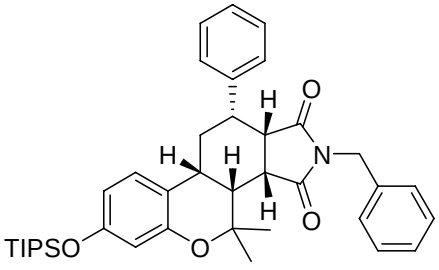
General Procedure A1-B; yield 96.3% as a white solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.25(m, 3H), 6.89(d, *J* = 5.0, 1H), 6.66(m, 2H), 6.39(dd, *J* = 5.0, 1.4, 1H), 6.34(d, *J* = 1.4, 1H), 3.85(dd, *J* = 5.6, 3.9, 1H), 3.51(m, 3H), 3.43(s, 3H), 3.34(br s, 1H), 2.55(dd, *J* = 7.9, 6.9, 1H), 2.39(m, 1H), 2.19(dd, *J* = 4.3, 3.5, 1H), 1.75(s, 3H), 1.40(s, 3H), 1.33(dd, *J* = 7.9, 6.9, 1H), 1.23(m, 3H), 1.06(d, *J* = 7.1, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 177.8, 174.3, 157.9, 154.7, 131.6, 130.4, 129.3, 128.7, 126.4, 126.3, 124.9, 123.7, 114.4, 113.5, 109.2, 77.8, 60.7, 42.8, 42.5, 36.7, 32.4, 25.8, 24.0, 17.9, 12.6; MS (ESI+) Calcd for $C_{34}H_{48}NO_5Si$ $[M + H + Na]^+$ 601.31. Found 601.43.

6b-2



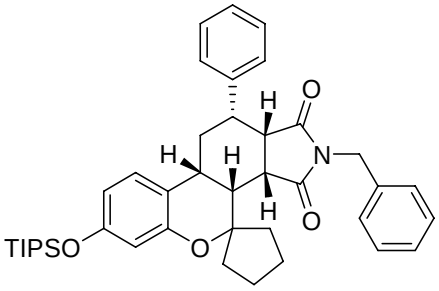
General Procedure A1-B; yield 93.6% as a white solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.24(m, 3H), 6.87(d, *J* = 8.3, 1H), 6.63(m, 2H), 6.39(d, *J* = 8.4, 1H), 3.86(t, *J* = 6.9, 1H), 3.53(t, *J* = 7.7, 1H), 3.43(s, 3H), 3.40(m, 2H), 3.35(br s, 1H), 2.66(m, 1H), 2.52(m, 1H), 2.41(m, 1H), 2.19(t, *J* = 6.3, 1H), 2.08(m, 1H), 1.98(m, 1H), 1.82(m, 1H), 1.71(m, 4H), 1.48(m, 1H), 1.20(m, 3H), 1.07(d, *J* = 6.6, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 176.4, 175.3, 155.8, 153.7, 131.9, 128.6, 128.1, 127.2, 126.3, 116.7, 112.3, 108.1, 86.5, 74.0, 59.0, 42.2, 41.0, 39.5, 38.7, 37.3, 33.8, 29.1, 28.7, 23.8, 23.6, 18.0, 12.7; MS (APCI+) Calcd for $C_{36}H_{50}NO_5Si$ $[M + H]^+$ 604.34. Found 604.80.

6a-3



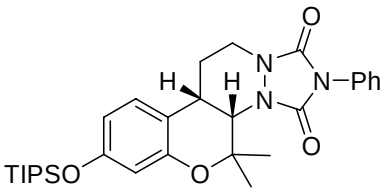
General Procedure A1-B; yield 95.0% as a white solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.23(m, 7H), 7.08(m, 3H), 6.71(m, 2H), 6.52(m, 2H), 4.54(d, *J* = 13.5, 1H), 4.27(d, *J* = 13.5, 1H), 3.65(dd, *J* = 13.1, 7.8, 1H), 3.40(dd, *J* = 8.3, 4.4, 1H), 3.27(t, *J* = 8.0, 1H), 2.37(d, *J* = 4.3, 1H), 2.26(d, *J* = 14.3, 1H), 1.68(s, 3H), 1.59(s, 3H), 1.31(m, 3H), 1.13(d, *J* = 6.2, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 175.2, 175.0, 155.7, 154.0, 140.7, 135.9, 129.2, 128.3, 128.1, 127.8, 127.6, 127.1, 126.9, 115.8, 112.5, 108.1, 74.4, 47.1, 42.0, 40.4, 38.30, 38.26, 30.0, 29.0, 28.0, 27.5, 18.0, 12.7; MS (APCI+) Calcd for $C_{39}H_{50}NO_4Si$ $[M + H]^+$ 624.34. Found 624.14.

6b-3



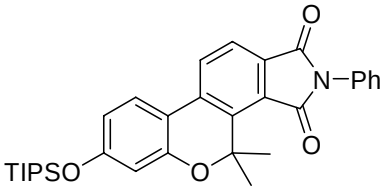
General Procedure A1-B; yield 94.6% as a white solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.22(m, 6H), 7.04(m, 4H), 6.89(d, *J* = 8.9, 1H), 6.43(m, 2H), 4.42(d, *J* = 13.7, 1H), 4.12(d, *J* = 13.7, 1H), 3.41(m, 2H), 3.27(m, 1H), 2.52(m, 2H), 2.29(dd, *J* = 7.9, 4.1, 1H), 1.82(m, 8H), 1.47(m, 1H), 1.26(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 175.4, 175.2, 155.6, 153.7, 140.9, 135.9, 129.2, 128.3, 128.1, 127.8, 127.6, 127.2, 126.9, 116.9, 112.6, 108.4, 86.1, 47.0, 42.0, 41.8, 38.9, 38.3, 38.1, 37.6, 30.0, 29.8, 23.8, 23.7, 18.0, 12.7; MS (APCI+) Calcd for $C_{41}H_{52}NO_4Si$ $[M + H]^+$ 650.36. Found 650.16.

6a-4



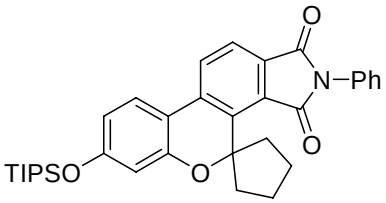
General Procedure A1-B; yield 95.9% as a pale brown; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.50(m, 4H), 7.38(t, *J* = 7.1, 1H), 6.99(d, *J* = 8.3, 1H), 6.55(dd, *J* = 8.3, 2.3, 1H), 6.43(d, *J* = 2.2, 1H), 4.61(d, *J* = 6.8, 1H), 4.17(m, 1H), 3.25(dt, *J* = 11.9, 3.2, 1H), 3.12(m, 1H), 2.27(m, 1H), 2.12(m, 1H), 1.46(d, *J* = 9.6, 6H), 1.25(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 156.4, 154.7, 153.1, 150.0, 131.3, 129.2, 128.4, 128.2, 125.4, 117.5, 114.1, 109.7, 79.0, 56.2, 45.7, 33.5, 29.8, 27.7, 24.2, 17.9, 12.6; MS (APCI+) Calcd for $C_{30}H_{42}N_3O_4Si$ $[M + H]^+$ 536.29. Found 536.11.

7a-1



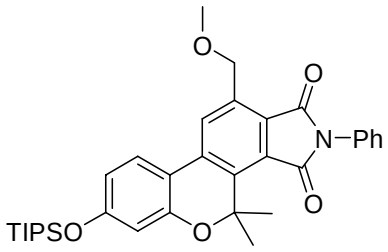
General Procedure A1-C; yield 88.1% as a green solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.97(d, *J* = 8.0, 1H), 7.89(d, *J* = 7.9, 1H), 7.55(m, 3H), 7.41(m, 3H), 6.60(dd, *J* = 8.6, 2.4, 1H), 6.44(d, *J* = 2.2, 1H), 1.93(s, 6H), 1.20(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 167.1, 166.7, 159.3, 154.3, 139.7, 136.8, 131.7, 131.0, 129.1, 128.2, 127.0, 126.8, 125.0, 123.3, 114.7, 113.9, 109.4, 79.3, 27.0, 17.9, 12.7; MS (APCI+) Calcd for $C_{32}H_{38}NO_4Si$ $[M + H]^+$ 528.25. Found 528.17.

7b-1



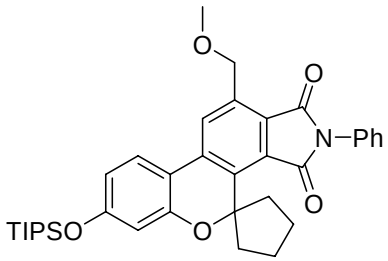
General Procedure A1-C; yield 86.3% as a green solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.95(d, *J* = 7.9, 1H), 7.87(d, *J* = 7.8, 1H), 7.50(m, 3H), 7.41(m, 3H), 6.59(dd, *J* = 8.5, 2.2, 1H), 6.47(d, *J* = 2.2, 1H), 2.51(m, 2H), 2.21(m, 2H), 2.04(m, 4H), 1.26(m, 3H), 1.12(d, *J* = 7.1, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 167.4, 166.9, 159.2, 154.1, 139.1, 137.9, 131.7, 130.9, 129.2, 128.2, 126.9, 126.7, 126.6, 125.0, 123.2, 114.7, 114.6, 109.6, 90.2, 39.6, 24.8, 17.9, 12.7; MS (APCI+) Calcd for $C_{34}H_{40}NO_4Si$ $[M + H]^+$ 554.26. Found 554.01.

7a-2



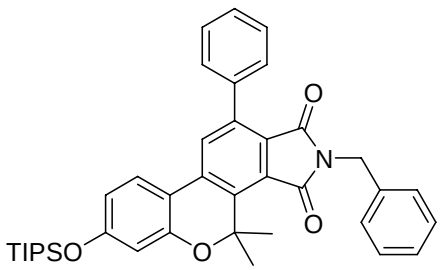
General Procedure A1-C; yield 87.4% as a green solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 8.12(s, 1H), 7.54(m, 6H), 6.61(td, *J* = 8.5, 1.7, 1H), 6.50(d, *J* = 2.2, 1H), 5.02(s, 2H), 3.56(s, 3H), 1.91(s, 6H), 1.28(m, 3H), 1.12(d, *J* = 7.1, 18H); ^{13}C NMR ($CDCl_3$, 500 MHz) 167.0, 159.3, 154.4, 138.5, 138.2, 136.8, 131.6, 129.2, 129.1, 128.2, 127.2, 126.9, 126.3, 125.4, 125.2, 114.6, 114.0, 109.3, 79.3, 69.6, 59.1, 29.7, 26.9, 26.8, 17.9, 12.7; MS (APCI+) Calcd for $C_{34}H_{42}NO_5Si$ $[M + H]^+$ 572.28. Found 572.03.

7b-2



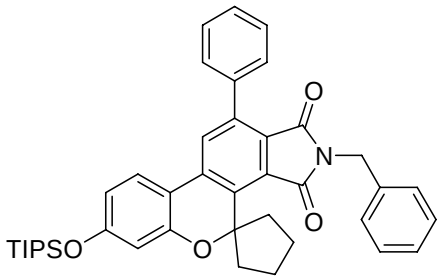
General Procedure A1-C; yield 85.2% as a green solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 8.11(s, 1H), 7.52(m, 4H), 7.38(m, 2H), 6.60(d, *J* = 8.4, 1H), 6.47(s, 1H), 5.01(s, 2H), 3.55(s, 3H), 2.51(m, 2H), 2.19(m, 2H), 2.04(m, 4H), 1.28(m, 3H), 1.12(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 167.3, 167.1, 159.2, 154.2, 138.2, 137.9, 131.6, 129.1, 128.2, 127.0, 126.2, 125.3, 125.1, 114.8, 114.6, 109.5, 90.2, 69.6, 59.1, 39.5, 24.9, 17.9, 12.7; MS (APCI+) Calcd for $C_{36}H_{44}NO_5Si$ $[M + H]^+$ 598.29. Found 598.18.

7a-3



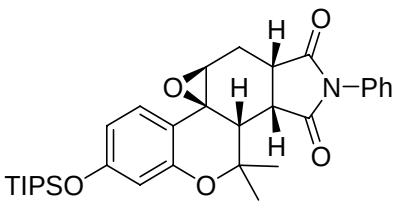
General Procedure A1-C; yield 86.8% as a green solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.75(s, 1H), 7.50(m, 6H), 7.41(m, 2H), 7.29(m, 3H), 6.56(dd, *J* = 8.5, 2.3, 1H), 6.49(d, *J* = 2.3, 1H), 4.78(s, 2H), 1.94(s, 6H), 1.26(m, 3H), 1.11(d, *J* = 7.1, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 167.3, 166.8, 159.3, 154.4, 140.3, 138.4, 136.7, 136.5, 136.0, 129.3, 128.8, 128.7, 128.65, 128.61, 128.3, 128.0, 127.8, 126.7, 124.9, 114.6, 113.8, 109.3, 79.4, 41.7, 27.0, 17.9, 12.7; MS (APCI+) Calcd for $C_{39}H_{44}NO_4Si$ $[M + H]^+$ 618.30. Found 618.08.

7b-3



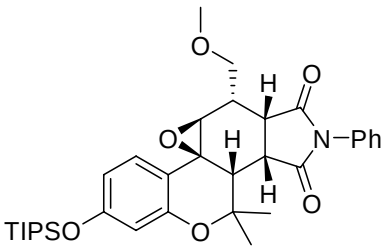
General Procedure A1-C; yield 85.3% as a green solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.68(s, 1H), 7.42(m, 6H), 7.32(m, 2H), 7.21(m, 3H), 6.48(dd, *J* = 8.5, 2.0, 1H), 6.40(d, *J* = 2.0, 1H), 4.70(s, 2H), 2.45(m, 2H), 2.12(m, 2H), 2.01(m, 4H), 1.20(m, 3H), 1.04(d, *J* = 7.1, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 167.5, 167.0, 159.1, 154.2, 140.3, 137.7, 137.1, 136.7, 136.5, 129.3, 128.7, 128.63, 128.59, 128.4, 128.0, 127.7, 126.6, 125.0, 114.6, 109.6, 90.3, 39.5, 24.9, 17.9, 12.7; MS (APCI+) Calcd for $C_{41}H_{46}NO_4Si$ $[M + H]^+$ 644.31. Found 644.14.

8a-1



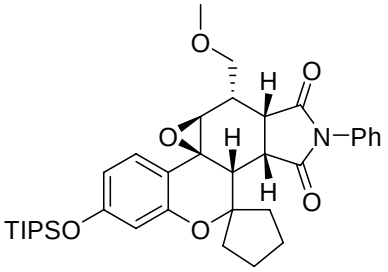
General Procedure A1-D; yield 76.1% as a pale pink solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.44(m, 3H), 7.27(m, 2H), 7.20(d, *J* = 8.4, 1H), 6.54(d, *J* = 2.2, 1H), 6.50(d, *J* = 4.1, 1H), 4.96(s, 1H), 3.91(d, *J* = 7.2, 1H), 3.45(m, 1H), 2.61(m, 1H), 1.83(m, 1H), 1.75(s, 1H), 1.61(m, 1H), 1.50(s, 3H), 1.26(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 177.8, 174.3, 157.9, 154.7, 131.6, 130.4, 129.3, 128.7, 126.4, 124.9, 123.7, 114.4, 113.5, 109.2, 77.8, 60.7, 42.5, 36.7, 32.4, 25.8, 24.0, 17.9, 12.6; MS (APCI+) Calcd for $C_{32}H_{42}NO_5Si$ $[M + H]^+$ 548.28. Found 548.03.

8a-2



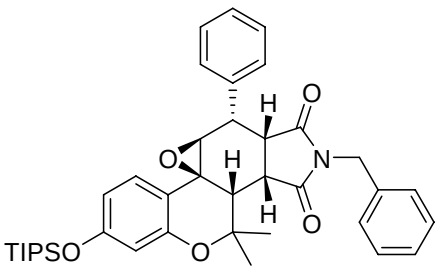
General Procedure A1-D; yield 75.2% as a pale pink solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.47(m, 2H), 7.41(m, 1H), 7.33(m, 2H), 7.22(m, 1H), 6.51(dd, *J* = 8.3, 2.3, 1H), 6.47(d, *J* = 2.3, 1H), 4.88(d, *J* = 3.4, 1H), 3.85(d, *J* = 8.0, 1H), 3.65(dd, *J* = 8.0, 5.5, 1H), 3.51(m, 2H), 3.24(s, 3H), 2.80(dd, *J* = 5.4, 3.5, 1H), 1.80(s, 3H), 1.62(m, 1H), 1.47(s, 3H), 1.25(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 500 MHz) 176.4, 174.7, 157.7, 154.6, 131.8, 129.4, 129.1, 128.5, 126.3, 124.0, 114.6, 113.2, 109.1, 77.9, 71.6, 64.3, 59.1, 42.1, 40.3, 39.0, 25.9, 23.9, 17.9, 12.8; MS (APCI+) Calcd for $C_{34}H_{46}NO_6Si$ $[M + H]^+$ 592.30. Found 592.06.

8b-2



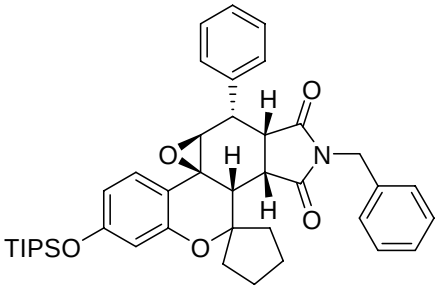
General Procedure A1-D; yield 73.1% as a pale pink solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.47(m, 2H), 7.38(m, 1H), 7.31(m, 2H), 7.22(m, 1H), 6.51(dd, *J* = 8.4, 2.3, 1H), 6.46(d, *J* = 2.3, 1H), 4.87(br s, 1H), 3.87(d, *J* = 8.0, 1H), 3.65(m, 1H), 3.50(m, 2H), 3.23(s, 3H), 2.83(m, 1H), 2.45(m, 1H), 1.86(m, 8H), 1.24(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 176.5, 174.7, 157.5, 154.5, 131.9, 130.2, 129.1, 128.5, 126.2, 124.1, 123.8, 115.5, 113.2, 109.4, 89.1, 71.5, 64.4, 59.1, 42.5, 40.4, 39.0, 35.8, 33.0, 23.4, 22.5, 17.9, 12.7; MS (APCI+) Calcd for $C_{36}H_{48}NO_6Si$ $[M + H]^+$ 618.32. Found 618.04.

8a-3



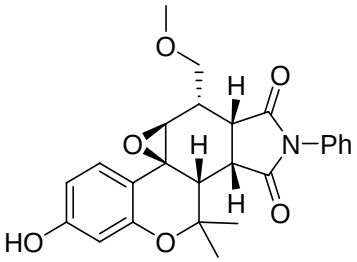
General Procedure A1-D; yield 77.4% as a pale brown solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.19(m, 4H), 7.12(m, 7H), 6.49(m, 2H), 4.98(br s, 1H), 3.99(d, *J* = 14.1, 1H), 3.87(d, *J* = 14.1, 1H), 3.76(m, 1H), 3.65(m, 2H), 2.00(s, 1H), 1.71(s, 1H), 1.67(s, 1H), 1.24(m, 3H), 1.10(d, *J* = 6.8, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 177.0, 174.3, 158.0, 154.7, 136.2, 135.3, 130.0, 128.8, 128.6, 128.5, 128.1, 127.7, 126.3, 123.7, 114.3, 113.4, 109.1, 64.7, 45.8, 41.7, 41.4, 41.0, 25.9, 23.4, 17.9, 12.7 ; MS (APCI+) Calcd for $C_{39}H_{48}NO_5Si$ $[M + H]^+$ 638.32. Found 638.23.

8b-3



General Procedure A1-D; yield 74.5% as a pale brown solid; ^{1}H NMR ($CDCl_3$, 500 MHz) 7.19(m, 4H), 7.10(m, 7H), 6.50(m, 2H), 4.97(d, *J* = 1.0, 1H), 3.97(d, *J* = 14.5, 1H), 3.86(d, *J* = 14.0, 1H), 3.76(m, 1H), 3.66(m, 2H), 2.26(m, 2H), 2.11(m, 2H), 1.94(m, 3H), 1.83(m, 2H), 1.25(m, 3H), 1.11(d, *J* = 8.0, 18H); ^{13}C NMR ($CDCl_3$, 500 MHz) 177.0, 174.2, 157.8, 154.7, 136.2, 135.3, 131.0, 128.7, 128.6, 128.54, 128.51, 128.1, 127.6, 124.5, 123.6, 115.2, 113.4, 109.4, 89.0, 64.9, 45.9, 41.7, 41.5, 41.4, 35.7, 32.3, 23.2, 22.4, 17.9, 12.7; MS (ESI+) Calcd for $C_{41}H_{50}NO_5Si$ $[M + H]^+$ 664.34. Found 664.31.

11a-2

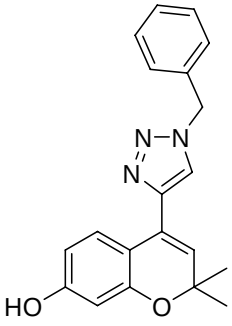


Compound **8a-2**(0.050 g, 0.08456 mmol) was dissolved in HF/pyridine/THF(5:5:90, 1ml). The mixture was tumbled for 3 h. After then, ethoxytrimethylsilane(2ml) was added to quench HF. After 30 m, The mixture was condensed to provide a product(quantitative yield) as a pale pink solid; ^{1}H NMR (acetone-d_6, 300 MHz) 7.51(m, 2H), 7.40(m, 3H), 7.29(d, *J* = 8.5, 1H), 6.45(dd, *J* = 8.4, 2.4, 1H), 6.36(d, *J* = 2.4, 1H), 4.90(d, *J* = 2.4, 1H), 3.65(dd, *J* = 5.9, 2.2, 1H), 3.43(m, 2H), 3.21(s, 3H), 2.77(m, 1H), 2.06(m, 2H), 1.75(s, 3H), 1.50(s, 3H); ^{13}C NMR (acetone- d_6, 300 MHz) 176.4, 175.3, 158.6, 154.6, 133.0, 128.6, 127.9, 126.8, 124.9, 114.4, 108.0, 103.6, 77.3, 70.9, 62.8, 58.2, 41.8, 41.4, 38.8, 25.4, 23.6; MS (APCI-) Calcd for $C_{34}H_{46}NO_6Si$ $[M - H]^-$ 434.17. Found 434.08.

1-2. Pathway A2

General procedure A2-A: Click chemistry(1,3-dipolar cyclization) to obtain compounds 14a~b
A solution of terminal alkyne compound (0.281 mmol), azide compound (0.561 mmol), Copper powder (10 mol%) and $CuSO_4$ (10mmol%) in toluene(3ml) was heated overnight at 80 ℃. After reaction completion, the mixture was filtered through Celite® and the filtrate was condensed under reduced pressure. Then, the resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:5) to yield a desired product.

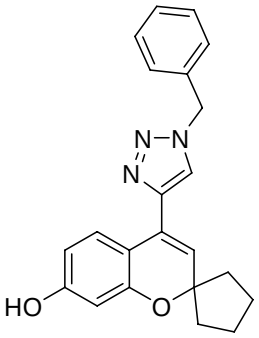
4-(1-benzyl-1H-1,2,3-triazol-4-yl)-2,2-dimethyl-2H-chromen-7-ol(20a-1)



General procedure A for Click chemistry provided a product **19a-1** (78.2 %) as a yellow oil; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.52(s, 1H), 7.38(m, 3H), 7.30(m, 2H), 7.19(d, *J* =8.3, 1H), 6.44(d, *J* =2.2, 1H) 6.40 (dd, *J* = 8.3, 2.2, 1H), 5.97(s, 1H), 5.58(s, 2H), 1.45(s, 6H), 1.23(m, 3H), 1.08(d, *J* = 7.0, 18 H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.3, 154.5, 145.3, 134.7, 129.2, 128.8, 128.0, 127.7, 125.3, 123.8, 121.5, 114.6, 112.6, 108.9, 75.8, 54.2, 27.2, 17.9, 12.6; MS (ESI+) Calcd for $C_{29}H_{40}N_3O_2Si$ $[M + H]^+$ 490.28. Found 490.53. Deprotection of TIPS group was proceeded with following procedure. To a solution of **19a-1** (100 mg, 0.204 mmol) in THF (3 ml) was added dropwise tetrabutylammonium fluoride (0.266 mmol, 1.0 M solution in THF). Then, the mixture was stirred for 10 min at 0℃. The solvent was evaporated under reduced pressure and

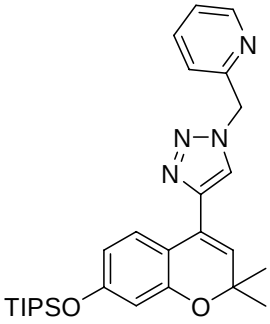
the residue was dissolved with EA and washed with H_2O. The organic layer was dried over anhydrous $MgSO_4$ and filtered. After condensation of the filtrate under reduced pressure, the resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:1) to provide a product (66.5 mg, 97.7 %) as a yellow solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.50(s, 1H), 7.39(m, 3H), 7.31(m, 2H), 7.18(d, *J* =8.3, 1H), 6.39(d, *J* =2.2, 1H) 6.37 (dd, *J* = 8.3, 2.2, 1H), 5.93(s, 1H), 5.57(s, 2H), 1.44(s, 6H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.2, 154.8, 145.2, 134.5, 129.2, 128.8, 128.1, 127.5, 125.7, 123.6, 121.6, 114.1, 107.9, 104.4, 76.0, 54.3, 27.3; MS (ESI+) Calcd for $C_{20}H_{20}N_3O_2$ $[M + H]^+$ 334.15. Found 334.42.

4-(1-benzyl-1H-1,2,3-triazol-4-yl)- 2-spirocyclopentyl-2H-chromen-7-ol(20b-1)



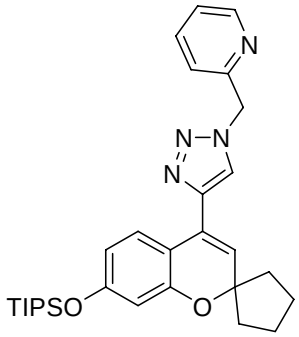
General procedure A for Click chemistry gave a product **19b-1** (77.3 %) as a yellow oil; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.51(s, 1H), 7.37(m, 3H), 7.28(m, 2H), 7.21(d, *J* =8.3, 1H), 6.39(m, *J* = 2.2, 2H), 6.04(s, 1H), 5.57(s, 2H), 2.16(m, 2H), 1.89(m, 2H), 1.68(m, 4H), 1.27(m, 2H), 1.09(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.1, 154.6, 145.3, 134.7, 129.1, 128.7, 128.0, 126.9, 125.2, 124.5, 121.4, 115.4, 112.5, 109.1, 86.8, 54.2, 38.5, 23.5, 17.9, 12.7; MS (ESI+) Calcd for $[C_{31}H_{41}N_3O_2Si + H]^+$ 516.30. Found 516.16. Compound **19b-1** was synthesized using a previous deprotection procedure for **19a-1**. Silica gel flash column chromatography (EA:Hexane = 1:1) afforded a product (96.8%) as a brown solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.51(s, 1H), 7.37(m, 3H), 7.28(m, 2H), 7.14(d, *J* = 8.3, 1H), 6.38(d, *J* = 2.2, 1H) 6.33 (dd, *J* = 8.3, 2.2, 1H), 6.00(s, 1H), 5.57(s, 2H), 2.14(m, 2H), 1.86(m, 2H), 1.68(m, 4H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.2, 154.8, 145.2, 134.5, 129.2, 128.9, 128.1, 126.7, 125.5, 124.3, 121.6, 114.8, 108.0, 104.6, 86.9, 54.3, 38.5, 23.4; MS (ESI+) Calcd for $C_{22}H_{22}N_3O_2$ $[M + H]^+$ 360.16. Found 360.30.

2-((4-(2,2-dimethyl-7-(triisopropylsilyloxy)-2H-chromen-3-yl)-1H-1,2,3-triazol-1-yl)methyl)pyridine(19a-2)



General Procedure A2-A; yield 75.6% as a yellow oil; eluent (EA:Hexane = 1:2); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.61(br s, 1H), 7.80(s, 1H), 7.71(t, *J* = 7.7, 1H), 7.27(m, 3H), 6.43(m, 2H), 6.02(s, 1H), 5.70(s, 2H), 1.46(s, 6H), 1.23(m, 3H), 1.09(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.3, 154.5, 149.8, 145.2, 137.4, 127.6, 125.3, 123.8, 123.5, 122.2, 122.1, 114.6, 112.6, 108.9, 75.8, 55.7, 27.2, 17.9, 12.7; MS (ESI+) Calcd for $C_{28}H_{39}N_4O_2Si$ $[M + H]^+$ 491.28. Found 490.90.

2-((4-(2-spirocyclopentyl-7-(triisopropylsilyloxy)-2H-chromen-3-yl)-1H-1,2,3-triazol-1-yl)methyl)pyridine(19b-2)



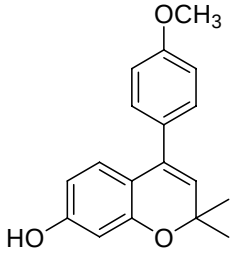
General Procedure A2-A; yield 74.4% as a yellow oil; eluent (EA:Hexane = 1:2); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.52(d, *J* = 4.4, 1H), 7.71(s, 1H), 7.62(t, *J* = 7.7, 1H), 7.19(m, 3H), 6.33(m, 2H), 6.00(s, 1H), 5.61(s, 2H), 2.07(m, 2H), 1.82(m, 2H), 1.61(m, 4H), 1.20(m, 3H), 1.02(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.1, 154.6, 154.5, 149.8, 145.3, 137.4, 126.8, 125.2, 124.5, 123.4, 122.4, 122.1, 115.4, 112.5, 109.1, 86.8, 55.7, 38.5, 23.5, 17.9, 12.7; MS (ESI+) Calcd for $C_{30}H_{41}N_4O_2Si$ $[M + H]^+$ 517.29. Found 517.23.

1-3. Pathway A3

General procedure A3-A: Suzuki coupling reaction to obtain compounds 15a~b

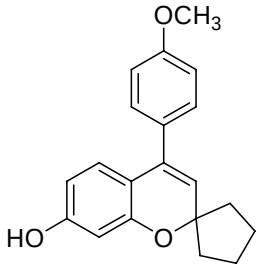
To a solution of **3a~b** compound (0.208 mmol) and $Pd(PPh_3)_4$ (12.0 mg, 0.010 mmol) in a solvent mixture of toluene (1 ml) and ethanol (1 ml) under N_2 was added a solution of boron reagent (0.229 mmol) and 10% Na_2CO_3(0.624 mmol) in a solvent mixture of toluene (1 ml) and ethanol (1 ml). Then, the mixture was heated for 3 h at 65℃. The resulting solid was removed by filtration through Celite®. The filtrate was extracted with EA and washed with H_2O, saturated $NaHCO_3$ solution, and brine. The organic layer was dried over $MgSO_4$, and filtered. After condensation of the filtrate under reduced pressure, the resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:50) to provide a desired product.

4-(4-methoxyphenyl)-2,2-dimethyl-2H-chromen-7-ol (25a-1)



General procedure A3-A for Suzuki coupling reaction gave a product **24a-1** (98.2 %) as a white solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.27(d, *J* = 8.6, 2H), 6.91(d, *J* = 8.6, 2H), 6.86(d, *J* = 8.4, 1H), 6.45(d, *J* = 2.4, 1H), 6.35(dd, *J* = 8.3, 2.4, 1H), 5.43(s, 1H), 3.84(s, 3H), 1.46(s, 6H), 1.24(m, 3H), 1.09(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 159.5, 157.0, 154.5, 134.1, 131.1, 129.8, 126.2, 125.9, 116.4, 113.6, 112.3, 108.7, 76.0, 55.3, 27.5, 17.9, 12.6; MS (ESI+) Calcd for $C_{27}H_{39}O_3Si$ $[M + H]^+$ 439.26. Found 439.20. Deprotection of TIPS group was proceeded with following procedure. To a solution of **24a-1** (100 mg, 0.228 mmol) in THF (3 ml) was added dropwise tetrabutylammonium fluoride (0.251 mmol, 1.0 M solution in THF). Then, the mixture was stirred for 10 min at 0℃. The solvent was evaporated under reduced pressure and the residue was dissolved with EA and washed with H_2O. The organic layer was dried over $MgSO_4$, filtered. After condensation of the filtrate under reduced pressure, the resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:10) to give a product(62.8 mg, 97.6 %) as a brown solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.26(d, *J* = 8.6, 2H), 6.91(d, *J* = 8.6, 2H), 6.87(d, *J* = 8.4, 1H), 6.40(d, *J* = 2.2, 1H), 6.31(dd, *J* = 8.4, 2.2, 1H), 5.43(s, 1H), 3.84(s, 3H), 1.46(s, 6H); ^{13}C NMR ($CDCl_3$, 300 MHz) 159.1, 156.6, 154.8, 134.0, 131.0, 129.8, 126.7, 125.7, 116.1, 113.7, 107.5, 104.1, 76.3, 55.4, 27.6; MS (APCI+) Calcd for $C_{18}H_{19}O_3$ $[M + H]^+$ 283.13. Found 283.11.

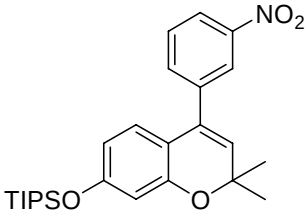
4-(4-methoxyphenyl)-2-spirocyclopentyl -2H-chromen-7-ol (25b-1)



General procedure A3-A for Suzuki coupling reaction gave a product **24b-**

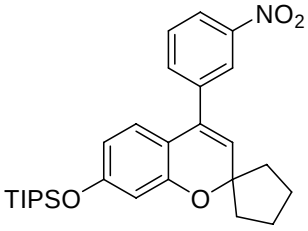
1 (97.1 %) as a yellow oil ; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.28(d, *J* = 9.0, 2H), 6.91(d, *J* = 8.6, 2H), 6.85(d, *J* = 8.4, 1H), 6.42(d, *J* = 2.3, 1H), 6.35(dd, *J* = 8.4, 2.3, 1H), 5.50(s, 1H), 3.84(s, 3H), 2.18(m, 2H), 1.91(m, 2H), 1.67(m, 4H), 1.26(m, 3H), 1.09(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 159.1, 156.9, 154.6, 135.0, 131.1, 129.8, 126.0, 125.0, 117.1, 113.6, 112.2, 108.9, 87.1, 55.3, 38.7, 23.5, 17.9, 12.7; MS (ESI+) Calcd for $C_{29}H_{40}O_3Si$ $[M + H]^+$ 465.27. Found 465.53. Compound **25b-1** was synthesized using a previously reported deprotection procedure of **25a-1**. Silica gel flash column chromatography (EA:Hexane = 1:10) afforded a product (98.1 %) as a brown solid ; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.29(d, *J* = 8.6, 2H), 6.93(d, *J* = 8.6, 2H), 6.89(d, *J* = 8.5, 1H), 6.40(d, *J* = 2.4, 1H), 6.32(dd, *J* = 8.3, 2.4, 1H), 5.51(s, 1H), 3.86(s, 3H), 2.22(m, 2H), 1.92(m, 2H), 1.70(m, 4H); ^{13}C NMR ($CDCl_3$, 300 MHz) 159.1, 156.5, 154.9, 134.8, 131.1, 129.8, 126.5, 124.8, 116.8, 113.7, 107.5, 104.3, 87.3, 55.3, 38.9, 23.5; MS (APCI+) Calcd for $C_{20}H_{20}O_3$ $[M + H]^+$ 309.14. Found 309.10.

(2,2-dimethyl-4-(3-nitrophenyl)-2H-chromen-7-yloxy)triisopropylsilane(24a-2)



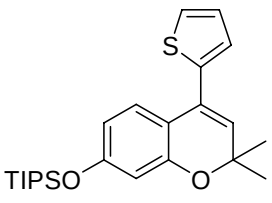
General Procedure A3-A; yield 97.2% as a yellow oil; eluent (EA:Hexane = 1:50); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.23(s, 1H), 8.21(d, *J* = 7.5, 1H), 7.68(d, *J* = 7.7, 1H), 7.55(t, *J* = 7.7, 1H), 6.73(d, *J* = 8.4, 1H), 6.48(d, *J* = 2.4, 1H), 6.38(dd, *J* = 8.4, 2.4, 1H), 5.56(s, 1H), 1.49(s, 6H), 1.25(m, 3H), 1.10(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.7, 154.5, 148.4, 140.5, 134.9, 133.1, 129.2, 128.0, 125.6, 123.6, 122.6, 115.2, 112.7, 109.0, 76.0, 27.3, 17.9, 12.6; MS (FAB+) Calcd for $C_{26}H_{36}NO_4Si$ $[M + H]^+$ 454. Found 454.

(2-spirocyclopentyl-4-(3-nitrophenyl)-2H-chromen-7-yloxy)triisopropylsilane(24b-2)



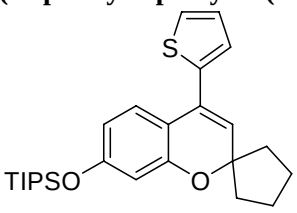
General Procedure A3-A; yield 93.3% as a light brown oil; eluent (EA:Hexane = 1:50); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.23(s, 1H), 8.21(d, *J* = 9.2, 1H), 7.68(d, *J* = 7.7, 1H), 7.55(t, *J* = 7.7, 1H), 6.73(d, *J* = 8.4, 1H), 6.46(d, *J* = 2.3, 1H), 6.37(dd, *J* = 8.4, 2.3, 1H), 5.61(s, 1H), 2.21(m, 2H), 1.93(m, 2H), 1.70(m, 4H), 1.27(m, 3H), 1.10(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.5, 154.5, 148.4, 140.5, 134.8, 133.8, 129.2, 127.2, 125.5, 123.6, 122.5, 115.9, 112.6, 109.2, 87.0, 38.7, 23.5, 17.9, 12.7; MS (ESI+) Calcd for $C_{28}H_{38}NO_4Si$ $[M + H]^+$ 480.25. Found 480.52.

(2,2-dimethyl-4-(thiophen-2-yl)-2H-chromen-7-yloxy)triisopropylsilane (24a-3)



General Procedure A3-A; yield 93.1% as a light brown oil; eluent (EA:Hexane = 1:50); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.29(d, *J* = 1.2, 1H), 7.21(d, *J* = 8.3, 1H), 7.10(m, 2H), 6.48(d, *J* = 2.3, 1H), 6.44(dd, *J* = 8.3, 2.3, 1H), 5.68(s, 1H), 1.48(s, 6H), 1.29(m, 3H), 1.12(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.4, 154.5, 140.3, 128.0, 127.4, 127.2, 126.2, 126.0, 124.5, 115.6, 112.5, 108.8, 75.8, 27.3, 17.9, 12.6; MS (APCI+) Calcd for $C_{24}H_{35}O_2SSi$ $[M + H]^+$ 415.20. Found 415.18.

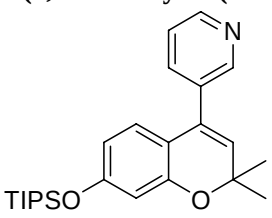
(2-spirocyclopentyl-4-(thiophen-2-yl)-2H-chromen-7-yloxy)triisopropylsilane (24b-3)



General Procedure A3-A; yield 87.4% as a yellow oil; eluent (EA:Hexane = 1:50); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.27(s, 1H), 7.19(d, *J* = 8.1, 1H), 7.01(m, 2H), 6.41(m, 2H), 5.73(s, 1H), 2.17(m, 2H),

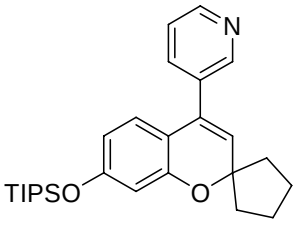
1.90(m, 2H), 1.67(m, 4H), 1.26(m, 3H), 1.11(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz); 157.2, 154.5, 140.4, 128.7, 127.1, 126.6, 126.0, 125.9, 124.5, 116.4, 112.4, 109.0, 86.9, 38.5, 23.5, 18.0, 12.7: MS (ESI+) Calcd for $C_{26}H_{37}O_2SSi$ $[M + H]^+$ 441.22. Found 441.16.

3-(2,2-dimethyl-7-(triisopropylsilyloxy)-2H-chromen-4-yl)pyridine(24a-4)



General Procedure A3-A; yield 89.2% as a light brown oil; eluent (EA:Hexane = 1:10); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.60(d, *J* = 1.7, 1H), 8.58(d, *J* = 1.5, 1H), 7.66(dt, *J* = 7.8, 1.7, 1H), 7.31(dd, *J* = 7.9, 4.9, 1H), 6.76(d, *J* = 8.4, 1H), 6.47(d, *J* = 2.4, 1H), 6.37(dd, *J* = 8.4, 2.4, 1H), 5.51(s, 1H), 1.49(s, 6H), 1.25(m, 3H), 1.10(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.5, 154.5, 149.6, 148.9, 136.0, 134.4, 131.8, 127.7, 125.6, 123.0, 115.5, 112.5, 108.9, 76.0, 27.4, 17.9, 12.7; MS (ESI+) Calcd for $C_{25}H_{36}NO_2Si$ $[M + H]^+$ 410.24. Found 410.20.

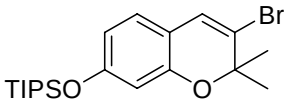
3-(2-spirocyclopentyl-7-(triisopropylsilyloxy)-2H-chromen-4-yl)pyridine(24b-4)



General Procedure A3-A; yield 88.3% as a brown oil; eluent (EA:Hexane = 1:10); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.60(m, 2H), 7.67(dt, *J* = 7.8, 1.7, 1H), 7.32(dd, *J* = 7.9, 4.9, 1H), 6.76(d, *J* = 8.4, 1H), 6.45(d, *J* = 2.4, 1H), 6.36(dd, *J* = 8.4, 2.4, 1H), 5.59(s, 1H), 2.19(m, 2H), 1.92(m, 2H), 1.71(m, 4H), 1.27(m, 3H), 1.10(d, *J* =7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.3, 154.5, 149.6, 148.9, 136.1, 134.4, 132.4, 126.9, 125.6, 123.1, 116.2, 112.5, 109.1, 87.0, 38.7, 23.5, 17.9, 12.6; MS (ESI+) Calcd for $C_{27}H_{38}NO_2Si$ $[M + H]^+$ 436.26. Found 436.31.

2. Pathway B

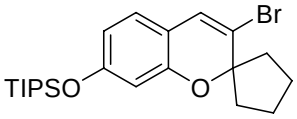
(3-bromo-2,2-dimethyl-2H-chromen-7-yloxy)triisopropylsilane(13a)



The mixture of **12a** (1.34 g, 4.94 mmol) and imidazole (0.505 g, 7.41 mmol) was stirred in anhydrous CH_2Cl_2 (30 ml) under N_2. Then, TIPSCl (1.239 g, 1.375 ml, 6.426 mmol) was added dropwise at 0℃ via syringe and the mixture was stirred for 3 h at room temperature. Deionized water (30 ml) was poured and the mixture was more stirred for 10 min. Then, the reaction mixture was extracted with EA and the combined organic layer was washed with aqueous NH_4Cl solution, saturated $NaHCO_3$ and brine. The organic layer was dried over $MgSO_4$ and filtered. Then, the filtrate was condensed under reduced pressure. The reduction and dehydration were directly carried out without further purification. To a solution of previous prepared compound in toluene (30 ml) at 0℃ under N_2 was slowly added dropwise DIBAL (5.93 ml, 1.0 M solution in toluene). the mixture was stirred for 15 min at 0℃ and then saturated sodium sulfate solution (20 ml) was slowly added at 0℃ in ice bath, and the resulting white precipitate is removed with filtration through Celite® and washed with excess ether. The combined ether was washed with brine and dried over $MgSO_4$ and filtered. Then, the filtrate was condensed under reduced pressure. After drying for 3 h under high vacuum, the resultant was dissolved with TsOH (85.1 mg) in toluene (30 ml). Then, the mixture was stirred for 8 h at 100℃. The solvent was evaporated under reduced pressure and the residue was dissolved with EA and washed with saturated $NaHCO_3$, brine. The organic layer was dried over $MgSO_4$, filtered. After condensation of the filtrate under reduced pressure, the resultant was purified with silica gel flash column chromatography (EA:Hex = 1:50) to give a product (1.53 g, 75.2 %) as

a colorless oil; ^{1}H NMR ($CDCl_3$, 300 MHz) 6.80(d, *J* = 8.1, 1H), 6.70(s, 1H), 6.43(dd, *J* = 8.2, 2.2, 1H), 6.39 (d, *J* = 1.8, 1 H), 1.55(s, 6H), 1.27(m, 3H), 1.12(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.3, 152.6, 126.1, 125.5, 122.0, 116.0, 113.2, 108.4, 79.9, 26.4, 17.9, 12.6; MS (APCI+) Calcd for $C_{20}H_{32}BrO_2Si$ $[M + H]^+$ 411.13. Found 410.97.

(3-bromo-2-spirocyclopentyl -2H-chromen-7-yloxy)triisopropylsilane(13b)

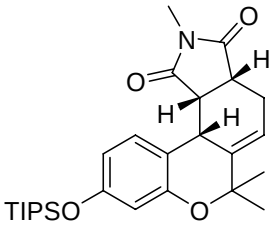


Compound **13b** was synthesized using a previously reported procedure of **13a**. Silica gel column chromatography (EA:Hexane=1:50) afforded a product(71.4%) as a colorless oil; ^{1}H NMR ($CDCl_3$, 300 MHz) 6.79(d, *J* = 8.2, 1H), 6.70(s, 1H), 6.42(dd, *J* = 8.1, 2.3, 1H), 6.36 (d, *J* = 8.2, 2.1, 1H), 2.09(m, 4H), 1.90(m, 2H), 1.73(m, 2H), 1.26(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.2, 152.6, 126.4, 126.0, 121.0, 116.6, 113.1, 108.6, 90.4, 37.2, 24.0, 17.9, 12.6; MS (APCI+) Calcd for $C_{22}H_{34}BrO_2Si$ $[M + H]^+$ 437.14. Found 437.28.

2-1. Pathway B1

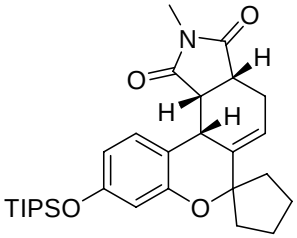
: Proceeded by the same reaction conditions that were optimized in pathway A1.

14a-1



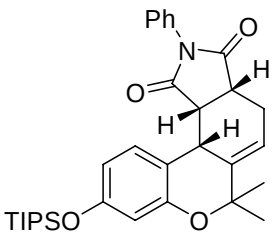
General Procedure A1-A; yield 86.5% as a yellow solid; eluent (EA:Hexane = 1:5); ^{1}H NMR ($CDCl_3$, 600 MHz) 7.15(d, *J* = 8.3, 1H), 6.59(dd, *J* = 8.3, 2.3, 1H), 6.46(d, *J* = 2.3, 1H), 5.82(m, 1H), 3.54(d, *J* = 6.2, 1H), 3.45(dd, *J* = 8.6, 6.5, 1H), 3.21(t, *J* = 7.7, 1H), 2.87(m, 1H), 2.83(s, 3H), 2.21(m, 1H), 1.35(s, 3H), 1.31(s, 3H), 1.26(m, 3H), 1.12(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 179.6, 176.2, 155.9, 154.7, 145.2, 127.9, 118.0, 115.7, 113.9, 109.9, 76.4, 44.7, 40.0, 34.4, 27.1, 26.6, 24.7, 24.5, 17.9, 12.7; MS (ESI+) Calcd for $C_{27}H_{40}NO_4Si$ $[M + H]^+$470.3 Found. 470.5

14b-1



General Procedure A1-A; yield 81.3% as a yellow syrup; eluent (EA:Hexane=1:5); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.16(d, *J* = 8.3, 1H), 6.59(dd, *J* = 8.3, 2.3, 1H), 6.45(d, *J* = 2.3, 1H), 5.84(m, 1H), 3.54(d, *J* = 5.9, 1H), 3.47(dd, *J* = 8.5, 6.3, 1H), 3.22(t, *J* = 7.5, 1H), 2.88(m, 1H), 2.83(s, 3H), 2.21(m, 1H), 1.83(m, 4H), 1.63(m, 4H), 1.25(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 179.6, 176.2, 155.7, 155.2, 143.3, 127.9, 117.3, 116.5, 114.0, 110.0, 87.7, 44.5, 40.1, 37.4, 36.4, 35.1, 24.8, 24.6, 23.4, 23.2, 17.9, 12.6; MS (APCI+) Calcd for $C_{29}H_{42}NO_4Si$ $[M + H]^+$496.28 Found 496.28.

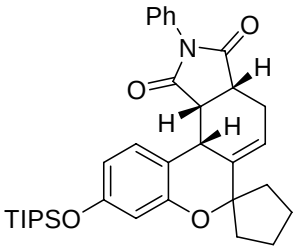
14a-2



General Procedure A1-A; yield 83.7% as a light yellow solid; eluent (EA:Hexane = 1:5); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.36(m, 3H), 7.15(m, 3H), 6.58(dd, *J* = 8.3, 2.5, 1H), 6.45(d, *J* = 2.4, 1H), 5.92(m, 1H), 3.60(m, 2H), 3.38(t, *J* = 6.9, 1H), 2.97(ddd, *J* = 13.5, 7.5, 1.5, 1H),

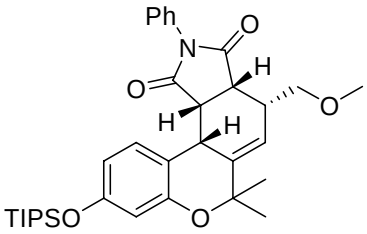
2.31(m, 1H), 1.84(m, 4H), 1.32(s, 1H), 1.23(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 178.4, 174.9, 155.9, 154.9, 145.5, 131.9, 128.9, 128.3, 127.9, 126.3, 118.2, 115.6, 113.9, 110.1, 76.5, 44.9, 40.3, 34.8, 27.2, 26.9, 24.8, 17.9, 12.6; MS (APCI+) Calcd for $C_{32}H_{42}NO_4Si$ $[M + H]^+$ 532.28 Found 532.17.

14b-2



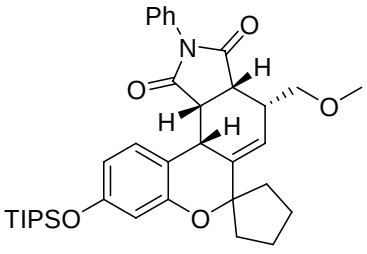
General Procedure A1-A; yield 80.3% as a orange solid; eluent (EA:Hexane = 1:5); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.37(m, 3H), 7.15(m, 3H), 6.58(dd, *J* = 8.3, 2.5, 1H), 6.43(d, *J* = 2.4, 1H), 5.95(m, 1H), 3.60(m, 2H), 3.40(t, *J* = 6.9, 1H), 2.97(ddd, *J* = 13.5, 7.5, 1.5, 1H), 2.25(m, 1H), 1.82(s, 4H), 1.67(m, 4H), 1.25(m, 3H), 1.08(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 178.5, 174.9, 155.8, 155.3, 143.7, 131.9, 128.9, 128.3, 128.0, 126.3, 117.5, 116.3, 114.0, 110.2, 87.9, 44.7, 40.3, 37.6, 36.7, 35.5, 24.9, 23.5, 23.3, 17.9, 12.6; MS (APCI+) Calcd for $C_{34}H_{44}NO_4Si$ $[M + H]^+$ 558.30 Found 558.21.

14a-3



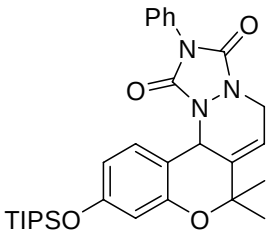
General Procedure A1-A; reaction at 60℃(Diels–Alder reaction); yield 81.2 % as a yellow solid; eluent (EA:Hexane = 1:4); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.32(m, 3H), 7.14(m, 3H), 6.59(dd, *J* = 8.3, 2.5, 1H), 6.45(d, *J* = 2.4, 1H), 5.77(s, 1H), 4.04(m, 1H), 3.87(t, *J* = 8.8, 1H), 3.64(br s, 1H), 3.55(m, 1H), 3.45(s, 4H), 2.70(br s, 1H), 1.45(s, 3H), 1.31(s, 3H), 1.20(m, 3H), 1.08(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 176.1, 174.2, 156.0, 154.9, 145.1, 131.8, 129.1, 128.9, 128.3, 128.1, 126.3, 121.1, 115.4, 114.0, 110.2, 72.7, 59.1, 45.6, 42.0, 37.4, 35.5, 27.1, 26.9, 17.9, 12.6; MS (APCI+) Calcd for $C_{34}H_{46}NO_5Si$ $[M + H]^+$ 576.31 Found 576.88.

14b-3



General Procedure A1-A; Reaction at 60℃ (Diels–Alder reaction); yield 77.8 % as a orange solid; eluent (EA:Hexane = 1:4); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.37(m, 3H), 7.17(d, *J* = 8.3, 1H), 7.11(d, *J* = 7.4, 2H), 6.58(dd, *J* = 8.3, 2.5, 1H), 6.44(d, *J* = 2.4, 1H), 5.79(t, *J* = 3.1, 1H), 4.05(dd, *J* = 9.2, 7.1, 1H), 3.87(t, *J* = 8.8, 1H), 3.66(br s, 1H), 3.57(m, 1H), 3.48(s, 4H), 2.70(br s, 1H), 1.86(m, 4H), 1.64(m, 2H), 1.56(m, 2H), 1.25(m, 3H), 1.08(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 176.1, 174.2, 155.9, 155.3, 143.3, 131.9, 128.9, 128.3, 128.2, 126.4, 120.3, 116.2, 114.0, 110.3, 88.0, 72.8, 59.1, 45.4, 42.1, 37.8, 37.4, 36.2, 26.8, 23.6, 23.3, 17.9, 12.6; MS (APCI+) Calcd for $C_{36}H_{48}NO_5Si$ $[M + H]^+$ 602.32 Found 602.17.

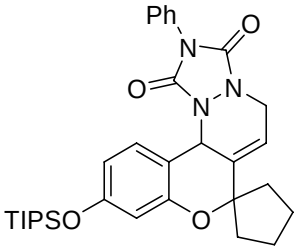
14a-4



General Procedure A1-A; yield 83.3% as a light yellow solid; eluent (EA:Hexane = 1:5); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.63(d, *J* = 7.8, 2H), 7.52(t, *J* = 7.4, 2H), 7.41(t, *J* = 7.4, 1H), 6.92(d, *J* = 8.4, 1H), 6.47(dd, *J* = 8.4, 2.3, 1H), 6.42(d, *J* = 2.2, 1H), 5.80(m, 1H), 5.69(s, 1H), 4.30(dd, *J* = 16.3, 4.4, 1H), 4.08(dt, *J* = 16.3, 2.3, 1H), 1.59(s, 3H), 1.57(s, 3H),

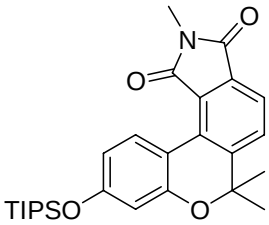
1.23(m, 3H), 1.08(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.1, 154.0, 153.8, 151.5, 137.8, 131.3, 129.2, 128.3, 125.5, 124.1, 116.3, 113.4, 112.5, 109.3, 78.9, 50.3, 44.2, 27.7, 26.9, 17.9, 12.6; MS (APCI+) Calcd for $C_{30}H_{40}N_3O_4Si$ $[M + H]^+$ 534.27 Found 534.95.

14b-4



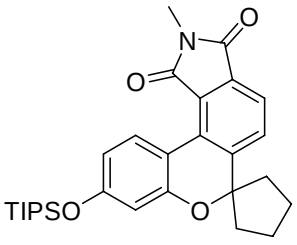
General procedure A1-A provide a desired product **19b-4** (82.9 %) as a light yellow; eluent (EA:Hexane = 1:5); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.62(d, *J* = 7.7, 2H), 7.52(t, *J* = 7.3, 2H), 7.41(t, *J* = 7.3, 1H), 7.07(d, *J* = 8.5, 1H), 6.44(dd, *J* = 8.5, 2.3, 1H), 6.36(d, *J* = 2.2, 1H), 5.90(m, 1H), 5.76(s, 1H), 4.32(dd, *J* = 16.4, 4.6, 1H), 4.07(dt, *J* = 16.4, 2.3, 1H), 2.22(m, 1H), 2.03(m, 4H), 1.80(m, 3H), 1.23(m, 3H), 1.08(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.2, 154.1, 154.0, 151.5, 134.6, 131.2, 129.2, 128.3, 125.5, 125.4, 115.5, 113.0, 108.9, 89.1, 50.9, 44.5, 37.5, 35.8, 23.2, 23.2, 17.9, 12.6; MS (APCI+) Calcd for $C_{32}H_{42}N_3O_4Si$ $[M + H]^+$ 560.29 Found 560.98.

16a-1



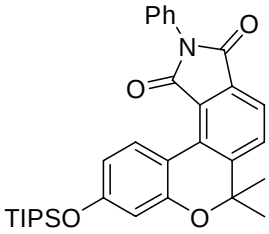
General Procedure A1-C; reaction at room temperature (Diels-Alder reaction); yield 94.7% as a grass-green solid; ^{1}H NMR ($CDCl_3$, 300 MHz); 8.49(d, *J* = 8.7, 1H), 7.64(d, *J* = 7.7, 1H), 7.47(d, *J* = 7.6, 1H), 6.60(dd, *J* = 8.8, 2.5, 1H), 6.41(d, *J* = 2.5, 1H), 3.12(s, 3H), 1.55(s, 6H), 1.23(m, 3H), 1.05(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 168.8, 168.0, 159.3, 155.4, 147.6, 133.4, 131.2, 130.4, 128.4, 124.9, 121.1, 113.8, 113.3, 109.4, 78.0, 27.0, 17.9, 12.7; MS (FAB+) Calcd for $C_{27}H_{36}NO_4Si$ $[M + H]^+$ 466 Found 466.

16b-1



General Procedure A1-C; reaction at room temperature (Diels-Alder reaction); yield 94.3% as a grass-green solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 8.52(d, *J* = 8.8, 1H), 7.70(d, *J* = 7.7, 1H), 7.54(d, *J* = 7.7, 1H), 6.66(dd, *J* = 8.8, 2.5, 1H), 6.51(d, *J* = 2.4, 1H), 3.19(s, 3H), 2.21(m, 2H), 1.89(m, 6H), 1.30(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 168.8, 168.0, 159.1, 155.7, 146.4, 133.3, 131.3, 131.2, 127.9, 127.7, 121.0, 116.2, 114.0, 113.8, 109.5, 89.1, 37.6, 23.6, 17.9, 12.7; MS (APCI+) Calcd for $C_{29}H_{38}NO_4Si$ $[M + H]^+$ 492.25 Found 492.19.

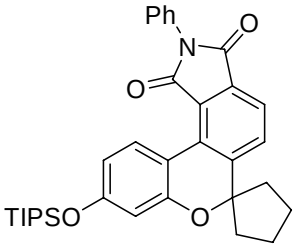
16a-2



General Procedure A1-C; reaction at room temperature (Diels-Alder reaction); yield 92.3% as a grass-green solid; ^{1}H NMR ($CDCl_3$, 300 MHz); 8.56(d, *J* = 8.8, 1H), 7.83(d, *J* = 7.7, 1H), 7.62(d, *J* = 7.7, 1H), 7.49(m, 5H), 6.63(dd, *J* = 8.8, 2.4, 1H), 6.54(d, *J* = 2.4, 1H), 1.65(s, 6H), 1.27(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 167.8, 166.8, 159.5, 155.5, 148.2, 132.9, 131.8, 131.4, 131.0, 129.1, 128.9, 128.2,

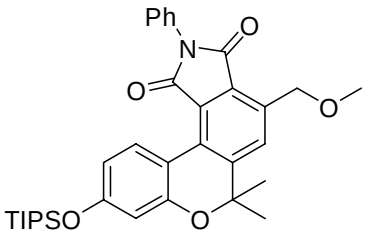
127.0, 124.3, 121.7, 113.8, 113.2, 109.4, 78.1, 27.1, 17.9, 12.7; MS (FAB+) Calcd for $C_{32}H_{38}NO_4Si$ $[M + H]^+$ 528 Found 528.

16b-2



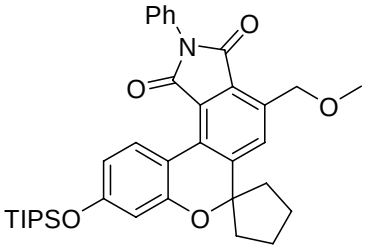
General Procedure A1-C; reaction at room temperature (Diels-Alder reaction); yield 92.8% as a grass-green solid; ^{1}H NMR ($CDCl_3$, 300 MHz); 8.53(d, *J* = 8.7, 1H), 7.81(d, *J* = 7.5, 1H), 7.62(d, *J* = 7.5, 1H), 7.48(m, 5H), 6.63(dd, *J* = 8.5, 2.3, 1H), 6.53(d, *J* = 2.3, 1H), 2.24(m, 2H), 1.92(m, 6H), 1.26(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz); 167.7, 166.8, 159.3, 155.8, 147.0, 132.8, 131.8, 131.5, 129.1, 128.4, 128.2, 127.0, 124.3, 121.6, 113.9, 109.5, 89.2, 37.6, 23.7, 17.9, 12.7; MS (APCI+) Calcd for $C_{34}H_{40}NO_4Si$ $[M + H]^+$ 554.26 Found 554.19.

16a-3



General Procedure A1-C; reaction at 60 ℃(Diels-Alder reaction); yield 87.3% as a grass-green solid; ^{1}H NMR ($CDCl_3$, 300 MHz); 8.48(d, *J* = 8.8, 1H), 7.77(s, 1H), 7.42(m, 5H), 6.61(dd, *J* = 8.8, 2.4, 1H), 6.54(d, *J* = 2.4, 1H), 5.03(s, 2H), 3.55(s, 3H), 1.65(s, 6H), 1.27(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 167.6, 167.0, 159.3, 155.5, 148.5, 136.8, 131.7, 131.3, 129.8, 129.1, 128.2, 128.0, 127.6, 127.0, 124.5, 113.7, 113.1, 109.4, 78.2, 69.6, 59.0, 27.1, 17.9, 12.7; MS (APCI+) Calcd for $C_{34}H_{42}NO_5Si$ $[M + H]^+$ 572.28 Found 572.24.

16b-3

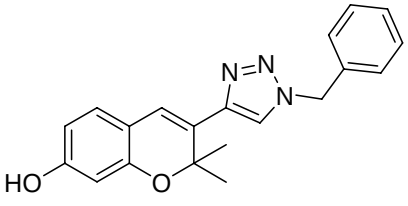


General Procedure A1-C; reaction at 60 ℃(Diels-Alder reaction); yield 86.3% as a grass-green solid; ^{1}H NMR ($CDCl_3$, 300 MHz); 8.45(d, *J* = 8.8, 1H), 7.78(s, 1H), 7.45(m, 5H), 6.61(dd, *J* = 8.7, 2.1, 1H), 6.52(d, *J* = 2.0, 1H), 5.03(s, 2H), 3.56(s, 3H), 2.24(m, 2H), 1.94(m, 6H), 1.28(m, 3H), 1.11(d, *J* = 7.1, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 167.6, 167.1, 159.1, 155.7, 147.2, 136.7, 131.7, 131.3, 130.7, 129.1, 128.2, 128.0, 127.0, 126.8, 124.5, 113.8, 109.5, 89.3, 69.6, 59.0, 37.6, 23.7, 17.9, 12.7; MS (APCI+) Calcd for C36H44NO5Si $[M + H]^+$ 598.29 Found 598.17.

2-2. Pathway B2

: Proceeded by the same reaction conditions that were optimized in pathway A2.

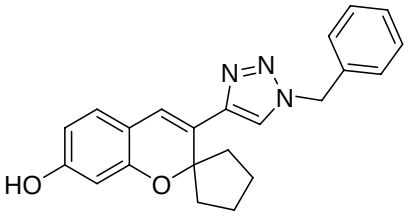
1-benzyl-4-(2,2-dimethyl-7-(triisopropylsilyloxy)-2H-chromen-3-yl)-1H-1,2,3-triazole(23a-1)



General procedure A2-A for Click chemistry gave a product

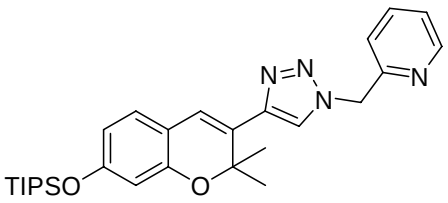
22a-1 (78.3 %) as a yellow oil. After then, Deprotection was directly proceed. To a solution of **22a-1**(100 mg, 0.204 mmol) in THF (3 ml) was added dropwise tetrabutylammonium fluoride (0.270 ml, 0.265 mmol, 1.0 M solution in THF). Then, the mixture was stirred for 10 min at room temperature. The solvent was evaporated under reduced pressure and the residue was dissolved with EA and washed with H_2O. The organic layer was dried over anhydrous $MgSO_4$ and filtered. After condensation of the filtrate under reduced pressure, the resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:1) to give a product (65.4 mg, 96.1 %) as a yellow solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.43(s, 1H), 7.40(m, 3H), 7.30(m, 2H), 6.86 (d, *J* = 8.8, 1H), 6.58(s, 1H), 6.34(m, 2H), 5.53(s, 2H), 1.65(s, 6H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.1, 154.0, 146.5, 134.6, 129.2, 128.8, 128.1, 127.8, 127.5, 121.9, 120.4, 115.2, 108.1, 103.7, 78.8, 54.2, 27.1; MS (ESI+) Calcd for $C_{20}H_{20}N_3O_2$ $[M + H]^+$ 334.15. Found 334.42

1-benzyl-4-(2-spiropentyl-7-(triisopropylsilyloxy)-2H-chromen-3-yl)-1H-1,2,3-triazole(23b-1)



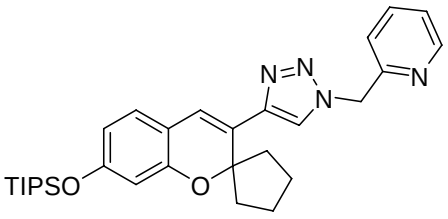
General procedure A2-A for Click chemistry gave a product **22b-1** (75.3%) as a yellow oil. Compound **23b-1** was synthesized using a previously reported deprotection procedure of **23a-1**. Silica gel column chromatography (EA:Hexane = 1:1) afforded a product (97.3 %) as a yellow solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.39(d, *J* = 9.2, 3H), 7.29(m, 2H), 6.84(d, *J* = 7.9, 1H), 6.63 (s, 1H), 6.36(d, *J* = 2.2, 1H), 6.33(s, 1H), 5.52(s, 2H), 2.14(m, 4H), 1.90(m, 2H), 1.76(m, 2H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.2, 153.8, 146.6, 134.5, 129.2, 128.8, 128.1, 127.5, 125.8, 123.4, 120.3, 115.7, 108.2, 103.9, 89.5, 54.2, 37.2, 23.9; MS (ESI+) Calcd for $C_{22}H_{22}N_3O_2$ $[M + H]^+$ 360.16. Found 360.30

2-((4-(2,2-dimethyl-7-(triisopropylsilyloxy)-2H-chromen-3-yl)-1H-1,2,3-triazol-1-yl)methyl)pyridine(22a-2)



General Procedure A2-A; yield 76.2% as a brown oil; eluent (EA:Hexane = 1:2); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.62(d, *J* = 4.8, 1H), 7.72(m, 2H), 7.28(m, 2H), 6.87(d, *J* = 8.8, 1H), 6.64 (s, 1H), 6.41(m, 2H), 5.66(s, 2H), 1.66(s, 6H), 1.25(m, 3 H), 1.11(d, *J* = 7.0, 18 H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.5, 154.4, 153.6, 149.8, 146.5, 137.4, 127.9, 127.1, 123.5, 122.5, 122.1, 121.0, 115.2, 112.9, 108.2, 78.6, 55.6, 26.9, 17.9, 12.6; MS (ESI+) Calcd for $C_{28}H_{39}N_4O_2Si$ $[M + H]^+$ 491.28. Found 491.32

2-((4-(2-spiropentyl-7-(triisopropylsilyloxy)-2H-chromen-3-yl)-1H-1,2,3-triazol-1-yl)methyl)pyridine(22b-2)



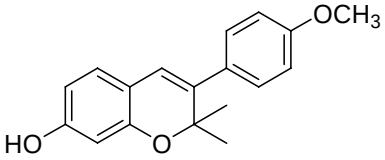
General Procedure A2-A; yield 73.2% as a brown oil; eluent (EA:Hexane = 1:2); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.62(d, *J* = 4.4, 1H), 7.71(m, 2H), 7.24(m, 2H), 6.87(d, *J* = 8.0, 1H), 6.71 (s, 1H), 6.40(m, 2H), 5.66(s, 2H), 2.17(m, 4H), 1.94(m, 2H), 1.79(m, 2H), 1.26(m, 3H), 1.10(d, *J* = 7.0, 18 H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.4, 154.4, 153.5, 149.8, 146.7, 137.4, 127.0, 126.2, 123.5, 123.4,

122.5, 120.9, 116.2, 112.9, 108.4, 89.4, 55.6, 37.1, 23.9, 17.9, 12.6; MS (ESI+) Calcd for $C_{30}H_{41}N_4O_2Si$ $[M + H]^+$ 517.29. Found 517.55

2-3. Pathway B3

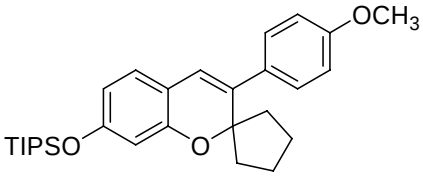
: Proceeded by the same reaction conditions that were optimized in pathway A3.

3-(4-methoxyphenyl)-2,2-dimethyl-2H-chromen-7-ol(27a-1)



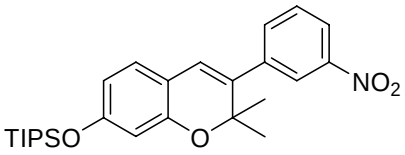
General procedure A3-A for Suzuki coupling reaction gave a product **26a-1** (98.1 %) as a white solid. After then, Deprotection was directly proceed. To a solution of **26a-1** (100 mg, 0.228 mmol) in THF(3 ml) was added dropwise tetrabutylammonium fluoride(0.251 mmol, 1.0 M solution in THF). Then, the mixture was stirred for 10 min at 0℃. The solvent was evaporated under reduced pressure and the residue was dissolved with EA and washed with H_2O. The organic layer was dried over anhydrous $MgSO_4$ and filtered. After condensation of the filtrate under reduced pressure, the resultant was purified with silica gel flash column chromatography (EA:Hexane = 1:10) to give a product (62.8 mg, 97.6 %) as a brown solid; ^{1}H NMR ($CDCl_3$, 300 MHz) 7.22(d, *J* = 8.7, 2H), 6.88(m, 3H), 6.37(m, 2H), 6.19(s, 1H), 4.84(br s, 1H), 3.82(s, 3H), 1.50(s, 2H); ^{13}C NMR ($CDCl_3$, 300 MHz) 158.9, 156.4, 153.7, 138.9, 132.2, 129.3, 127.2, 121.4, 116.6, 113.5, 108.0, 103.7, 79.1, 55.3, 27.0; MS (APCI+) Calcd for $C_{18}H_{19}O_3$ $[M + H]^+$ 283.13. Found 283.09.

3-(4-methoxyphenyl)-2-spirocyclopentyl -2H-chromen-7-ol(26b-1)



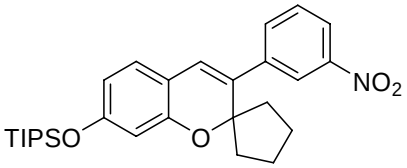
General procedure A3-A for Suzuki coupling reaction gave a product **26b-1** (64.3 %) as a yellow oil: ^{1}H NMR ($CDCl_3$, 300 MHz) 7.23(d, *J* = 8.7, 2H), 6.89(m, 3H), 6.46(m, 2H), 6.33(s, 1H), 3.84(s, 3H), 2.18(m, 2H), 1.91(m, 4H), 1.67(m, 2H), 1.28(m, 3H), 1.12(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 158.8, 156.7, 153.3, 137.2, 132.2, 129.3, 126.7, 122.8, 117.6, 113.5, 112.9, 108.6, 89.9, 55.3, 36.4, 23.5, 18.0, 12.7; MS (ESI+) Calcd for $C_{29}H_{41}O_3Si$ $[M + H]^+$ 465.27. Found 465.09

(2,2-dimethyl-3-(3-nitrophenyl)-2H-chromen-7-yloxy)triisopropylsilane(26a-2)



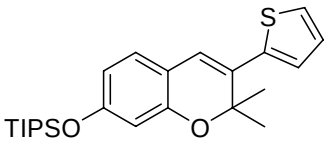
General Procedure A3-A; yield 96.2% as a yellow solid; eluent (EA:Hexane = 1:50); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.15(dt, *J* = 8.3, 1.1, 2H), 7.63(dt, *J* = 6.1, 1.1, 1H), 7.53(td, *J* = 7.7, 0.8, 1H), 6.93(d, *J* = 7.7, 1H), 6.48(d, *J* = 2.3, 1H), 6.44(s, 1H), 6.38(s, 1H), 1.54(s, 6H), 1.25(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.8, 153.7, 148.1, 141.3, 136.6, 134.2, 129.1, 127.4, 124.2, 123.0, 122.1, 116.1, 113.3, 108.4, 78.3, 26.9, 17.9, 12.7; MS (ESI+) Calcd for $C_{26}H_{36}NO_4Si$ $[M + H]^+$ 454.23. Found 454.06

(2-spirocyclopentyl-3-(3-nitrophenyl)-2H-chromen-7-yloxy)triisopropylsilane(26b-2)



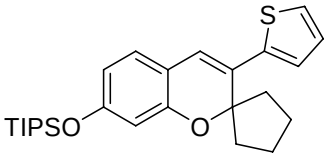
General Procedure A3-A; yield 63.1% as a yellow oil; eluent (EA:Hexane = 1:50); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.14(dt, *J* = 8.3, 1.1, 2H), 7.61(dt, *J* = 6.1, 1.1, 1H), 7.50(td, *J* = 7.7, 0.8, 1H), 6.93(d, *J* = 7.7, 1H), 6.47(d, *J* = 2.3, 1H), 6.43(s, 2H), 2.23(m, 2H), 1.95(m, 2H), 1.72(m, 4H), 1.27(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.6, 153.6, 148.1, 141.3, 134.8, 134.1, 129.1, 127.3, 125.3, 122.9, 122.0, 116.8, 113.3, 108.7, 89.3, 36.5, 23.4, 17.9, 12.7; MS (APCI+) Calcd for $C_{28}H_{38}NO_4Si$ $[M + H]^+$ 480.25. Found 480.05.

(2,2-dimethyl-3-(thiophen-2-yl)-2H-chromen-7-yloxy)triisopropylsilane(26a-3)



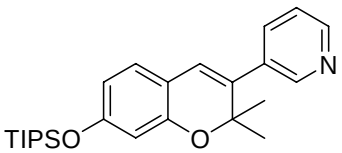
General Procedure A3-A; yield 86.4% as a dark brown; eluent (EA:Hexane = 1:50); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.22(m, 1H), 7.02(d, *J* = 2.0, 1H), 7.01(s, 1H), 6.91(d, *J* = 7.5, 1H), 6.53(s, 1H), 6.46(d, *J* = 2.3, 1H), 6.43(s, 2H), 1.62(s, 6H), 1.28(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.4, 153.3, 141.5, 132.0, 127.1, 125.0, 124.2, 122.9, 116.0, 113.1, 108.2, 78.8, 26.9, 17.9, 12.7; MS (ESI+) Calcd for $C_{24}H_{35}O_2SSi$ $[M + H]^+$ 415.20. Found 415.02

(2-spirocyclopentyl-3-(thiophen-2-yl)-2H-chromen-7-yloxy)triisopropylsilane(26b-3)



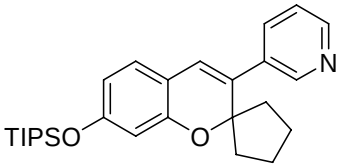
General Procedure A3-A; yield 59.1% as a black oil; eluent (EA:Hexane = 1:50); ^{1}H NMR ($CDCl_3$, 300 MHz) 7.19(m, 1H), 6.99(t, *J* = 5.0, 3.6, 1H), 6.94(d, *J* = 2.9, 1H), 6.87(d, *J* = 8.1, 1H), 6.55(s, 1H), 6.41(dd, *J* = 8.1, 2.3, 1H), 6.38(d, *J* = 1.9, 1H), 2.16(m, 2H), 2.03(m, 4H), 1.72(br s, 2H), 1.26(m, 3H), 1.10(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.3, 153.2, 141.7, 130.4, 127.1, 127.0, 124.6, 124.1, 124.0, 116.7, 113.1, 108.5, 89.8, 36.9, 24.1, 17.9, 12.7; MS (APCI+) Calcd for $C_{26}H_{37}O_2SSi$ $[M + H]^+$ 441.22. Found 441.13.

3-(2,2-dimethyl-7-(triisopropylsilyloxy)-2H-chromen-3-yl)pyridine(26a-4)



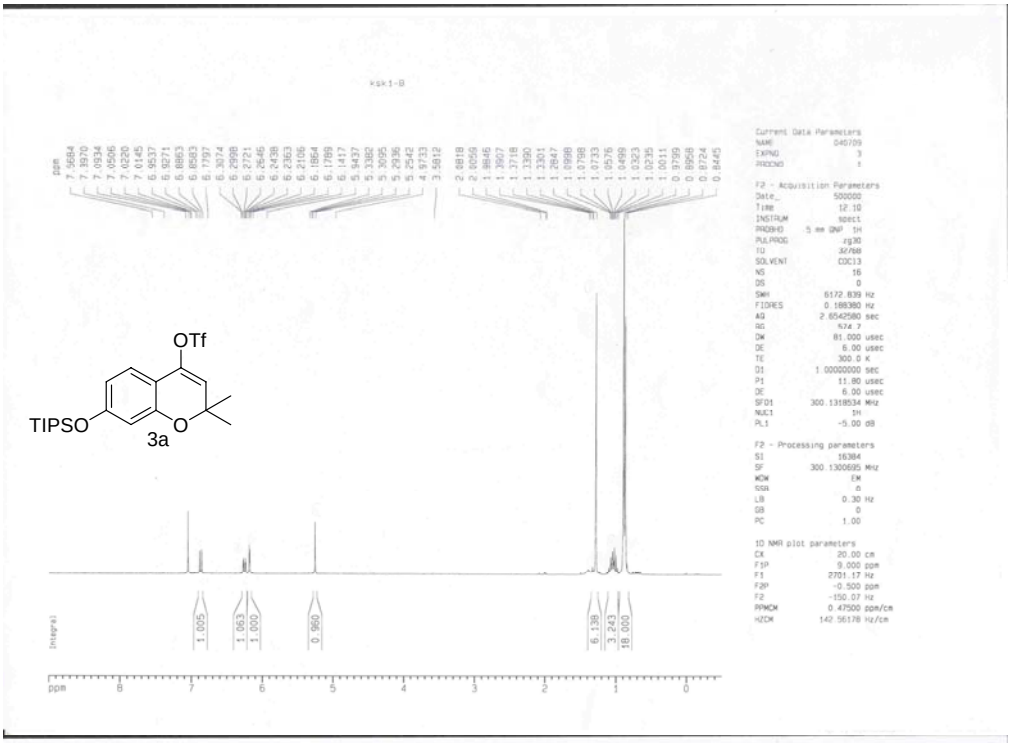
General Procedure A3-A; yield 83.1% as a white solid; eluent (EA:Hexane = 1:10; ^{1}H NMR ($CDCl_3$, 300 MHz) 8.60(d, *J* = 0.6, 1H), 8.56(dd, *J* = 4.4, 1.6, 1H), 7.62(dt, *J* = 6.1, 1.9, 1H), 7.30(d, *J* = 7.2, 1H), 6.93(dd, *J* = 7.9, 1.3, 1H), 6.49(d, *J* = 2.4, 1H), 6.45(s, 1H), 6.3(s, 1H), 1.53(s, 6H), 1.28(m, 3H), 1.12(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.6, 153.6, 149.0, 148.5, 135.5, 135.4, 127.3, 123.7, 122.9, 116.2, 113.2, 108.4, 26.9, 17.9, 12.7; MS (ESI+) Calcd for $C_{25}H_{36}NO_2Si$ $[M + H]^+$ 410.24. Found 410.17

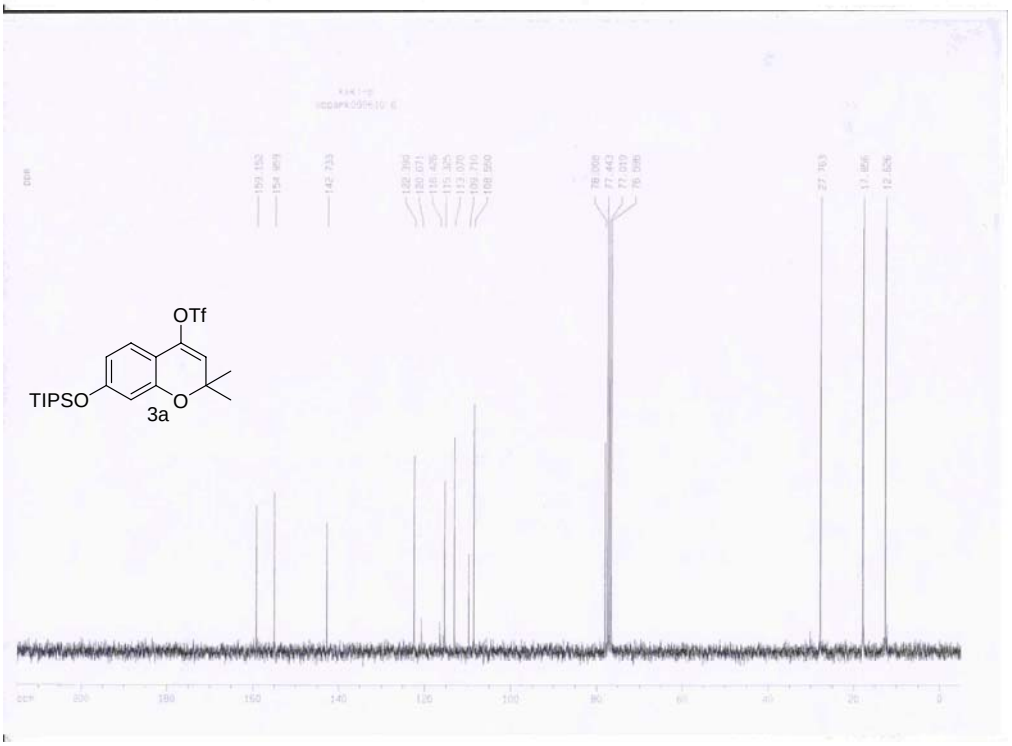
3-(2-spirocyclopentyl-7-(triisopropylsilyloxy)-2H-chromen-3-yl)pyridine(26b-4)

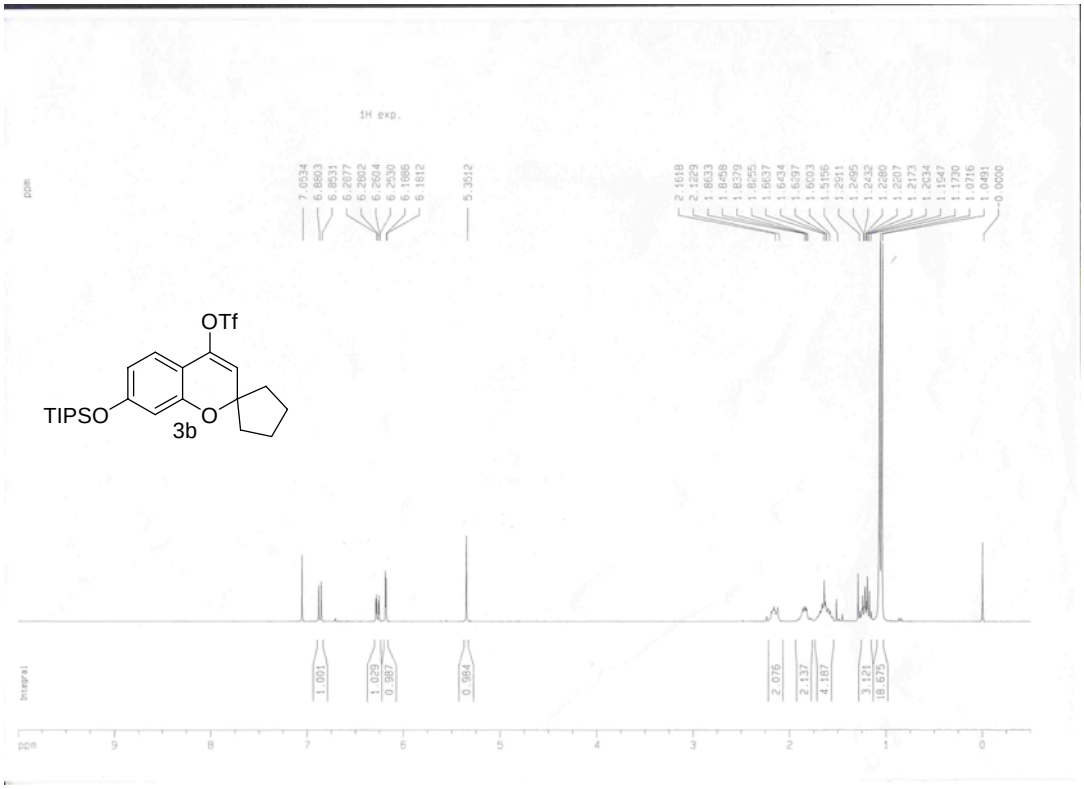


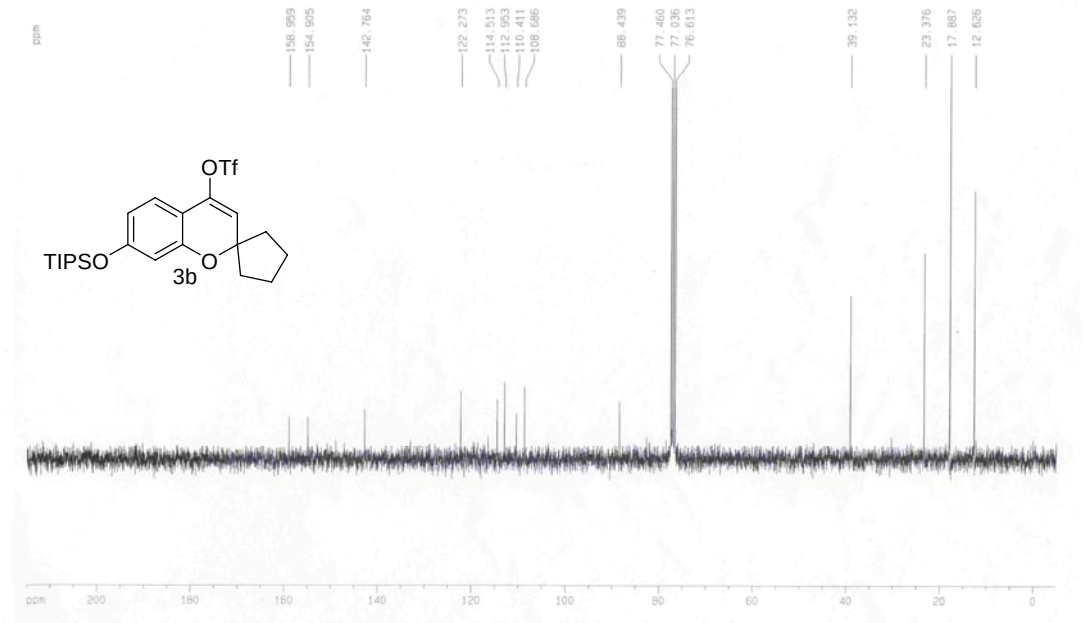
General Procedure A3-A; yield 58.3% as a light brown oil; eluent (EA:Hexane = 1:10); ^{1}H NMR ($CDCl_3$, 300 MHz) 8.56(m, 2H), 7.58(d, *J* = 6.1, 1H), 7.26(dd, *J* = 7.6, 5.1, 1H), 6.93(d, *J* = 8.0, 1H), 6.45(dd, *J* = 8.3, 2.4, 1H), 6.43(s, 1H), 6.38(s, 1H), 2.20(m, 2H), 1.92(m, 2H), 1.71(m, 4H), 1.27(m, 3H), 1.11(d, *J* = 7.0, 18H); ^{13}C NMR ($CDCl_3$, 300 MHz) 157.4, 153.5, 148.9, 148.3, 135.5, 135.4, 133.7, 127.2, 124.9, 122.9, 116.9, 113.2, 108.6, 89.4, 36.4, 23.3, 17.9, 12.7; MS (APCI+) Calcd for $C_{27}H_{38}NO_2Si$ $[M + H]^+$ 436.26. Found 436.22.

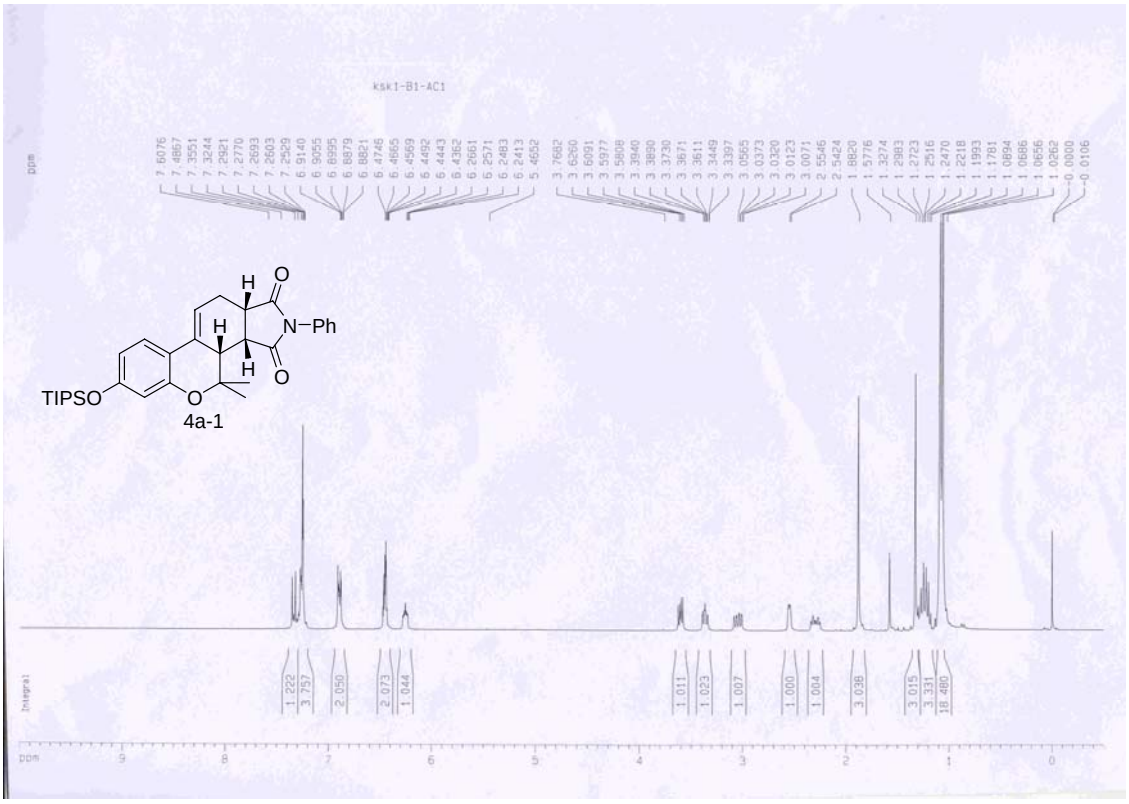
Ⅳ. Spectrum

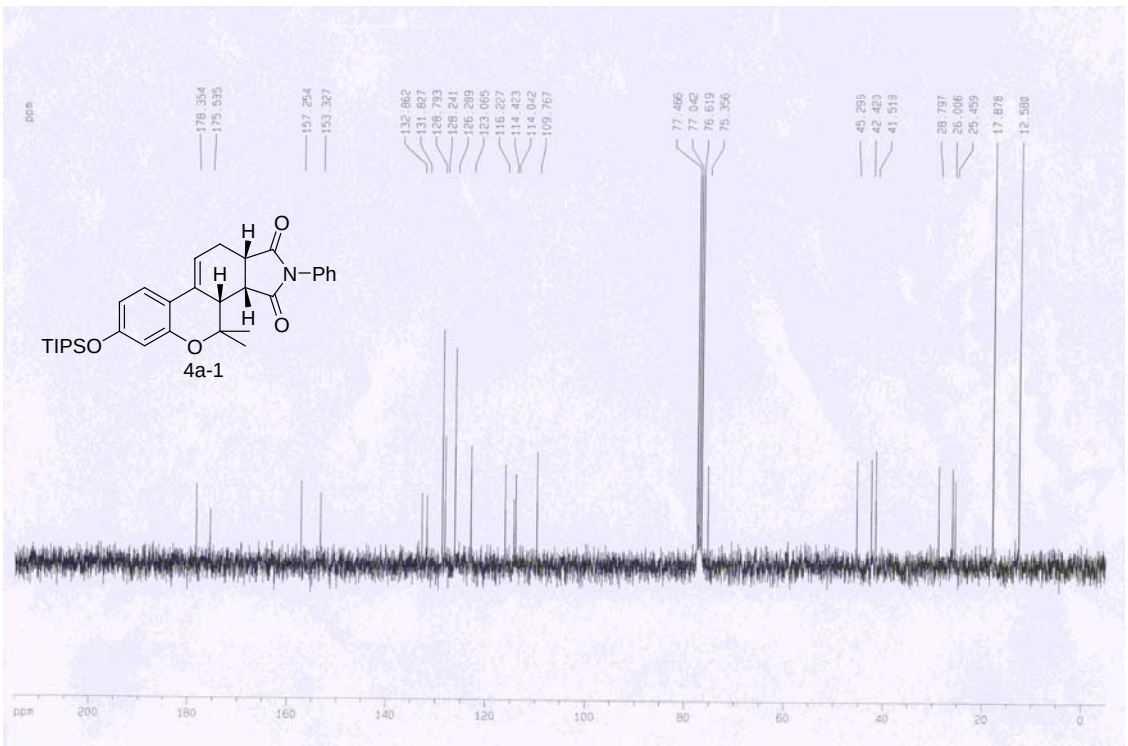

OTf
TIPSO
O
3a

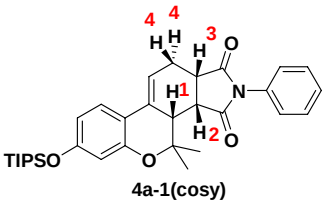

OTf
TIPSO
O
3a


1H exp.
OTf
TIPSO
O
3b

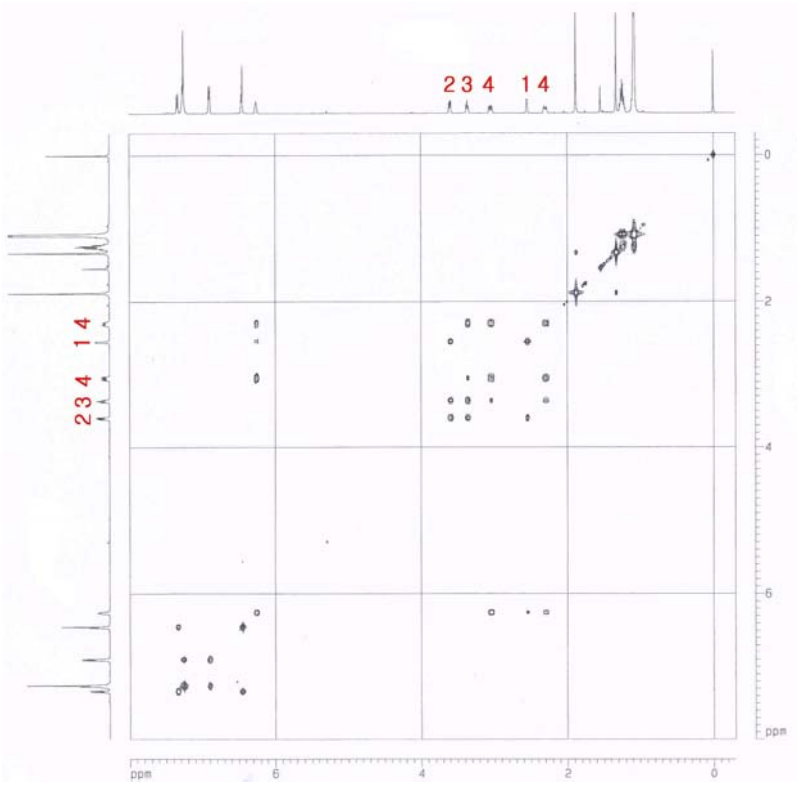

OTf
TIPSO
O
3b

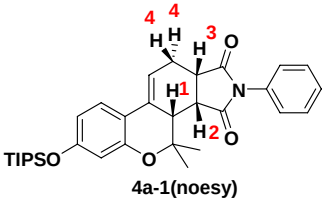

ksk1-B1-AC1
TIPSO
O
H
H
H
O
N−Ph
O
4a-1


TIPSO
O
H
H
H
O
N−Ph
O
4a-1

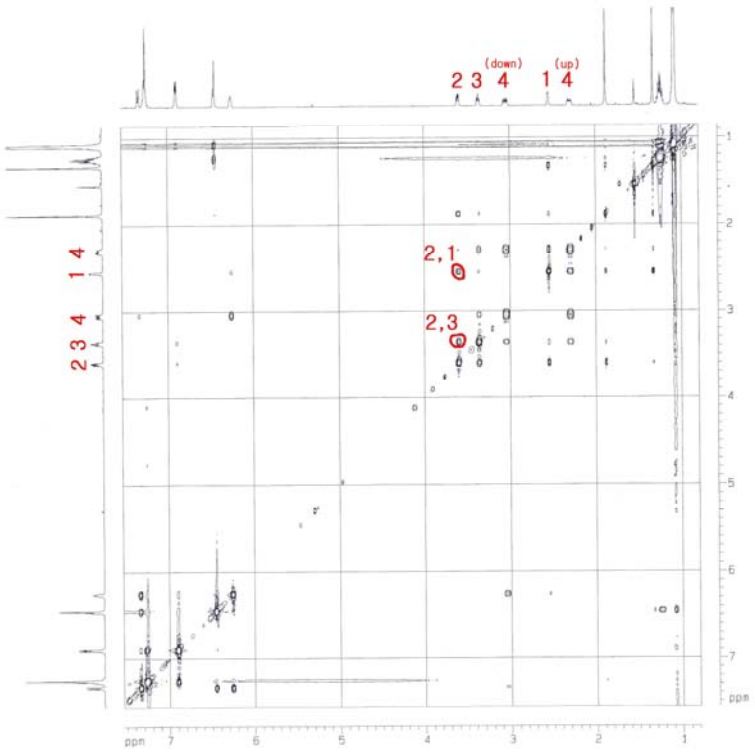


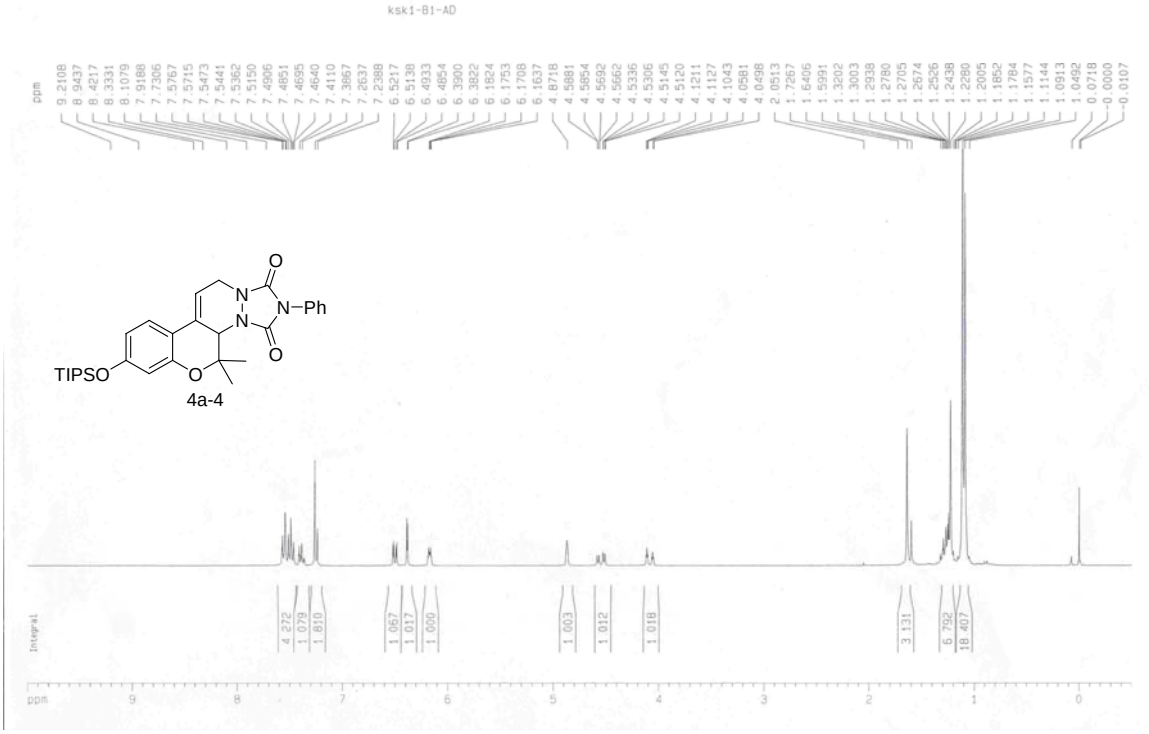
4a-1(cosy)

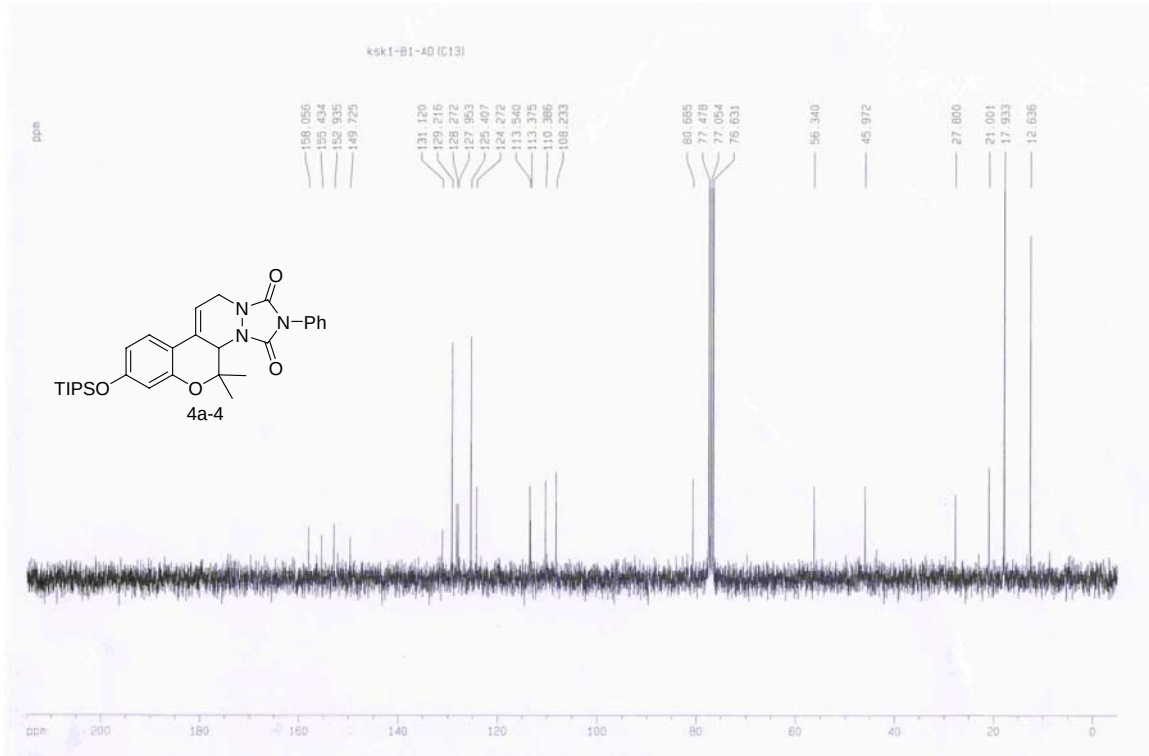


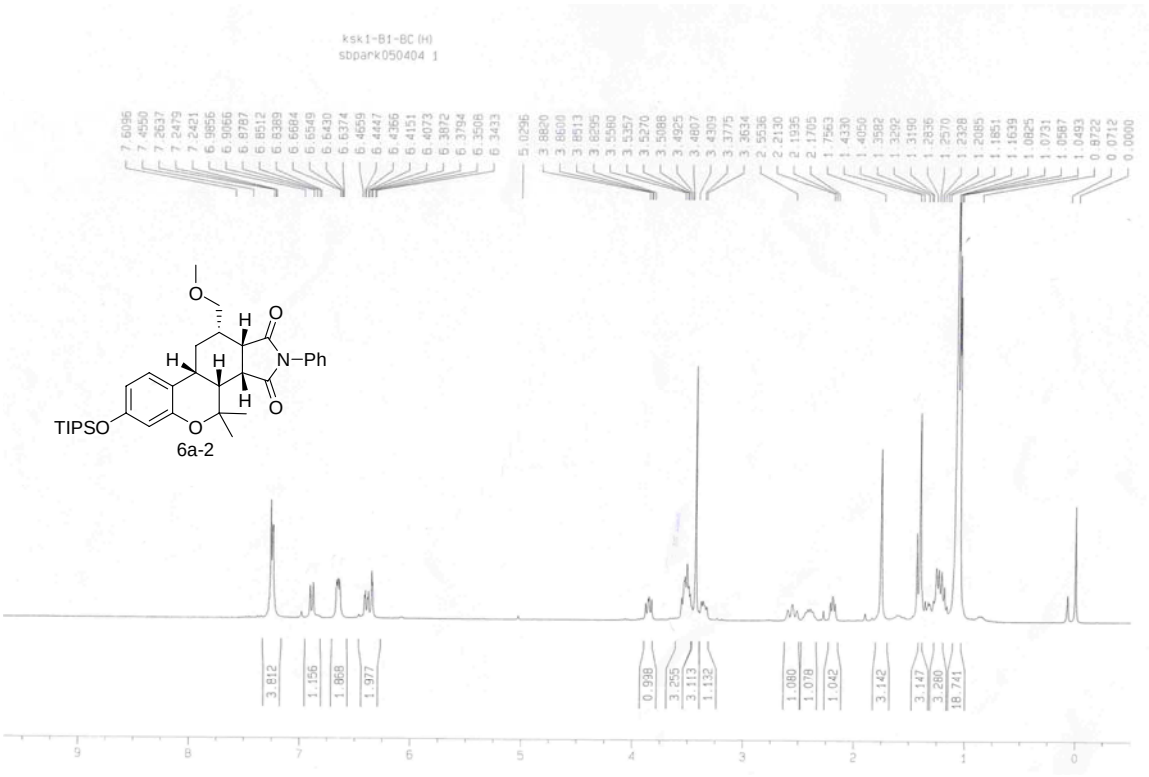


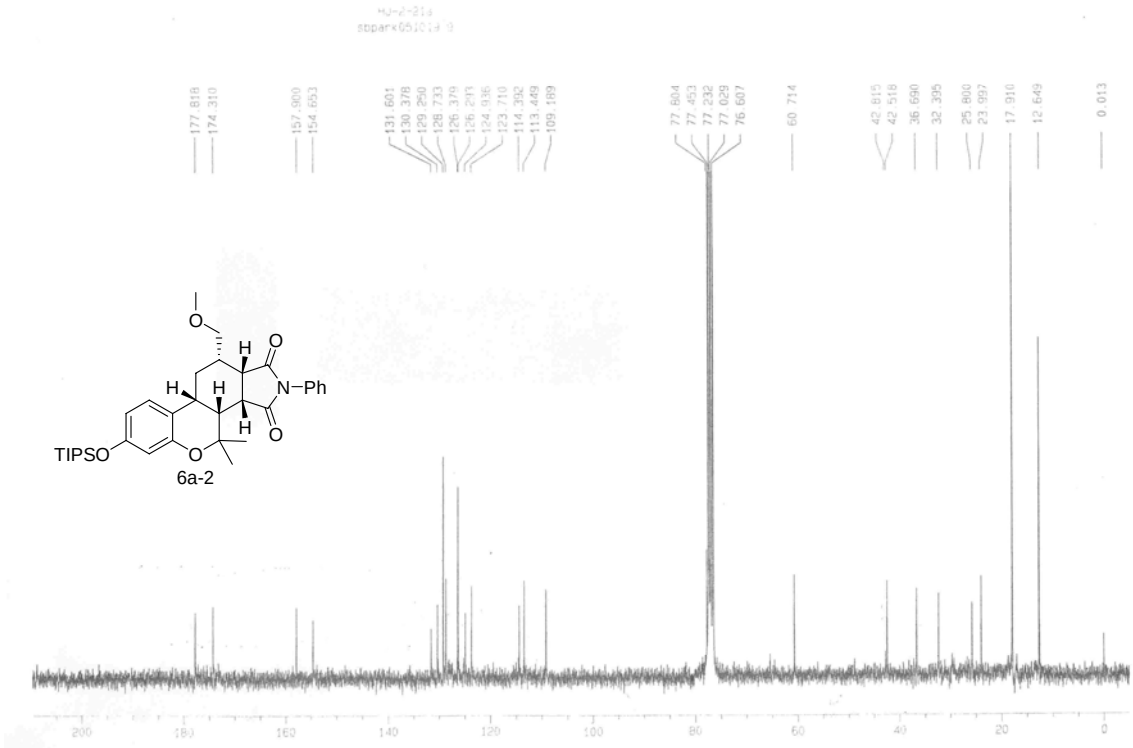
4a-1(noesy)

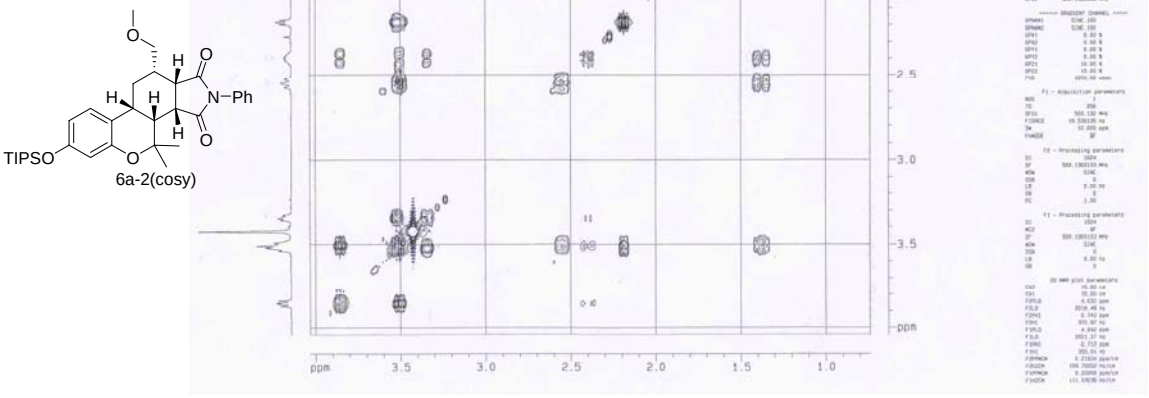



ksk1-B1-AD
TIPSO
N–Ph
4a-4

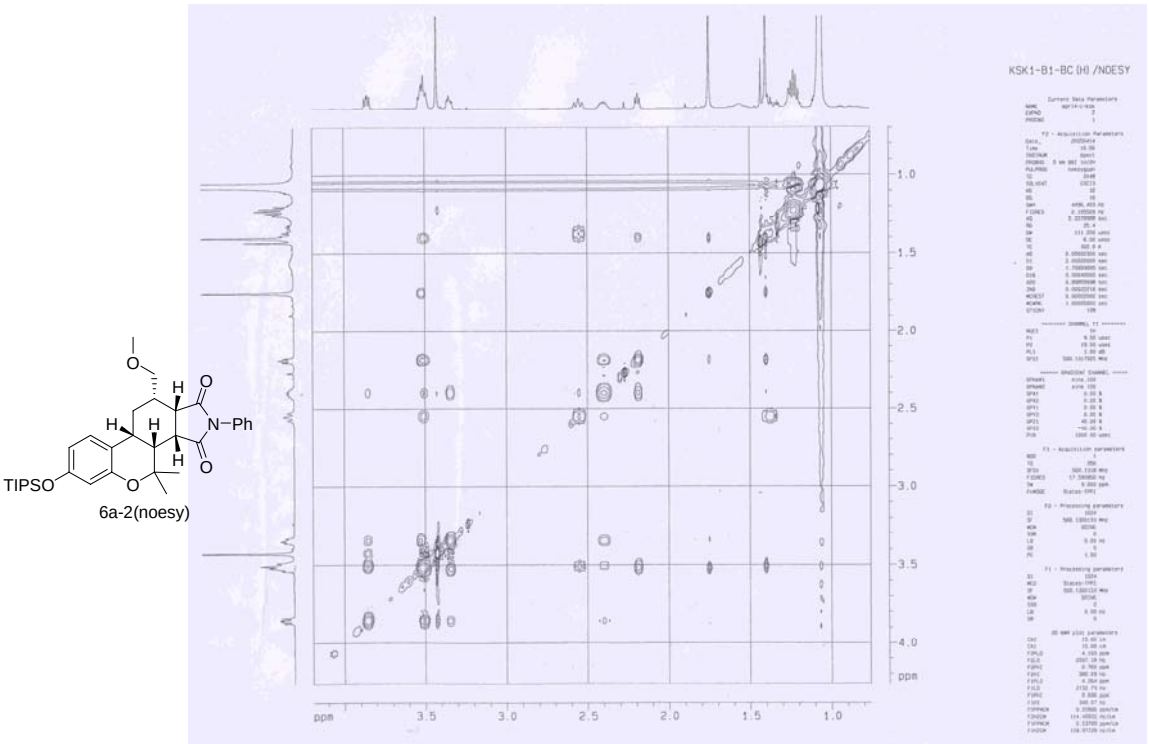

ksk1-B1-AD (C13)
TIPSO
N–Ph
4a-4


ksk1-B1-BC(H)
sbpark050404 1
TIPSO
N–Ph
6a-2

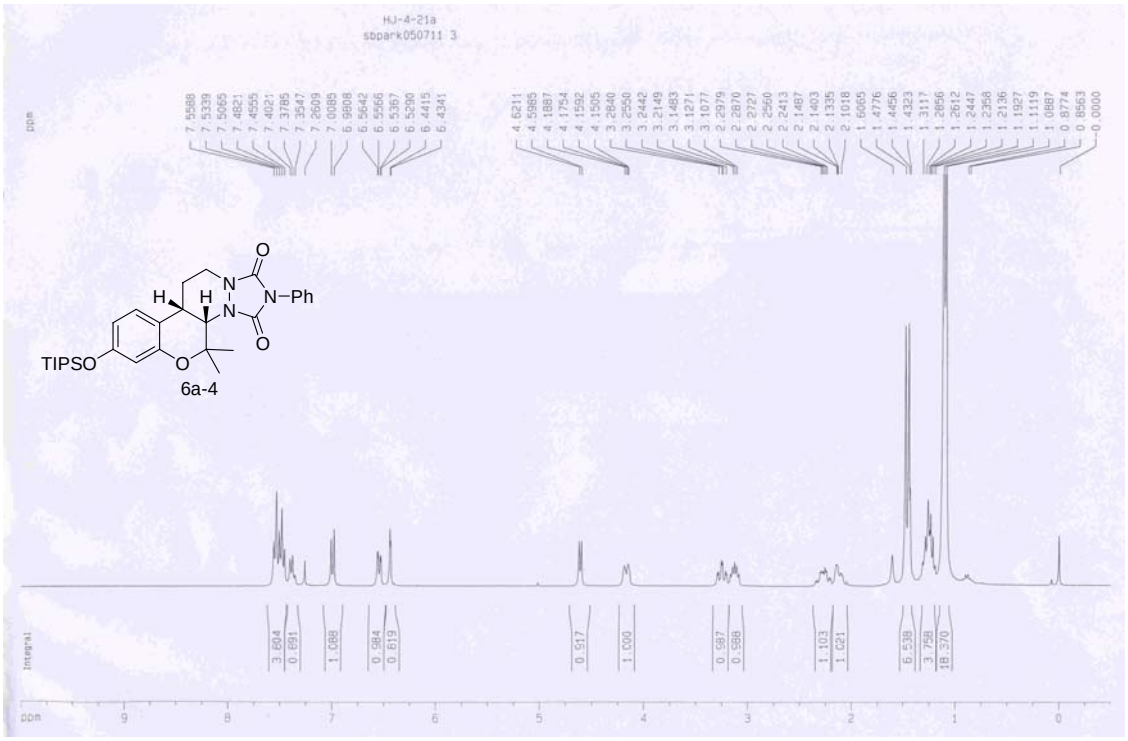

TIPSO
N–Ph
6a-2

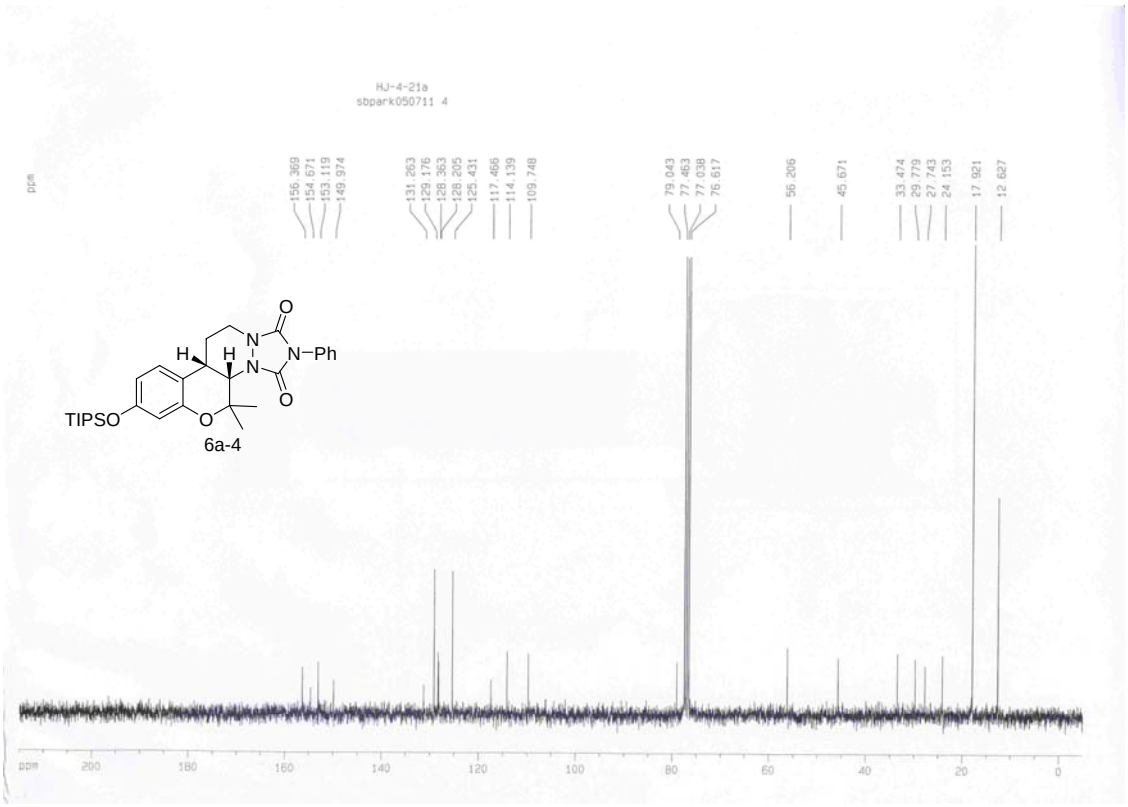


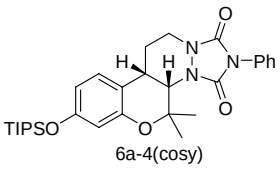
6a-2(cosy)



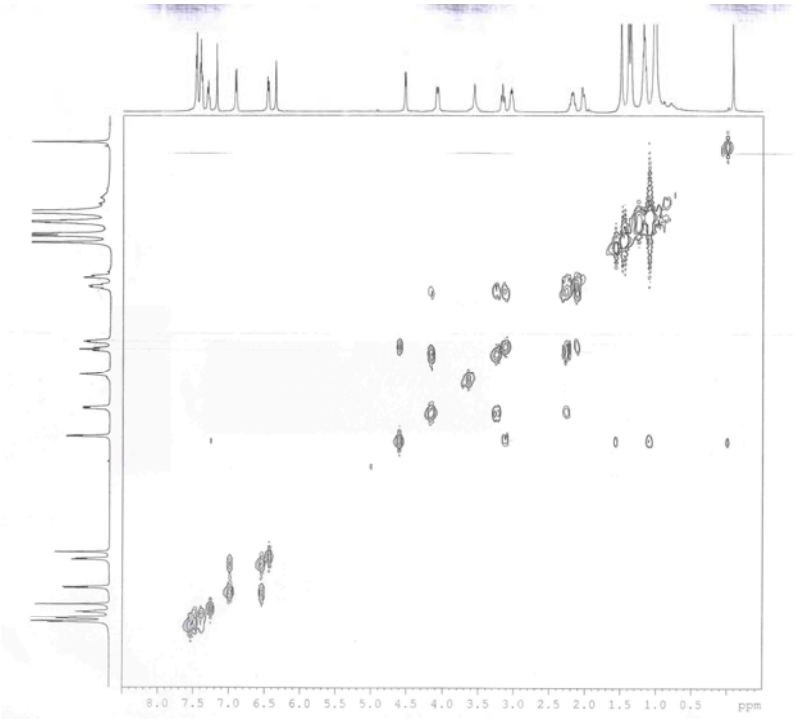
6a-2(noesy)

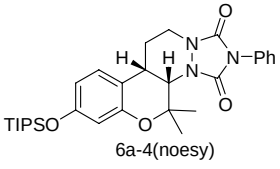

HJ-4-21a
sbpark050711 3
TIPSO
6a-4


HJ-4-21a
sbpark050711 4
TIPSO
6a-4

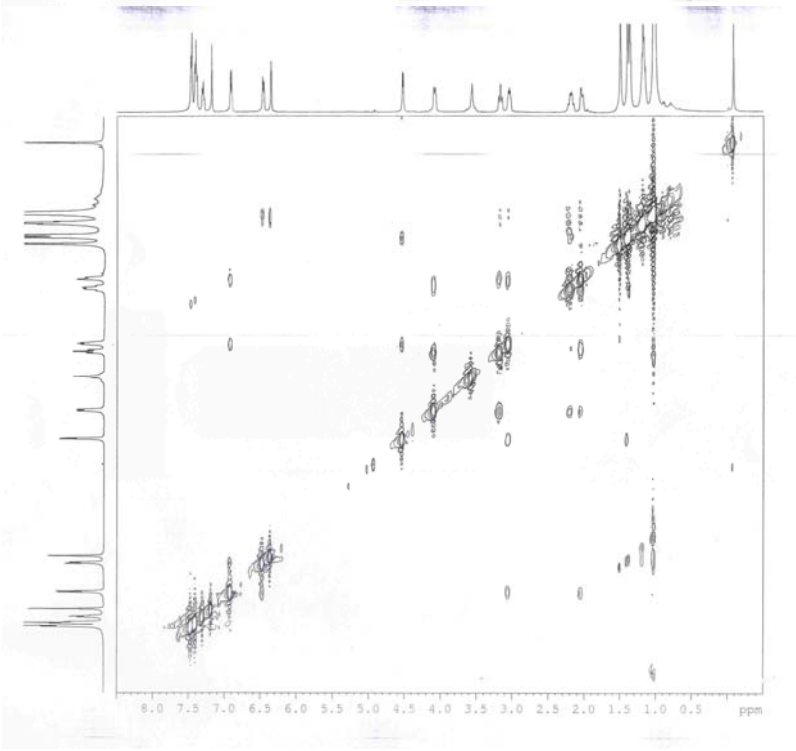


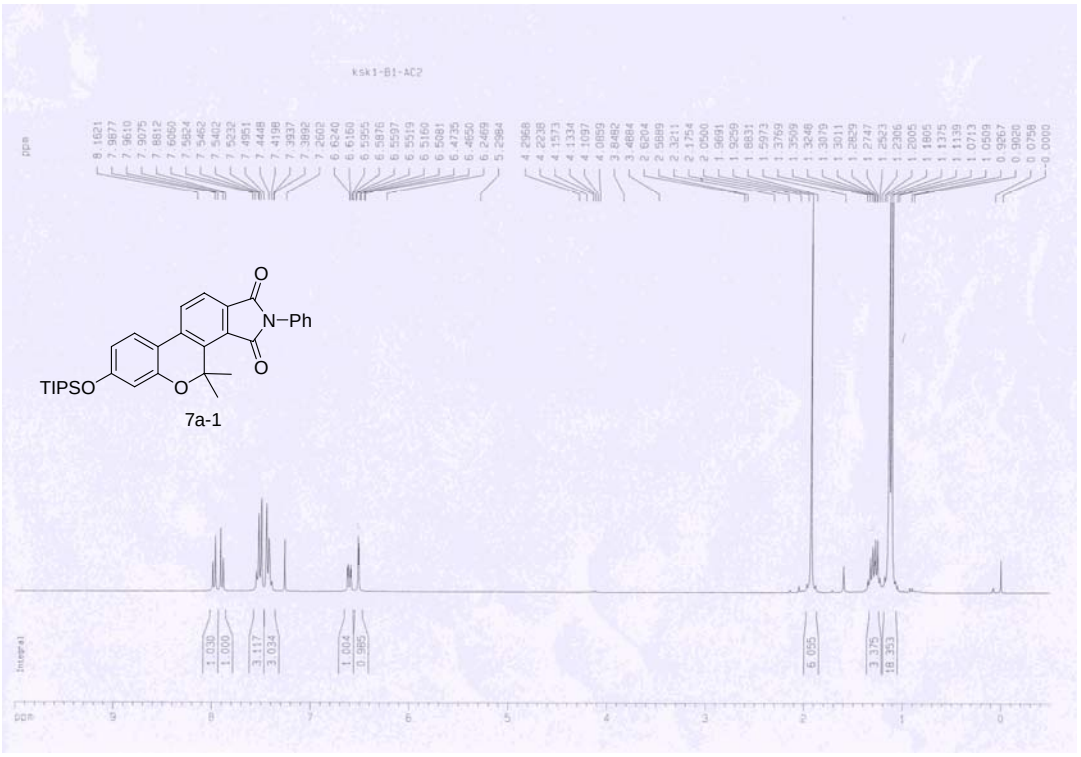
6a-4(cosy)



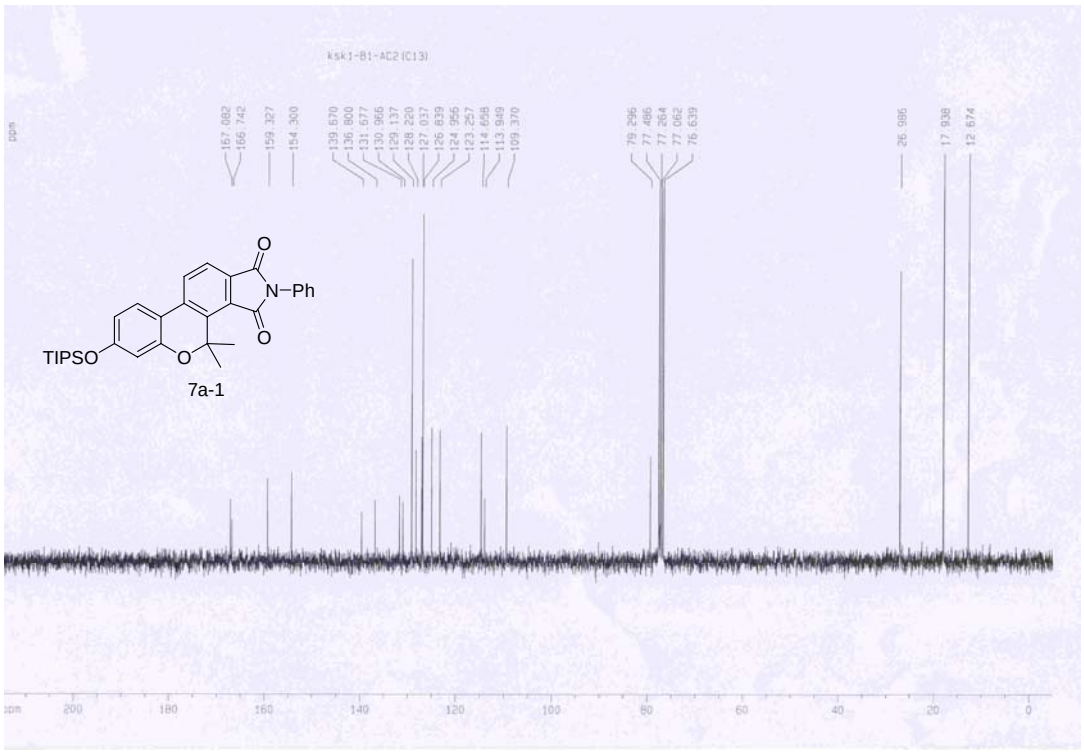


6a-4(noesy)

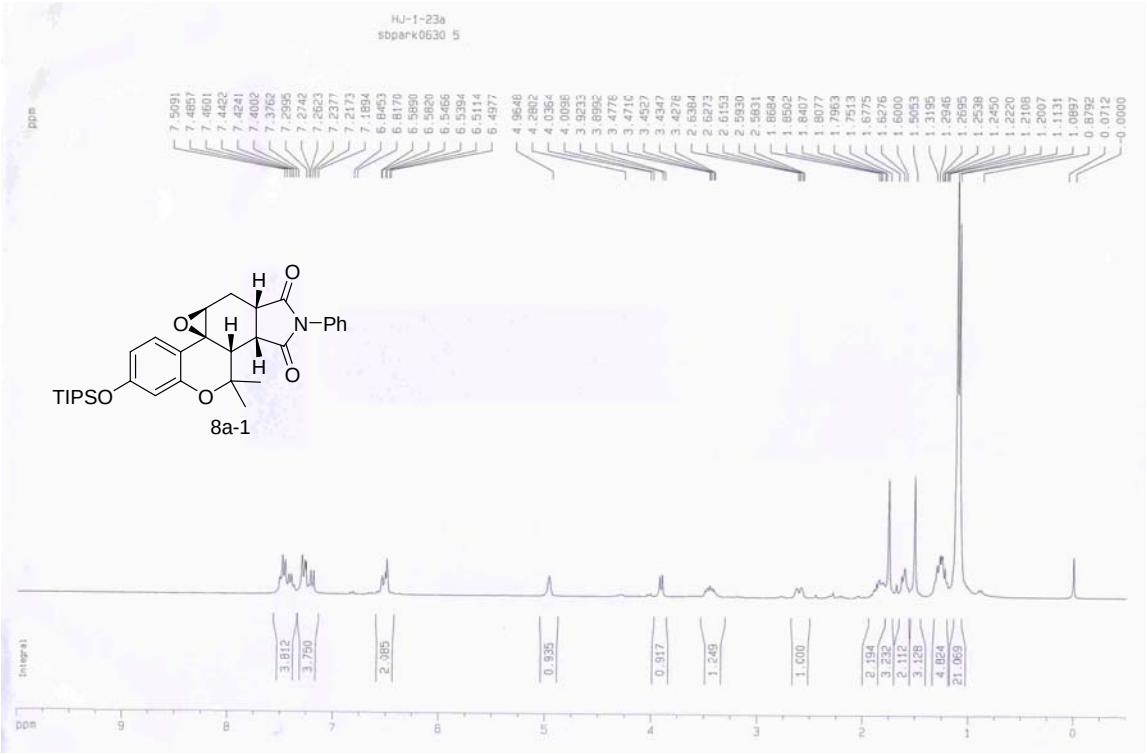


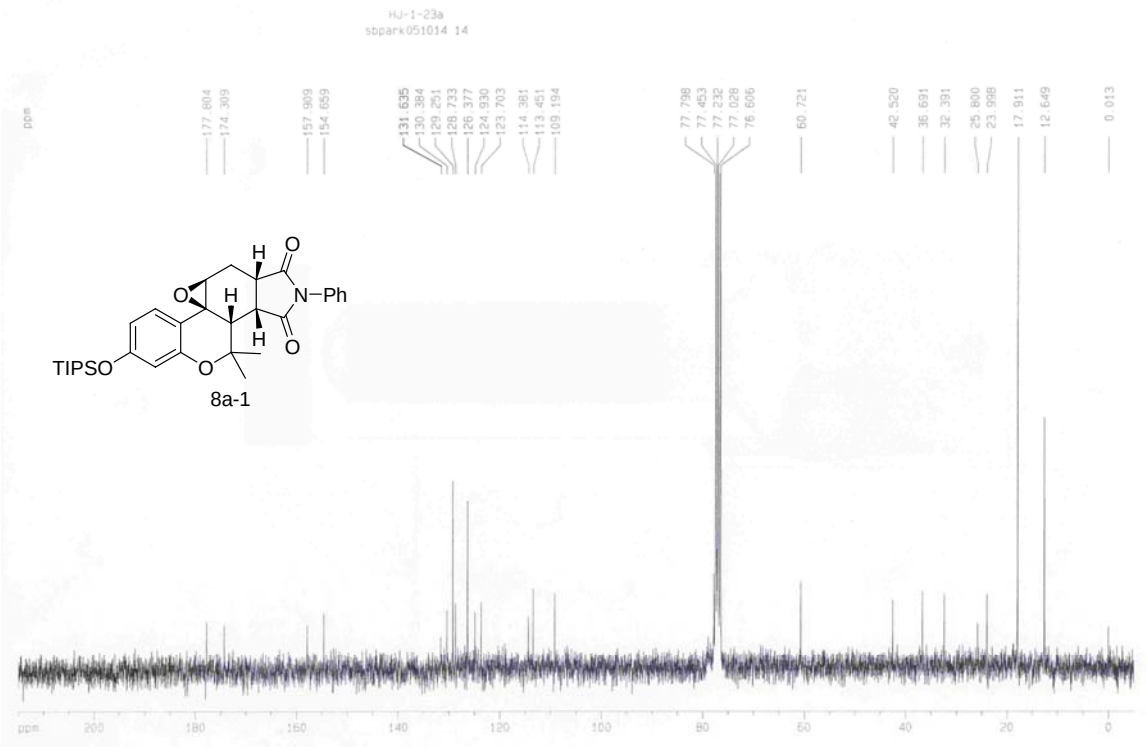


7a-1



7a-1


HJ-1-23a
sbpark0630 5
TIPSO
N–Ph
8a-1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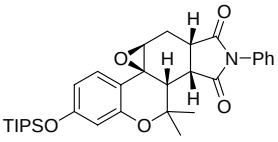
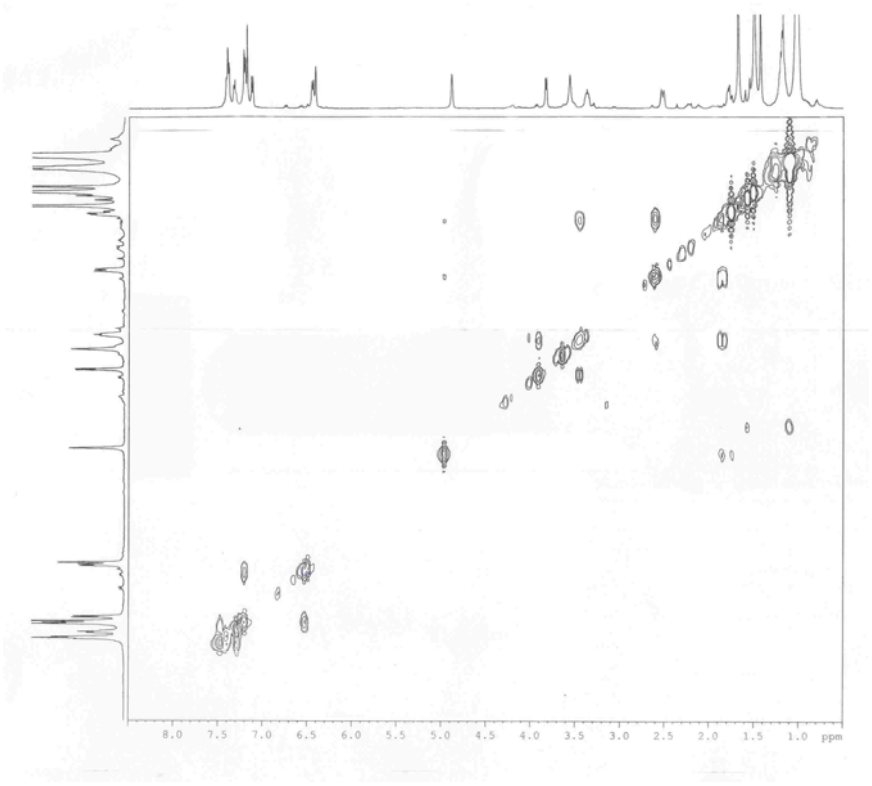
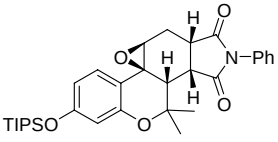
sbpark051014 14
TIPSO
N–Ph
8a-1

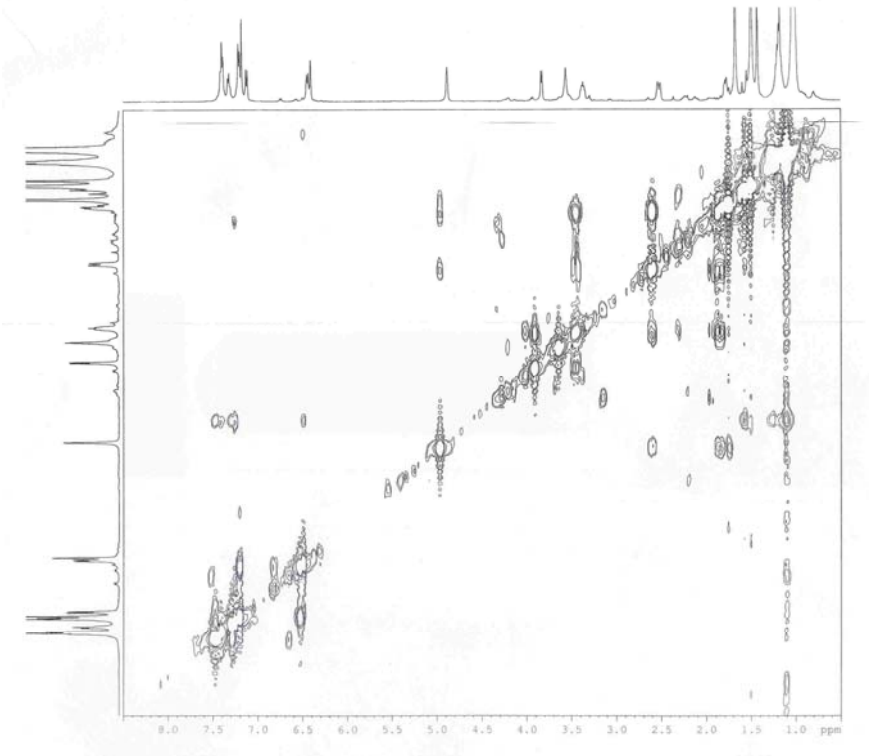


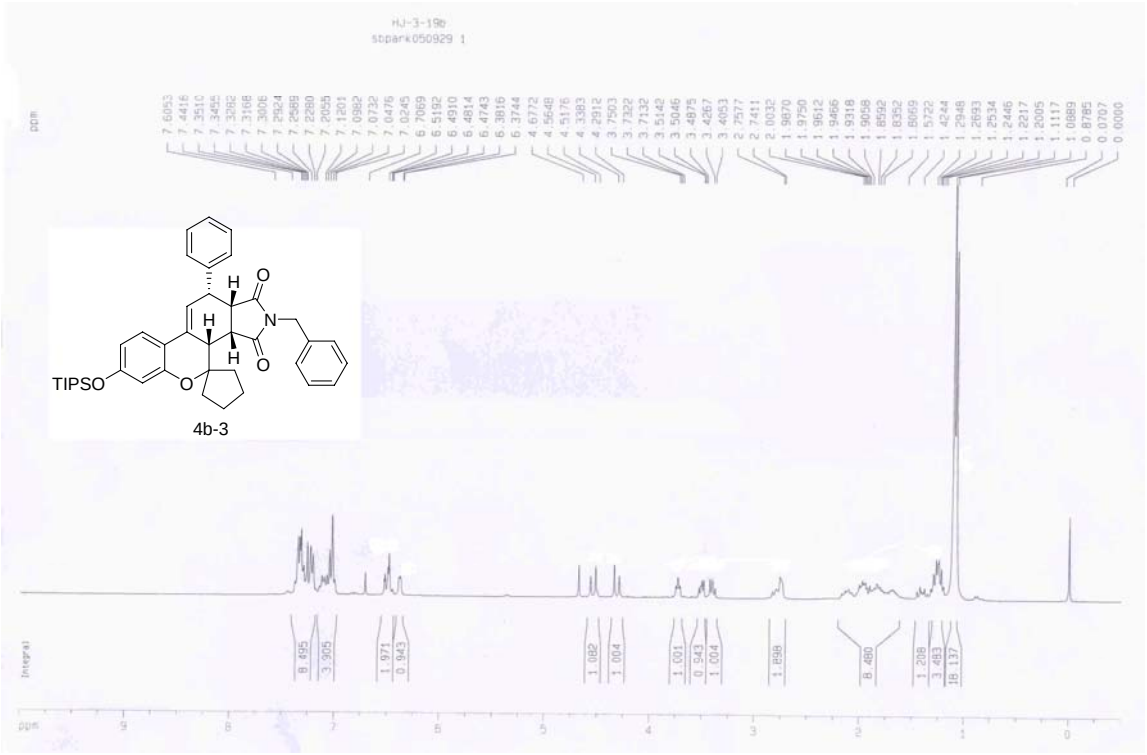
8a-1(cosy)





8a-1(noesy)




HJ-3-19b
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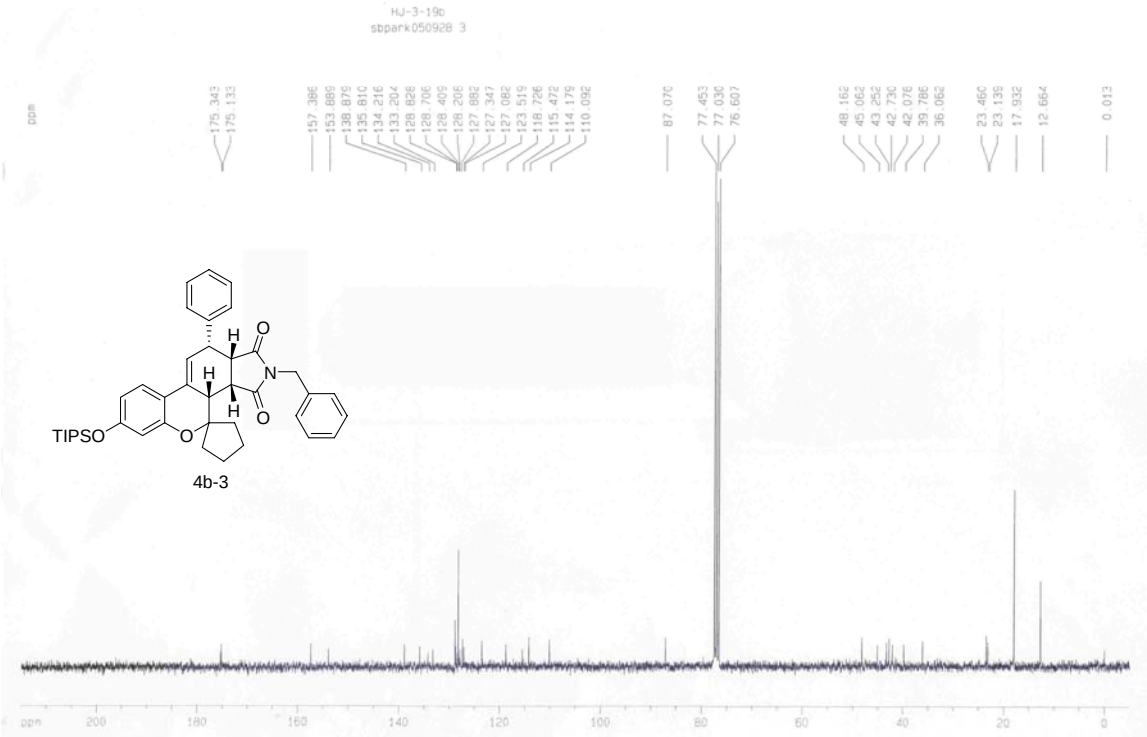
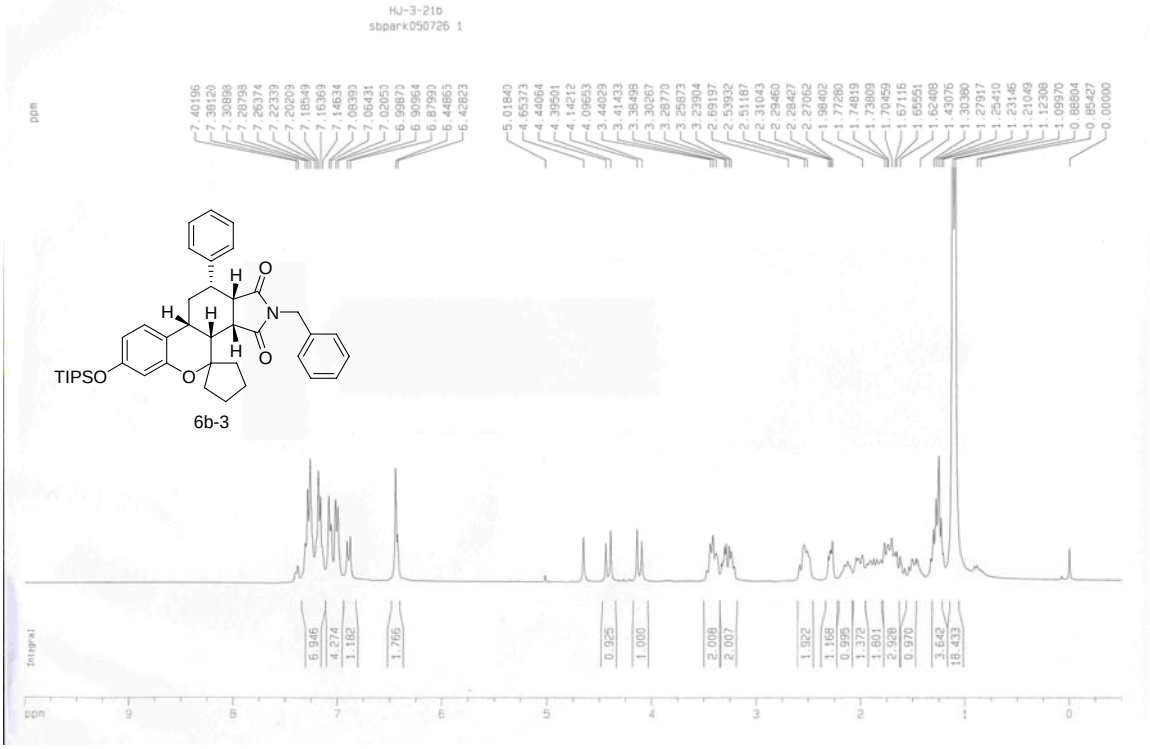
ppm
Integral
TIPSO
4b-3


HJ-3-19b
sbpark050928 3
ppm
TIPSO
4b-3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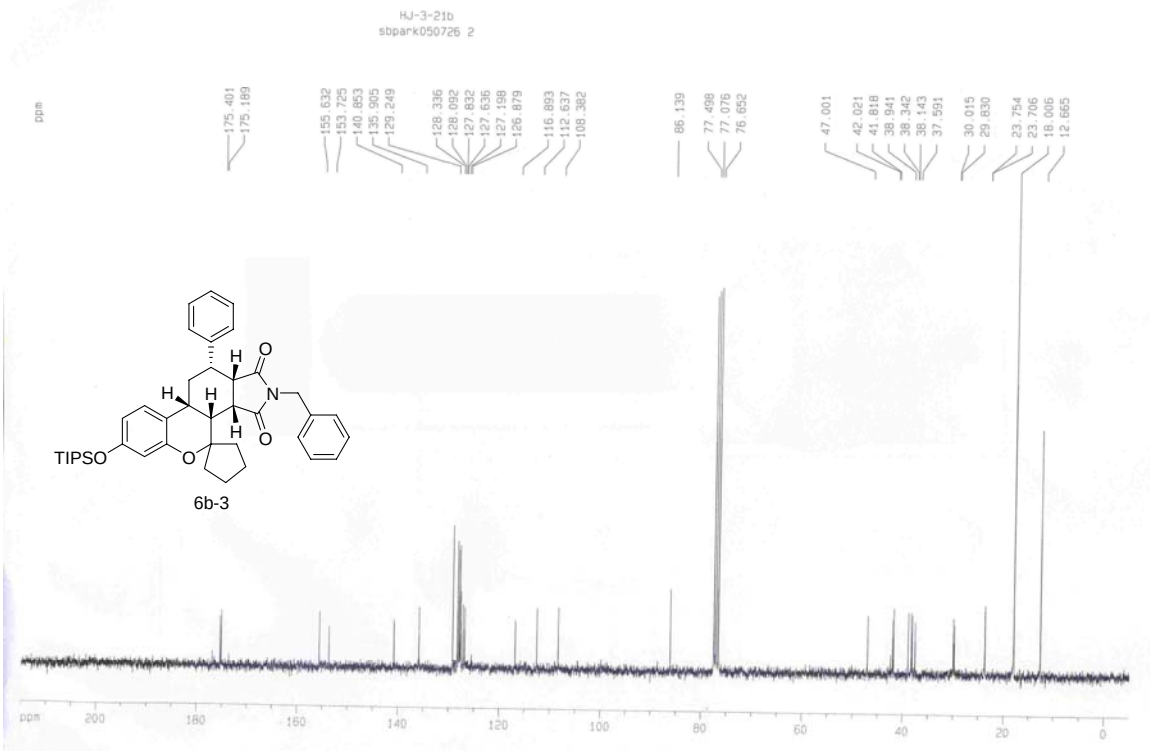
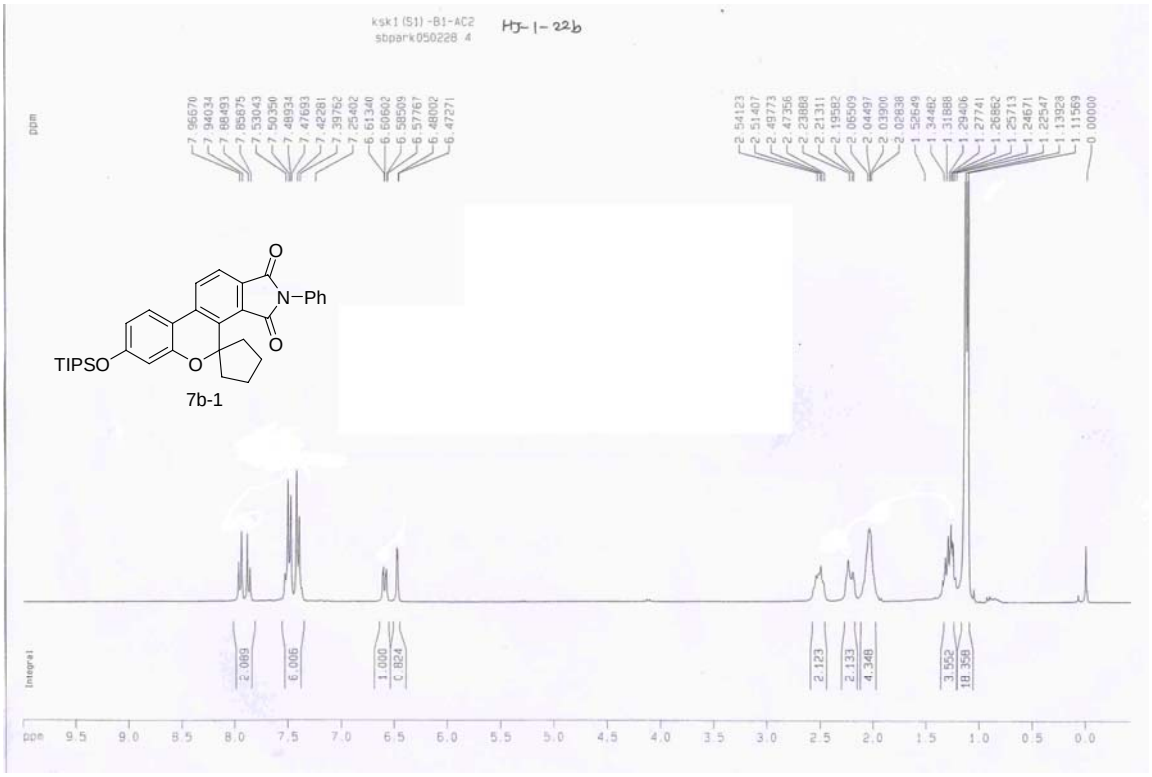
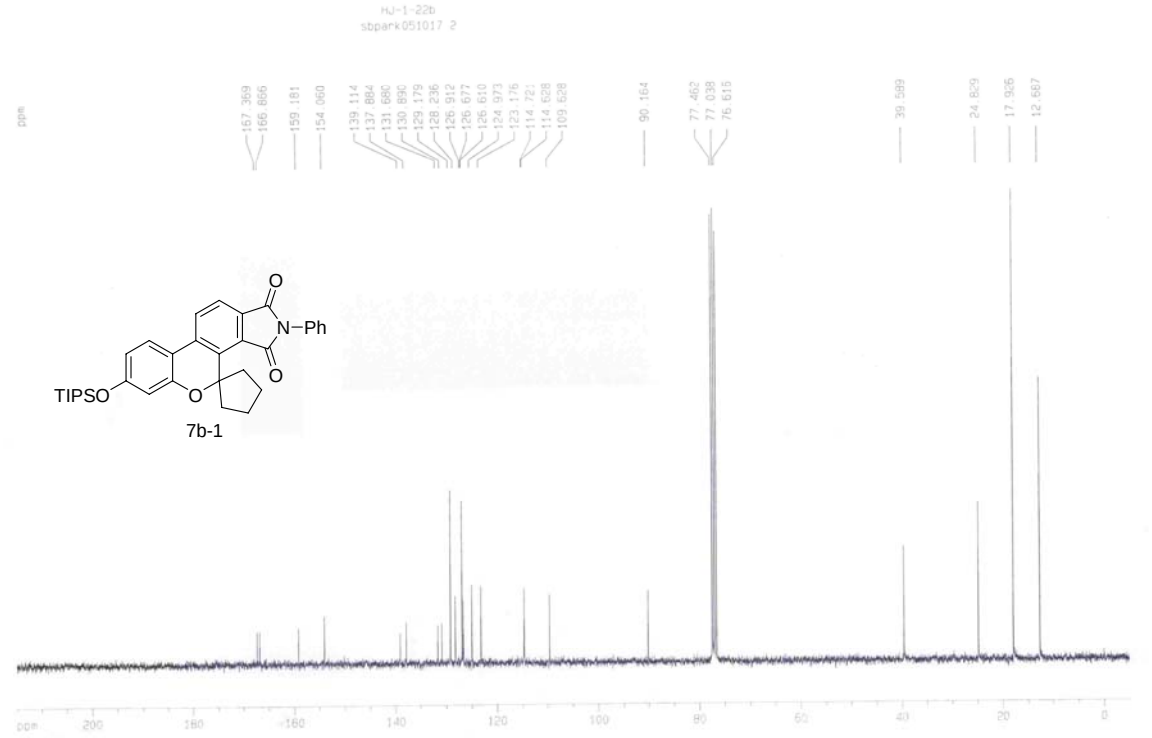
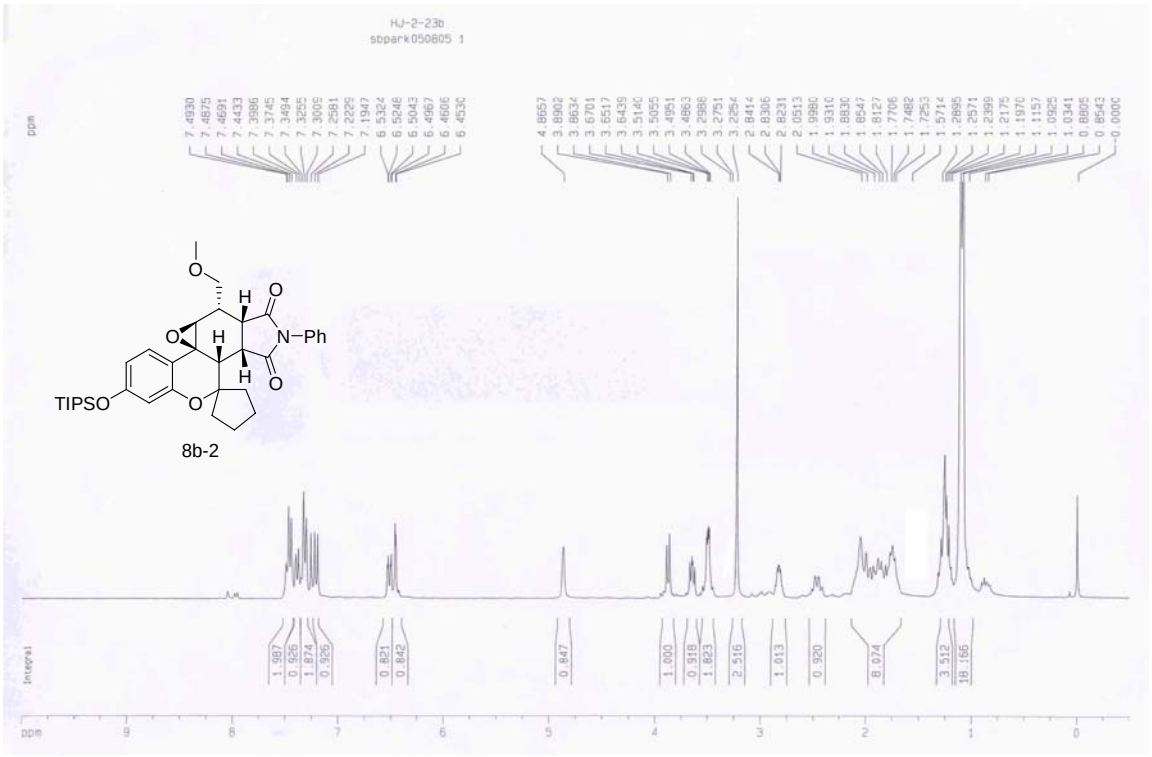
sbpark050726 1
ppm
TIPSO
6b-3


HJ-3-21b
sbpark050726 2
ppm
TIPSO
6b-3


HJ-1-22b
TIPSO
N–Ph
7b-1


HJ-1-22b
TIPSO
N–Ph
7b-1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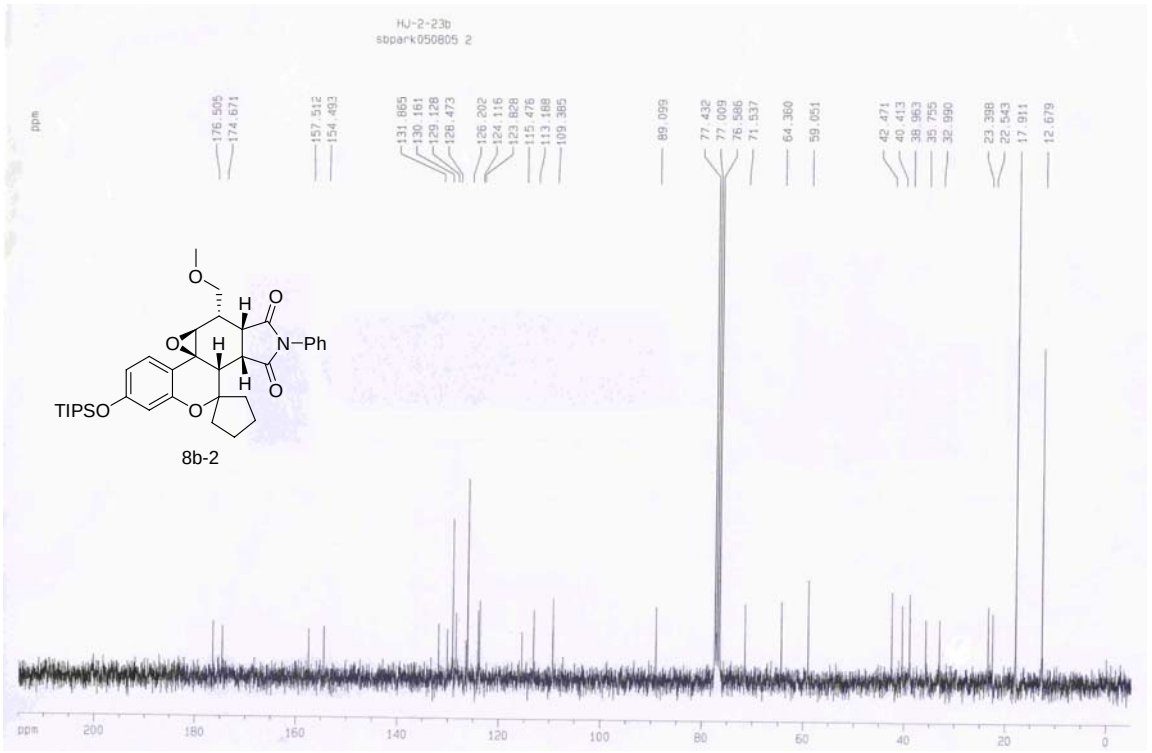
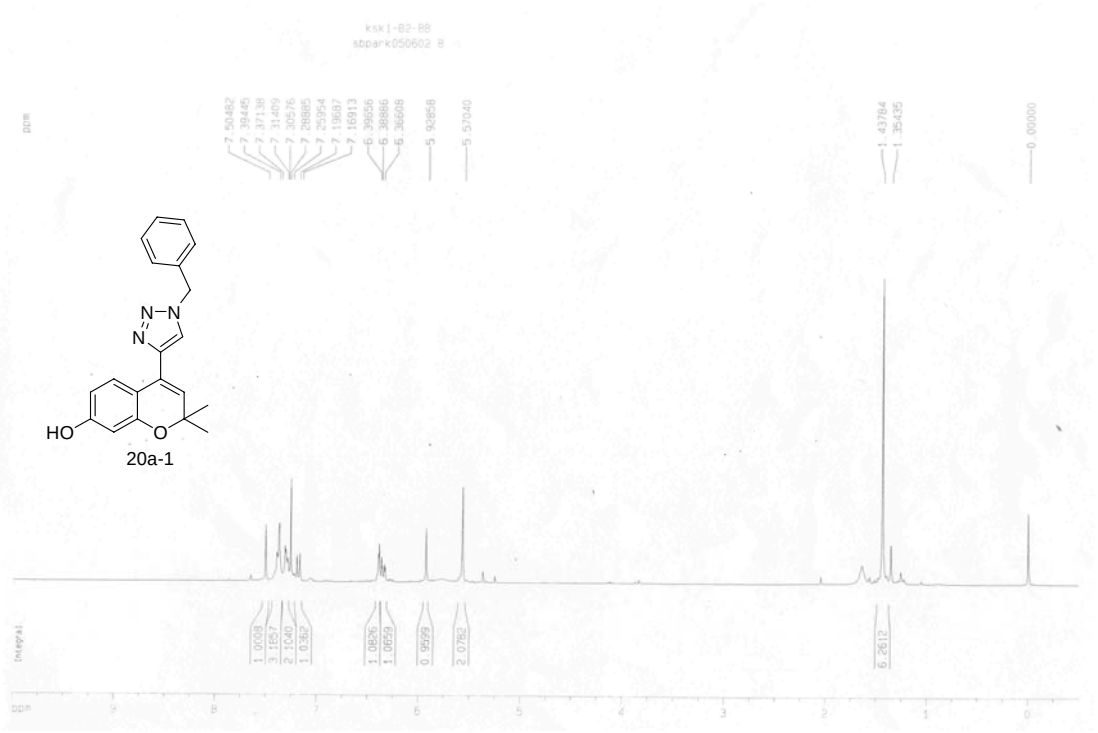
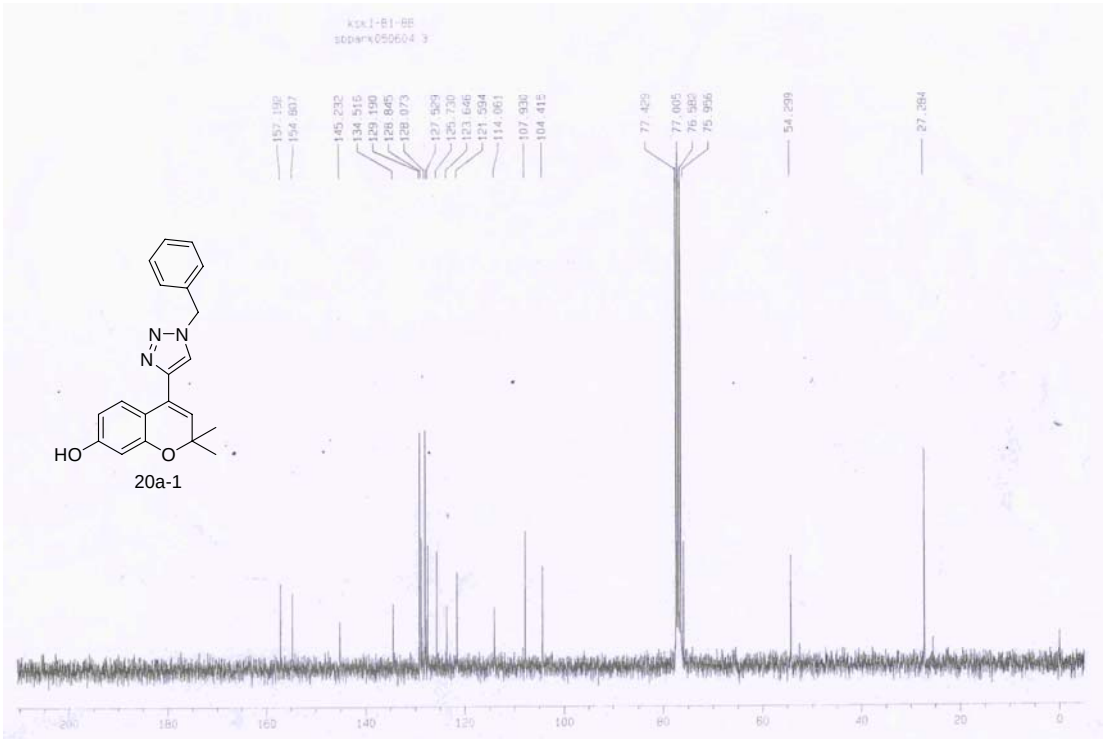
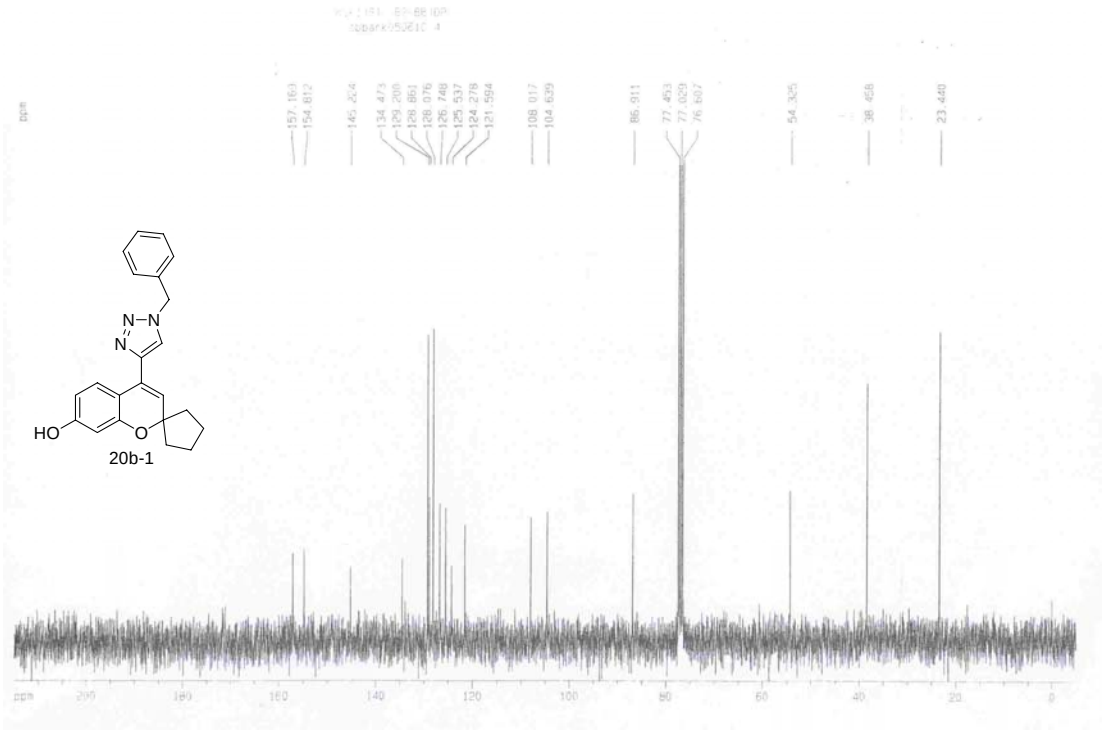
ppm
Integral
TIPSO
N–Ph
8b-2


HJ-2-23b
sbpark050805 2
ppm
TIPSO
N–Ph
8b-2

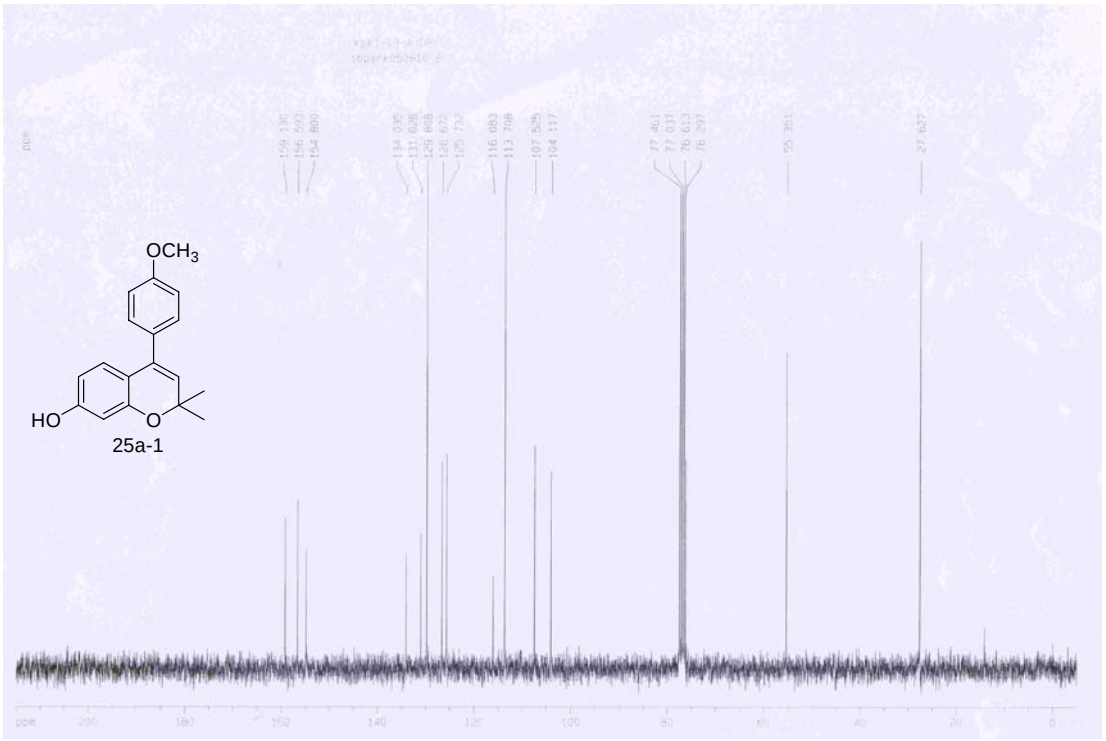

HO
O
N
N
N
20a-1


HO
O
N
N
N
20a-1


HO
O
N
N
N
20b-1

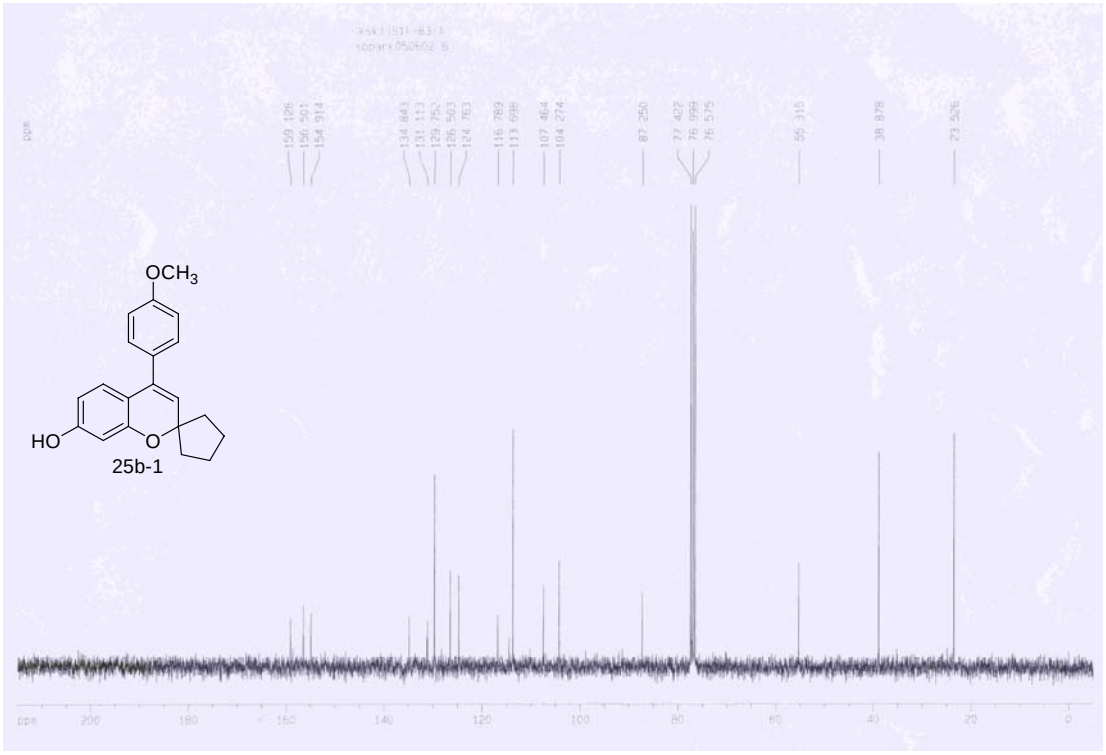

HO
O
N
N
N
20b-1

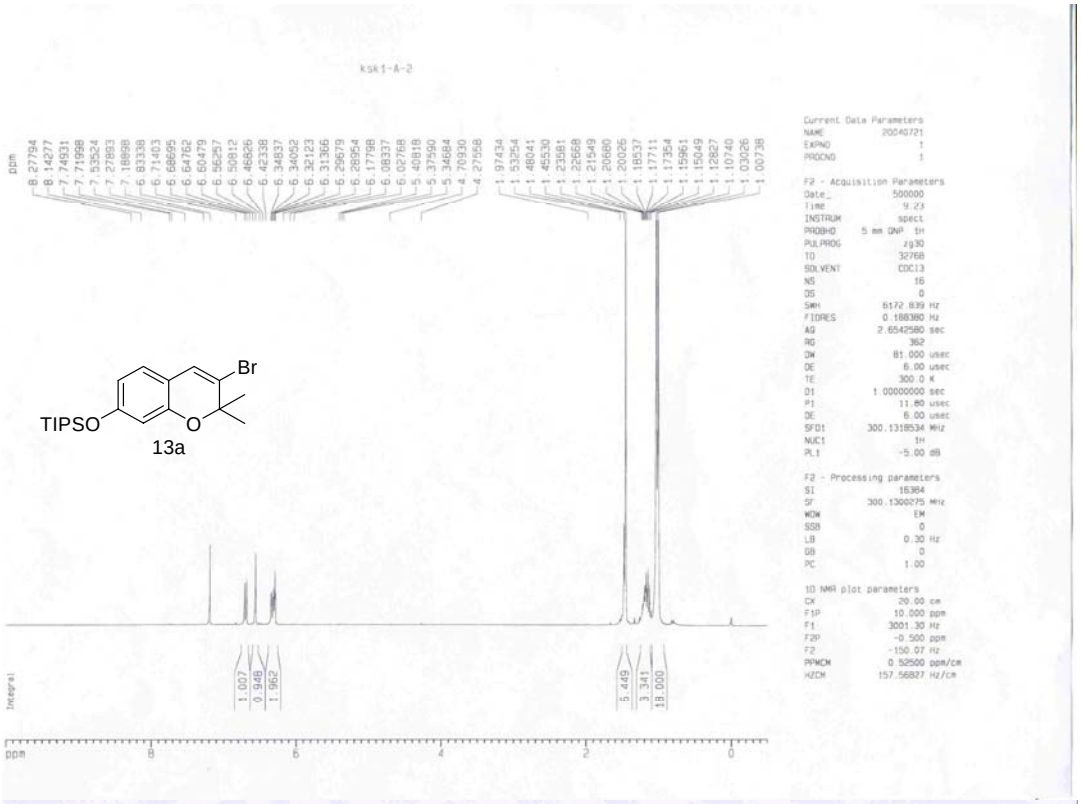
25a-1

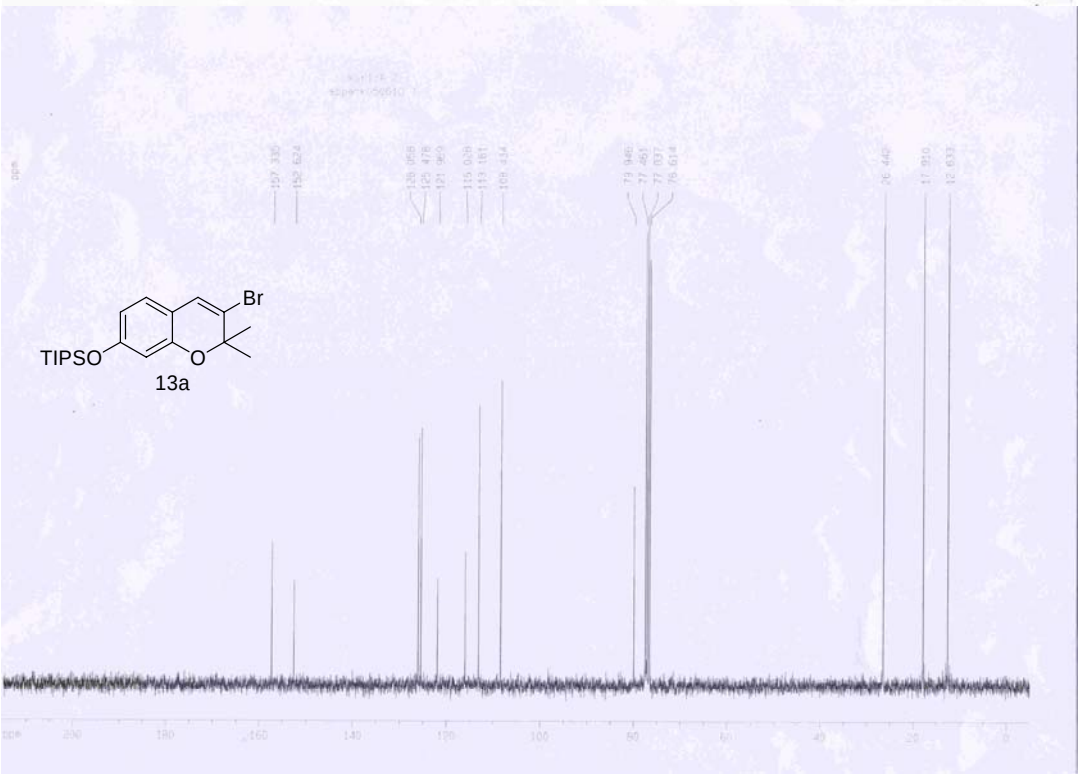


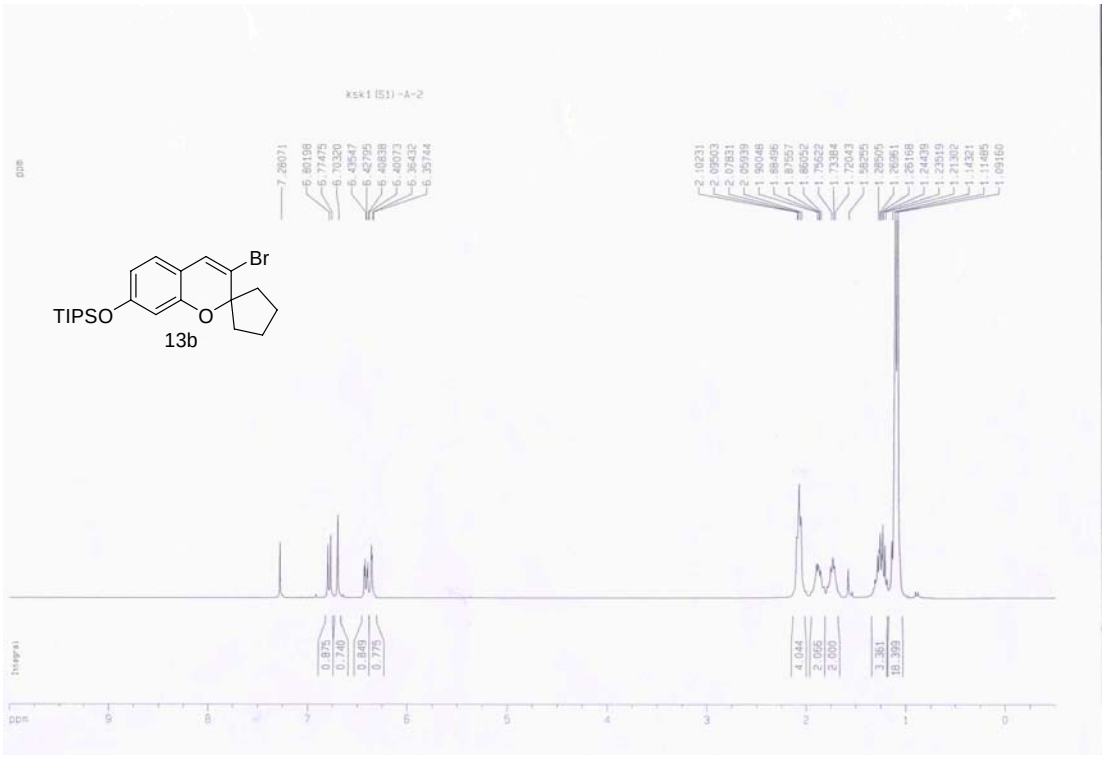
25a-1

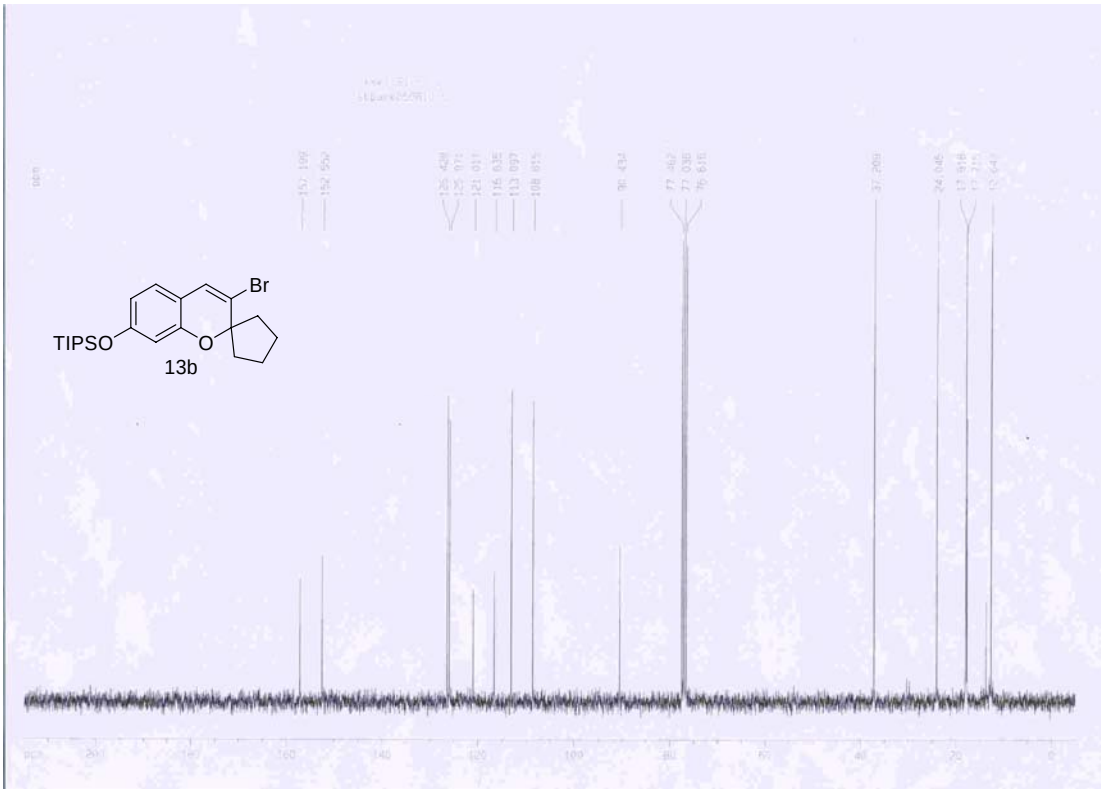

OCH3
HO
O
25b-1

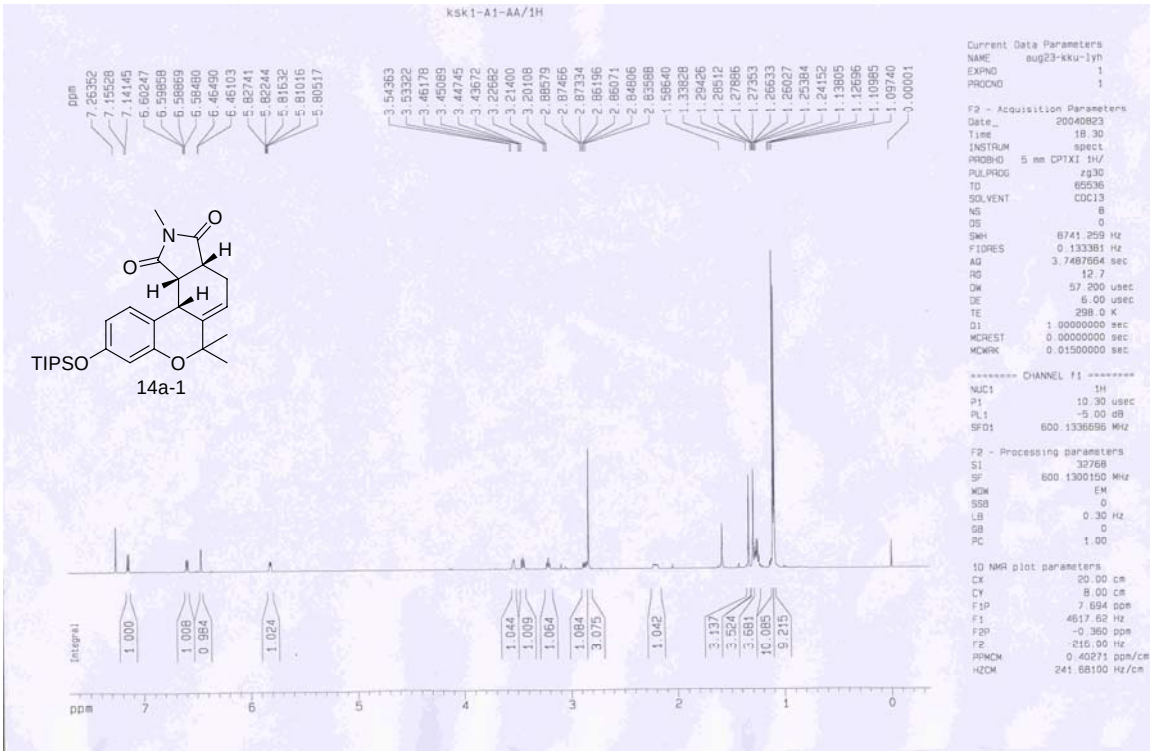

OCH3
HO
O
25b-1

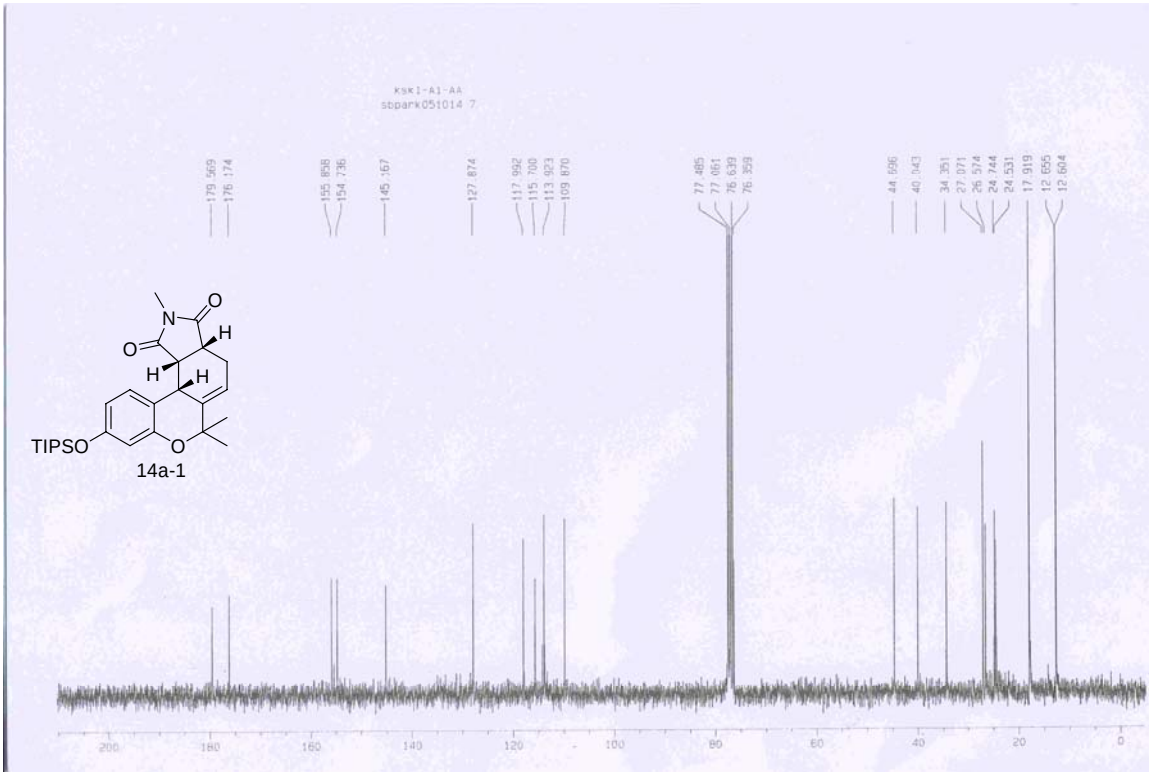

ksk1-A-2
TIPSO
Br
O
13a

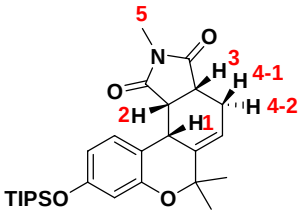

TIPSO
Br
O
13a


Br
TIPSO
O
13b

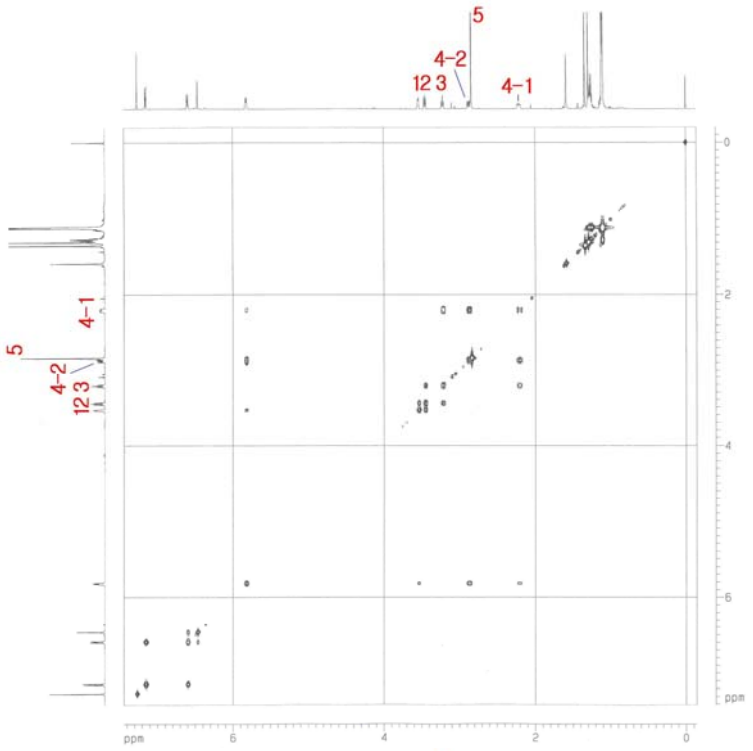

Br
TIPSO
O
13b

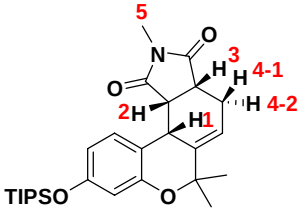

ksk1-A1-AA/1H
TIPSO
14a-1


ksk1-A1-AA
stpark051014 7
TIPSO
14a-1

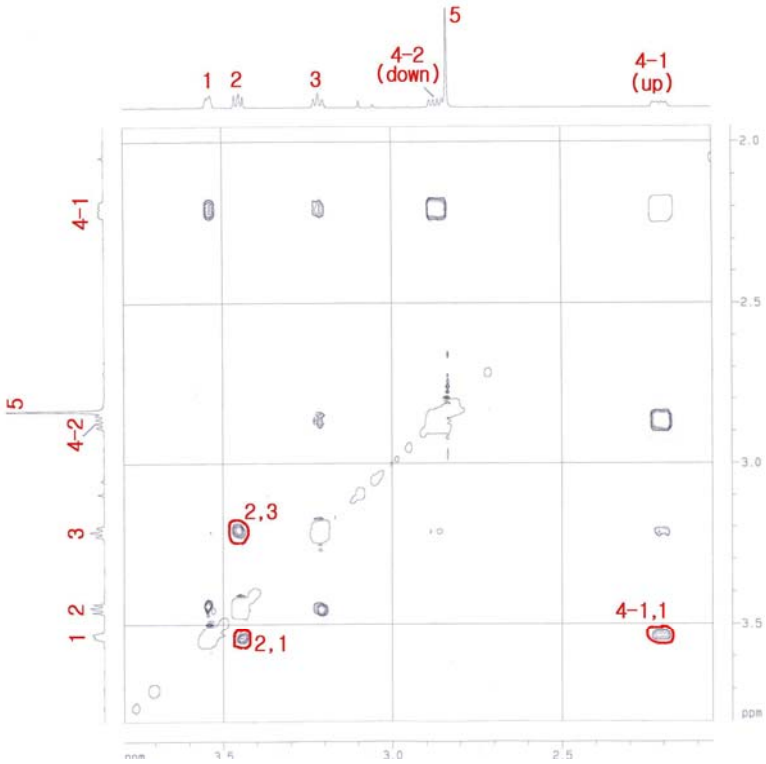


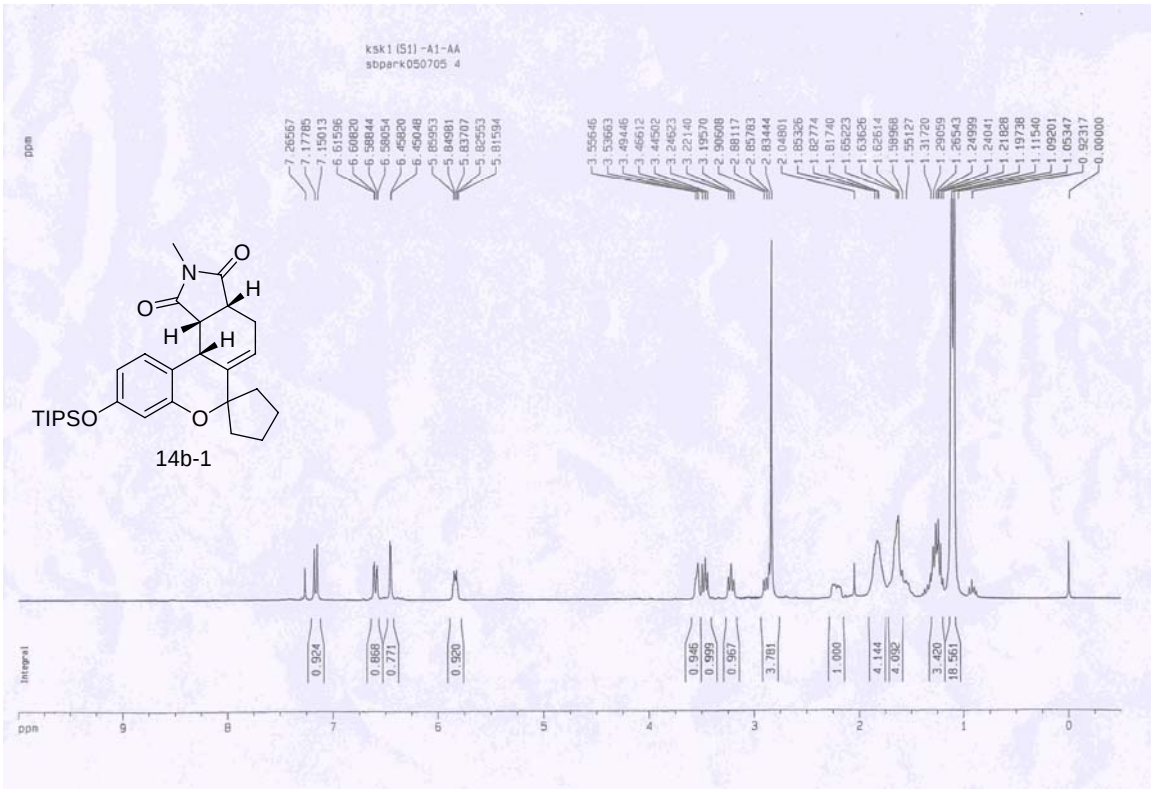
14a-1(cosy)

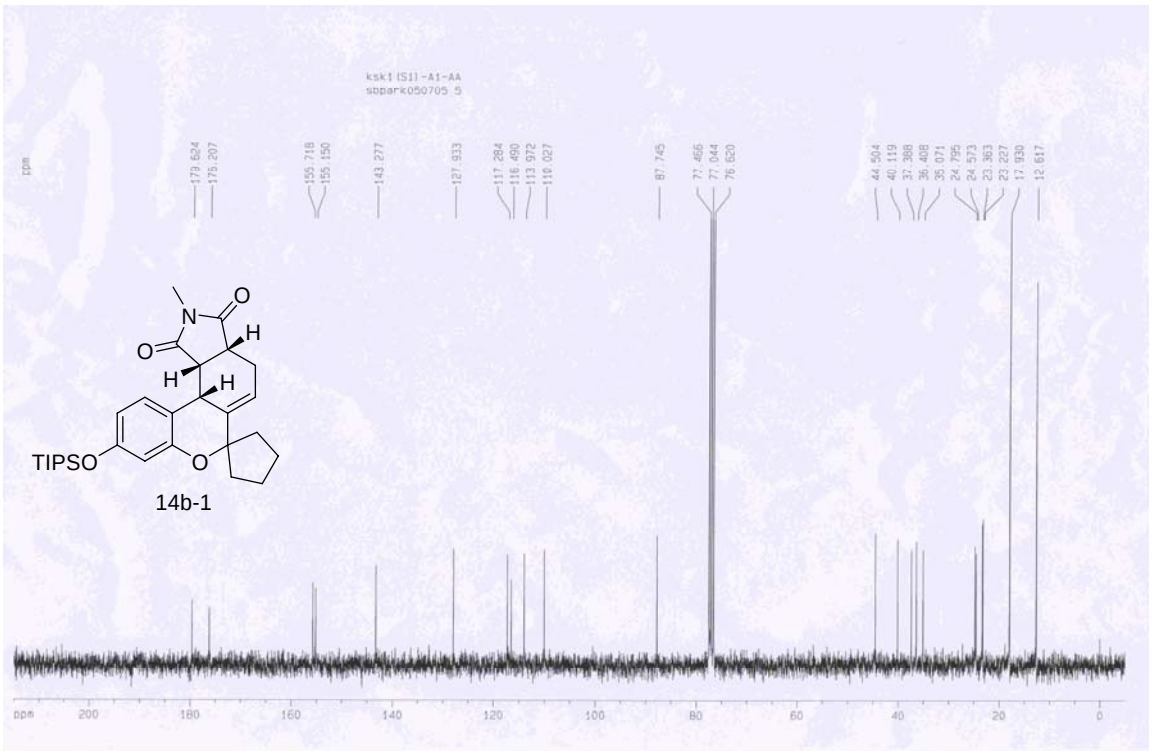


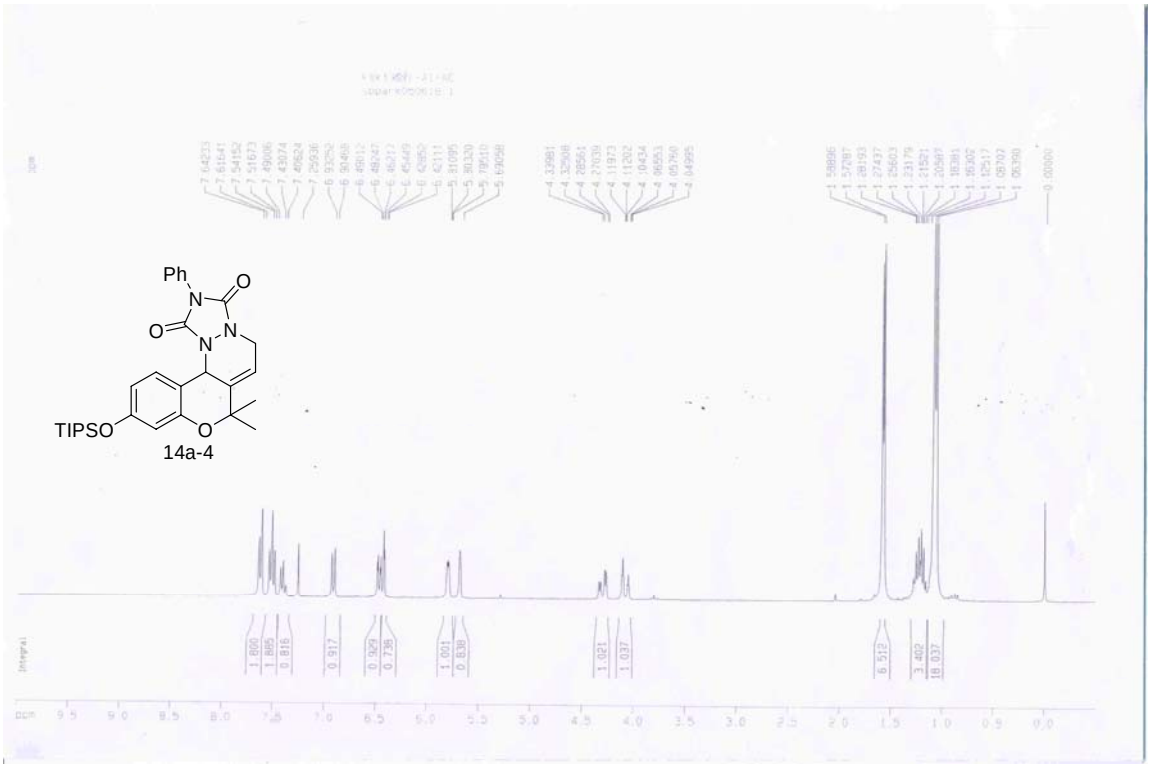


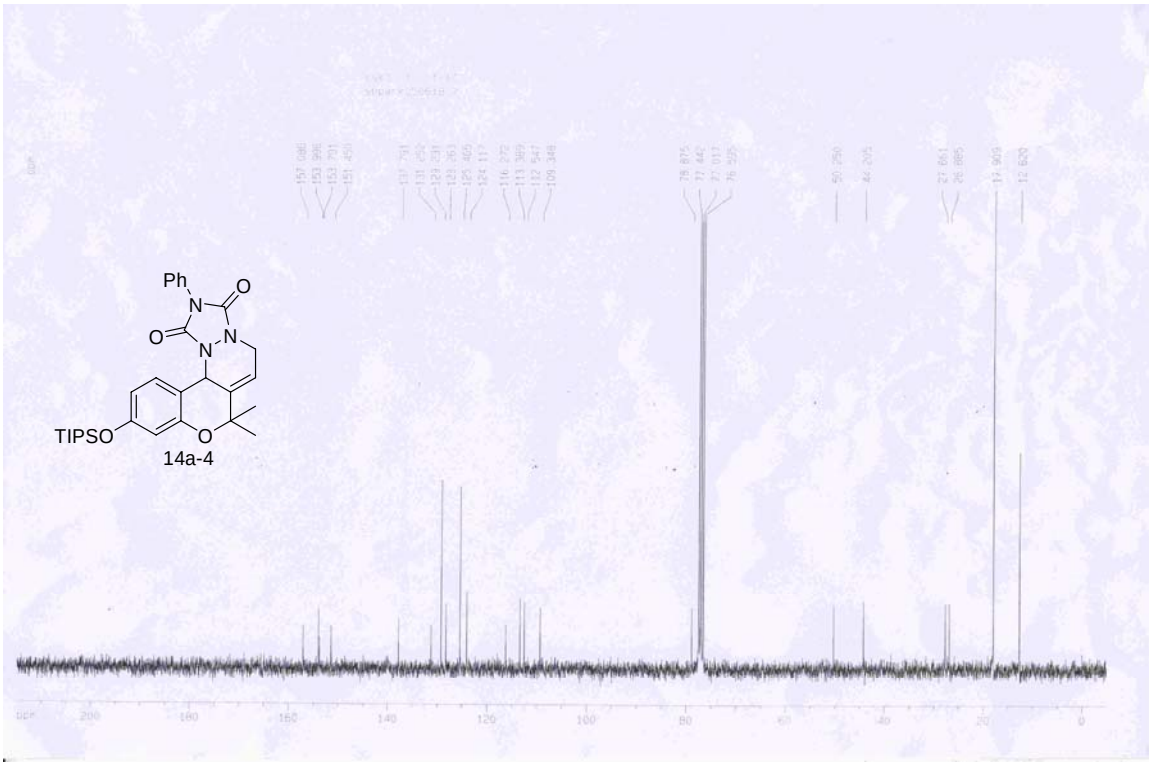
14a-1(cosy)

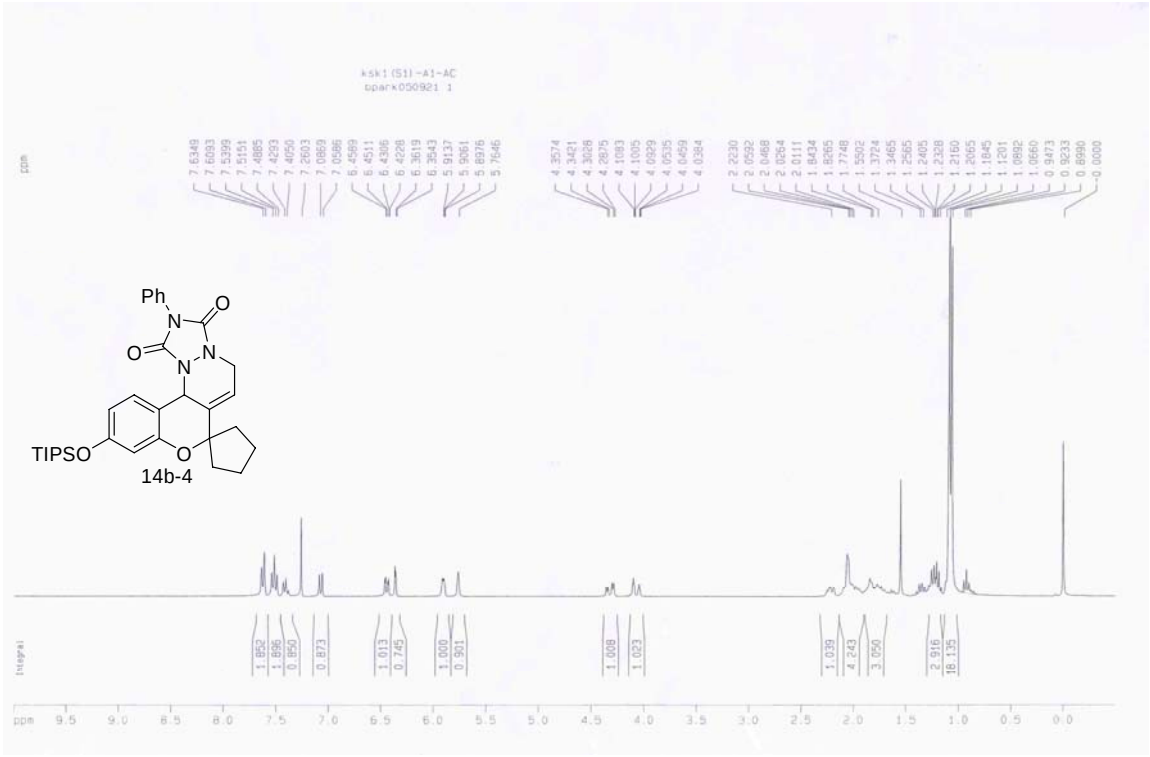


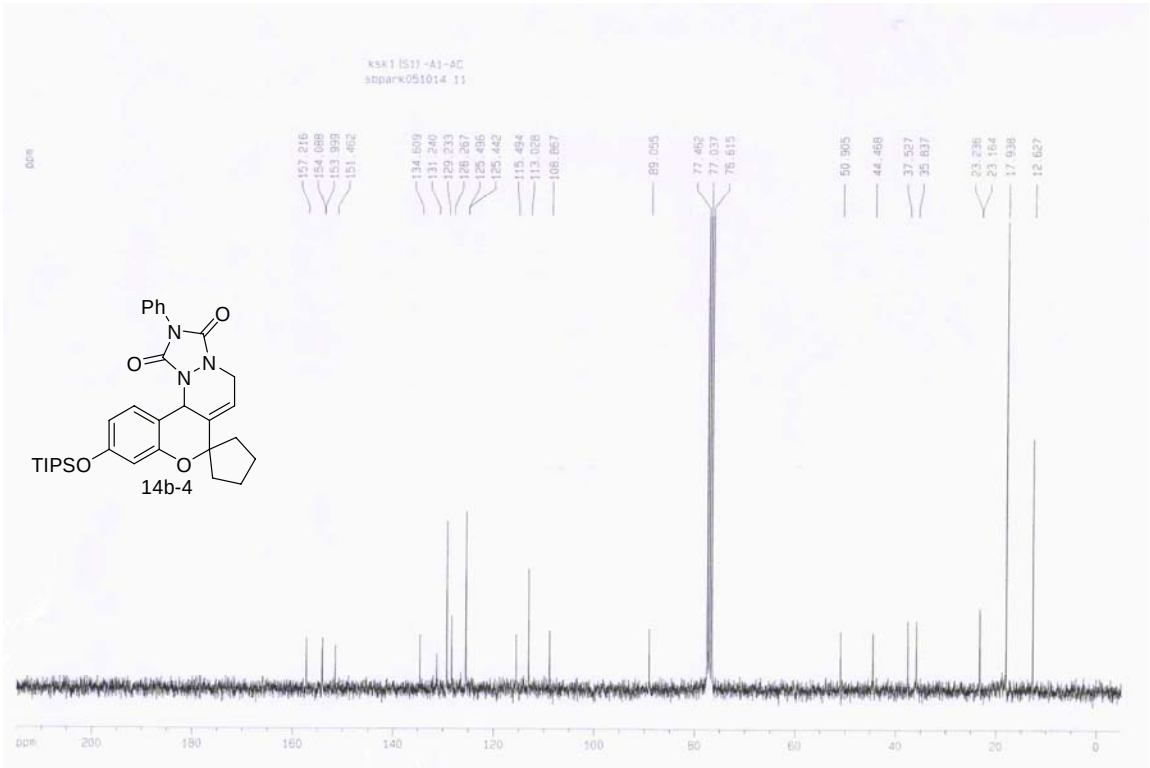

ksk1 (S1) -A1-AA
sbpark050705 4
ppm
Integral
TIPSO
O
N
H
14b-1

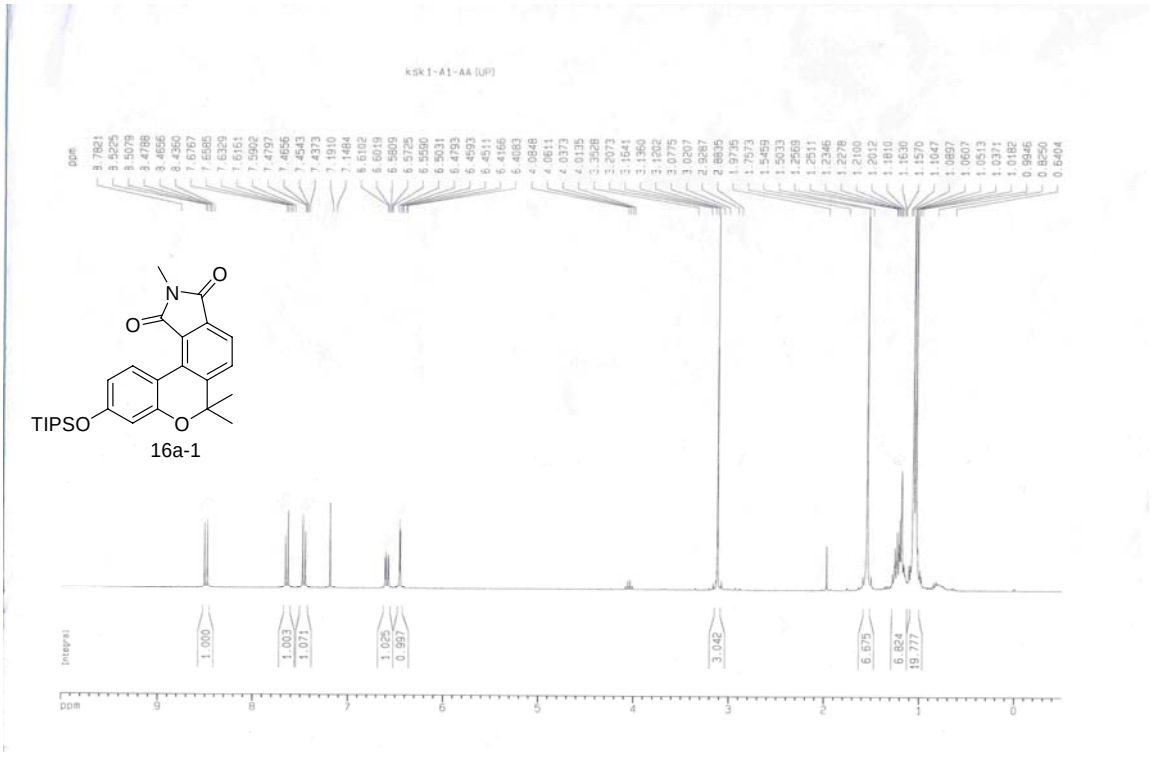

ksk1 (S1) -A1-AA
sbpark050705 5
ppm
TIPSO
O
N
H
14b-1

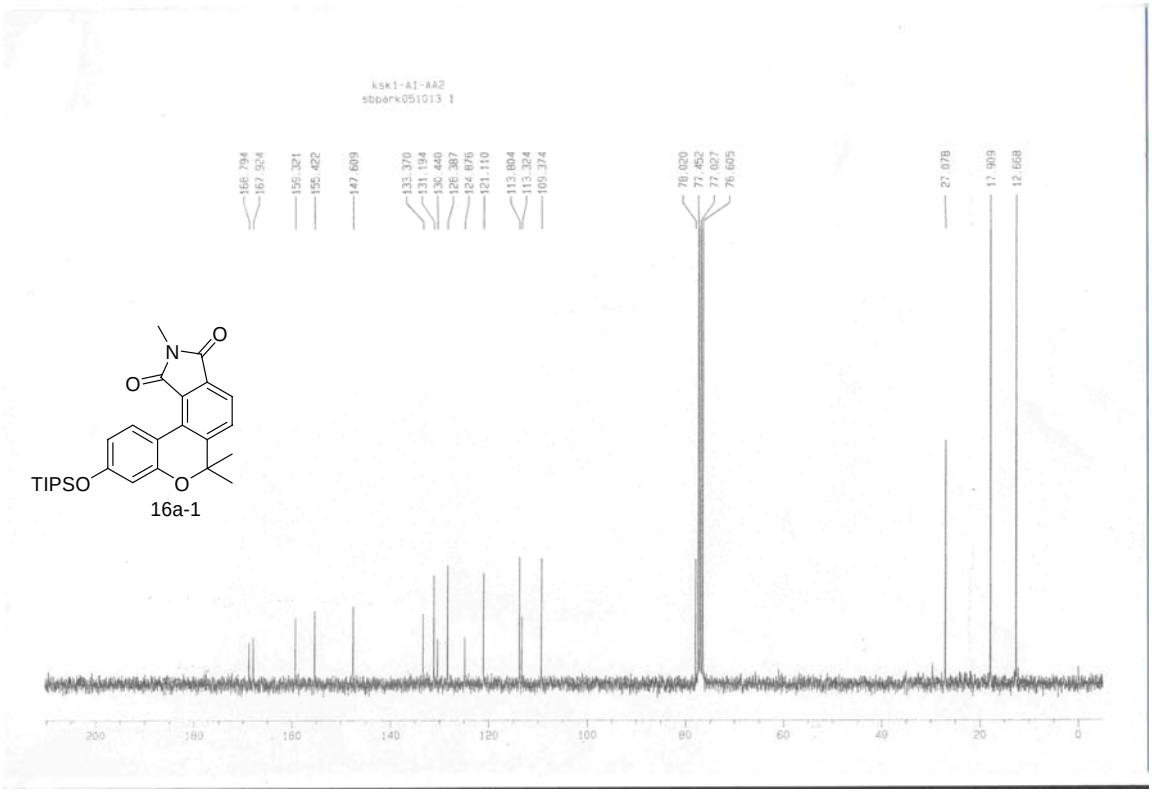

Ph
N
O
O
N
N
TIPSO
O
14a-4

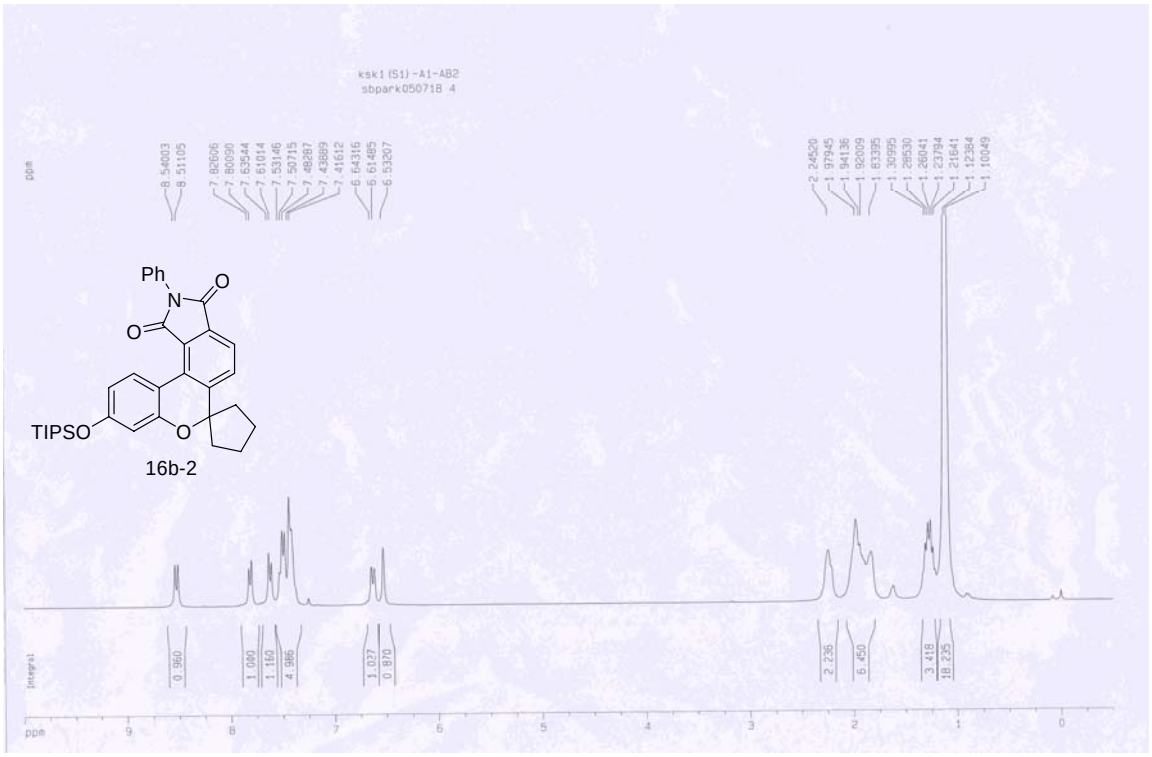

Ph
N
O
O
N
N
TIPSO
O
14a-4

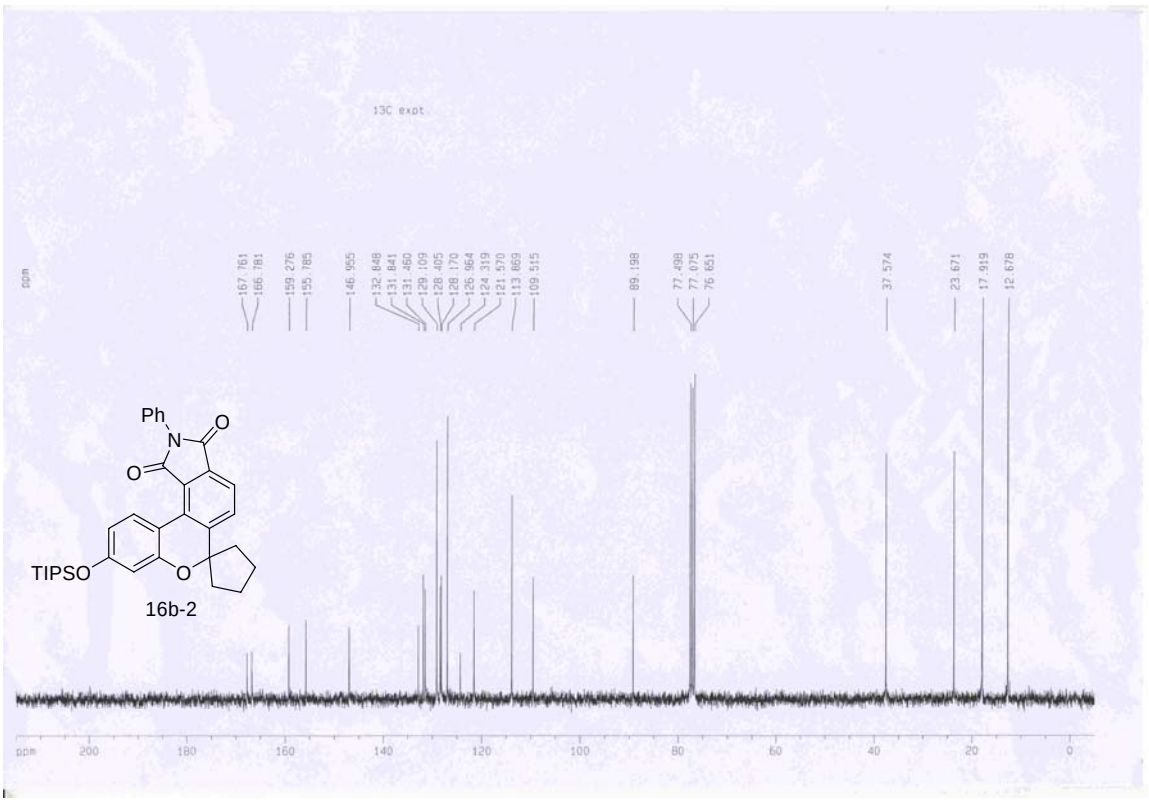

Ph
N
O
O
N
N
TIPSO
O
14b-4

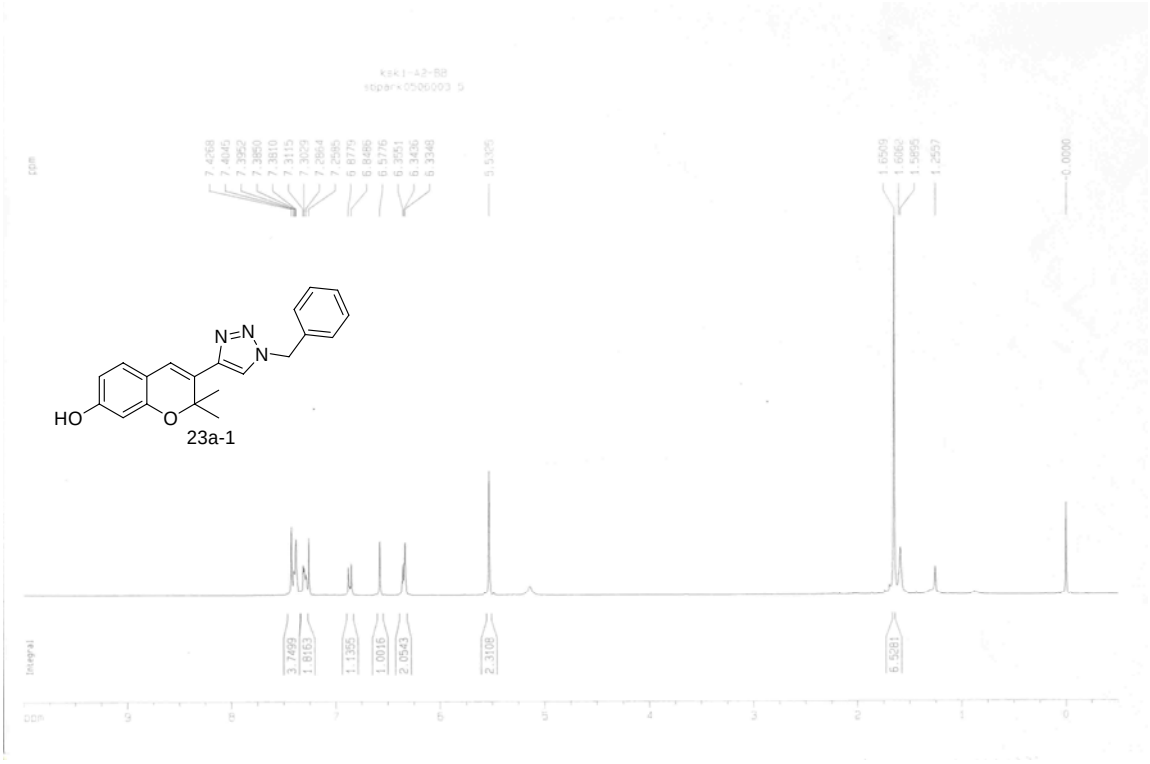

Ph
N
O
O
N
N
TIPSO
O
14b-4

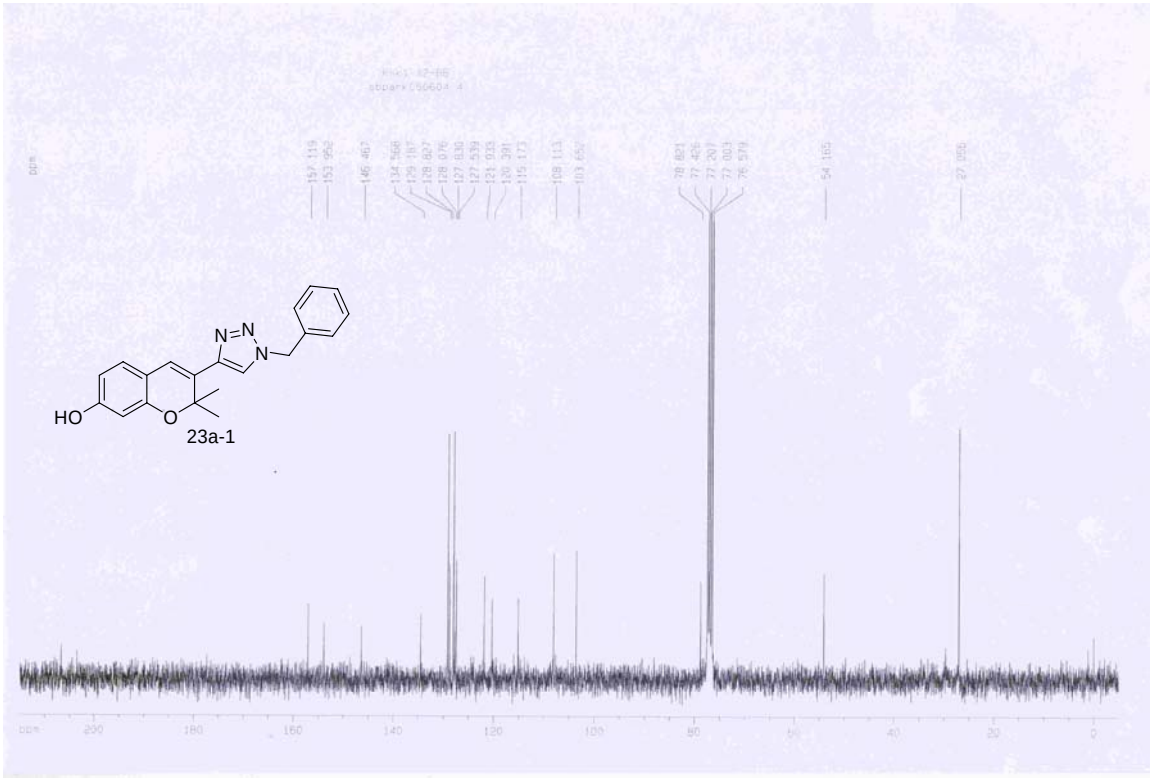

ksk1-A1-AA [UP]
TIPSO
16a-1

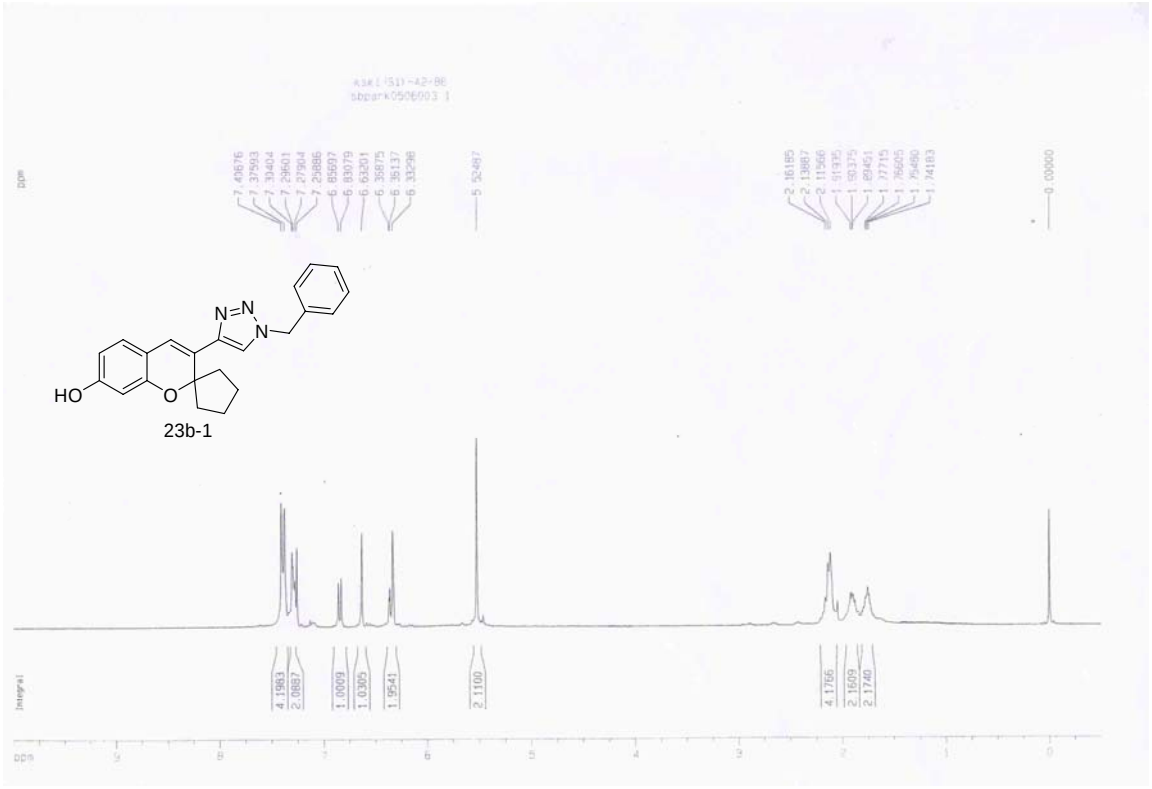

ksk1-A1-AA2
sbpark051013 1
TIPSO
16a-1

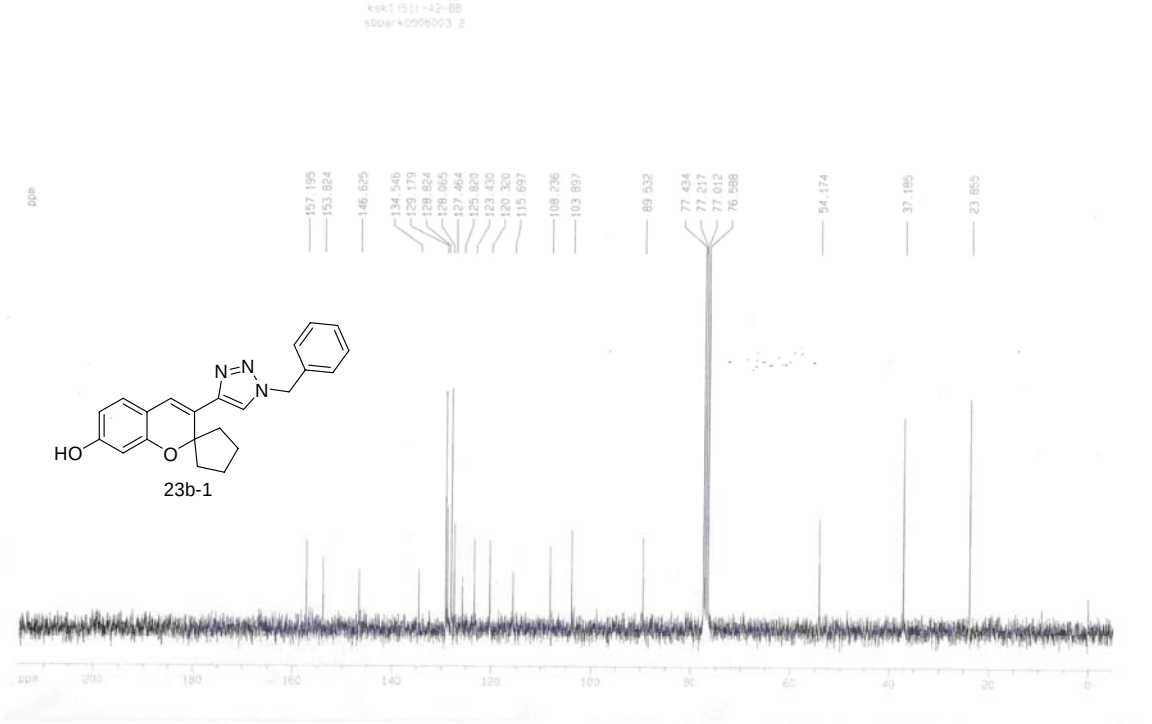

kskl(S1)-A1-AB2
sbpark050718 4
ppm
8.54003
8.51105
7.82606
7.80090
7.63544
7.61014
7.53146
7.50715
7.48287
7.43889
7.41612
6.64316
6.61485
6.53207
2.24520
1.97945
1.94136
1.92009
1.83395
1.30995
1.28530
1.26041
1.23794
1.21641
1.12384
1.10049
Ph
N
O
O
TIPSO
O
16b-2
Integral
0.960
1.000
1.150
4.986
1.027
0.870
2.236
6.456
3.418
18.235
ppm

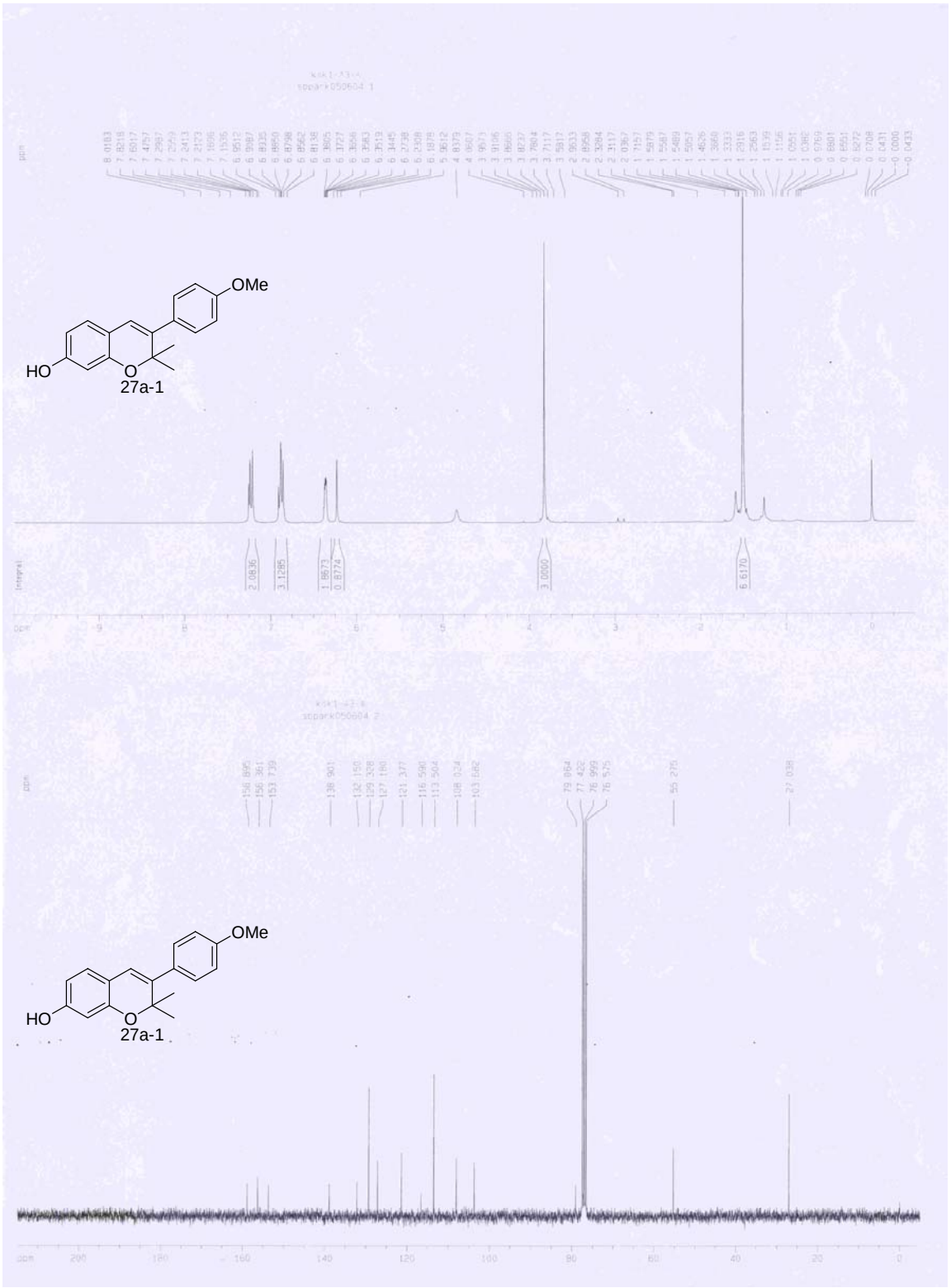

13C expt
ppm
167.761
166.781
159.276
155.785
146.955
132.848
131.841
131.460
129.109
128.405
128.170
126.964
124.319
121.570
113.869
109.515
89.198
77.498
77.075
76.651
37.574
23.671
17.919
12.678
Ph
N
O
O
TIPSO
O
16b-2
ppm

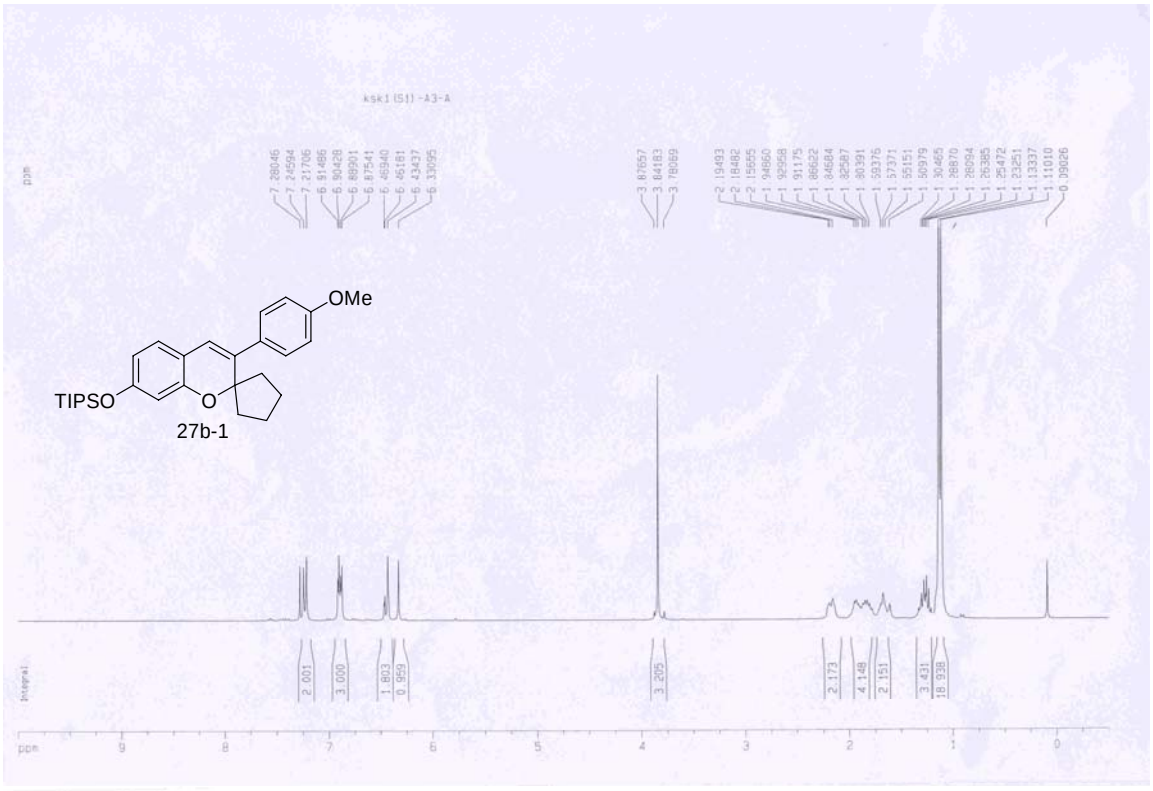

HO
O
N=N
N
23a-1

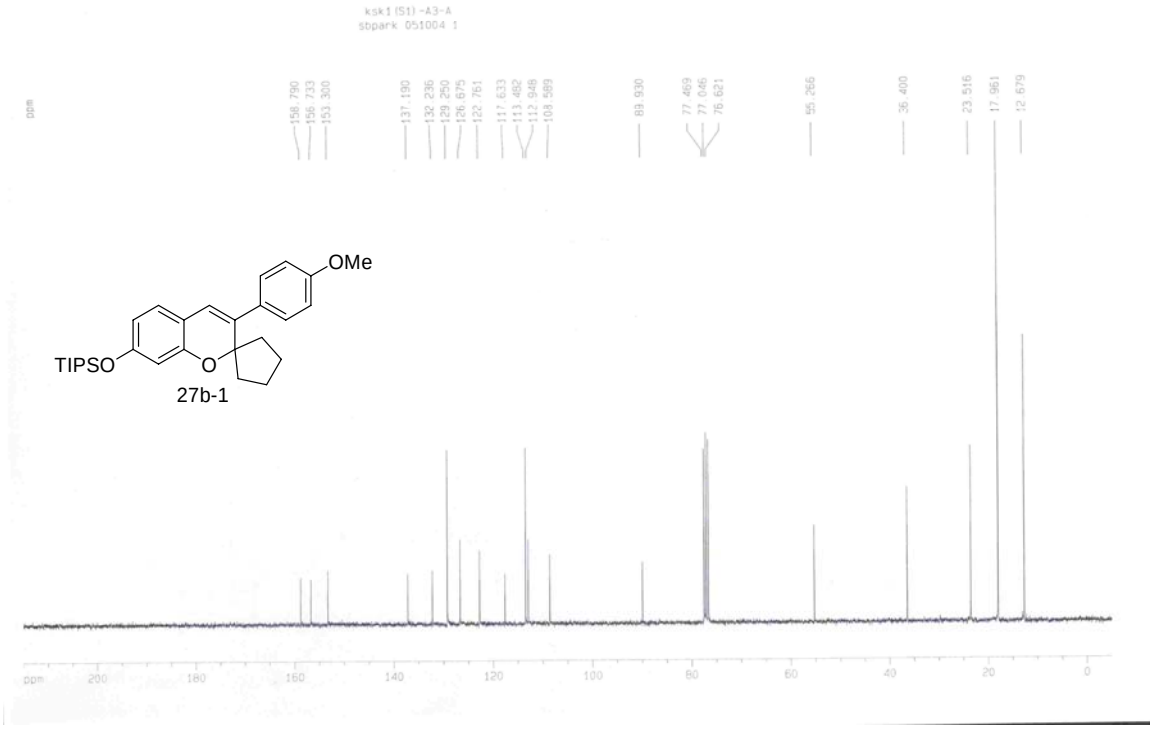

HO
O
N=N
N
23a-1


HO
O
N
N
N
23b-1


HO
O
N
N
N
23b-1


OMe
HO
O
27a-1
OMe
HO
O
27a-1


ksk1 (S1) -A3-A
OMe
TIPSO
O
27b-1


ksk1 (S1) -A3-A
sbpark 051004 1
OMe
TIPSO
O
27b-1