Supporting Information

Construction of 4-hydroxycoumarin derivatives with adjacent quaternary and tertiary stereocenters *via* ternary catalysis

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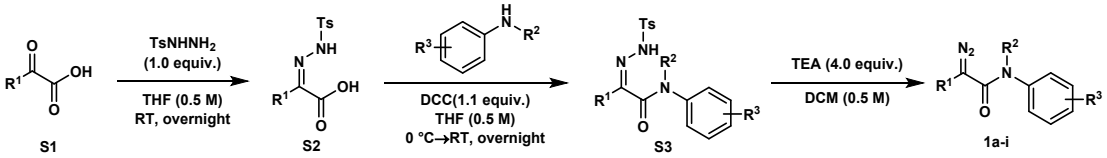
1. General information

General: All ^{1}H NMR (400 MHz, 500 MHz) and ^{13}C NMR (100 MHz or 125 MHz) and ^{19}F NMR (376 MHz, 471 MHz) spectra were recorded on 400 MHz or 500 MHz Brucker spectrometers in $CDCl_3$; chemical shifts were reported in ppm with the solvent signal as reference, and coupling constants (*J*) were given in Hertz. The peak information was described as: s =singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. High-resolution mass spectrometry (HRMS) data were collected on Waters Micromass Q-TOF micro Synapt High Definition Mass Spectrometer. Low-resolution mass spectrometry (LRMS) data were collected on Waters SQD2 with Waters H-Class UPLC. Single crystal X-ray diffraction data (**4af, 7a, 8**) were recorded on Bruker-AXS SMART APEX II single crystal X-ray diffractometer. Yields for all compounds were isolated yields for all isomers.

2. Experimental procedures

2.1 General procedure for synthesis of diazoacetamides

Diazoacetamides **1a-i** were known products and prepared according to the following procedures.



Keto acid **S1** (1.0 equiv.) and 4-methylbenzenesulfonhydrazide (1.0 equiv.) were uniformly dispersed in THF (0.5 M) under stirring condition at room temperature overnight. After completion, the suspension was concentrated under reduced pressure and the crude was recrystallized from a mixture of Petroleum ether/EtOAc during 12 hours at room temperature. The desired product **S2** was collected by filtration, washed with PE, and dried under high vacuum.

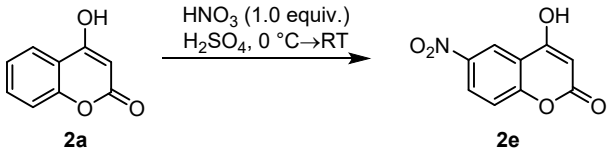
To a stirred solution of *N*-substituted aniline (1.0 equiv.) and acid **S2** (1.2 equiv.) in THF (0.5 M), DCC (1.1 equiv.) was added slowly at 0 °C. The mixture was warmed to room temperature and stirred overnight. While TLC analysis showed completion of the reaction, the mixture was filtered to separate the generated salt. Then, the liquid residue was concentrated in vacuo to give the crude **S3** without further purification.

To a suspension of crude **S3** (1.0 equiv.) in DCM (0.5 M) stirred at room temperature, TEA (4.0 equiv.) was added and the mixture was stirred for additional 5 hrs, when TLC analysis showed completion of the reaction. Then, the mixture was concentrated under reduced pressure. The residue was purified by preparative column chromatography (silica gel, eluted with EtOAc: Petroleum ether

= 1:50-1:15, note: 3% Et_3N was added in the eluent) to obtain diazoacetamides **1a-i**.

2.2 General procedure for synthesis of substituted 4-hydroxycoumarins

Substituted 4-hydroxycoumarins **2a-d**, **2f-h** were commercial products and bought from Bidepharm company. Substituted 4-hydroxycoumarin **2e** was known product and prepared using the following procedure[1].

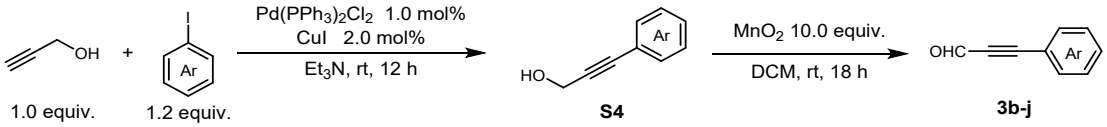


2a **2e**

To a suspension of 4-hydroxy-2*H*-chromen-2-one **2a** (1.0 g, 6.2 mmol) in concentrated H_2SO_4 (4 mL) was added concentrated HNO_3 (0.4 mL, 1.0 equiv.) in one portion under an ice bath. The mixture was stirred for another 1h at room temperature and then carefully poured into cold water (30 mL). The crude product was extracted with EtOAc (30 mL × 2) and the combined organic layer was washed with water (30 mL × 2), brine, dried over anhydrous Na_2SO_4 and concentrated under vacuum. The residue was purified by column chromatography on silica gel (petroleum ether/ethyl acetate = 4/1) to provide **2e** as a white solid.

2.3 General procedure for synthesis of substituted alkynaldehydes

Substituted alkynaldehydes **3a** and **3k** were commercial products and bought from Bidepharm company. Other substituted alkynaldehydes **3b-j** were known products and prepared according to the literature procedures [2].



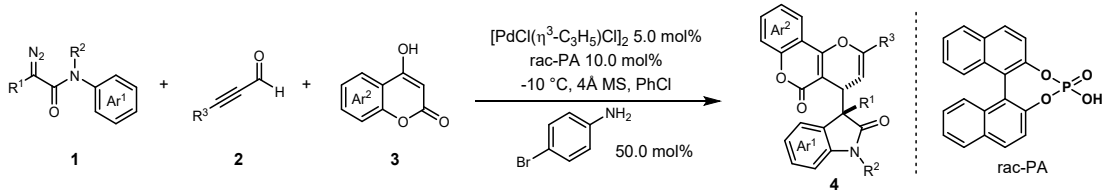
1.0 equiv. 1.2 equiv. **S4** **3b-j**

To a solution of iodoarene (1.2 equiv.) in trimethylamine (0.34 M) was added $Pd(PPh_3)_2Cl_2$ (1.0 mol %) and CuI (2.0 mol %). The reaction was stirred for 5 min before the addition of propargyl alcohol (1.0 equiv.). The resulting mixture was stirred for 12 h. After TLC analysis showed completion of the reaction, the mixture was quenched with saturated $NaHCO_3$(aq) and extracted with ethyl acetate (3 × 20 mL). The combined organic layer was washed with saturated brine, dried over anhydrous $MgSO_4$, filtered and concentrated. The crude product was purified by column chromatography (petroleum ether/EtOAc, 10:1 – 3:1) to give **S4**.

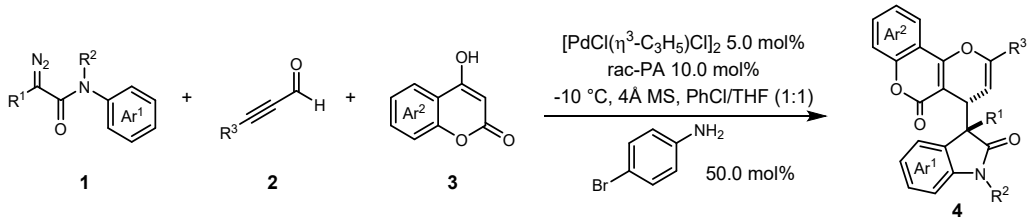
Manganese (IV) oxide (10.0 equiv.) was added to a stirred solution of corresponding propargyl

alcohol **S4** (1.0 equiv.) in DCM (0.25 M). The mixture was stirred at room temperature for 18 h, then filtered through silica gel and concentrated in vacuo. The residue was purified by column chromatography on silica gel (petroleum ether/EtOAc, 10:1) to afford the desired product **3b-j**.

2.4 General procedure for the three-component reaction

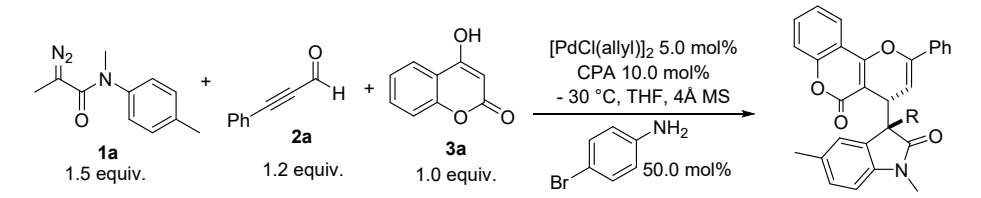


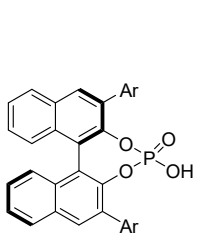
Condition A: To an oven-dried test tube with a stirring bar were added substituted 4-hydroxycoumarins **3** (0.10 mmol, 1.0 equiv.), $[PdCl(\eta^3\text{-}C_3H_5)Cl]_2$ (1.8 mg, 5.0 mol%), rac-PA (3.5 mg, 10.0 mol%), 4-bromoaniline (0.05 mmol, 50.0 mol%), 4Å MS (50 mg) and anhydrous PhCl (1.0 mL), and this suspension was later stirred at -10 °C. Then diazoacetamides **1** (0.15 mmol, 1.5 equiv.) and substituted alkynaldehydes **2** (0.12 mmol, 1.2 equiv.) dissolved in anhydrous PhCl (1.0 mL) were injected into the suspension over 1h *via* a syringe pump. After completion of the addition, stirring was continued at -10 °C for 8h. Then the mixture was filtered and concentrated under vacuum to give a residue which was subjected to ^{1}H NMR spectroscopy analysis for the determination of diastereoselectivity (*dr* value). Carful purification of the crude product by flash chromatography on silica gel (eluent: petroleum ether/EtOAc = 10/1~3/1) afforded pure products.



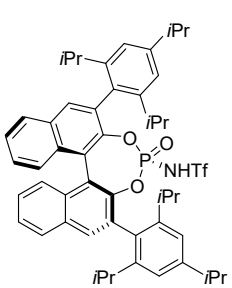
Condition B: To an oven-dried test tube with a stirring bar were added substituted 4-hydroxycoumarins **3** (0.10 mmol, 1.0 equiv.), $[PdCl(\eta^3\text{-}C_3H_5)Cl]_2$ (1.8 mg, 5.0 mol%), rac-PA (3.5 mg, 10.0 mol%), 4-bromoaniline (0.05 mmol, 50.0 mol%), 4Å MS (50 mg) and anhydrous THF (1.0 mL), and this suspension was later stirred at -10 °C. Then diazoacetamides **1** (0.15 mmol, 1.5 equiv.) and substituted alkynaldehydes **2** (0.12 mmol, 1.2 equiv.) dissolved in anhydrous PhCl (1.0 mL) were injected into the suspension over 1h *via* a syringe pump. After completion of the addition, stirring was continued at -10 °C for 8h. Then the mixture was filtered and concentrated under vacuum to give a residue which was subjected to ^{1}H NMR spectroscopy analysis for the determination of diastereoselectivity (*dr* value). Carful purification of the crude product by flash chromatography on silica gel (eluent: petroleum ether/EtOAc = 10/1~3/1) afforded pure products.

2.4.1 Asymmetric attempt of the three-component reaction under the catalysis of CPA

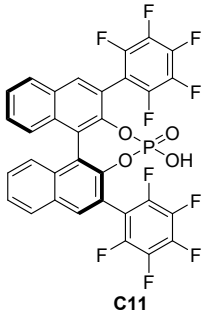




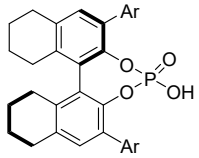
C1 R = 9-anthryl
C2 R = 2-naphthyl
C3 R = 9-phenanthryl
C4 R = 2,4,6-triisopropylC_6H_2
C5 R = $SiPh_3$
C6 R = 4-$CF_3C_6H_4$
C7 R = 4-$OMeC_6H_4$
C8 R = 4-$NO_2C_6H_4$
C9 R = 3,5-$(CF_3)_2C_6H_2$



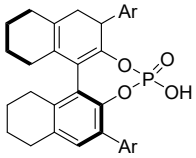
C10



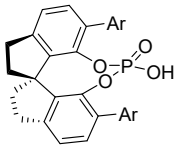
C11



C12 Ar=4-NO_2-C_6H_4



C13 Ar=1-pyrenyl



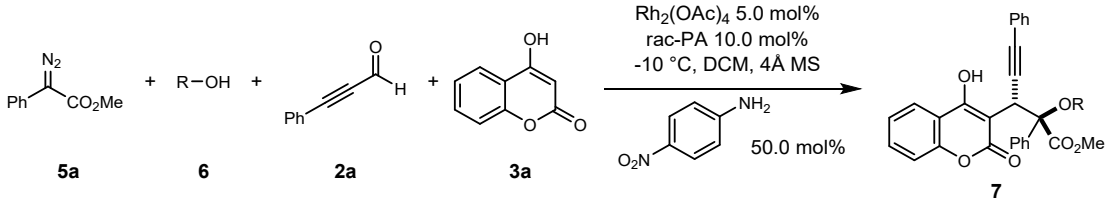
C14 Ar=$SiPh_3$

entry	CPA	yield%	*dr*	*ee*%（major）
1	**C1**	14	56:44	8
2	**C2**	20	74:26	4
3	**C3**	14	58:42	8
4	**C4**	15	67:33	0
5	**C5**	17	71:29	0
6	**C6**	16	77:23	4
7	**C7**	21	71:29	0
8	**C8**	30	75:25	8
9	**C9**	48	78:22	0
10	**C10**	61	77:23	0
11	**C11**	39	85:15	0
12	**C12**	47	74:26	0
13	**C13**	49	52:48	0
14	**C14**	42	85:15	0

The reactions were conducted on a 0.05 mmol scale: **1a**:**2a**:**3a** = 1.5:1.2:1.0, $[PdCl(\eta^3\text{-}C_3H_5)]_2$ (5.0 mol%), CPA (10 mol%), 4-$BrC_6H_4NH_2$ (50 mol%), 4Å MS (50 mg). **1a**, **2a** in 1.0 mL THF were added into a solution of **3a**, $[PdCl(\eta^3\text{-}C_3H_5)]_2$, CPA, 4-$BrC_6H_4NH_2$, and 50 mg 4Å MS in 1.0

mL THF *via* a syringe pump for 1 h, and the resulting mixture was stirred overnight. The yields were determined by ^{1}H NMR spectroscopy analyses using 1, 3, 5-trimethoxybenzene as an internal standard. *dr*. values were determined through ^{1}H NMR spectroscopy analyses, *ee* values were determined through HPLC analysis on a chiral stationary phase.

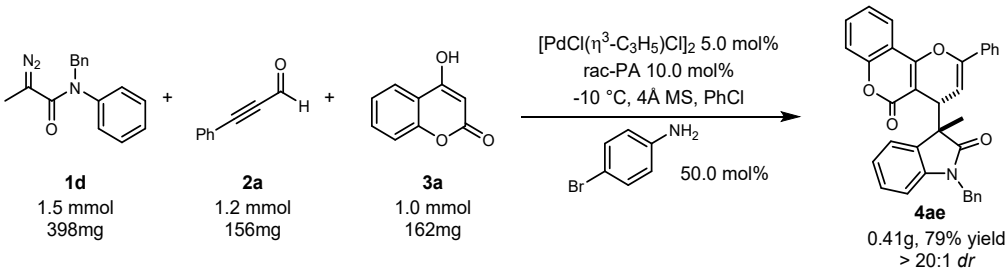
2.5 General procedure for the four-component reaction



5a **6** **2a** **3a** **7**

To an oven-dried test tube with a stirring bar were added substituted alcohols **6** (0.60 mmol, 3.0 equiv.), 4-hydroxycoumarin **3a** (0.20 mmol, 1.0 equiv.), $Rh_2(OAc)_4$ (4.4 mg, 5.0 mol%), rac-PA (7.0 mg, 10.0 mol%), 4-nitroaniline (0.10 mmol, 50.0 mol%), 4Å MS (100 mg) and anhydrous DCM (2.0 mL), and this suspension was later stirred at -10 °C. Then diazoacetates **5a** (0.30 mmol, 1.5 equiv.) and phenylpropiolaldehyde **2a** (0.60 mmol, 3.0 equiv.) dissolved in anhydrous DCM (2.0 mL) were injected into the suspension over 1h *via* a syringe pump. After completion of the addition, stirring was continued at -10 °C for 2h. Then the mixture was filtered and concentrated under vacuum to give a residue which was subjected to ^{1}H NMR spectroscopy analysis for the determination of diastereoselectivity (*dr* value). Carful purification of the crude product by flash chromatography on silica gel (eluent: petroleum ether/EtOAc = 10/1~3/1) afforded pure products.

2.6 General procedure for scale up



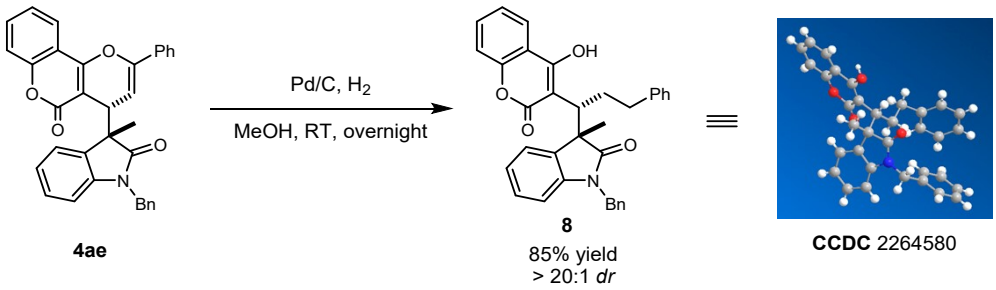
1d 1.5 mmol 398mg | **2a** 1.2 mmol 156mg | **3a** 1.0 mmol 162mg

4ae 0.41g, 79% yield > 20:1 *dr*

To an oven-dried test tube with a stirring bar were added 4-hydroxycoumarins **3a** (1.0 mmol, 1.0 equiv.), $[PdCl(\eta^3\text{-}C_3H_5)Cl]_2$ (18 mg, 5.0 mol%), rac-PA (35 mg, 10.0 mol%), 4-bromoaniline (0.05 mmol, 50.0 mol%), 4Å MS (500 mg) and anhydrous PhCl (10 mL), and this suspension was later stirred at -10 °C. Then *N*-benzyl-2-diazo-*N*-phenylpropanamide **1d** (1.5 mmol, 1.5 equiv.) and 3-phenylpropiolaldehyde **2a** (1.2 mmol, 1.2 equiv.) dissolved in anhydrous PhCl (10 mL) were injected into the suspension over 1h *via* a syringe pump. After completion of the addition, stirring was continued at -10 °C for 8h. Then the mixture was filtered and concentrated under vacuum to give a residue which was subjected to ^{1}H NMR spectroscopy analysis for the determination of diastereoselectivity (*dr* value). Carful purification of the crude product by flash chromatography on silica gel (eluent: petroleum ether/EtOAc = 10/1~3/1) afforded 0.41g pure product **4ae** in 79% yield

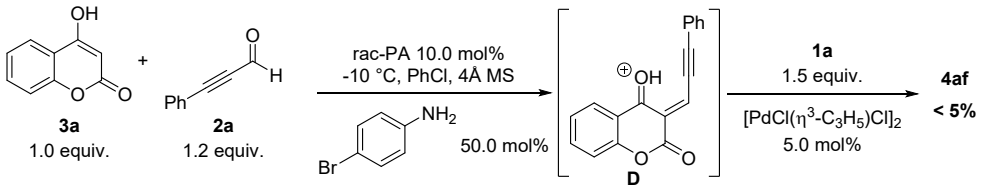
with > 20:1 *dr*.

2.7 General procedure for synthesis of 8

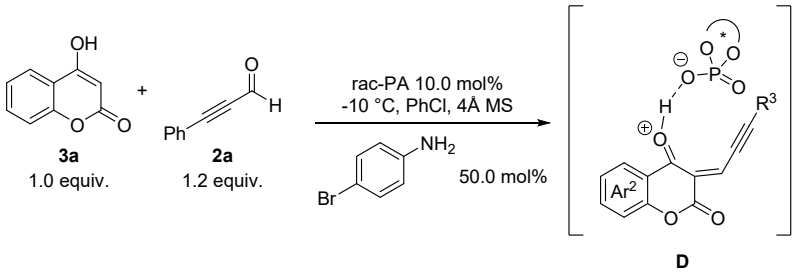


Following a modified procedure reported in the supporting information of Gong[3]. To a 25-mL oven-dried round-bottom flask containing a magnetic stirring bar, **4ae** (102.2 mg, 0.2 mmol) in 5 mL of MeOH, was added wet 10% Pd/C (38 mg, 40 mol %). The heterogeneous mixture was placed under 40-60 psi H_2 atmosphere and stirred overnight at room temperature. After the hydrogenolysis was complete, as indicated by TLC analysis, the mixture was then filtered through a pad of Celite to remove Pd/C, and the solid was washed with MeOH. The combined filtrate was concentrated under vacuum, and the residue was purified by silica chromatography column (eluent: Petroleum ether/EtOAc = 10:1 to 3:1) to give 87.6 mg of pure product **8** as white solid, 85% yield, > 20:1 *dr*.

3. Control experiments

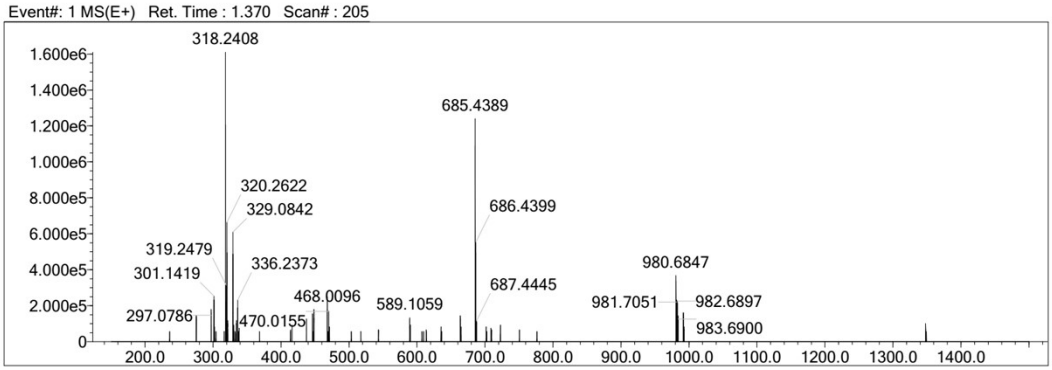


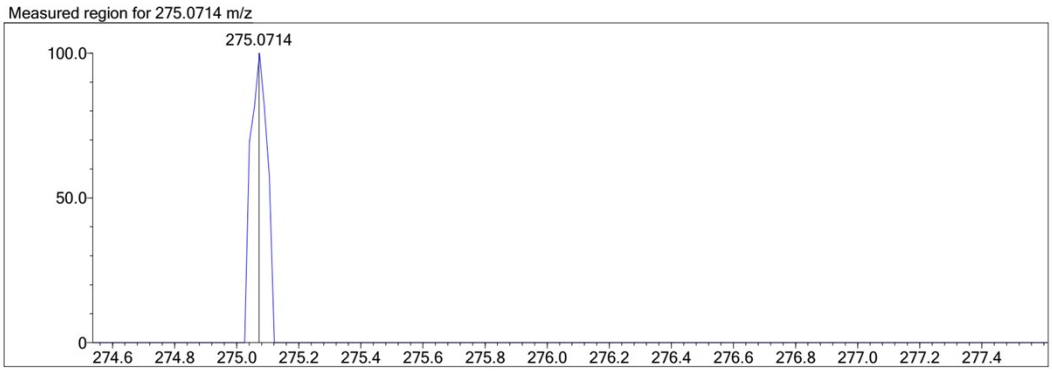
To a 10 mL oven-dried test tube equipped with a magnetic stirring bar were added 4-hydroxycoumarin **3a** (0.10 mmol, 1.0 equiv.), phenylpropiolaldehyde **2a** (0.12 mmol, 1.2 equiv.), rac-PA (3.5 mg, 10.0 mol%), 4-bromoaniline (0.05 mmol, 50.0 mol%), 4Å MS (50 mg) and anhydrous PhCl (1.0 mL). This suspension was firstly stirred at RT for 0.5h and later moved into -10 °C low-temperature reactor for another 0.5h. Then, $[PdCl(\eta^3\text{-}C_3H_5)Cl]_2$ (1.8 mg, 5.0 mol%) was added and diazoacetamides **1a** (0.15 mmol, 1.5 equiv.) dissolved in anhydrous PhCl (1.0 mL) were injected into the above suspension over 1h *via* a syringe pump. The resulting mixture was stirred at -10 °C until the diazo compound decomposed completely. TLC analysis showed that no desired product **4af** was produced and most of the diazo compound was converted into the C-H insertion product **11**.

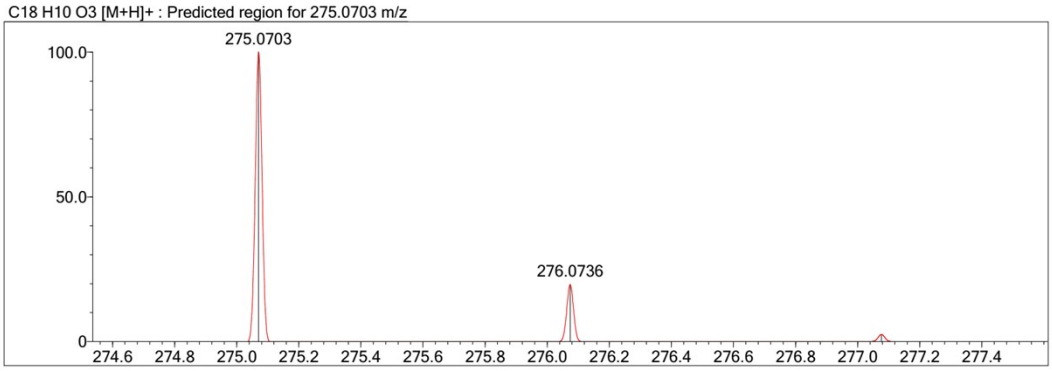


To a 10 mL oven-dried test tube equipped with a magnetic stirring bar were added 4-hydroxycoumarin **3a** (0.10 mmol, 1.0 equiv.), phenylpropiolaldehyde **2a** (0.12 mmol, 1.2 equiv.), rac-PA (3.5 mg, 10.0 mol%), 4-bromoaniline (0.05 mmol, 50.0 mol%), 4Å MS (50 mg) and anhydrous PhCl (1.0 mL). This suspension was stirred at -10 °C for 0.5h. Then, the reaction mixture was sent to test ESI-HRMS quickly and the result was showed below.

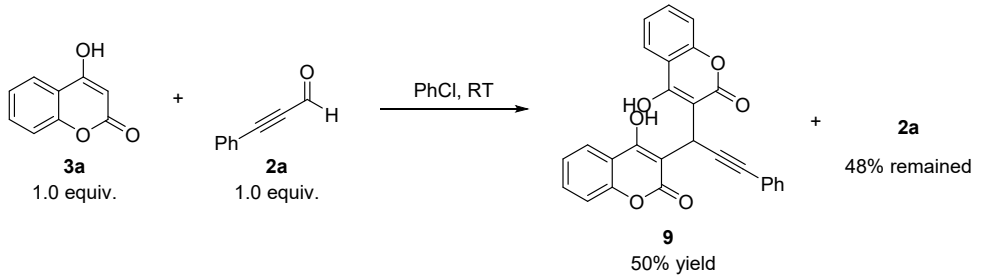
HRMS-ESI of Intermediate **D**: calcd. for $C_{18}H_{11}O_3$ $[M+H]^+$: 275.0703; found: 275.0714.



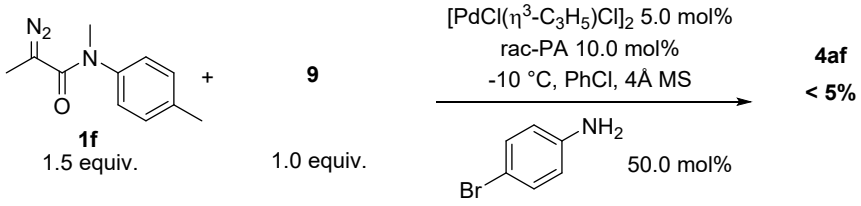




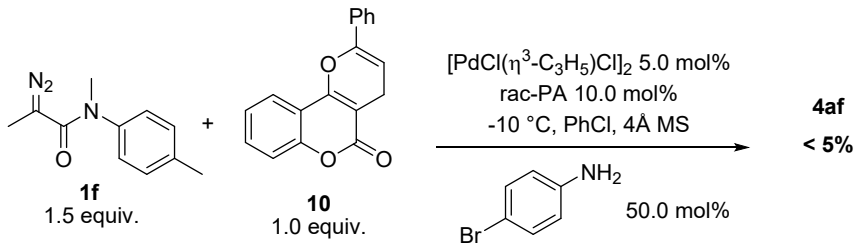
Rank	Score	Formula (M)	Ion	Meas. m/z	Pred. m/z	Df. (mDa)	Df. (ppm)	Iso	DBE
1	0.00	C18 H10 O3	[M+H]+	275.0714	275.0703	1.1	4.00	0.00	14.0



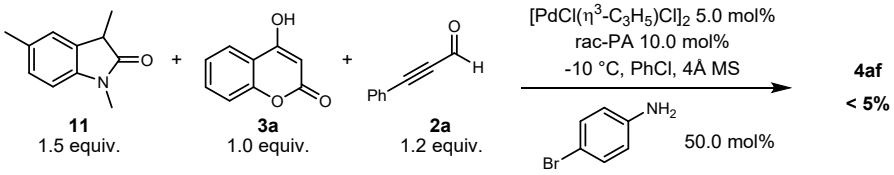
To a 10 mL oven-dried test tube equipped with a magnetic stirring bar were added 4-hydroxycoumarin **3a** (0.10 mmol, 1.0 equiv.), phenylpropiolaldehyde **2a** (0.12 mmol, 1.2 equiv.), and anhydrous PhCl (1.0 mL). This suspension was stirred at RT until the 4-hydroxycoumarin **3a** was consumed completely. Then, the reaction solvent PhCl was removed under vacuo and the crude reaction mixtures above were recorded with ^{1}H NMR spectra, showing that **9** was obtained in 50% yield and **2a** was remained of 48%.



To a 10 mL oven-dried test tube equipped with a magnetic stirring bar were added the adduct **9** (0.10 mmol, 1.0 equiv.), $[PdCl(\eta^3\text{-}C_3H_5)Cl]_2$ (1.8 mg, 5.0 mol%), rac-PA (3.5 mg, 10.0 mol%), 4-bromoaniline (0.05 mmol, 50.0 mol%), 4Å MS (50 mg) and anhydrous PhCl (1.0 mL), and this suspension was later stirred at -10 °C. Then diazoacetamides **1a** (0.15 mmol, 1.5 equiv.) dissolved in anhydrous PhCl (1.0 mL) was injected into the suspension over 1h *via* a syringe pump. After completion of the addition, stirring was continued at -10 °C for 8h. TLC analysis and crude ^{1}H NMR showed that no desired product **4af** was detected and only the C-H insertion product **5** derived from diazoacetamides **1a** occurred.



To a 10 mL oven-dried test tube equipped with a magnetic stirring bar were added the adduct **10** (0.10 mmol, 1.0 equiv.), $[PdCl(\eta^3\text{-}C_3H_5)Cl]_2$ (1.8 mg, 5.0 mol%), rac-PA (3.5 mg, 10.0 mol%), 4-bromoaniline (0.05 mmol, 50.0 mol%), 4Å MS (50 mg) and anhydrous PhCl (1.0 mL), and this suspension was later stirred at -10 °C. Then diazoacetamides **1a** (0.15 mmol, 1.5 equiv.) dissolved in anhydrous PhCl (1.0 mL) was injected into the suspension over 1h *via* a syringe pump. After completion of the addition, stirring was continued at -10 °C for 8h. TLC analysis and crude ^{1}H NMR showed that no desired product **4af** was detected and only the C-H insertion product **5** derived from diazoacetamides **1a** occurred.



To a 10 mL oven-dried test tube equipped with a magnetic stirring bar were added 4-hydroxycoumarin **3a** (0.10 mmol, 1.0 equiv.), $[PdCl(\eta^3\text{-}C_3H_5)Cl]_2$ (1.8 mg, 5.0 mol%), rac-PA (3.5 mg, 10.0 mol%), 4-bromoaniline (0.05 mmol, 50.0 mol%), 4Å MS (50 mg) and anhydrous PhCl (1.0 mL), and this suspension was later stirred at -10 °C. Then the C-H insertion product **11** derived from diazoacetamides **1a** (0.15 mmol, 1.5 equiv.) and phenylpropiolaldehyde **2a** (0.12 mmol, 1.2 equiv.) dissolved in anhydrous PhCl (1.0 mL) were injected into the suspension over 1h *via* a syringe pump. After completion of the addition, stirring was continued at -10 °C for 8h. TLC analysis and crude ^{1}H NMR showed that most of the material **11** remained intact and no desired product **4af** was detected.

4. General Procedure for the *in vitro* Anti-tumor Activity Study

Cell viability was measured by CCK-8 assay

Human cancer cell line HCT116 was obtained from Cell Cook. Cells were cultured in RPMI1640 medium containing 10% fetal bovine serum and 1% penicillin/streptomycin (Gibco) in a humidified incubator containing 5% CO_2 at 37 °C. Human cancer cell lines MCF-7 was obtained from Procell and cells were cultured in MEM medium containing 10% fetal bovine serum, 1% penicillin/streptomycin (Gibco) and 0.01 mg/mL insulin (Procell) in a humidified incubator containing 5% CO_2 at 37 °C. For cell viability, cells were seeded in 96-well plates at 5000 cells per well. After 24 hours, serially diluted compounds were added and cells were cultured for another 48 hours. Cell viability was measured using a Cell Counting Kit-8 (CCK-8) assay according to the manufacturer's instructions (Yeasen Biotechnology, China).

These representative products **4ab**, **4ae**, **4af**, **4bc**, **4be**, **4cc**, **4cd**, and **4cf** on cell viability was evaluated *via* CCK8 assay in HCT116 (colon cancer), MCF-7 (breast cancer) and SJSA-1 (osteosarcoma) human cancer cell lines, and the *in vitro* anti-tumor activity results have been listed in **Table S1**.

Table S1. Anti-tumor Activity Study of Compounds **4ab**, **4ae**, **4af**, **4bc**, **4be**, **4cc**, **4cd**, and **4cf** (Inhibitory rate at 20 μM)

Compound	Cancer cell line		
	HCT-116	MCF-7	SJSA-1
	Inhibition (%)	Inhibition (%)	Inhibition (%)
4ab	90.33 ± 0.98 IC_{50}: 9.988 ± 0.590 μM	64.87 ± 1.35	79.1 ± 2.47
4ae	15.32 ± 4.33	31.21 ± 2.48	78.14 ± 2.11
4af	91.84 ± 0.04 IC_{50}: 10.71 ± 1.273 μM	70.01 ± 2.31	67.42 ± 1.8
4bc	36.6 ± 6.14	78.38 ± 1.46	30.56 ± 1.94
4be	<1	57.98 ± 2.54	89.23 ± 0.28
4cc	5.68 ± 3.22	61.27 ± 2.39	45.99 ± 6.38
4cd	41.55 ± 4.21	54.44 ± 3.98	23.88 ± 3.01
4cg	42.47 ± 4.01	80.35 ± 0.43	32.6± 4.36

5. References

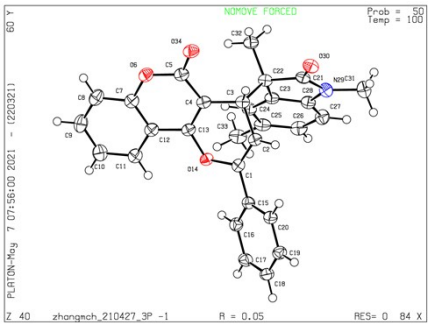
[1] X. Feng, Z. Qin, X. Cheng, D. Liu, Y. Peng, H. Huang, B. Song, J. Bian and Z. Li, *J Org Chem*. **2021**, *86*, 12537-12548.

[2] a) N. Cabrera-Lobera, M. T. Quiros, W. W. Brennessel, M. L. Neidig, E. Bunuel and D. J. Cardenas, *Org Lett*. **2019**, *21*, 6552-6556; b) Ż. A. Ignatiuk, M. J. Janicki, R. W. Góra, K. Konieczny and R. Kowalczyk, *Advanced Synthesis & Catalysis*. **2019**, *361*, 1108-1116; c) M. Zhang, S. Yu, R. Hua, D. Zhang, H. Qiu and W. Hu, *Org Biomol Chem*. **2023**, *21*, 783-788.

[3] Y. H. Wen, F. Yang, S. Li, X. Yao, J. Song and L. Z. Gong, *J Am Chem Soc*. **2023**.

7. Single crystal X-ray diffraction data

Crystallographic Data for 4af-major.



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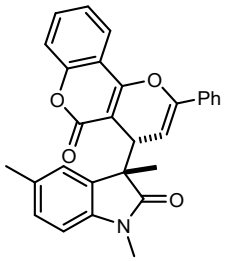


4af-major
CCDC: 2264577

Datablock: zhangmch_210427_3

Bond precision: C-C = 0.0020 A Wavelength=1.54184

Cell: a=10.0658(1) b=10.9123(2) c=11.3400(2)
alpha=112.602(1) beta=91.909(1) gamma=104.218(1)
Temperature: 100 K

	Calculated	Reported
Volume	1103.30(3)	1103.30(3)
Space group	P -1	P -1
Hall group	-P 1	-P 1
Moiety formula	C29 H23 N O4	C29 H23 N O4
Sum formula	C29 H23 N O4	C29 H23 N O4
Mr	449.48	449.48
Dx,g cm-3	1.353	1.353
Z	2	2
Mu (mm-1)	0.727	0.727
F000	472.0	472.0
F000'	473.44	
h,k,lmax	12,13,14	12,13,14
Nref	4686	4553
Tmin,Tmax	0.865,0.964	0.724,1.000
Tmin'	0.865	

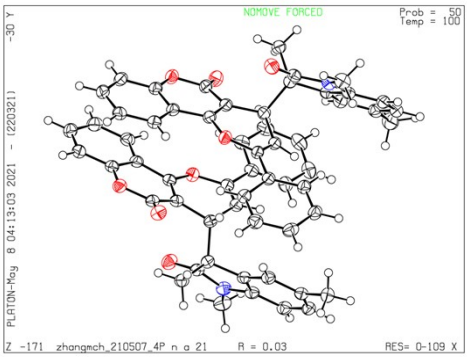
Correction method= # Reported T Limits: Tmin=0.724 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 0.972 Theta(max)= 77.040

R(reflections)= 0.0496(3918) wR2(reflections)= 0.1447(4553)

S = 1.036 Npar= 314

Crystallographic Data for 4af-minor.



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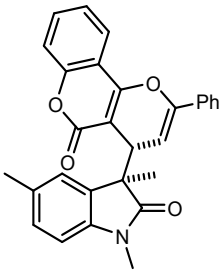


4af-minor
CCDC: 2264587

Datablock: zhangmch_210507_4

Bond precision: C-C = 0.0030 A Wavelength=1.54184

Cell: a=20.38188(12) b=10.28920(5) c=21.05443(11)
alpha=90 beta=90 gamma=90
Temperature: 100 K

	Calculated	Reported
Volume	4415.39(4)	4415.39(4)
Space group	P n a 21	P n a 21
Hall group	P 2c -2n	P 2c -2n
Moiety formula	C29 H23 N O4	C29 H23 N O4
Sum formula	C29 H23 N O4	C29 H23 N O4
Mr	449.48	449.48
Dx,g cm-3	1.352	1.352
Z	8	8
Mu (mm-1)	0.727	0.727
F000	1888.0	1888.0
F000'	1893.77	
h,k,lmax	25,13,26	25,13,26
Nref	9319[4789]	9215
Tmin,Tmax	0.840,0.865	0.566,1.000
Tmin'	0.804	

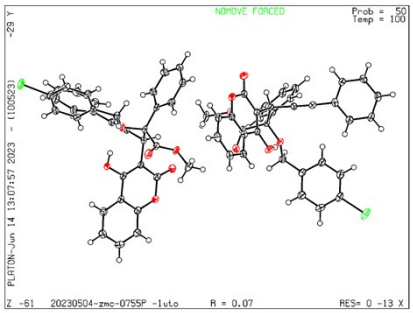
Correction method= # Reported T Limits: Tmin=0.566 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 1.92/0.99 Theta(max)= 77.014

R(reflections)= 0.0297(9041) wR2(reflections)= 0.0766(9215)

S = 1.067 Npar= 620

Crystallographic Data for 7a.



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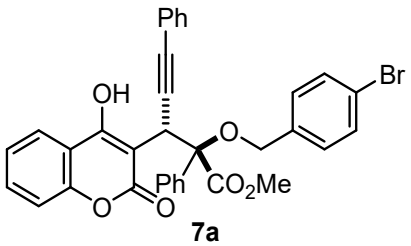


7a

CCDC: 2269933

Datablock: 20230504-zmc-0755-3_auto

Bond precision: C-C = 0.0080 A Wavelength=1.54184

Cell: a=8.6733(3) b=17.8722(4) c=19.6955(5)
alpha=66.991(2) beta=86.552(2) gamma=87.993(2)
Temperature: 100 K

	Calculated	Reported
Volume	2804.82(14)	2804.82(14)
Space group	P -1	P -1
Hall group	-P 1	-P 1
Moiety formula	C34 H25 Br O6	2(C34 H25 Br O6)
Sum formula	C34 H25 Br O6	C68 H50 Br2 O12
Mr	609.44	1218.90
Dx,g cm-3	1.443	1.443
Z	4	2
Mu (mm-1)	2.381	2.381
F000	1248.0	1248.0
F000'	1248.80	
h,k,lmax	10,21,23	10,21,23
Nref	9913	9853
Tmin,Tmax	0.735,0.788	0.487,1.000
Tmin'	0.666	

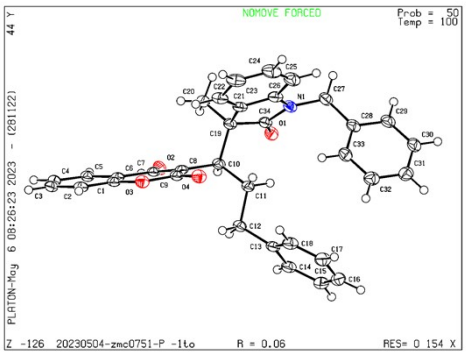
Correction method= # Reported T Limits: Tmin=0.487 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 0.994 Theta(max)= 66.597

R(reflections)= 0.0746(8568) wR2(reflections)= 0.2223(9853)

S = 1.096 Npar= 743

Crystallographic Data for 8.



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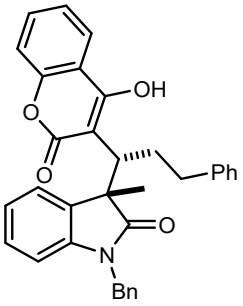


8
CCDC: 2264580

Datablock: 20230504-zmc0751-1_auto

Bond precision: C-C = 0.0024 A Wavelength=1.54184

Cell: a=8.5398(3) b=10.1848(5) c=16.9463(5)
alpha=95.502(3) beta=95.621(3) gamma=113.780(4)
Temperature: 100 K

	Calculated	Reported
Volume	1327.39(10)	1327.39(10)
Space group	P -1	P -1
Hall group	-P 1	-P 1
Moiety formula	C34 H29 N O4	C34 H29 N O4
Sum formula	C34 H29 N O4	C34 H29 N O4
Mr	515.58	515.58
Dx,g cm-3	1.290	1.290
Z	2	2
Mu (mm-1)	0.673	0.673
F000	544.0	544.0
F000'	545.61	
h,k,lmax	10,12,20	10,12,20
Nref	4747	4700
Tmin,Tmax	0.886,0.935	0.535,1.000
Tmin'	0.874	

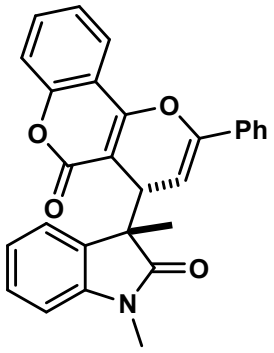
Correction method= # Reported T Limits: Tmin=0.535 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 0.990 Theta(max)= 67.073

R(reflections)= 0.0619(4201) wR2(reflections)= 0.1720(4700)

S = 1.055 Npar= 354

8. Analytical data of products



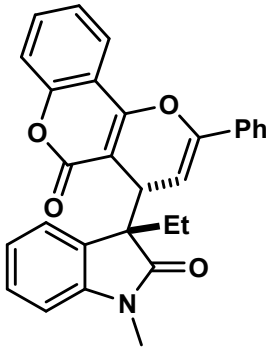
1,3-dimethyl-3-(5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4aa: 27.4 mg, light yellow solid, 63% yield, 94:6 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.85 (d, *J* = 7.1 Hz, 1H), 7.65 – 7.60 (m, 1H), 7.44 (d, *J* = 8.3 Hz, 1H), 7.38 – 7.32 (m, 6H), 7.17 (t, *J* = 7.5 Hz, 1H), 6.93 (d, *J* = 7.3 Hz, 1H), 6.84 (t, *J* = 7.5 Hz, 1H), 6.75 (d, *J* = 7.7 Hz, 1H), 5.53 (d, *J* = 5.9 Hz, 1H), 4.20 (d, *J* = 5.9 Hz, 1H), 3.26 (s, 3H), 1.49 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.8, 162.6, 159.1, 152.9, 151.1, 143.7, 132.5, 132.4, 131.6, 129.4, 128.7, 128.5, 124.9, 124.4, 123.2, 122.6, 122.3, 117.1, 114.7, 107.9, 100.9, 99.5, 54.7, 37.5, 26.4, 19.7.

HRMS-ESI: calcd. for $C_{28}H_{21}NO_4Na$ $[M+Na]^+$: 458.1363; found: 458.1342.



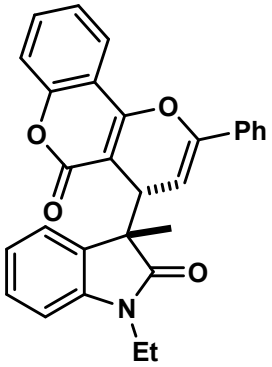
3-ethyl-1-methyl-3-(5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4ab: 31.4 mg, white solid, 70% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 (d, *J* = 7.7 Hz, 1H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.43 (d, *J* = 8.1 Hz, 1H), 7.37 – 7.32 (m, 6H), 7.17 (t, *J* = 7.2 Hz, 1H), 6.88 – 6.82 (m, 2H), 6.73 (d, *J* = 7.6 Hz, 1H), 5.53 (d, *J* = 5.5 Hz, 1H), 4.22 (d, *J* = 5.2 Hz, 1H), 3.26 (s, 3H), 2.37 – 2.28 (m, 1H), 2.04 – 1.95 (m, 1H), 0.44 (t, *J* = 6.9 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.0, 162.6, 159.2, 152.9, 151.0, 144.7, 132.4, 129.4, 129.3, 128.6, 128.5, 124.9, 124.4, 123.3, 122.6, 122.3, 117.1, 114.7, 107.8, 101.0, 99.5, 60.9, 37.7, 26.5, 26.2, 9.1.

HRMS-ESI: calcd. for $C_{29}H_{23}NO_4Na$ $[M+Na]^+$: 472.1519; found: 472.1502.



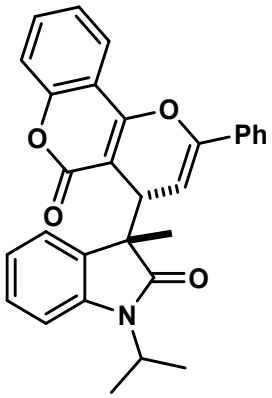
1-ethyl-3-methyl-3-(5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4ac: 31.4 mg, light yellow solid, 70% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.85 (d, *J* = 7.3 Hz, 1H), 7.64 – 7.60 (m, 1H), 7.43 (d, *J* = 8.3 Hz, 1H), 7.38 – 7.31 (m, 6H), 7.17 (t, *J* = 7.6 Hz, 1H), 6.94 (d, *J* = 7.3 Hz, 1H), 6.83 (t, *J* = 7.5 Hz, 1H), 6.75 (d, *J* = 7.8 Hz, 1H), 5.56 (d, *J* = 5.9 Hz, 1H), 4.22 (d, *J* = 5.9 Hz, 1H), 3.90 (dq, *J* = 14.4, 7.2 Hz, 1H), 3.67 (dq, *J* = 14.3, 7.1 Hz, 1H), 1.48 (s, 3H), 1.23 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.4, 162.6, 159.2, 152.9, 151.0, 142.7, 132.4, 132.3, 131.9, 129.4, 128.6, 128.4, 124.8, 124.4, 123.4, 122.6, 122.1, 117.1, 114.7, 108.0, 100.8, 99.6, 54.5, 37.5, 34.7, 19.8, 12.9.

HRMS-ESI: calcd. for $C_{29}H_{23}NO_4Na$ $[M+Na]^+$: 472.1519; found: 472.1500.



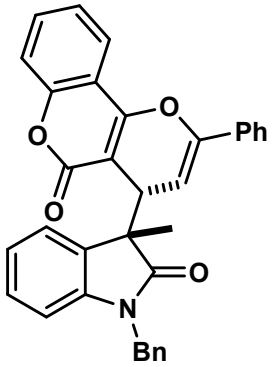
1-isopropyl-3-methyl-3-(5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4ad: 32.4 mg, white solid, 70% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.8 Hz, 1H), 7.62 (t, *J* = 7.7 Hz, 1H), 7.43 (d, *J* = 8.3 Hz, 1H), 7.38 – 7.31 (m, 6H), 7.14 (t, *J* = 7.7 Hz, 1H), 6.94 (d, *J* = 7.3 Hz, 1H), 6.90 (d, *J* = 7.8 Hz, 1H), 6.82 (t, *J* = 7.4 Hz, 1H), 5.56 (d, *J* = 5.8 Hz, 1H), 4.72 – 4.62 (m, 1H), 4.21 (d, *J* = 5.8 Hz, 1H), 1.47 (s, 3H), 1.45 (d, *J* = 7.1 Hz, 3H), 1.42 (d, *J* = 7.0 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.4, 162.6, 159.2, 152.9, 150.9, 142.3, 132.4, 132.3, 132.1, 129.3, 128.6, 128.1, 124.7, 124.4, 123.5, 122.6, 121.7, 117.0, 114.7, 109.7, 100.9, 99.7, 54.3, 43.8, 37.7, 20.0, 19.6, 19.5.

HRMS-ESI: calcd. for $C_{30}H_{25}NO_4Na$ $[M+Na]^+$: 486.1676; found: 486.1673.



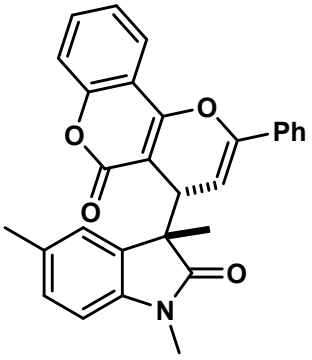
1-benzyl-3-methyl-3-(5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4ae: 40.9 mg, white solid, 80% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.85 (d, *J* = 7.7 Hz, 1H), 7.62 (t, *J* = 7.7 Hz, 1H), 7.43 (d, *J* = 8.3 Hz, 1H), 7.39 – 7.33 (m, 3H), 7.32 – 7.28 (m, 1H), 7.27 – 7.19 (m, 5H), 7.13 (d, *J* = 7.5 Hz, 2H), 7.07 (t, *J* = 7.7 Hz, 1H), 6.95 (d, *J* = 7.3 Hz, 1H), 6.81 (t, *J* = 7.5 Hz, 1H), 6.69 (d, *J* = 7.8 Hz, 1H), 5.49 (d, *J* = 5.9 Hz, 1H), 5.17 (d, *J* = 15.4 Hz, 1H), 4.69 (d, *J* = 15.4 Hz, 1H), 4.31 (d, *J* = 5.8 Hz, 1H), 1.54 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 179.0, 162.6, 159.3, 152.9, 151.1, 142.8, 136.2, 132.5, 132.3, 131.8, 129.3, 128.9, 128.6, 128.3, 127.9, 127.8, 125.0, 124.4, 123.2, 122.6, 122.4, 117.1, 114.7, 108.9, 100.8, 99.8, 54.7, 44.1, 37.5, 20.5.

HRMS-ESI: calcd. for $C_{34}H_{25}NO_4Na$ $[M+Na]^+$: 534.1676; found: 534.1651.



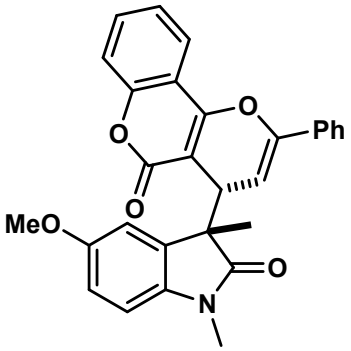
1,3,5-trimethyl-3-(5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4af: 37.3 mg, light yellow solid, 83% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 (d, *J* = 7.5 Hz, 1H), 7.63 (t, *J* = 7.4 Hz, 1H), 7.44 (d, *J* = 8.3 Hz, 1H), 7.38 – 7.33 (m, 6H), 6.96 (d, *J* = 7.7 Hz, 1H), 6.68 (s, 1H), 6.61 (d, *J* = 7.8 Hz, 1H), 5.53 (d, *J* = 5.9 Hz, 1H), 4.19 (d, *J* = 5.9 Hz, 1H), 3.23 (s, 3H), 2.05 (s, 3H), 1.48 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.7, 162.6, 159.1, 152.8, 150.9, 141.3, 132.41, 132.40, 131.6, 131.5, 129.4, 128.63, 128.56, 124.9, 124.4, 124.3, 122.3, 117.1, 114.7, 107.5, 100.8, 99.6, 54.8, 37.5, 26.3, 21.1, 19.6.

HRMS-ESI: calcd. for $C_{29}H_{23}NO_4Na$ $[M+Na]^+$: 472.1519; found: 472.1496.



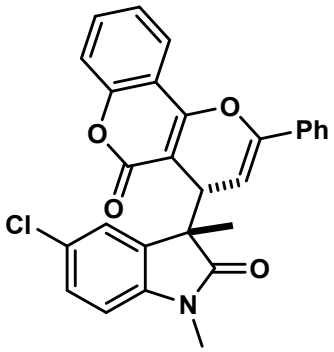
5-methoxy-1,3-dimethyl-3-(5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4ag: 30.2 mg, red brown solid, 65% yield, 89:11 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86 (d, *J* = 7.8 Hz, 1H), 7.62 (t, *J* = 7.8 Hz, 1H), 7.44 (d, *J* = 8.3 Hz, 1H), 7.38 – 7.33 (m, 6H), 6.72 – 6.69 (m, 1H), 6.66 – 6.63 (m, 1H), 6.53 – 6.50 (m, 1H), 5.54 (d, *J* = 5.9 Hz, 1H), 4.22 (d, *J* = 5.9 Hz, 1H), 3.43 (s, 3H), 3.24 (s, 3H), 1.48 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.5, 162.6, 159.2, 155.7, 152.9, 151.0, 137.2, 132.8, 132.5, 132.4, 129.5, 128.7, 124.9, 124.5, 122.5, 117.1, 114.7, 113.7, 110.1, 108.3, 100.8, 99.6, 55.6, 55.1, 37.5, 26.4, 19.9.

HRMS-ESI: calcd. for $C_{29}H_{23}NO_5Na$ $[M+Na]^+$: 488.1468; found: 488.1449.



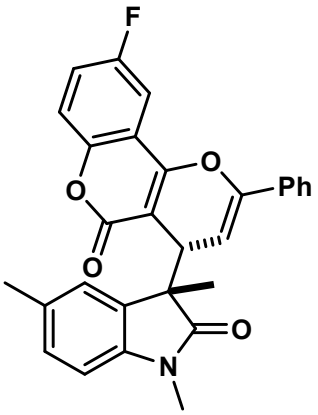
5-chloro-1,3-dimethyl-3-(5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4ah: 23.5 mg, light yellow solid, 50% yield, 83:17 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.89 (d, *J* = 7.8 Hz, 1H), 7.64 (t, *J* = 7.7 Hz, 1H), 7.44 (d, *J* = 8.3 Hz, 1H), 7.40 – 7.34 (m, 6H), 7.15 (dd, *J* = 8.2, 1.8 Hz, 1H), 6.90 (d, *J* = 1.6 Hz, 1H), 6.66 (d, *J* = 8.3 Hz, 1H), 5.53 (d, *J* = 5.9 Hz, 1H), 4.19 (d, *J* = 5.9 Hz, 1H), 3.24 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.3, 162.5, 159.4, 152.9, 151.3, 142.3, 133.4, 132.6, 132.2, 129.6, 128.8, 128.3, 127.7, 124.9, 124.6, 123.8, 122.6, 117.1, 114.5, 108.8, 100.4, 99.1, 54.9, 37.5, 26.5, 19.3.

HRMS-ESI: calcd. for $C_{28}H_{20}ClNO_4Na$ $[M+Na]^+$: 492.0973; found: 492.0960.



3-(9-fluoro-5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)-1,3,5-trimethylindolin-2-one

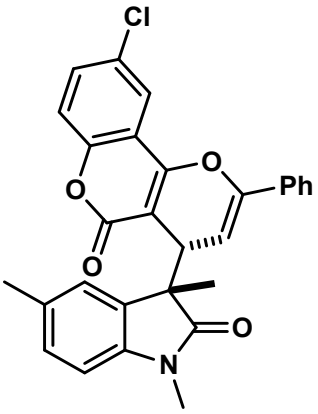
4ba: 29.0 mg, light yellow solid, 62% yield, 76:24 *dr* as determined by crude ^{1}H spectroscopy, but 85:15 *dr* after recrystallization.

^{1}H NMR (500 MHz, $CDCl_3$) (two diastereomers) δ 7.60 (dd, *J* = 8.1, 2.8 Hz, 1H), 7.48 (dd, *J* = 8.0, 2.8 Hz, 1H), 7.43 (dd, *J* = 9.0, 4.2 Hz, 1H), 7.40 – 7.37 (m, 1H), 7.37 – 7.31 (m, 6H), 7.30 – 7.27 (m, 1H), 5.54 (d, *J* = 5.9 Hz, 1H), 5.30 (d, *J* = 2.0 Hz, 1H), 4.16 (d, *J* = 5.9 Hz, 1H), 4.13 (d, *J* = 5.7 Hz, 1H), 3.23 (s, 3H), 3.02 (s, 1H), 2.35 (s, 1H), 2.10 (s, 3H), 1.48 (s, 1H), 1.46 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) (two diastereomers) δ 178.6, 162.2, 159.0 (d, *J* = 244.7 Hz), 158.3 (d, *J* = 2.7 Hz), 151.0, 148.98, 148.97, 148.94, 141.4, 132.7, 132.5, 132.4, 132.2, 131.7, 131.5, 129.64, 129.56, 128.8, 128.74, 128.71, 125.1, 124.9, 124.2, 123.7, 119.9 (d, *J* = 24.5 Hz), 118.9 (d, *J* = 8.3 Hz), 115.6 (d, *J* = 8.9 Hz), 108.1 (d, *J* = 25.4 Hz), 107.7, 107.6, 101.9, 101.3, 99.7, 99.6, 54.7, 54.0, 37.6, 26.4, 26.2, 21.3, 21.1, 19.8, 19.6.

^{19}F NMR (376 MHz, $CDCl_3$) (two diastereomers) δ -116.66, -117.08.

HRMS-ESI: calcd. for $C_{29}H_{22}FNO_4Na$ $[M+Na]^+$: 490.1425; found: 490.1415.



3-(9-chloro-5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)-1,3,5-trimethylindolin-2-one

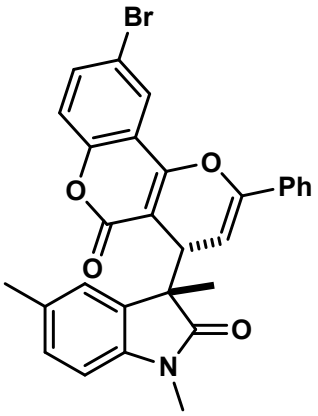
4bb: 34.3 mg, yellow solid, 71% yield, 75:25 *dr* as determined by crude ^{1}H spectroscopy, but only one isomer after recrystallization.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.76 (d, *J* = 2.2 Hz, 1H), 7.57 (dd, *J* = 8.8, 2.2 Hz, 1H), 7.41 – 7.33 (m, 6H), 6.98 (d, *J* = 7.8 Hz, 1H), 6.68 (s, 1H), 6.63 (d, *J* = 7.8 Hz, 1H), 5.54 (d, *J* = 5.9 Hz, 1H), 4.15 (d, *J* = 5.9 Hz, 1H), 3.22 (s, 3H), 2.11 (s, 3H), 1.46 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.5, 162.0, 158.0, 151.2, 151.1, 141.3, 132.4, 132.2, 131.7, 131.5, 130.0, 129.6, 128.8, 128.7, 125.0, 124.2, 121.8, 118.7, 115.9, 107.7, 101.9, 99.7, 54.6, 37.6, 26.4, 21.2,

19.5.

HRMS-ESI: calcd. for $C_{29}H_{22}ClNO_4Na$ $[M+Na]^+$: 506.1130; found: 506.1105.



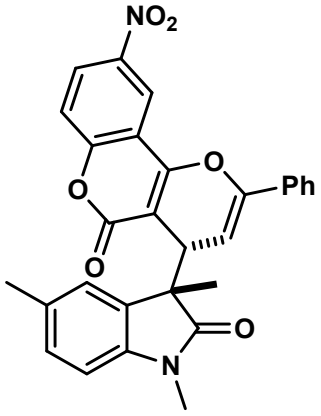
3-(9-bromo-5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)-1,3,5-trimethylindolin-2-one

4bc: 35.8 mg, yellow solid, 68% yield, 74:26 *dr* as determined by crude ^{1}H spectroscopy, but 86:14 *dr* after recrystallization.

^{1}H NMR (500 MHz, $CDCl_3$) (two diastereomers) δ 8.04 (s, 1H), 7.91 (s, 1H), 7.71 (d, *J* = 8.8 Hz, 1H), 7.65 (d, *J* = 8.8 Hz, 1H), 7.43 – 7.31 (m, 7H), 7.25 (d, *J* = 9.2 Hz, 1H), 7.19 (s, 1H), 7.10 (d, *J* = 7.7 Hz, 1H), 6.98 (d, *J* = 7.8 Hz, 1H), 6.71 (d, *J* = 8.0 Hz, 1H), 6.68 (s, 1H), 6.63 (d, *J* = 7.8 Hz, 1H), 5.54 (d, *J* = 5.9 Hz, 1H), 5.28 (d, *J* = 5.6 Hz, 1H), 4.15 (d, *J* = 5.9 Hz, 1H), 4.12 (d, *J* = 5.6 Hz, 1H), 3.22 (s, 3H), 3.02 (s, 1H), 2.36 (s, 1H), 2.11 (s, 3H), 1.46 (s, 1H), 1.46 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) (two diastereomers) δ 178.5, 161.9, 157.8, 151.7, 151.6, 151.1, 150.3, 141.3, 135.2, 135.0, 132.4, 132.2, 131.7, 131.5, 129.7, 129.6, 128.82, 128.76, 128.7, 125.4, 125.2, 125.0, 124.8, 124.2, 123.7, 118.9, 118.6, 117.3, 117.2, 116.4, 116.3, 107.7, 107.6, 101.9, 101.3, 99.7, 99.6, 54.6, 54.0, 37.6, 37.5, 26.4, 26.2, 21.3, 21.2, 19.8, 19.5.

HRMS-ESI: calcd. for $C_{29}H_{22}BrNO_4Na$ $[M+Na]^+$: 550.0624; found: 550.0607.



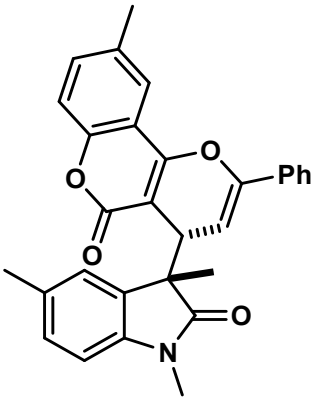
1,3,5-trimethyl-3-(9-nitro-5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4bd: 44.5 mg, red brown solid, 90% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.71 (s, 1H), 8.49 (d, *J* = 8.1 Hz, 1H), 7.57 (d, *J* = 9.0 Hz, 1H), 7.43 – 7.39 (m, 5H), 7.02 (d, *J* = 7.7 Hz, 1H), 6.74 (s, 1H), 6.68 (d, *J* = 7.9 Hz, 1H), 5.60 (d, *J* = 5.7 Hz, 1H), 4.12 (d, *J* = 5.7 Hz, 1H), 3.23 (s, 3H), 2.13 (s, 3H), 1.45 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.4, 161.0, 157.6, 156.1, 151.4, 144.2, 141.3, 131.84, 131.79, 131.4, 129.9, 129.0, 128.9, 127.1, 125.0, 124.0, 118.7, 118.4, 115.1, 107.9, 102.8, 99.5, 54.3, 37.6, 26.4, 21.2, 19.2.

HRMS-ESI: calcd. for $C_{29}H_{22}N_2O_6Na$ $[M+Na]^+$: 517.1370; found: 517.1363.

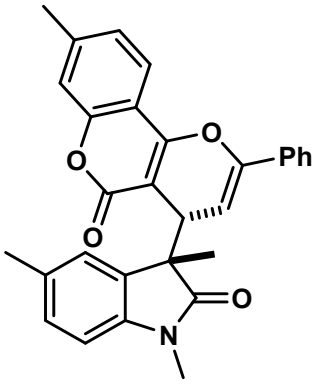


1,3,5-trimethyl-3-(9-methyl-5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one 4be: 13.9 mg, yellow solid, 30% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 (s, 1H), 7.42 (d, *J* = 8.2 Hz, 1H), 7.36 – 7.31 (m, 6H), 6.95 (d, *J* = 7.7 Hz, 1H), 6.67 (s, 1H), 6.61 (d, *J* = 7.8 Hz, 1H), 5.51 (d, *J* = 5.9 Hz, 1H), 4.18 (d, *J* = 5.9 Hz, 1H), 3.22 (s, 3H), 2.47 (s, 3H), 2.06 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.7, 162.8, 159.1, 151.0, 150.9, 141.3, 134.2, 133.4, 132.6, 131.59, 131.57, 129.4, 128.6, 128.5, 125.0, 124.4, 121.9, 116.8, 114.4, 107.5, 100.7, 99.7, 54.8, 37.5, 26.3, 21.2, 21.1, 19.7.

HRMS-ESI: calcd. for $C_{30}H_{25}NO_4Na$ $[M+Na]^+$: 486.1676; found: 486.1654.

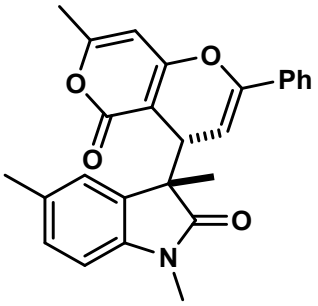


1,3,5-trimethyl-3-(8-methyl-5-oxo-2-phenyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one 4bf: 29.2 mg, yellow solid, 63% yield, 91:9 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, *J* = 8.0 Hz, 1H), 7.35 – 7.30 (m, 5H), 7.24 (s, 1H), 7.17 (d, *J* = 8.0 Hz, 1H), 6.95 (d, *J* = 7.8 Hz, 1H), 6.67 (s, 1H), 6.60 (d, *J* = 7.8 Hz, 1H), 5.51 (d, *J* = 5.9 Hz, 1H), 4.18 (d, *J* = 5.9 Hz, 1H), 3.23 (s, 3H), 2.51 (s, 3H), 2.06 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.8, 162.9, 159.4, 153.0, 150.8, 143.7, 141.3, 132.5, 131.61, 131.56, 129.3, 128.6, 128.5, 125.6, 124.9, 124.3, 122.0, 117.2, 112.2, 107.5, 99.8, 99.7, 54.9, 37.5, 26.3, 22.0, 21.1, 19.7.

HRMS-ESI: calcd. for $C_{30}H_{25}NO_4Na$ $[M+Na]^+$: 486.1676; found: 486.1657.



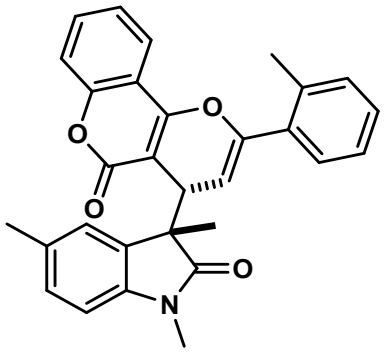
1,3,5-trimethyl-3-(7-methyl-5-oxo-2-phenyl-4*H*,5*H*-pyrano[4,3-*b*]pyran-4-yl)indolin-2-one

4bg: 23.1 mg, light yellow solid, 56% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 – 7.25 (m, 3H), 7.23 – 7.19 (m, 2H), 6.96 (d, *J* = 7.8 Hz, 1H), 6.78 (s, 1H), 6.60 (d, *J* = 7.9 Hz, 1H), 5.96 (s, 1H), 5.40 (d, *J* = 5.9 Hz, 1H), 4.05 (d, *J* = 5.9 Hz, 1H), 3.21 (s, 3H), 2.34 (s, 3H), 2.25 (s, 3H), 1.46 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.9, 164.4, 163.9, 161.9, 150.6, 141.3, 132.4, 131.8, 131.5, 129.2, 128.5, 124.8, 124.3, 107.5, 99.7, 99.1, 98.0, 55.0, 37.0, 26.3, 21.3, 20.2, 19.9.

HRMS-ESI: calcd. for $C_{26}H_{23}NO_4Na$ $[M+Na]^+$: 436.1519; found: 436.1502.



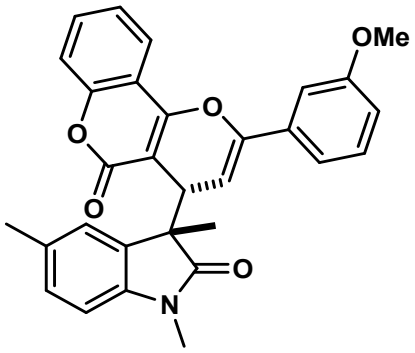
1,3,5-trimethyl-3-(5-oxo-2-(o-tolyl)-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4ca: 18.5 mg, yellow solid, 40% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.7 Hz, 1H), 7.61 (t, *J* = 7.6 Hz, 1H), 7.44 (d, *J* = 8.1 Hz, 1H), 7.30 (t, *J* = 7.4 Hz, 1H), 7.26 – 7.23 (m, 1H), 7.14 – 7.10 (m, 2H), 7.04 (d, *J* = 7.6 Hz, 1H), 6.86 (d, *J* = 7.3 Hz, 1H), 6.75 – 6.69 (m, 2H), 5.17 (d, *J* = 5.2 Hz, 1H), 4.26 (d, *J* = 5.1 Hz, 1H), 3.23 (s, 3H), 2.07 (s, 3H), 2.00 (s, 3H), 1.48 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.8, 162.7, 159.6, 152.8, 152.3, 141.5, 136.7, 133.0, 132.4, 131.9, 131.9, 130.6, 129.5, 129.3, 128.6, 125.8, 124.40, 124.35, 122.4, 117.0, 114.5, 107.6, 103.6, 100.5, 54.8, 37.4, 26.4, 21.1, 20.6, 19.8.

HRMS-ESI: calcd. for $C_{30}H_{25}NO_4Na$ $[M+Na]^+$: 486.1676; found: 486.1668.



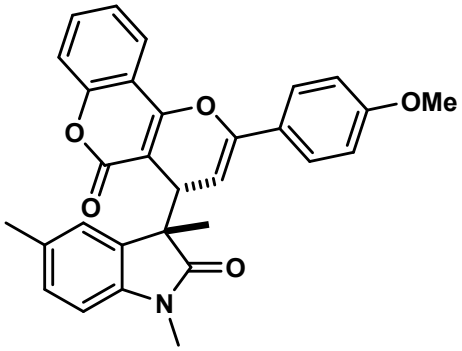
3-(2-(3-methoxyphenyl)-5-oxo-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)-1,3,5-trimethylindolin-2-one

4cb: 29.2 mg, red brown solid, 61% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.81 (d, *J* = 7.8 Hz, 1H), 7.65 – 7.60 (m, 1H), 7.44 (d, *J* = 8.3 Hz, 1H), 7.36 (t, *J* = 7.6 Hz, 1H), 7.27 – 7.23 (m, 1H), 6.96 (d, *J* = 7.8 Hz, 1H), 6.92 (d, *J* = 7.7 Hz, 1H), 6.89 – 6.84 (m, 2H), 6.67 (s, 1H), 6.62 (d, *J* = 7.8 Hz, 1H), 5.52 (d, *J* = 5.9 Hz, 1H), 4.18 (d, *J* = 5.9 Hz, 1H), 3.81 (s, 3H), 3.23 (s, 3H), 2.05 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.7, 162.6, 159.7, 159.1, 152.8, 150.7, 141.3, 133.8, 132.4, 131.6, 131.5, 129.7, 128.6, 124.5, 124.3, 122.3, 117.4, 117.1, 114.7, 114.4, 111.1, 107.5, 100.8, 99.9, 55.4, 54.8, 37.5, 26.4, 21.1, 19.6.

HRMS-ESI: calcd. for $C_{30}H_{25}NO_5Na$ $[M+Na]^+$: 502.1625; found: 502.1610.



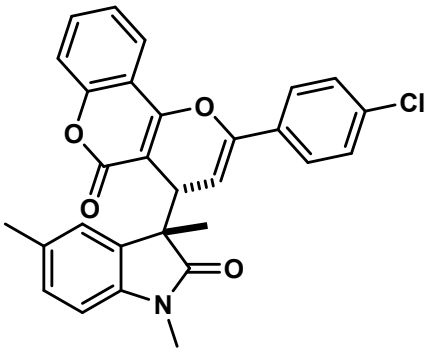
3-(2-(4-methoxyphenyl)-5-oxo-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)-1,3,5-trimethylindolin-2-one

4cc: 28.7 mg, yellow solid, 60% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.81 (d, *J* = 7.8 Hz, 1H), 7.62 (t, *J* = 7.8 Hz, 1H), 7.44 (d, *J* = 8.3 Hz, 1H), 7.36 (t, *J* = 7.6 Hz, 1H), 7.29 – 7.25 (m, 2H), 6.95 (d, *J* = 7.8 Hz, 1H), 6.85 (d, *J* = 8.7 Hz, 2H), 6.67 (s, 1H), 6.61 (d, *J* = 7.8 Hz, 1H), 5.40 (d, *J* = 5.9 Hz, 1H), 4.16 (d, *J* = 5.9 Hz, 1H), 3.81 (s, 3H), 3.23 (s, 3H), 2.05 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.8, 162.7, 160.5, 159.1, 152.8, 150.7, 141.3, 132.3, 131.59, 131.58, 128.5, 126.4, 125.0, 124.4, 124.3, 122.3, 117.1, 114.8, 114.0, 107.5, 100.9, 97.7, 55.5, 54.8, 37.5, 26.3, 21.1, 19.6.

HRMS-ESI: calcd. for $C_{30}H_{25}NO_5Na$ $[M+Na]^+$: 502.1625; found: 502.1607.

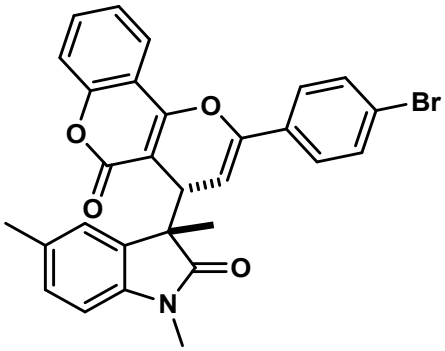


3-(2-(4-chlorophenyl)-5-oxo-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)-1,3,5-trimethylindolin-2-one 4cd: 31.9 mg, light yellow solid, 66% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, *J* = 7.7 Hz, 1H), 7.66 – 7.61 (m, 1H), 7.45 (d, *J* = 8.3 Hz, 1H), 7.37 (t, *J* = 7.6 Hz, 1H), 7.31 (d, *J* = 8.5 Hz, 2H), 7.26 (d, *J* = 8.6 Hz, 2H), 6.96 (d, *J* = 7.8 Hz, 1H), 6.67 (s, 1H), 6.61 (d, *J* = 7.9 Hz, 1H), 5.52 (d, *J* = 6.0 Hz, 1H), 4.19 (d, *J* = 6.0 Hz, 1H), 3.22 (s, 3H), 2.06 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.6, 162.5, 159.0, 152.8, 149.9, 141.3, 135.3, 132.5, 131.7, 131.4, 130.9, 128.9, 128.6, 126.1, 124.5, 124.3, 122.2, 117.2, 114.6, 107.5, 100.9, 100.1, 54.8, 37.5, 26.4, 21.1, 19.7.

HRMS-ESI: calcd. for $C_{29}H_{22}ClNO_4Na$ $[M+Na]^+$: 506.1130; found: 506.1109.

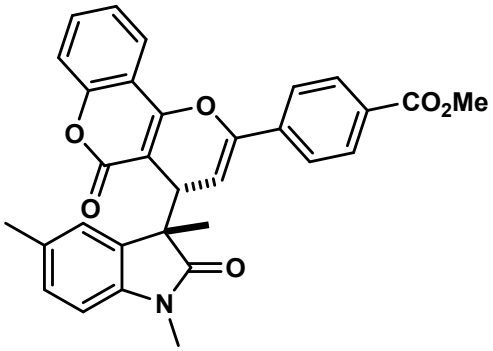


3-(2-(4-bromophenyl)-5-oxo-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)-1,3,5-trimethylindolin-2-one 4ce: 40.1 mg, red brown solid, 76% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (d, *J* = 7.7 Hz, 1H), 7.63 (t, *J* = 7.6 Hz, 1H), 7.48 – 7.43 (m, 3H), 7.37 (t, *J* = 7.6 Hz, 1H), 7.19 (d, *J* = 8.4 Hz, 2H), 6.96 (d, *J* = 7.8 Hz, 1H), 6.66 (s, 1H), 6.61 (d, *J* = 7.8 Hz, 1H), 5.53 (d, *J* = 5.9 Hz, 1H), 4.18 (d, *J* = 5.9 Hz, 1H), 3.22 (s, 3H), 2.05 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.6, 162.5, 159.0, 152.8, 150.0, 141.3, 132.5, 131.9, 131.7, 131.4, 131.3, 128.6, 126.3, 124.5, 124.3, 123.6, 122.2, 117.2, 114.5, 107.5, 100.9, 100.2, 54.8, 37.5, 26.4, 21.1, 19.7.

HRMS-ESI: calcd. for $C_{29}H_{22}BrNO_4Na$ $[M+Na]^+$: 550.0624; found: 550.0599.



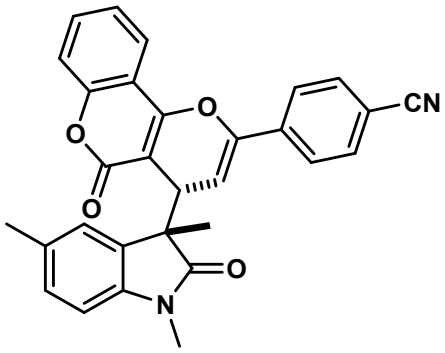
methyl 4-(5-oxo-4-(1,3,5-trimethyl-2-oxoindolin-3-yl)-4*H*,5*H*-pyrano[3,2-*c*]chromen-2-yl)benzoate

4cf: 23.3 mg, yellow solid, 46% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.00 (d, *J* = 8.2 Hz, 2H), 7.82 (d, *J* = 7.8 Hz, 1H), 7.65 (t, *J* = 7.8 Hz, 1H), 7.46 (d, *J* = 8.3 Hz, 1H), 7.42 – 7.37 (m, 3H), 6.95 (d, *J* = 7.8 Hz, 1H), 6.68 (s, 1H), 6.59 (d, *J* = 7.8 Hz, 1H), 5.66 (d, *J* = 6.0 Hz, 1H), 4.22 (d, *J* = 5.9 Hz, 1H), 3.93 (s, 3H), 3.22 (s, 3H), 2.06 (s, 3H), 1.48 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.5, 166.5, 162.5, 159.0, 152.9, 150.0, 141.3, 136.4, 132.6, 131.7, 131.3, 130.8, 130.0, 128.7, 124.60, 124.56, 124.3, 122.3, 117.2, 114.5, 107.6, 101.8, 100.8, 54.8, 52.4, 37.6, 26.4, 21.1, 19.7.

HRMS-ESI: calcd. for $C_{31}H_{25}NO_6Na$ $[M+Na]^+$: 530.1574; found: 530.1551.



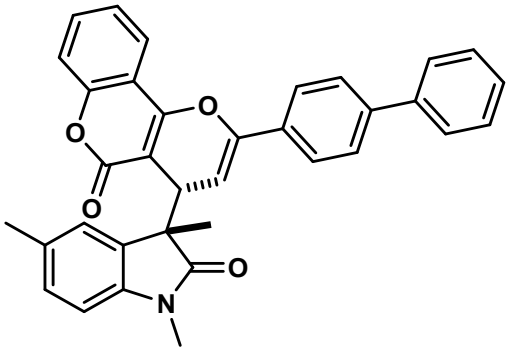
4-(5-oxo-4-(1,3,5-trimethyl-2-oxoindolin-3-yl)-4*H*,5*H*-pyrano[3,2-*c*]chromen-2-yl)benzonitrile

4cg: 19.4 mg, light yellow solid, 41% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, *J* = 7.8 Hz, 1H), 7.68 – 7.63 (m, 3H), 7.45 (t, *J* = 9.0 Hz, 3H), 7.39 (t, *J* = 7.6 Hz, 1H), 6.97 (d, *J* = 7.9 Hz, 1H), 6.68 (s, 1H), 6.61 (d, *J* = 7.8 Hz, 1H), 5.69 (d, *J* = 6.0 Hz, 1H), 4.23 (d, *J* = 6.0 Hz, 1H), 3.21 (s, 3H), 2.07 (s, 3H), 1.48 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.4, 162.3, 158.8, 152.8, 149.2, 141.2, 136.4, 132.7, 132.6, 131.8, 131.1, 128.7, 125.2, 124.6, 124.3, 122.1, 118.4, 117.3, 114.3, 112.9, 107.6, 103.0, 100.8, 54.8, 37.5, 26.4, 21.1, 19.7.

HRMS-ESI: calcd. for $C_{30}H_{22}N_2O_4Na$ $[M+Na]^+$: 497.1472; found: 497.1451.



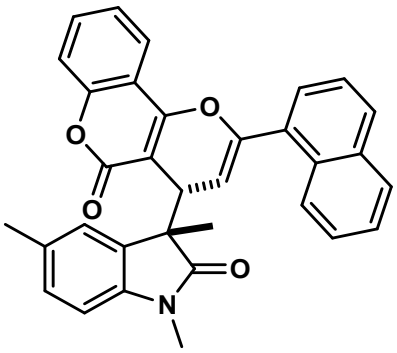
3-(2-([1,1'-biphenyl]-4-yl)-5-oxo-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)-1,3,5-trimethylindolin-2-one

4ch: 31.5 mg, yellow solid, 60% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86 (d, *J* = 7.8 Hz, 1H), 7.63 (t, *J* = 7.8 Hz, 1H), 7.59 – 7.55 (m, 4H), 7.47 – 7.35 (m, 7H), 6.97 (d, *J* = 7.8 Hz, 1H), 6.70 (s, 1H), 6.63 (d, *J* = 7.8 Hz, 1H), 5.58 (d, *J* = 5.9 Hz, 1H), 4.21 (d, *J* = 5.9 Hz, 1H), 3.25 (s, 3H), 2.07 (s, 3H), 1.49 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.7, 162.6, 159.1, 152.8, 150.7, 142.2, 141.3, 140.2, 132.4, 131.7, 131.5, 131.3, 129.0, 128.6, 127.9, 127.3, 127.1, 125.3, 124.5, 124.3, 122.3, 117.1, 114.7, 107.6, 100.9, 99.6, 54.8, 37.6, 26.4, 21.1, 19.7.

HRMS-ESI: calcd. for $C_{35}H_{27}NO_4Na$ $[M+Na]^+$: 548.1832; found: 548.1828.



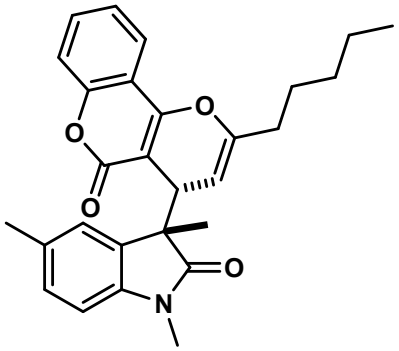
1,3,5-trimethyl-3-(2-(naphthalen-1-yl)-5-oxo-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4ci: 45.4 mg, yellow solid, 91% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (t, *J* = 8.0 Hz, 2H), 7.62 – 7.55 (m, 2H), 7.49 – 7.44 (m, 2H), 7.38 (t, *J* = 7.7 Hz, 1H), 7.33 (t, *J* = 7.6 Hz, 1H), 7.22 (t, *J* = 7.6 Hz, 1H), 7.17 – 7.11 (m, 3H), 6.80 (s, 1H), 6.72 (d, *J* = 7.9 Hz, 1H), 5.39 (d, *J* = 5.8 Hz, 1H), 4.35 (d, *J* = 5.8 Hz, 1H), 3.18 (s, 3H), 2.14 (s, 3H), 1.53 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.8, 162.8, 159.8, 152.9, 152.0, 141.7, 133.5, 132.5, 132.1, 132.0, 131.2, 131.0, 130.1, 128.7, 128.4, 127.3, 126.6, 126.3, 125.4, 125.1, 124.44, 124.42, 122.6, 117.0, 114.6, 107.9, 104.8, 100.6, 55.0, 37.7, 26.4, 21.1, 20.7.

HRMS-ESI: calcd. for $C_{33}H_{25}NO_4Na$ $[M+Na]^+$: 522.1676; found: 522.1684.



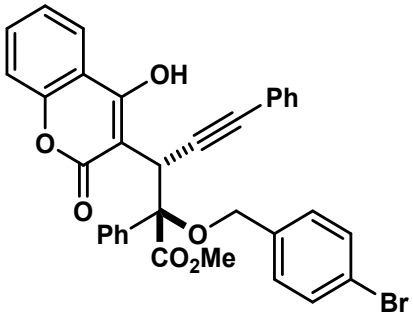
1,3,5-trimethyl-3-(5-oxo-2-pentyl-4*H*,5*H*-pyrano[3,2-*c*]chromen-4-yl)indolin-2-one

4cj: 23.1 mg, yellow oli, 52% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.7 Hz, 1H), 7.59 (t, *J* = 7.7 Hz, 1H), 7.41 (d, *J* = 8.3 Hz, 1H), 7.32 (t, *J* = 7.6 Hz, 1H), 7.03 (d, *J* = 7.8 Hz, 1H), 6.68 (d, *J* = 7.9 Hz, 1H), 6.61 (s, 1H), 4.79 (d, *J* = 5.6 Hz, 1H), 4.01 (d, *J* = 5.6 Hz, 1H), 3.21 (s, 3H), 2.07 (s, 3H), 1.97 – 1.92 (m, 2H), 1.40 (s, 3H), 1.27 – 1.19 (m, 4H), 1.10 – 1.04 (m, 2H), 0.86 (t, *J* = 7.3 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 178.9, 162.8, 159.3, 153.7, 152.7, 141.5, 132.2, 132.0, 131.6, 128.3, 124.24, 124.20, 122.3, 116.9, 114.6, 107.4, 100.5, 98.8, 54.7, 36.9, 32.1, 30.9, 26.5, 26.2, 22.4, 21.0, 19.9, 13.9.

HRMS-ESI: calcd. for $C_{28}H_{29}NO_4Na$ $[M+Na]^+$: 466.1989; found: 466.1971.



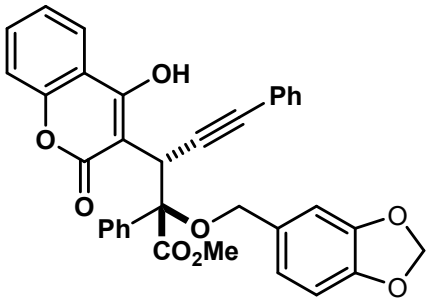
methyl 2-((4-bromobenzyl)oxy)-3-(4-hydroxy-2-oxo-2*H*-chromen-3-yl)-2,5-diphenylpent-4-ynoate

7a: 47.2 mg, white solid, 78% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 10.76 (s, 1H), 7.91 – 7.82 (m, 3H), 7.54 (t, *J* = 7.8 Hz, 1H), 7.50 (d, *J* = 8.2 Hz, 2H), 7.46 – 7.41 (m, 3H), 7.37 – 7.26 (m, 9H), 5.36 (s, 1H), 5.12 (d, *J* = 11.4 Hz, 1H), 4.44 (d, *J* = 11.4 Hz, 1H), 3.77 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 170.5, 163.6, 163.0, 152.8, 135.9, 134.9, 132.7, 132.0, 131.8, 129.7, 129.7, 128.7, 128.6, 128.5, 128.0, 124.4, 124.1, 122.9, 122.4, 116.5, 116.4, 102.2, 88.8, 86.1, 84.4, 69.0, 52.7, 40.4.

HRMS-ESI: calcd. for $C_{34}H_{25}BrO_6Na$ $[M+Na]^+$: 631.0727; found: 631.0746.



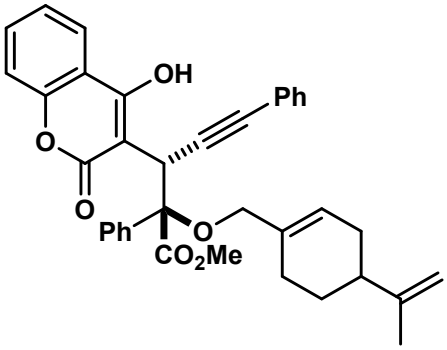
methyl 2-(benzo[*d*][1,3]dioxol-5-ylmethoxy)-3-(4-hydroxy-2-oxo-2*H*-chromen-3-yl)-2,5-diphenylpent-4-ynoate

7b: 81.5 mg, yellow oil, 71% yield, >20:1 *dr*.

^{1}H NMR (400 MHz, $CDCl_3$) δ 10.95 (s, 1H), 7.92 – 7.86 (m, 3H), 7.54 – 7.50 (m, 1H), 7.46 – 7.41 (m, 3H), 7.37 – 7.33 (m, 2H), 7.31 – 7.28 (m, 3H), 7.27 – 7.23 (m, 2H), 7.00 – 6.97 (m, 1H), 6.94 – 6.91 (m, 1H), 6.82 – 6.78 (m, 1H), 5.99 (s, 2H), 5.35 (s, 1H), 5.05 (d, *J* = 10.6 Hz, 1H), 4.37 (d, *J* = 10.6 Hz, 1H), 3.76 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 163.7, 163.1, 152.9, 148.1, 147.8, 135.1, 132.6, 131.9, 130.4, 129.6, 128.6, 128.41, 128.39, 128.1, 124.5, 124.0, 123.1, 122.1, 116.6, 116.4, 108.9, 108.5, 102.3, 101.3, 88.5, 85.9, 84.6, 69.7, 52.6, 40.5.

HRMS-ESI: calcd. for $C_{35}H_{26}O_8Na$ $[M+Na]^+$: 597.1520; found: 597.1531.



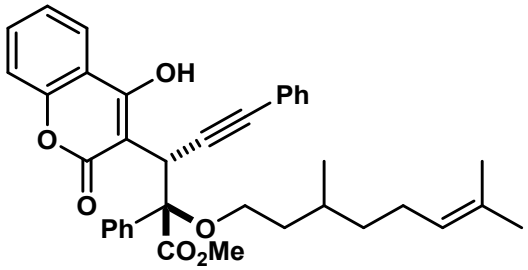
methyl 3-(4-hydroxy-2-oxo-2*H*-chromen-3-yl)-2,5-diphenyl-2-((4-(prop-1-en-2-yl)cyclohex-1-en-1-yl)methoxy)pent-4-ynoate

7c: 48.2 mg, yellow oil, 42% yield, >20:1 *dr*.

^{1}H NMR (400 MHz, $CDCl_3$) δ 11.28 (s, 1H), 7.98 (d, *J* = 8.0 Hz, 1H), 7.87 – 7.80 (m, 2H), 7.52 (t, *J* = 7.8 Hz, 1H), 7.44 – 7.37 (m, 5H), 7.30 – 7.25 (m, 5H), 5.92 (d, *J* = 14.8 Hz, 1H), 5.31 (s, 1H), 4.74 (s, 2H), 4.52 (t, *J* = 12.2 Hz, 1H), 3.90 – 3.84 (m, 1H), 3.72 (s, 3H), 2.26 – 2.13 (m, 4H), 2.07 – 1.97 (m, 1H), 1.88 – 1.81 (m, 1H), 1.75 (s, 3H), 1.58 – 1.47 (m, 1H).

^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 163.6, 163.0, 152.8, 149.5, 135.1, 133.5, 132.5, 131.7, 129.4, 128.40, 128.36, 128.0, 125.8, 125.6, 124.4, 123.9, 123.1, 116.7, 116.3, 108.9, 102.4, 88.2, 85.6, 84.7, 71.5, 52.4, 40.9, 40.7, 30.6, 27.4, 26.5, 20.9.

HRMS-ESI: calcd. for $C_{37}H_{34}O_6Na$ $[M+Na]^+$: 597.2248; found: 597.2235.



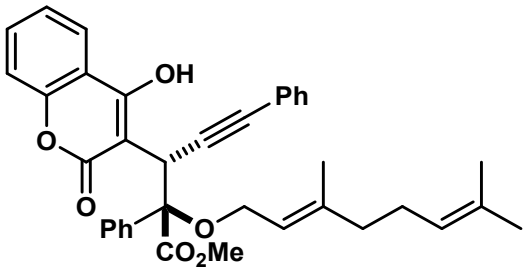
methyl 2-((3,7-dimethyloct-6-en-1-yl)oxy)-3-(4-hydroxy-2-oxo-2*H*-chromen-3-yl)-2,5-diphenylpent-4-ynoate

7d: 46.2 mg, yellow oil, 40% yield, 1:1 *dr*.

^{1}H NMR (400 MHz, $CDCl_3$) (two diastereomers) δ 11.32 (s, 1H), 11.29 (s, 1H), 8.00 – 7.96 (m, 2H), 7.84 – 7.80 (m, 4H), 7.55 – 7.51 (m, 2H), 7.44 – 7.41 (m, 6H), 7.40 – 7.37 (m, 4H), 7.31 – 7.28 (m, 6H), 7.28 – 7.26 (m, 3H), 5.30 – 5.28 (m, 2H), 5.10 – 5.04 (m, 2H), 4.08 – 4.01 (m, 2H), 3.72 (s, 6H), 3.55 – 3.46 (m, 2H), 2.00 – 1.81 (m, 6H), 1.68 – 1.63 (m, 9H), 1.58 (t, *J* = 5.3 Hz, 8H), 1.37 – 1.31 (m, 2H), 1.21 – 1.14 (m, 2H), 0.91 (d, *J* = 6.4 Hz, 3H), 0.85 (d, *J* = 6.5 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) (two diastereomers) δ 170.46, 170.43, 163.75, 163.05, 152.88, 135.38, 132.52, 131.80, 131.78, 131.38, 129.39, 129.37, 128.41, 128.36, 128.02, 124.73, 124.70, 124.43, 123.94, 123.19, 116.71, 116.37, 102.40, 88.29, 88.15, 85.64, 85.62, 84.64, 84.59, 66.79, 66.58, 52.42, 40.57, 40.51, 37.30, 37.21, 37.00, 36.83, 29.81, 29.59, 29.40, 25.79, 25.56, 25.54, 19.74, 19.53, 17.75.

HRMS-ESI: calcd. for $C_{37}H_{38}O_6Na$ $[M+Na]^+$: 601.2561; found: 601.2587.



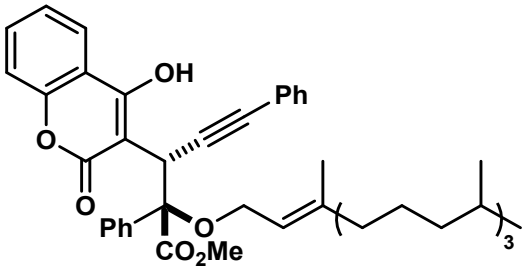
methyl (*E*)-2-((3,7-dimethylocta-2,6-dien-1-yl)oxy)-3-(4-hydroxy-2-oxo-2*H*-chromen-3-yl)-2,5-diphenylpent-4-ynoate

7e: 58.8 mg, yellow oil, 51% yield, >20:1 *dr*.

^{1}H NMR (400 MHz, $CDCl_3$) δ 11.37 (s, 1H), 7.97 (dd, *J* = 8.1, 1.5 Hz, 1H), 7.88 – 7.82 (m, 2H), 7.56 – 7.50 (m, 1H), 7.46 – 7.40 (m, 3H), 7.38 – 7.35 (m, 2H), 7.30 – 7.25 (m, 5H), 5.56 (t, *J* = 6.9 Hz, 1H), 5.29 (s, 1H), 5.15 (t, *J* = 6.0 Hz, 1H), 4.61 – 4.53 (m, 1H), 4.04 – 3.96 (m, 1H), 3.74 (s, 3H), 2.22 – 2.10 (m, 4H), 1.70 – 1.67 (m, 6H), 1.63 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 163.9, 163.1, 152.9, 143.7, 135.3, 132.5, 131.9, 131.8, 129.3, 128.4, 128.32, 128.27, 128.0, 124.4, 123.9, 123.3, 118.9, 116.8, 116.3, 102.2, 88.2, 85.5, 84.6, 64.8, 52.5, 40.8, 39.8, 26.6, 25.8, 17.8, 16.7.

HRMS-ESI: calcd. for $C_{37}H_{36}O_6Na$ $[M+Na]^+$: 599.2404; found: 599.2432.



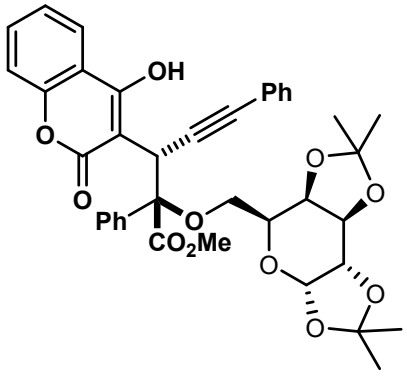
methyl (*E*)-3-(4-hydroxy-2-oxo-2H-chromen-3-yl)-2,5-diphenyl-2-((3,7,11,15-tetramethylhexadec-2-en-1-yl)oxy)pent-4-ynoate

7f: 93.3 mg, yellow oil, 65% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 11.40 (s, 1H), 7.97 (d, *J* = 8.2 Hz, 1H), 7.87 – 7.83 (m, 2H), 7.54 (t, *J* = 7.8 Hz, 1H), 7.45 – 7.41 (m, 3H), 7.38 – 7.35 (m, 2H), 7.30 – 7.26 (m, 5H), 5.55 (t, *J* = 7.0 Hz, 1H), 5.28 (s, 1H), 4.57 (t, *J* = 8.8 Hz, 1H), 3.99 (t, *J* = 7.8 Hz, 1H), 3.74 (s, 3H), 2.13 – 2.05 (m, 2H), 1.69 (s, 3H), 1.54 – 1.48 (m, 2H), 1.44 – 1.39 (m, 2H), 1.36 – 1.32 (m, 2H), 1.31 – 1.27 (m, 3H), 1.26 – 1.19 (m, 4H), 1.16 – 1.11 (m, 3H), 1.09 – 1.02 (m, 3H), 0.88 – 0.83 (m, 12H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 170.5, 164.0, 163.2, 152.9, 144.33, 144.27, 135.3, 132.5, 131.8, 129.3, 128.4, 128.33, 128.28, 128.0, 124.5, 123.9, 123.3, 118.6, 116.9, 116.4, 102.2, 88.2, 85.5, 84.6, 64.8, 52.5, 40.8, 40.1, 39.5, 37.60, 37.55, 37.4, 36.8, 32.94, 32.91, 28.1, 25.4, 24.9, 24.7, 22.9, 22.8, 19.9, 19.8, 16.6.

HRMS-ESI: calcd. for $C_{47}H_{58}O_6Na$ $[M+Na]^+$: 741.4126; found: 741.4047.



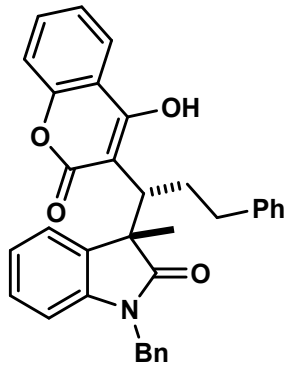
methyl 3-(4-hydroxy-2-oxo-2*H*-chromen-3-yl)-2,5-diphenyl-2-(((3a*S*,5*S*,5a*R*,8a*R*,8b*S*)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-5-yl)methoxy)pent-4-ynoate

7g: 99.6 mg, yellow oil, 73% yield, 77:23 *dr*.

^{1}H NMR (400 MHz, $CDCl_3$) (two diastereomers) δ 10.85 (s, 1H), 10.70 (s, 1H), 8.03 (d, *J* = 7.8 Hz, 1H), 7.99 (d, *J* = 7.8 Hz, 1H), 7.89 – 7.82 (m, 3H), 7.55 – 7.50 (m, 1H), 7.44 – 7.38 (m, 7H), 7.31 – 7.27 (m, 3H), 7.26 – 7.23 (m, 3H), 5.63 – 5.59 (m, 1H), 5.30 (s, 1H), 5.24 (s, 1H), 4.60 – 4.55 (m, 1H), 4.36 – 4.30 (m, 3H), 4.28 – 4.23 (m, 1H), 4.19 – 4.14 (m, 2H), 3.76 (s, 1H), 3.73 (s, 3H), 3.66 – 3.60 (m, 1H), 1.42 – 1.40 (m, 3H), 1.40 – 1.39 (m, 1H), 1.37 – 1.35 (m, 3H), 1.35 – 1.33 (m, 1H), 1.33 – 1.32 (m, 1H), 1.31 – 1.30 (m, 3H), 1.28 – 1.27 (m, 1H), 1.25 – 1.24 (m, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) (two diastereomers) δ 170.4, 170.2, 163.9, 163.7, 163.2, 163.1, 152.9, 152.8, 135.20, 135.15, 132.5, 132.0, 129.4, 129.3, 128.43, 128.38, 128.33, 128.28, 128.22, 128.19, 128.16, 128.1, 124.8, 123.8, 123.7, 123.2, 116.8, 116.3, 109.6, 108.8, 102.2, 102.0, 96.4, 89.3, 88.7, 86.0, 85.6, 84.4, 84.1, 71.5, 71.1, 70.94, 70.85, 70.6, 70.5, 68.0, 67.4, 67.1, 66.6, 52.5, 40.9, 40.6, 29.8, 26.1, 25.9, 25.2, 25.1, 24.5, 24.4.

HRMS-ESI: calcd. for $C_{39}H_{38}O_{11}Na$ $[M+Na]^+$: 705.2306; found: 705.2326.



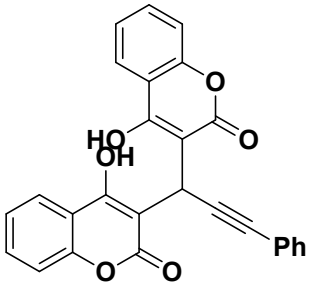
1-benzyl-3-(1-(4-hydroxy-2-oxo-2*H*-chromen-3-yl)-3-phenylpropyl)-3-methylindolin-2-one

8: 43.8 mg, white solid, 85% yield, >20:1 *dr*.

^{1}H NMR (500 MHz, $CDCl_3$) δ 9.16 (s, 1H), 7.82 (d, *J* = 7.9 Hz, 1H), 7.55 (d, *J* = 7.2 Hz, 1H), 7.48 (t, *J* = 7.7 Hz, 1H), 7.36 – 7.27 (m, 3H), 7.22 – 7.15 (m, 4H), 7.12 – 7.04 (m, 3H), 7.01 – 6.96 (m, 2H), 6.89 – 6.84 (m, 2H), 6.57 (d, *J* = 7.2 Hz, 1H), 5.13 (d, *J* = 15.7 Hz, 1H), 4.64 (d, *J* = 15.7 Hz, 1H), 4.21 (dd, *J* = 12.2, 3.7 Hz, 1H), 3.02 – 2.91 (m, 1H), 2.65 – 2.57 (m, 1H), 2.53 – 2.42 (m, 2H), 1.55 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 185.5, 164.3, 152.7, 141.9, 140.7, 134.8, 133.8, 132.1, 129.1, 128.8, 128.6, 128.5, 128.1, 127.7, 127.3, 126.9, 126.1, 124.9, 124.1, 123.8, 116.6, 116.2, 109.7, 104.0, 52.3, 44.1, 41.8, 34.7, 28.7, 25.1.

HRMS-ESI: calcd. for $C_{34}H_{29}NO_4Na$ $[M+Na]^+$: 538.1989; found: 538.1991.



3,3'-(3-phenylprop-2-yne-1,1-diyl)bis(4-hydroxy-2H-chromen-2-one)

9: 21.8 mg, light yellow solid, 50% yield.

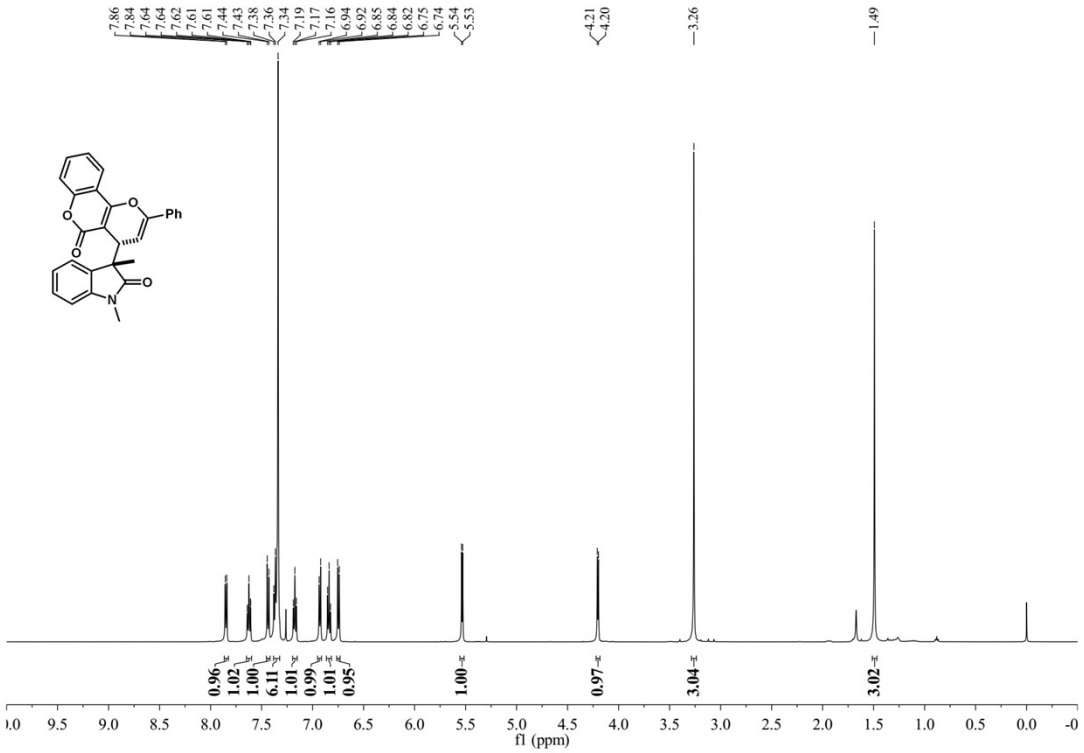
^{1}H NMR (400 MHz, DMSO) δ 7.95 (dd, *J* = 8.1, 1.5 Hz, 2H), 7.59 – 7.54 (m, 2H), 7.38 – 7.34 (m, 2H), 7.34 – 7.27 (m, 7H), 6.16 (s, 1H).

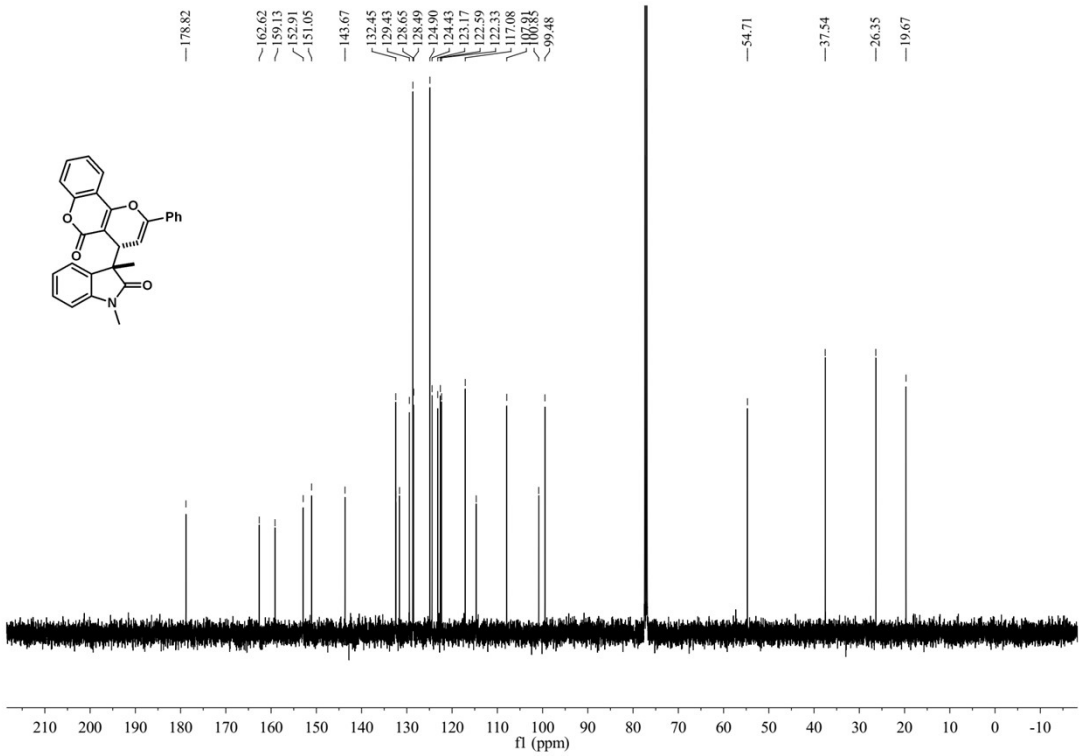
^{13}C NMR (100 MHz, DMSO) δ 166.2, 163.6, 152.3, 131.9, 131.5, 128.6, 128.0, 124.2, 123.7, 123.4, 118.7, 115.9, 102.4, 89.8, 78.9, 23.6.

HRMS-ESI: calcd. for $C_{27}H_{16}O_6$ $[M+Na]^+$: 459.0839; found: 459.0858.

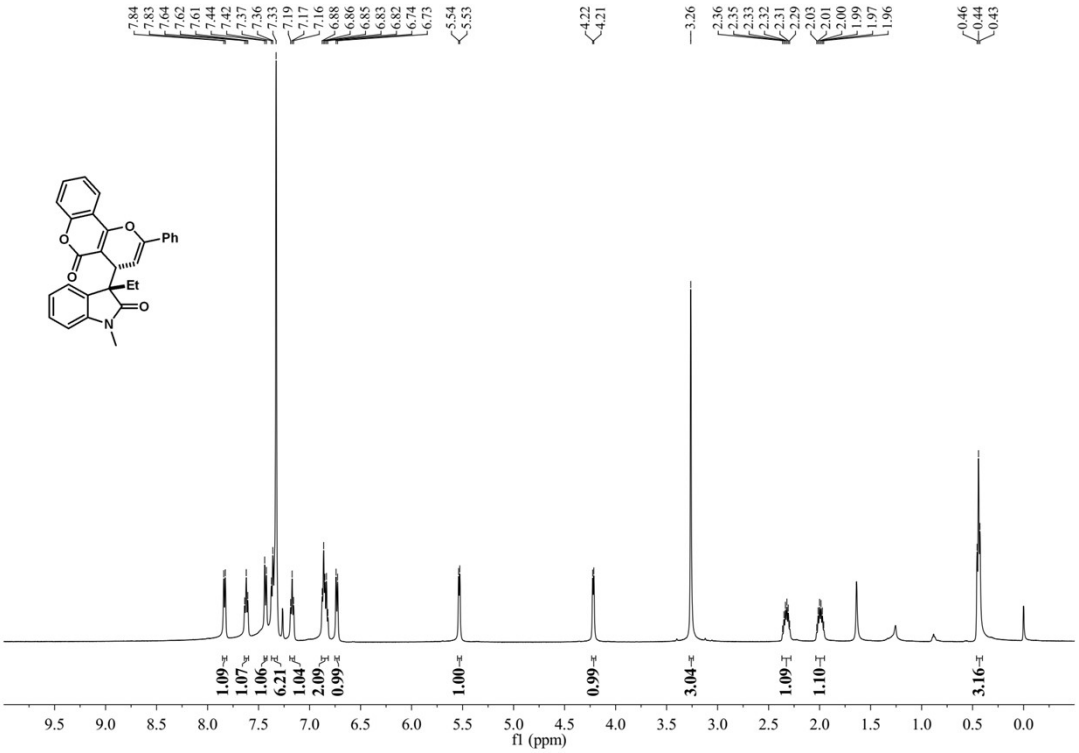
9. NMR spectra of products

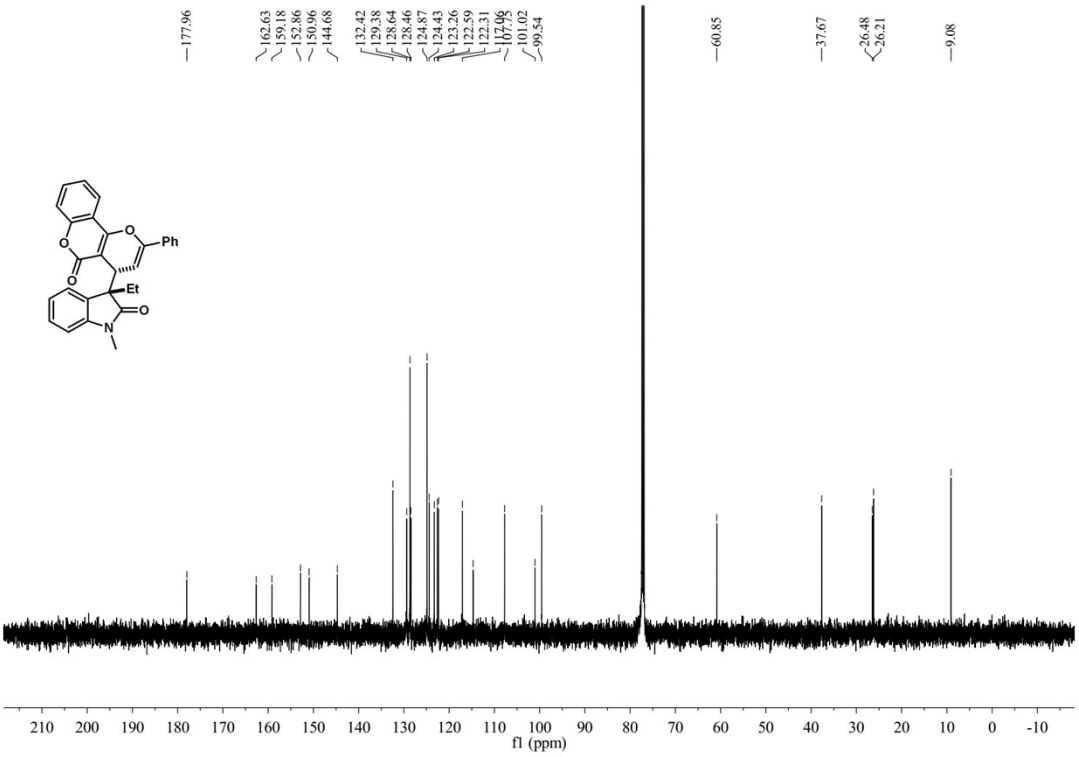
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4aa



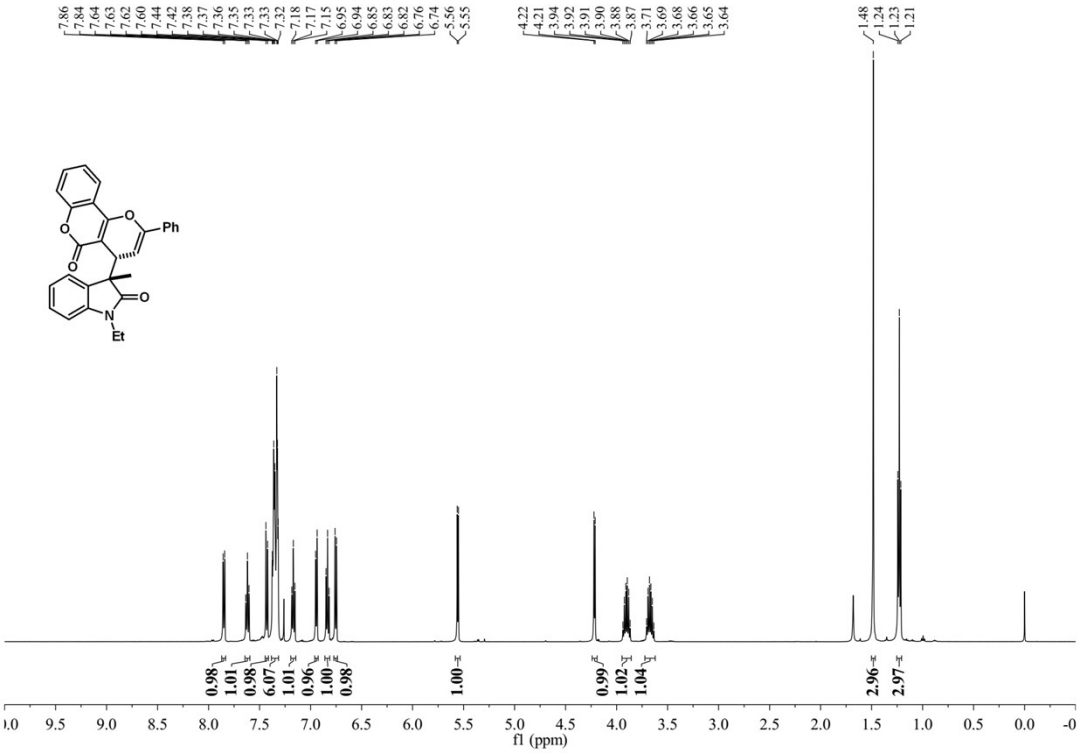


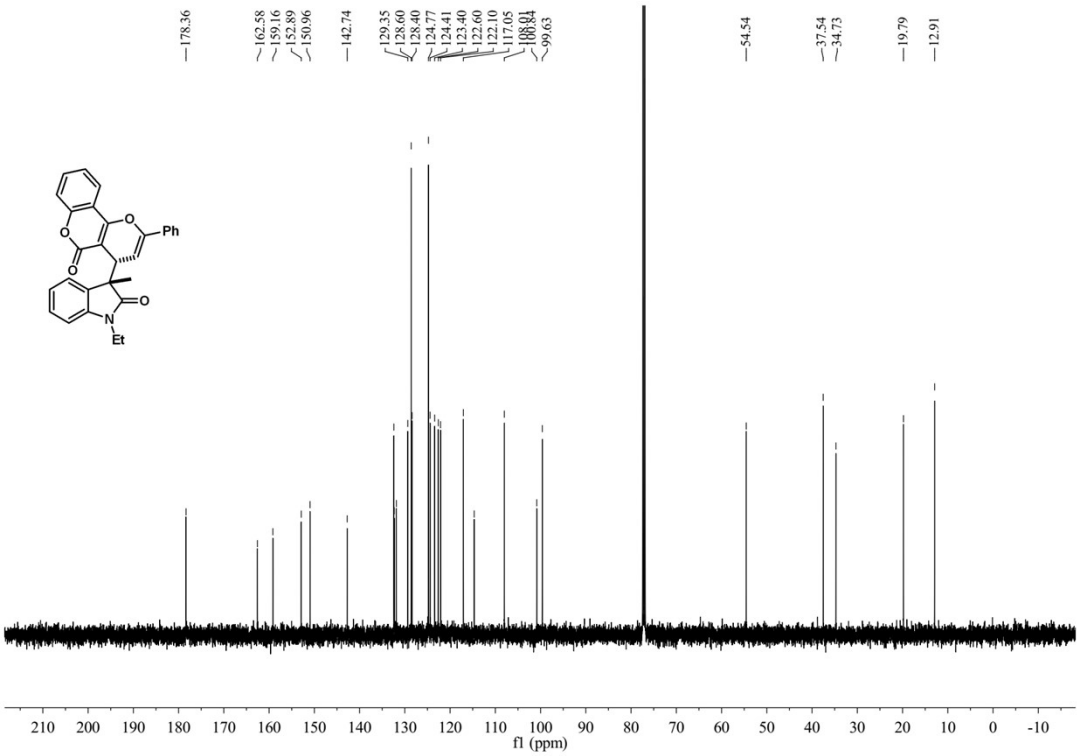
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ab



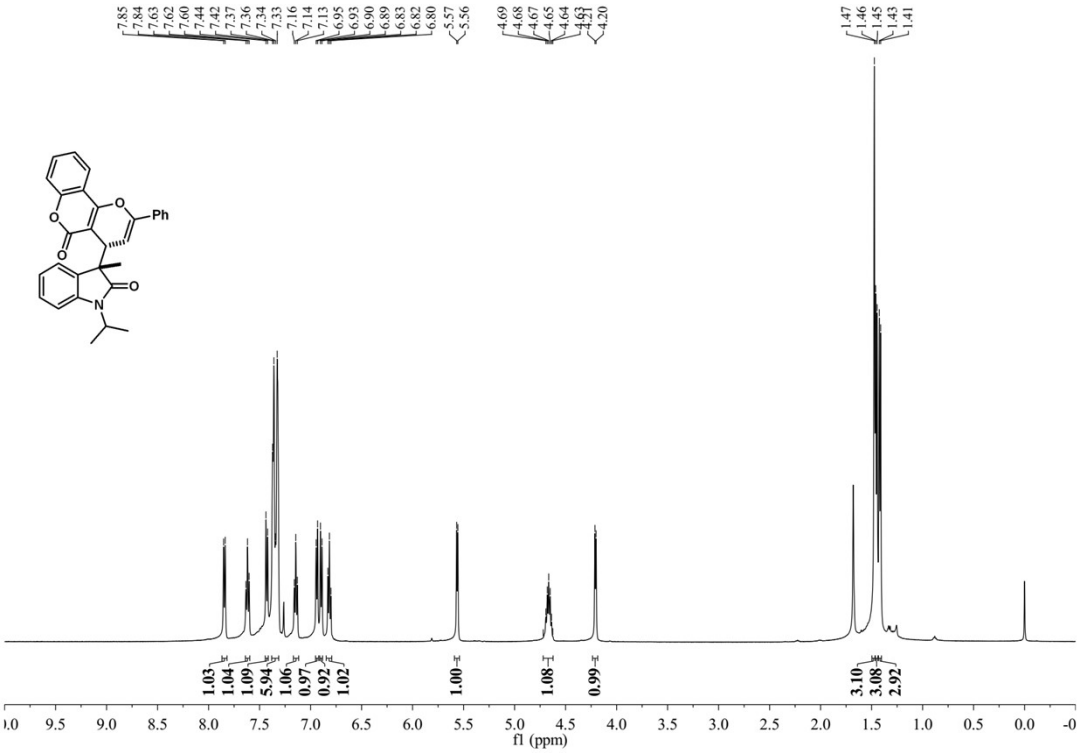


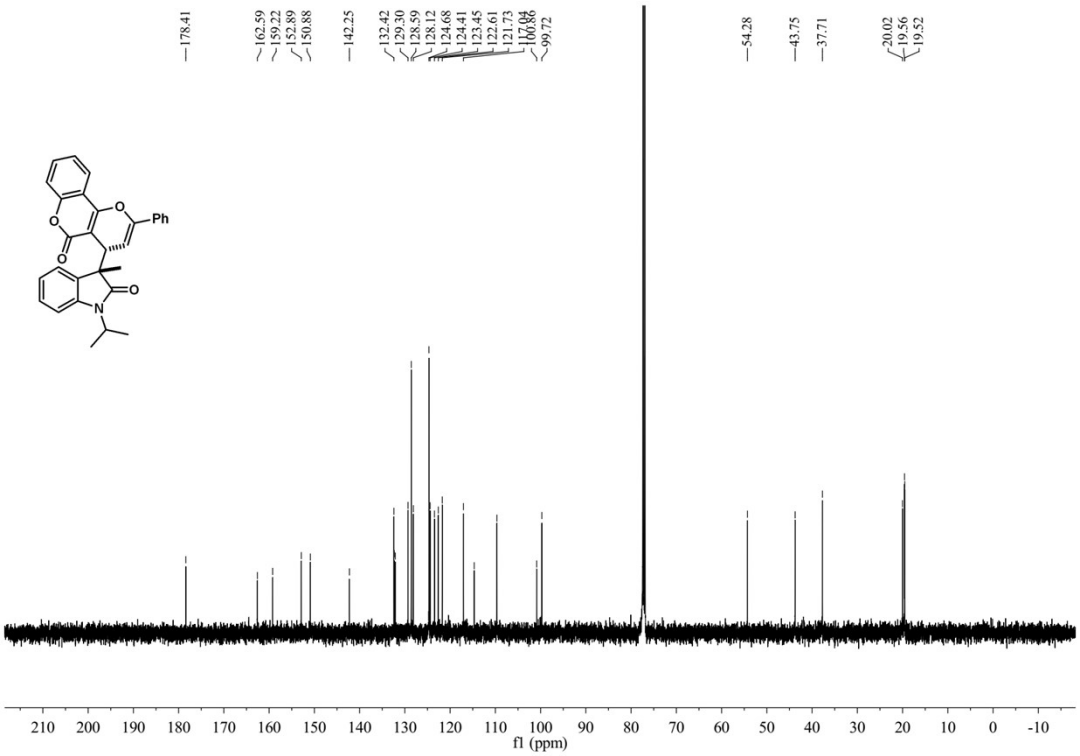
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ac



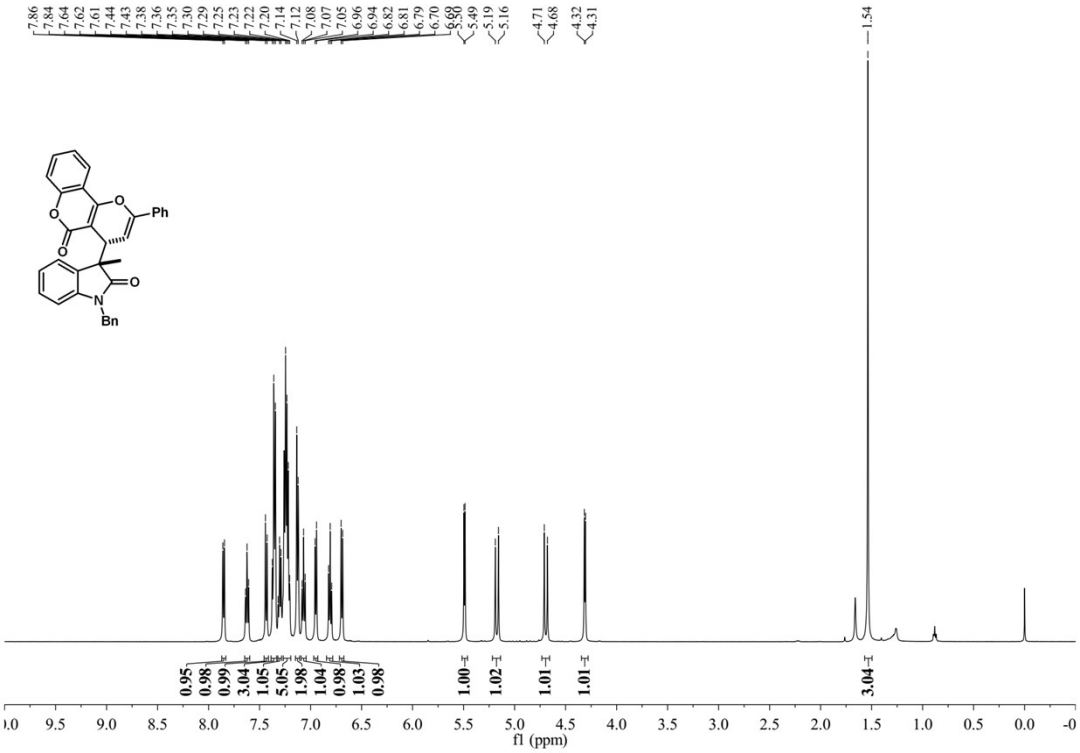


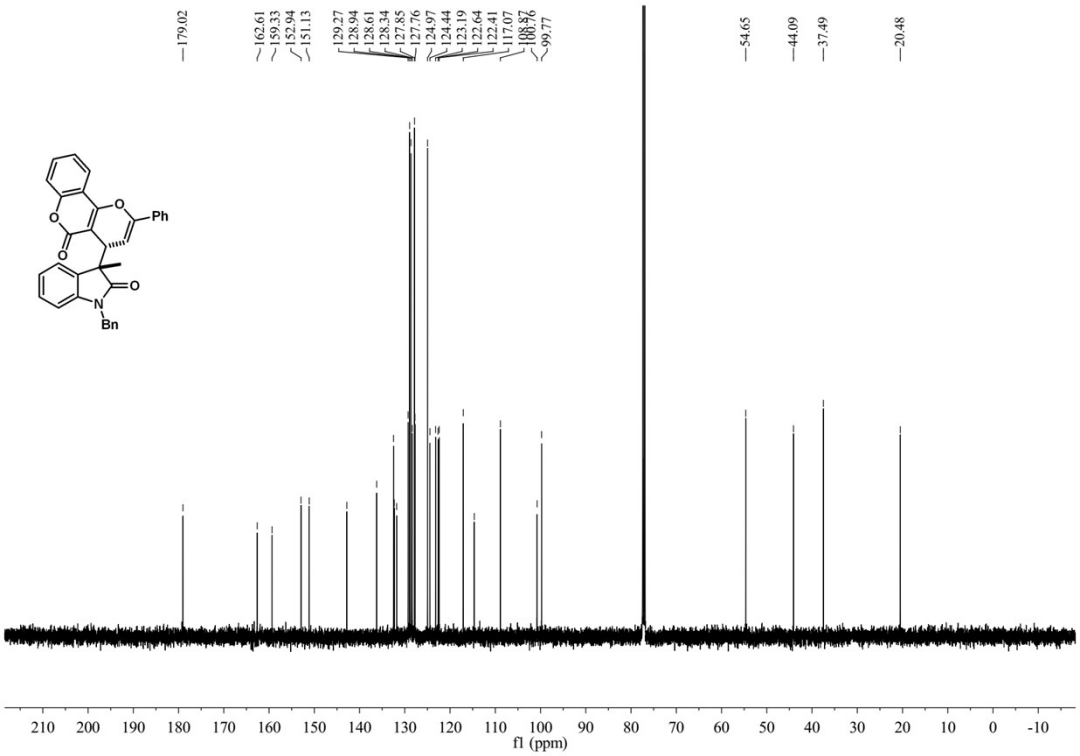
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ad



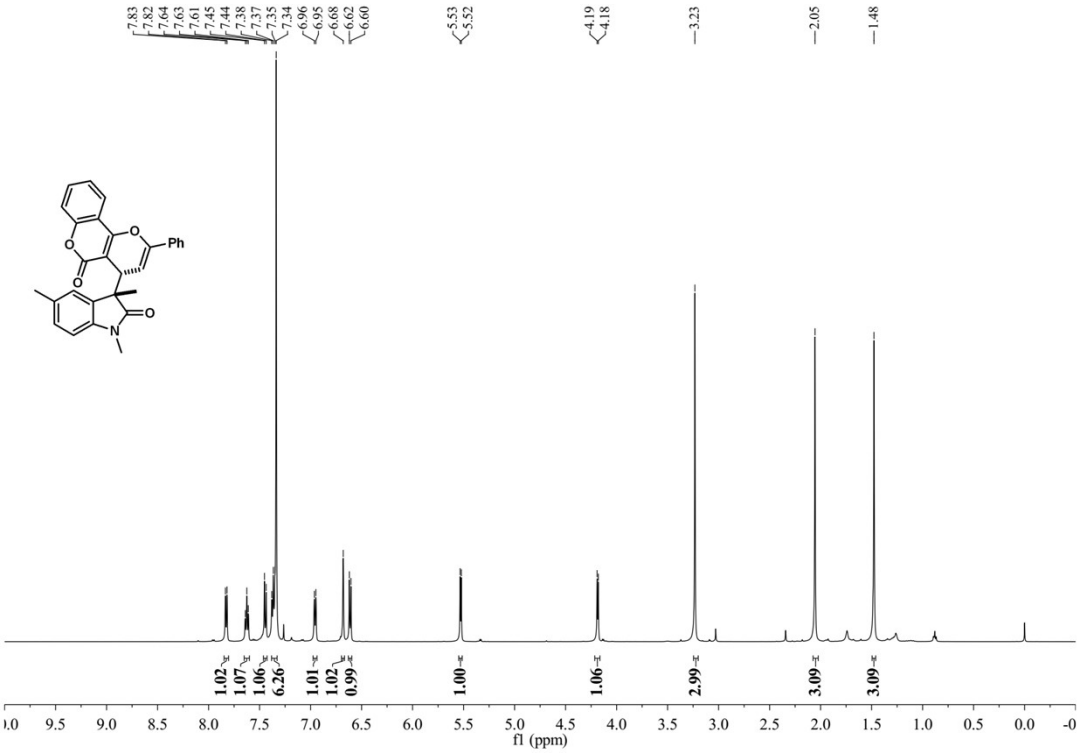


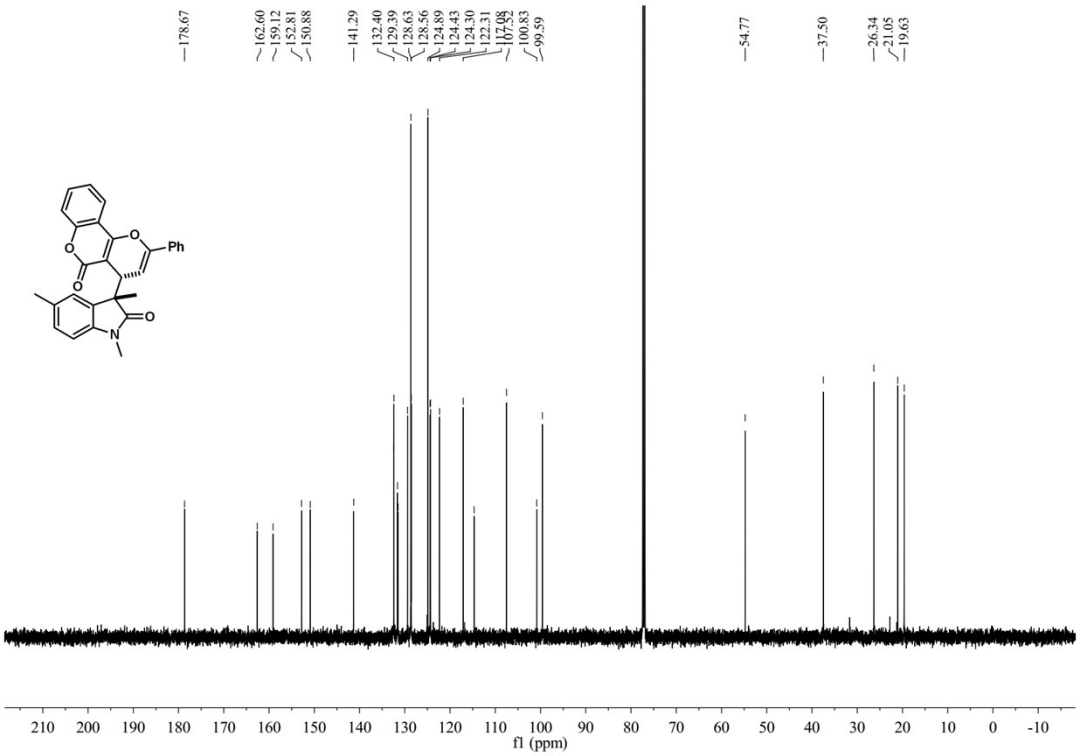
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ae



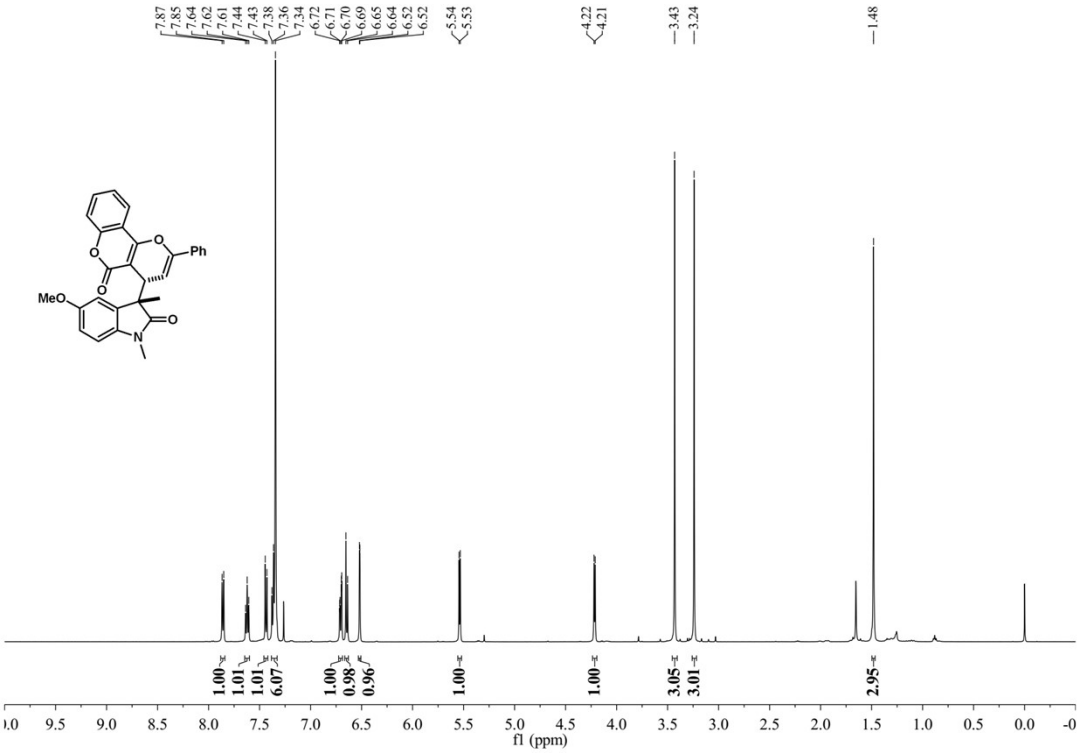


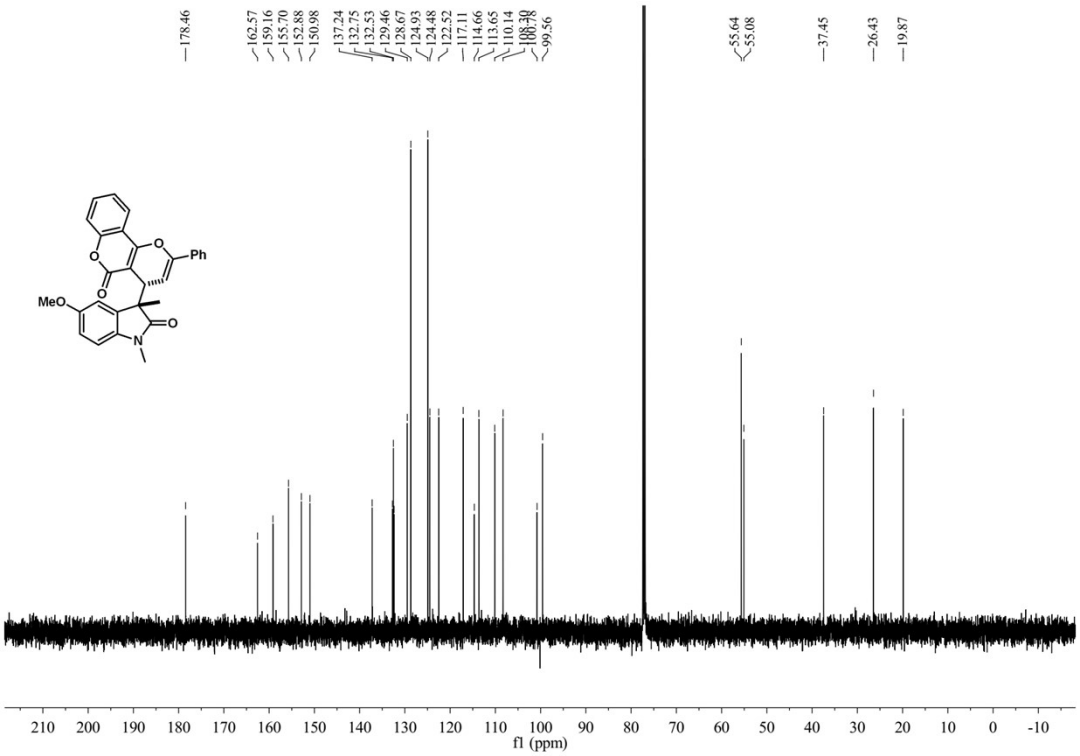
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4af



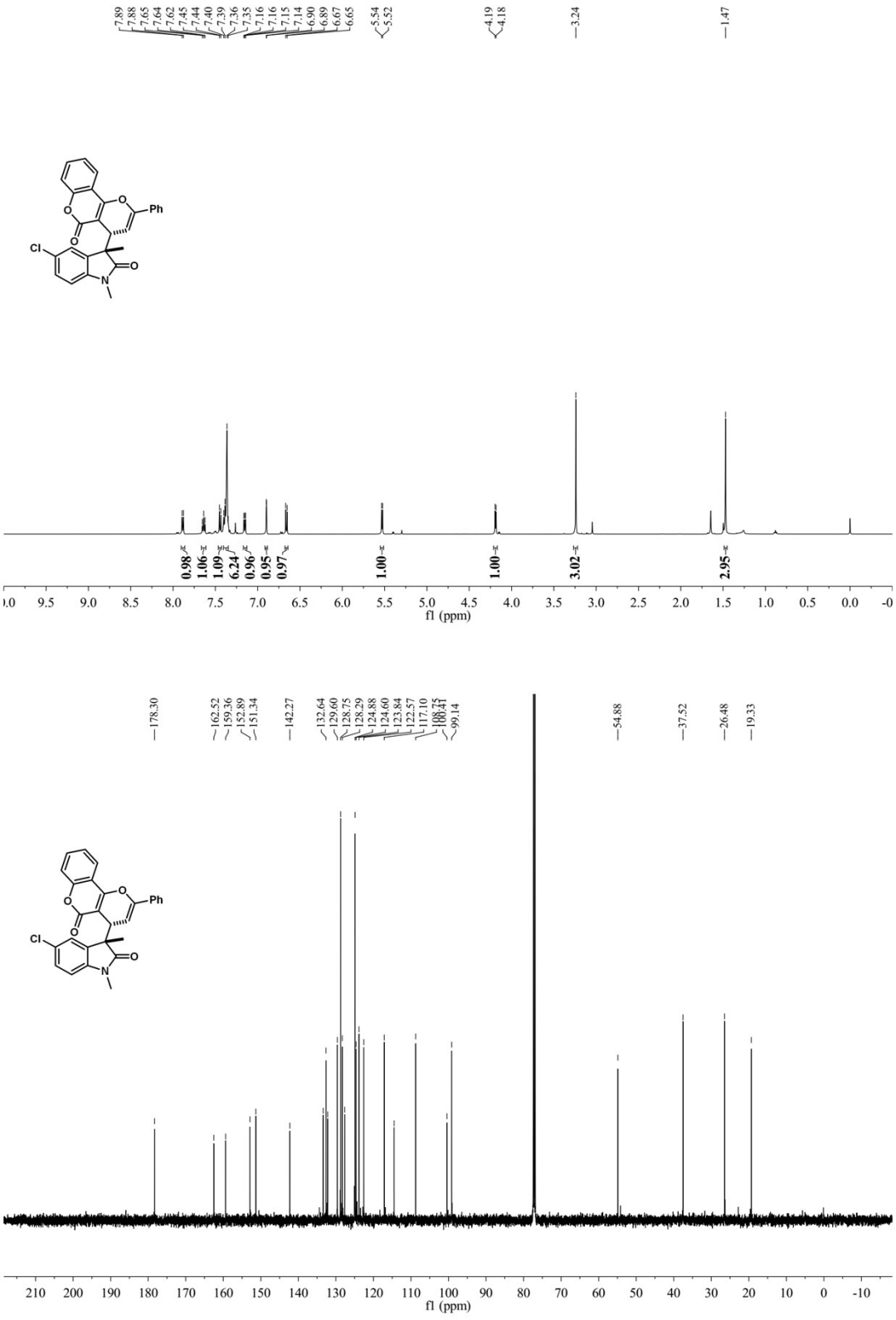


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ag

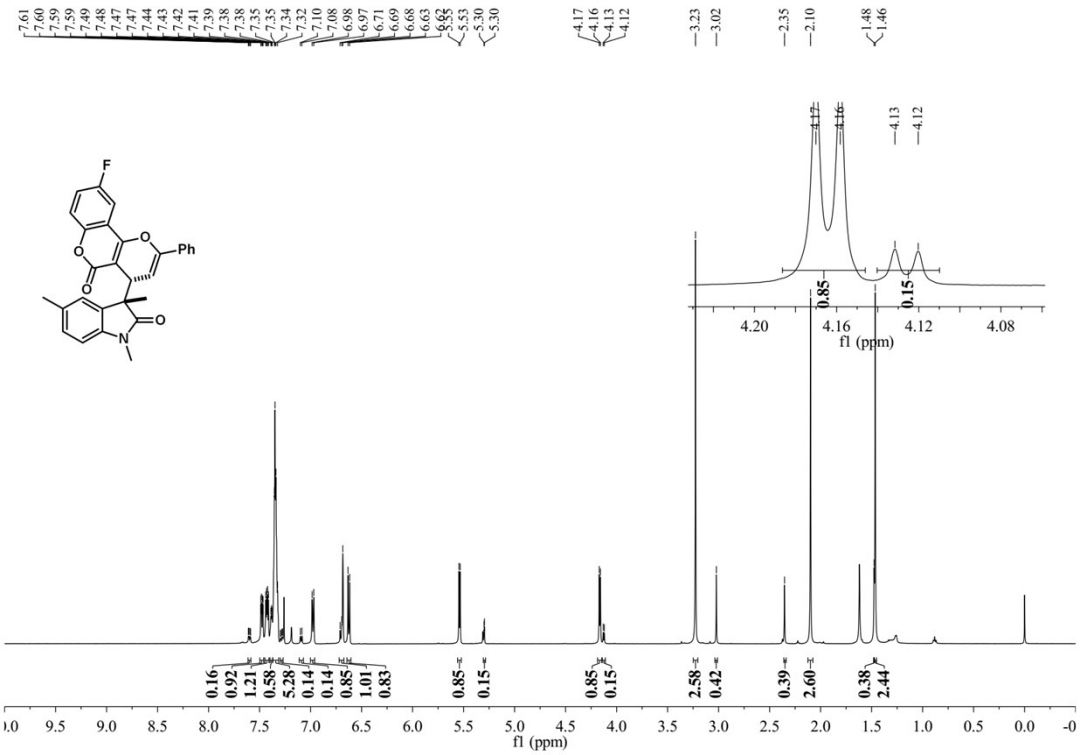


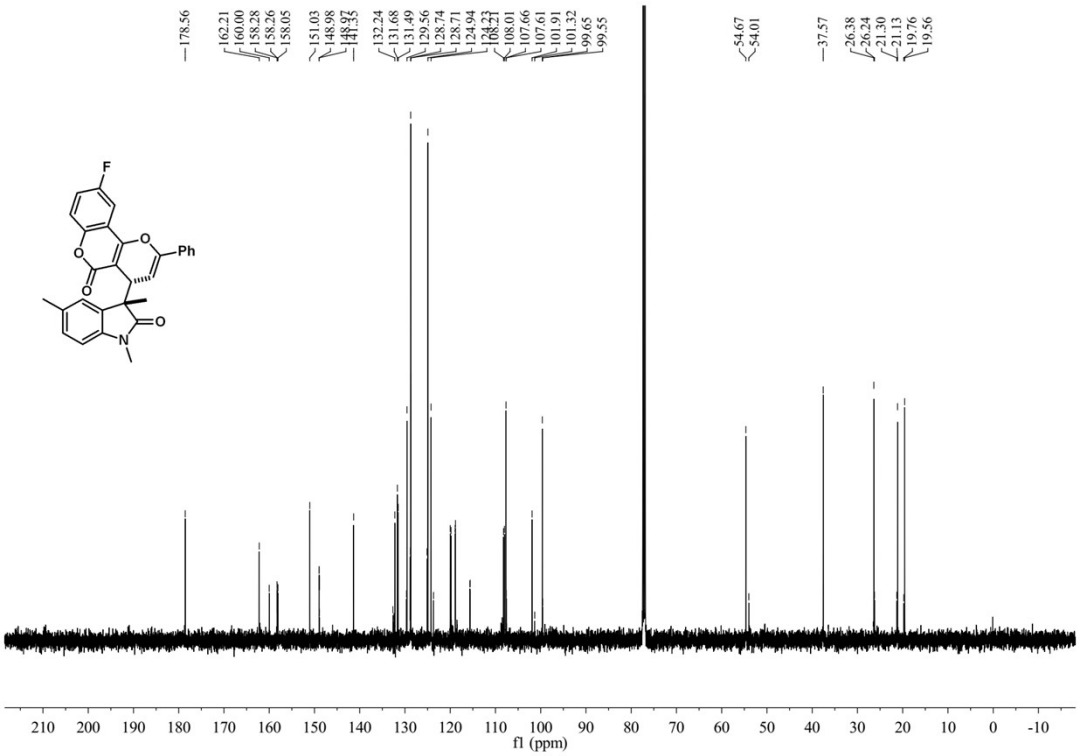


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ah

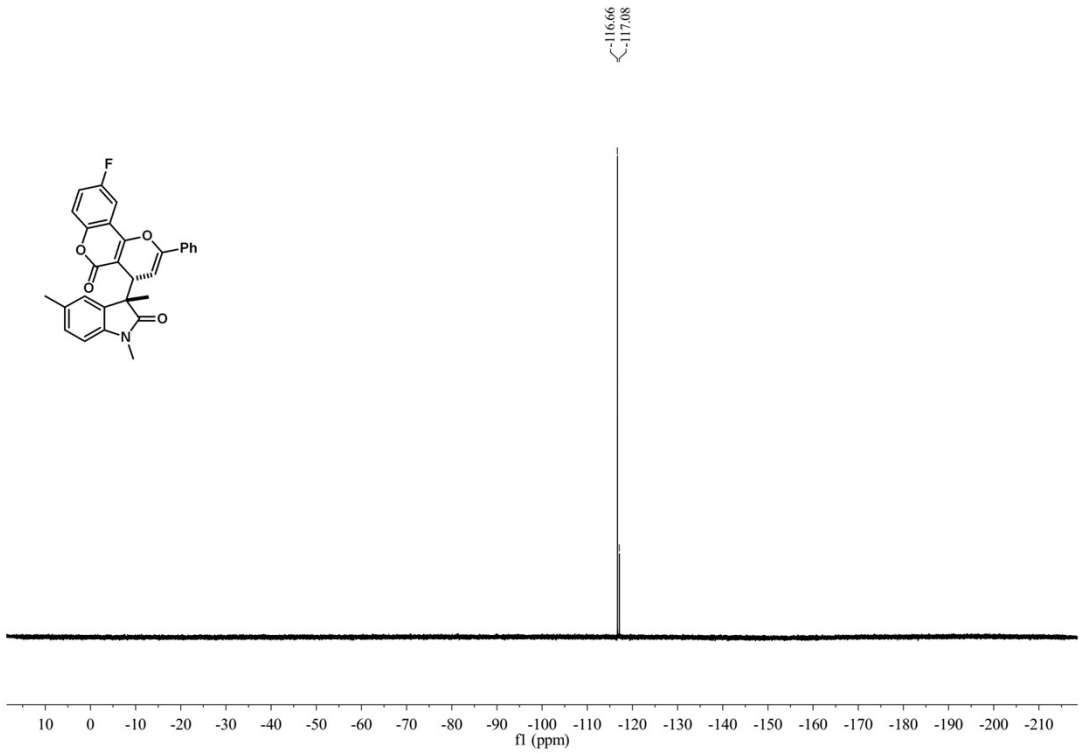


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ba

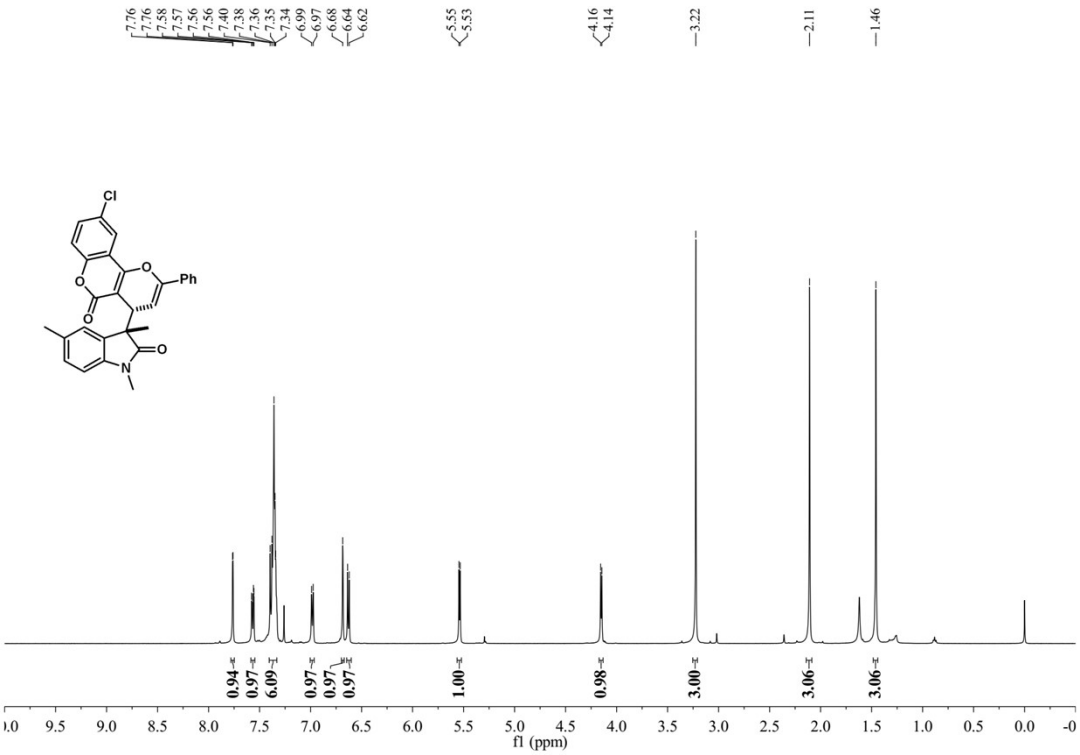


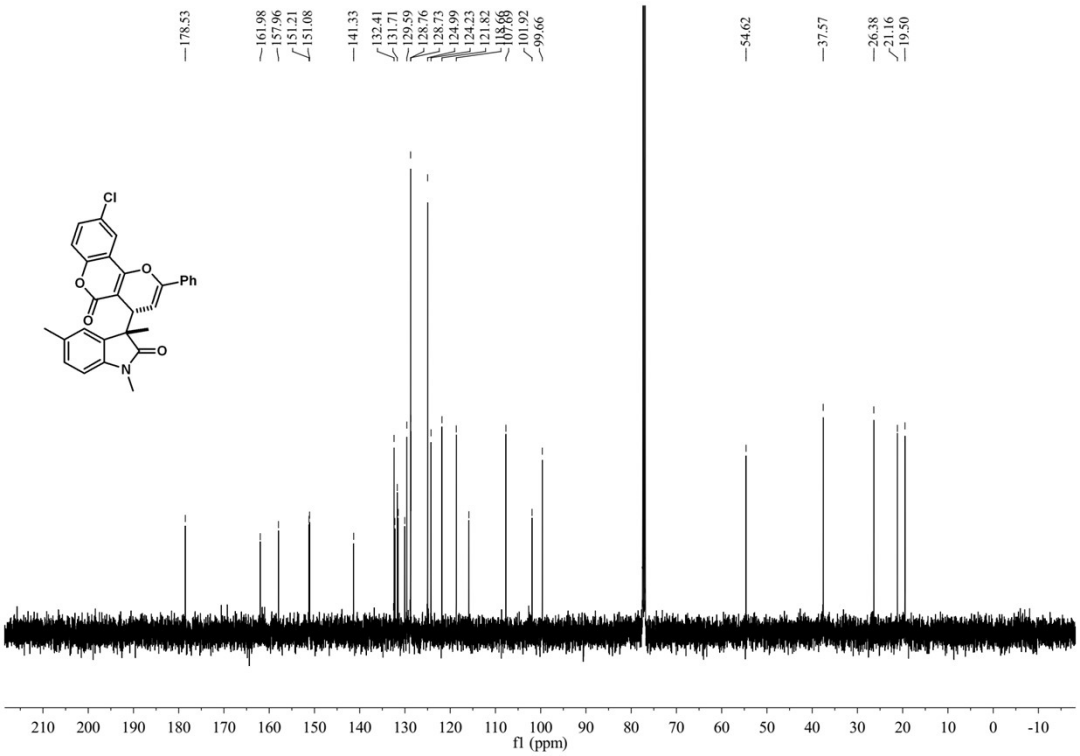


^{19}F NMR (376 MHz, $CDCl_3$) spectra for 4ba

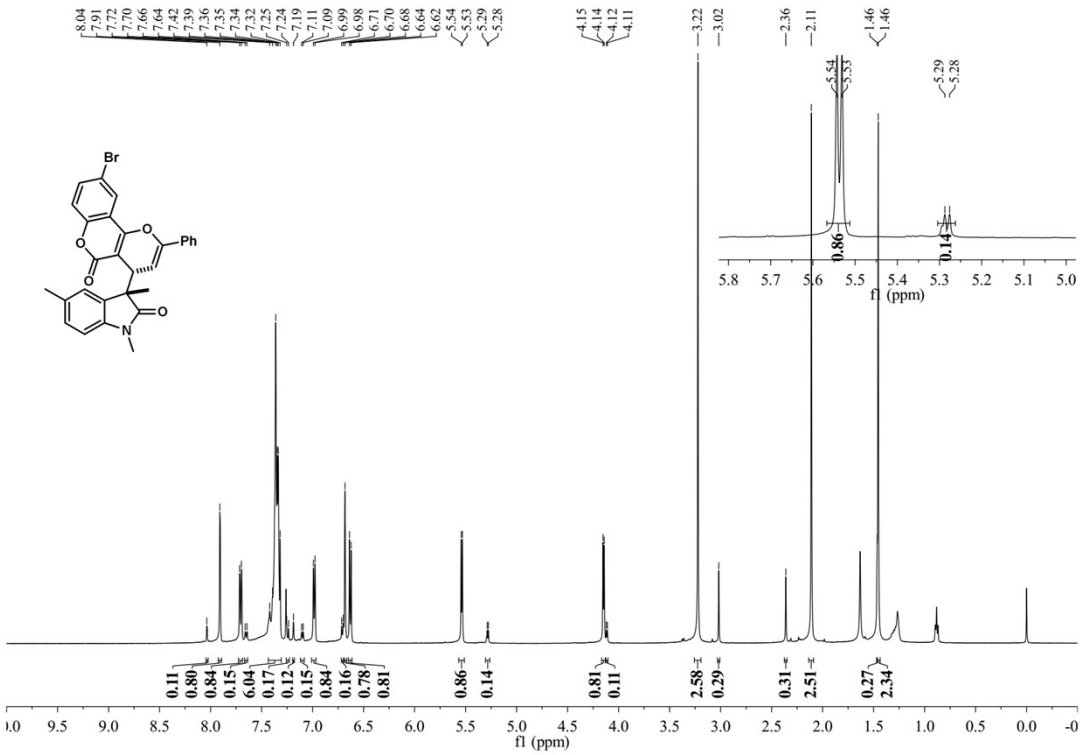


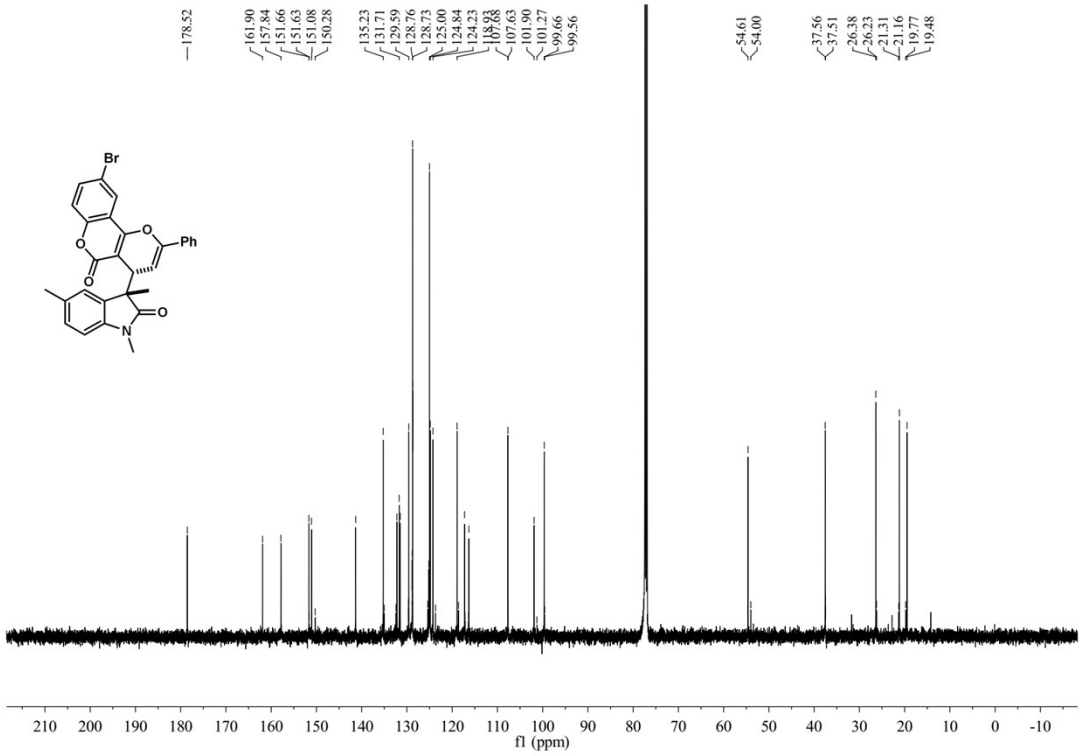
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4bb



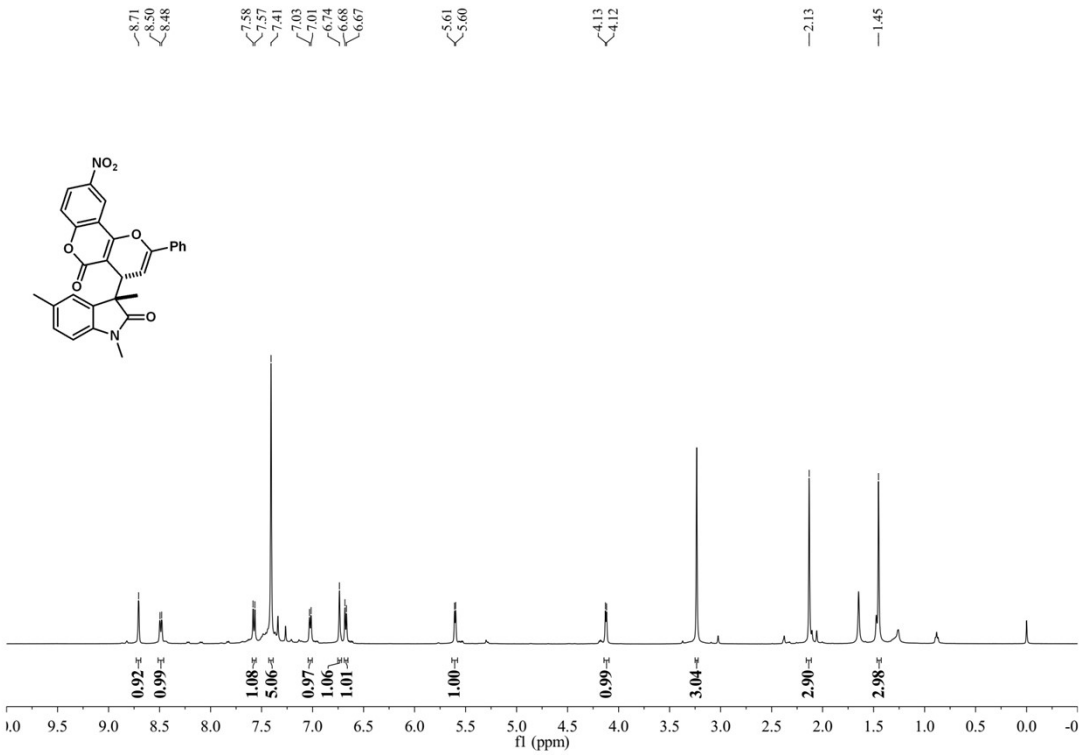


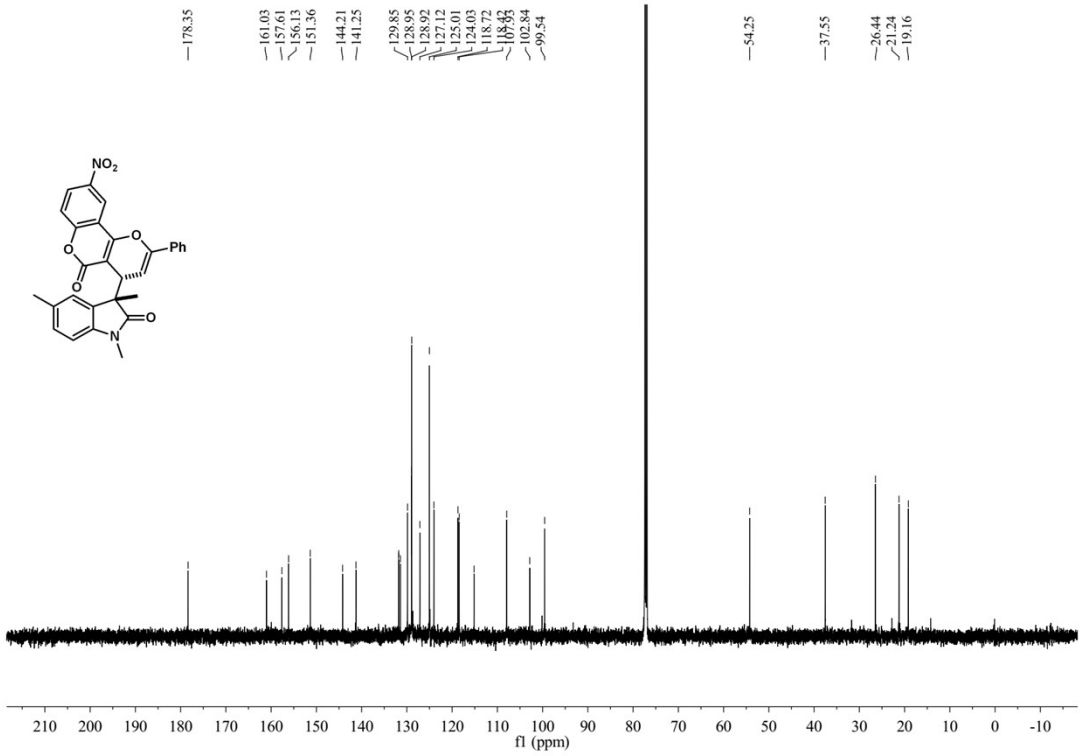
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4bc



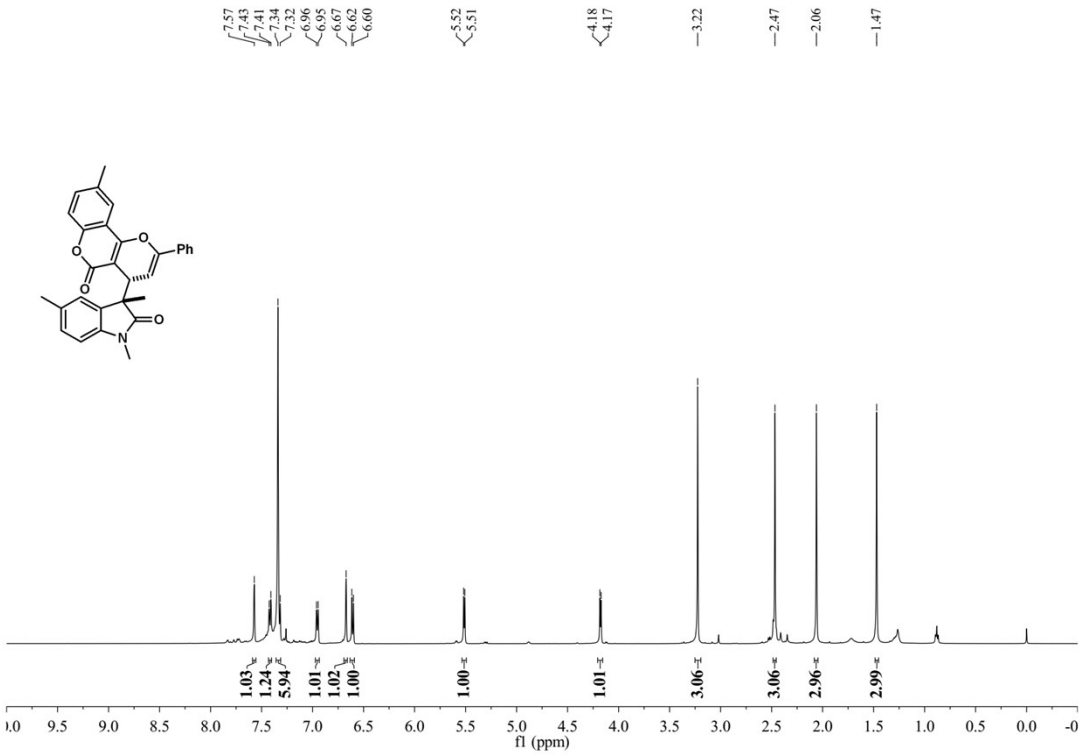


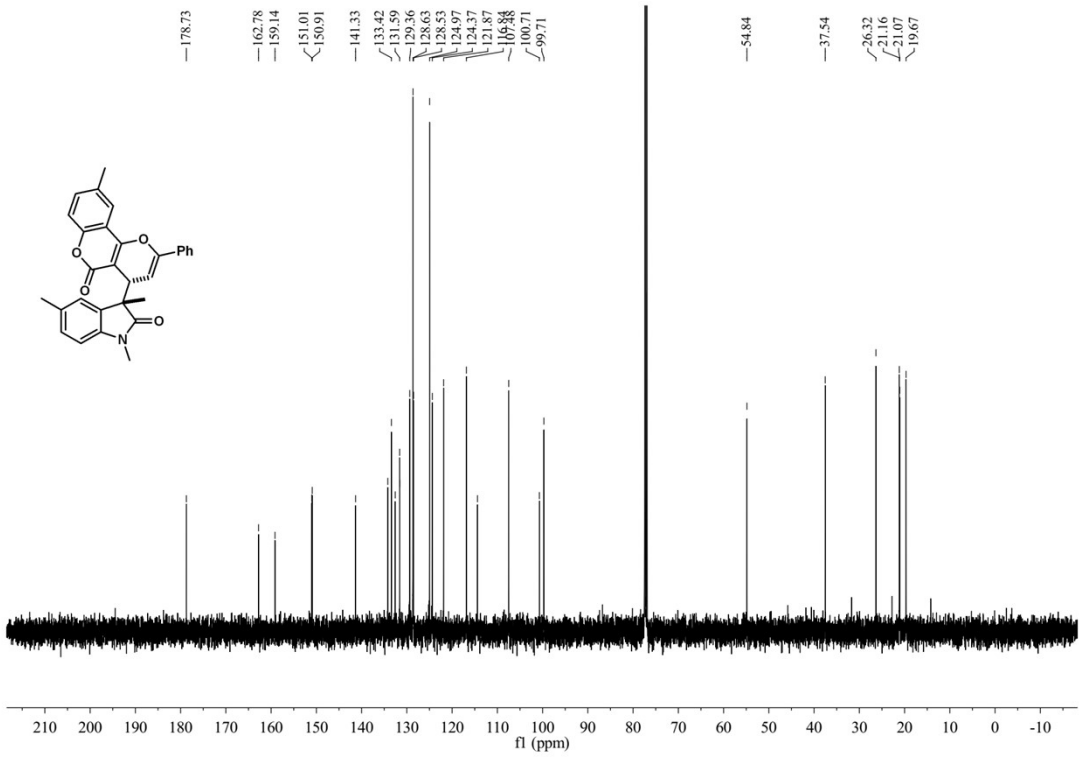
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4bd



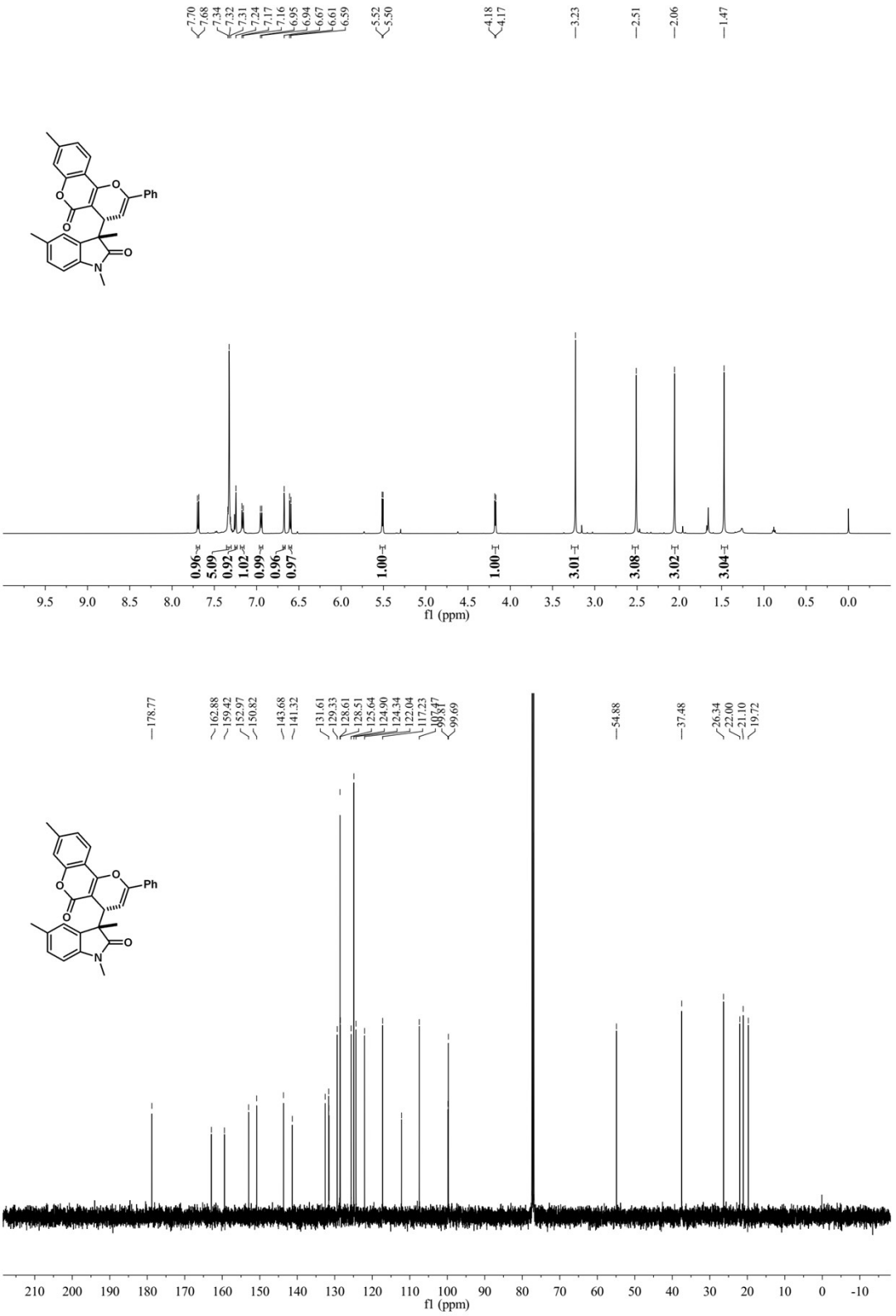


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4be

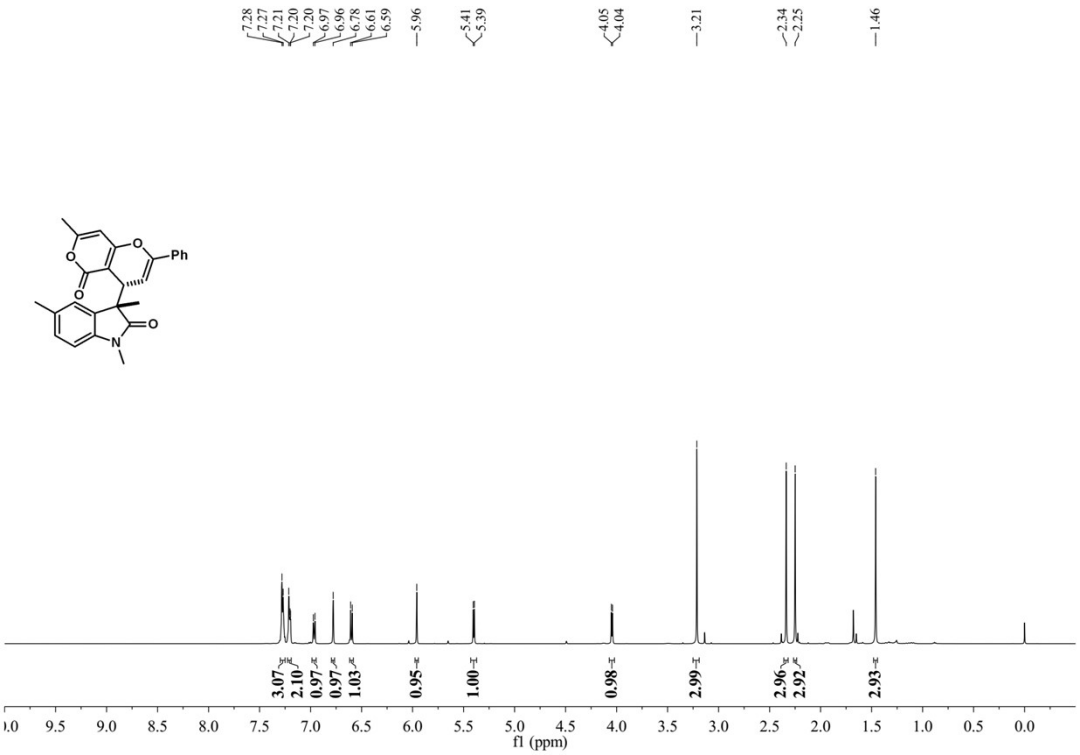


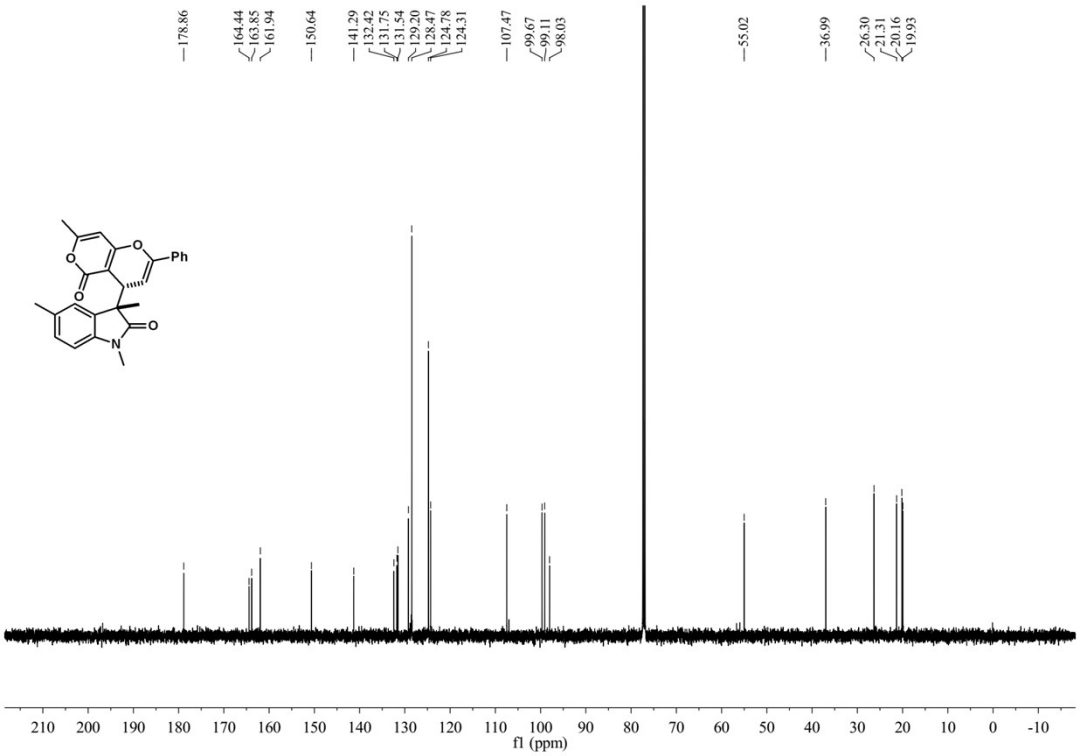


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4bf

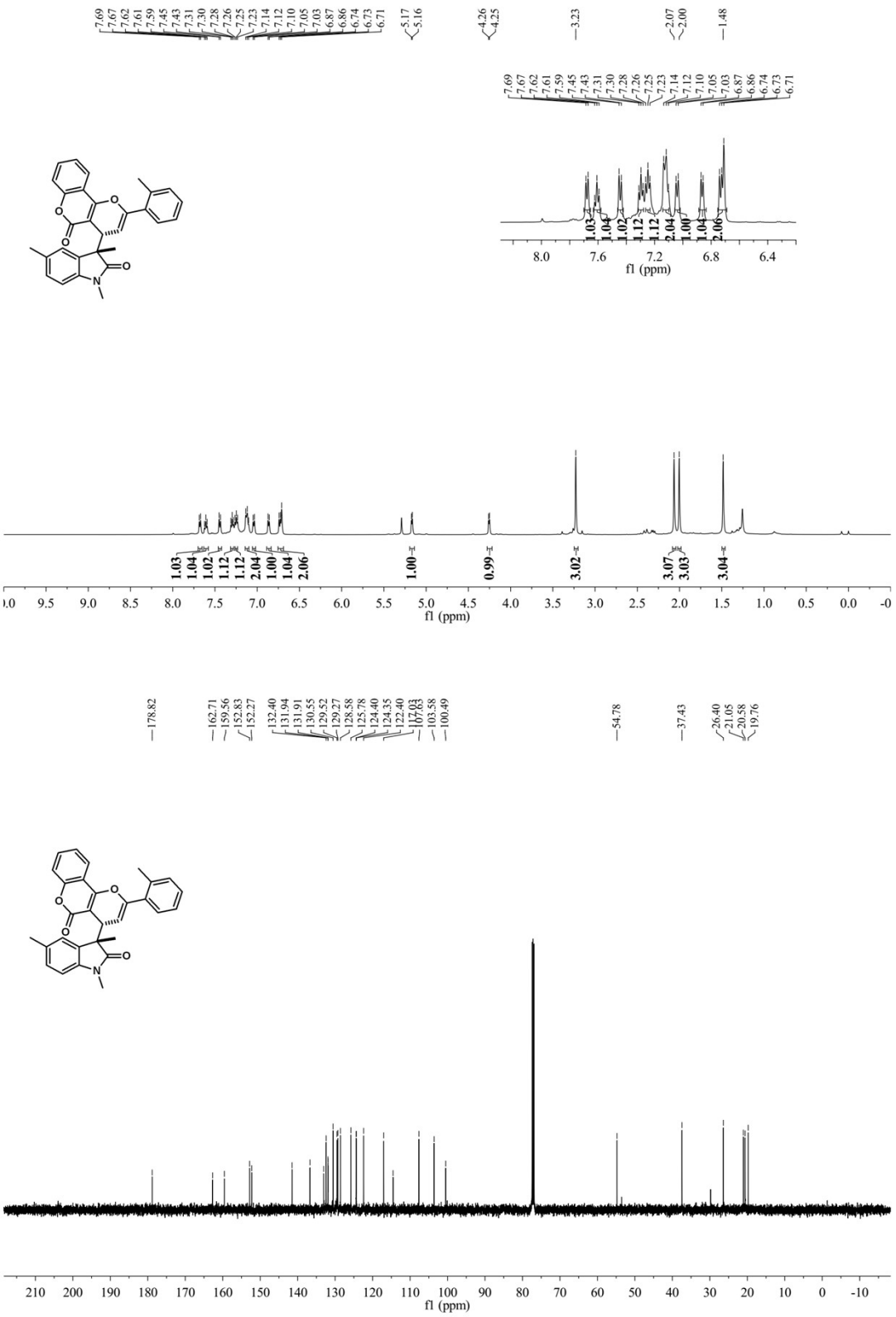


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4bg

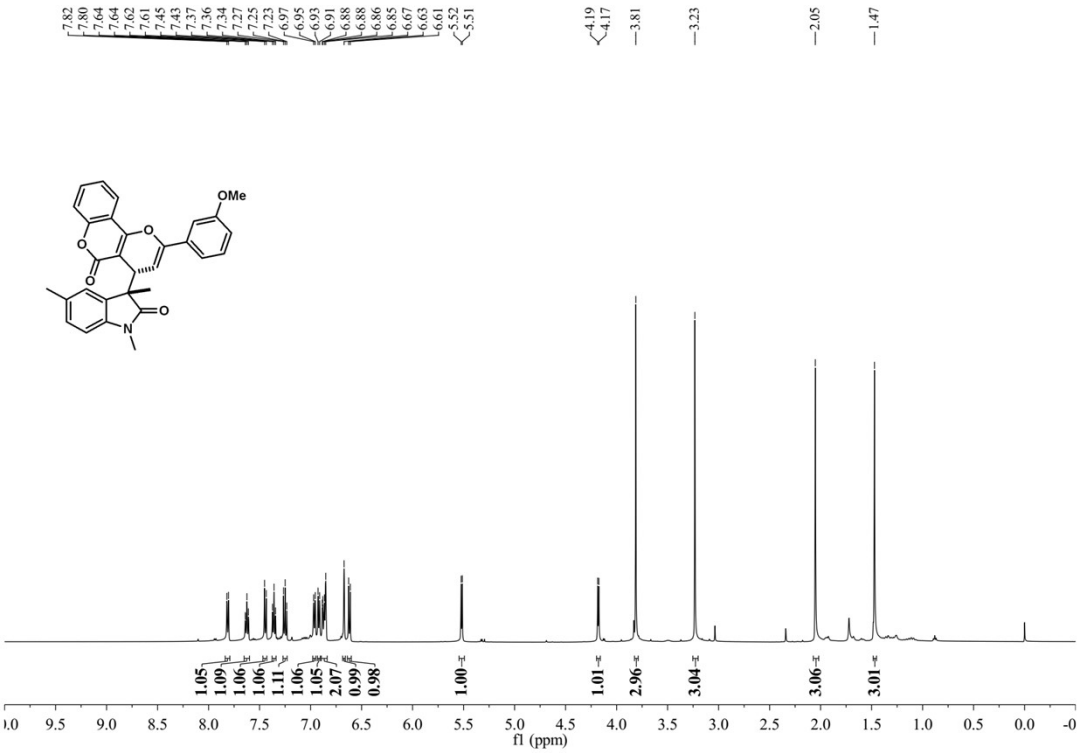


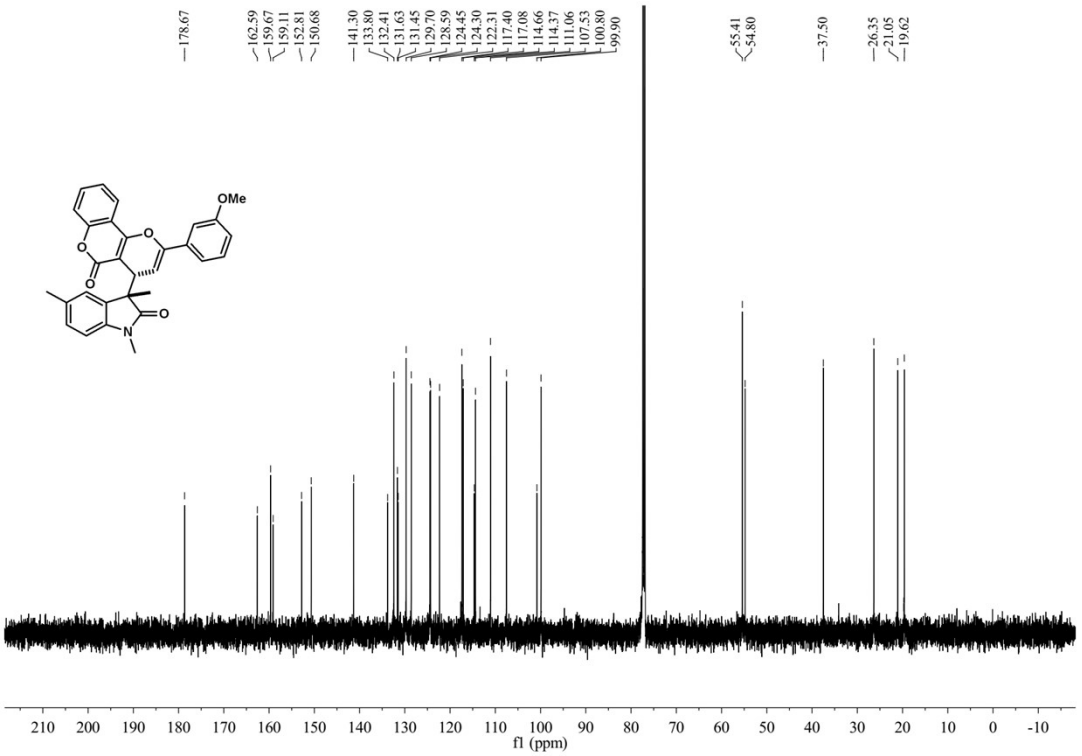


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ca

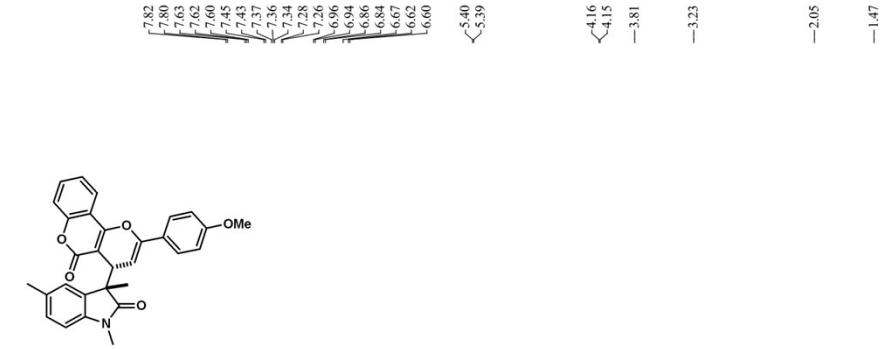


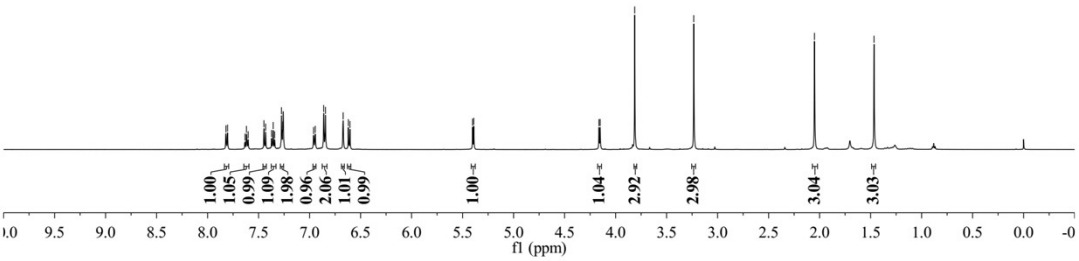
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4cb

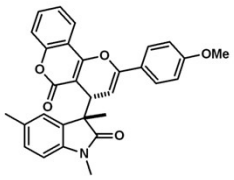


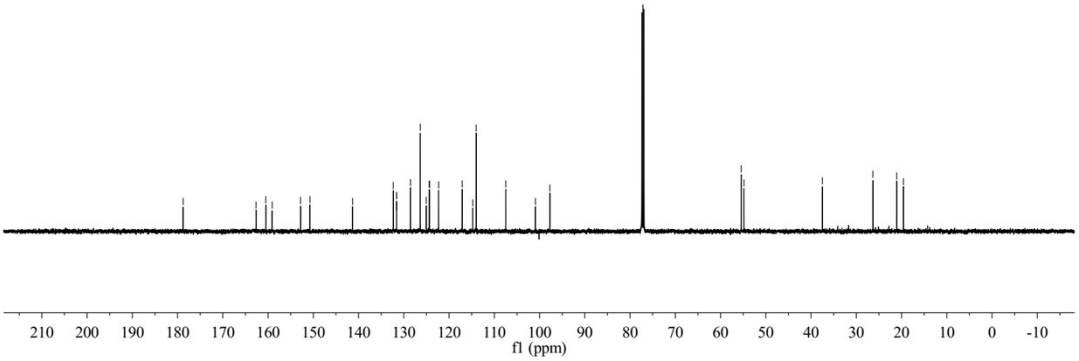


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4cc

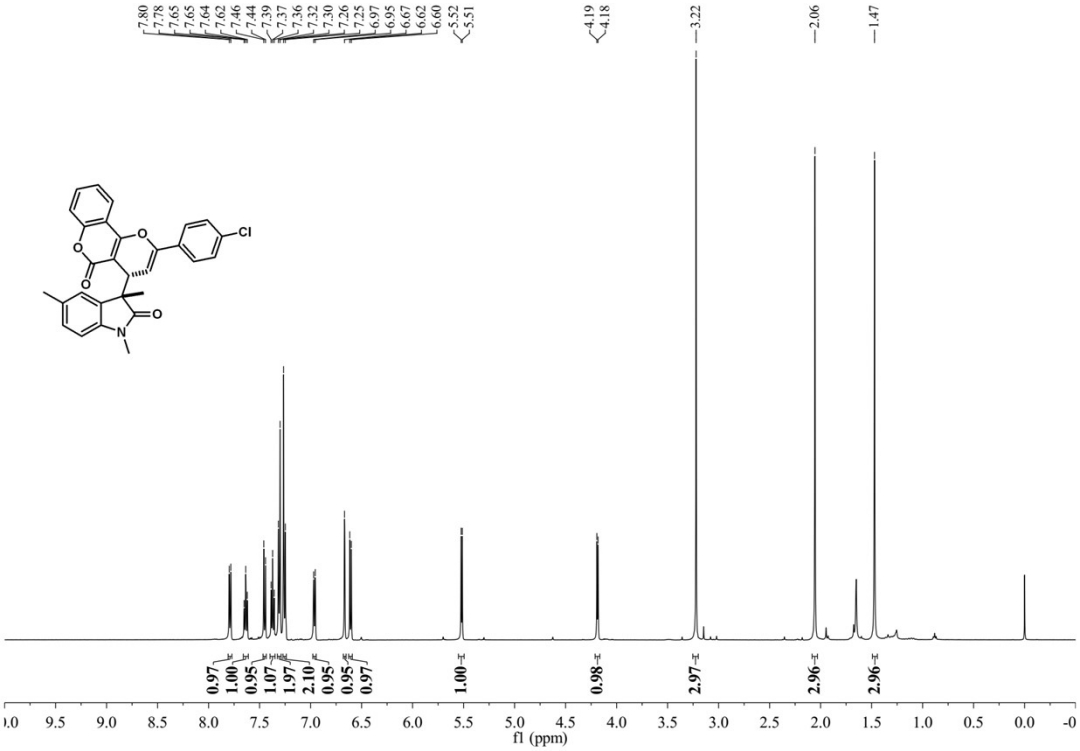


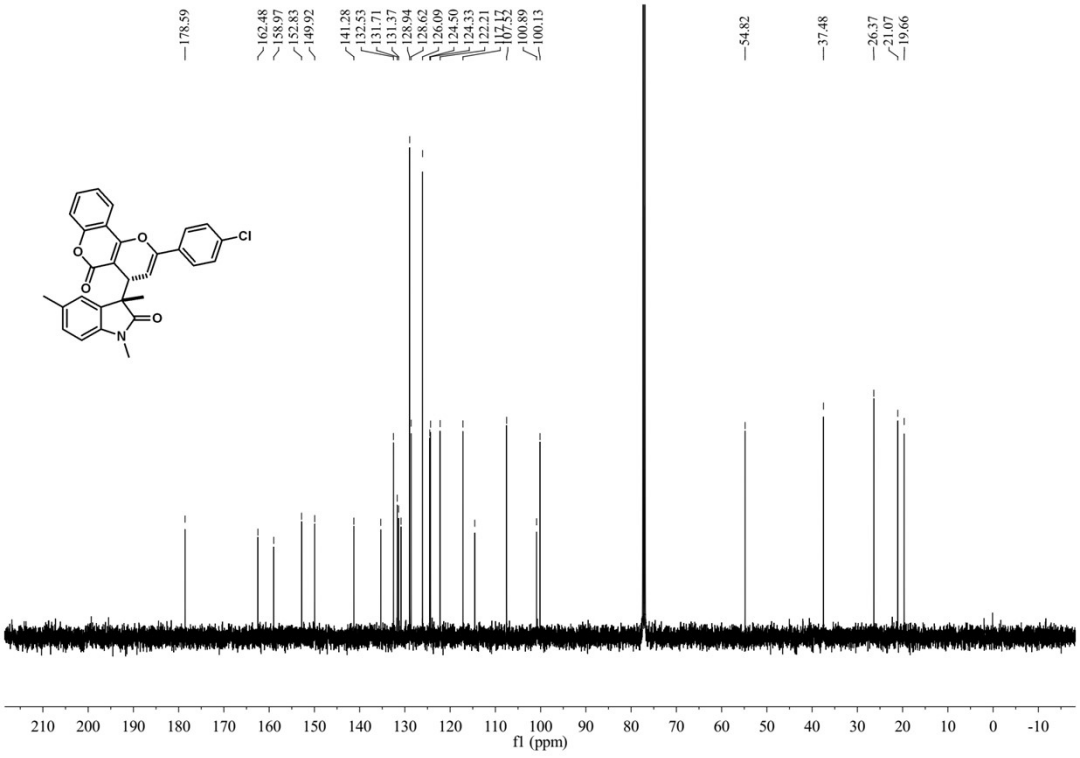




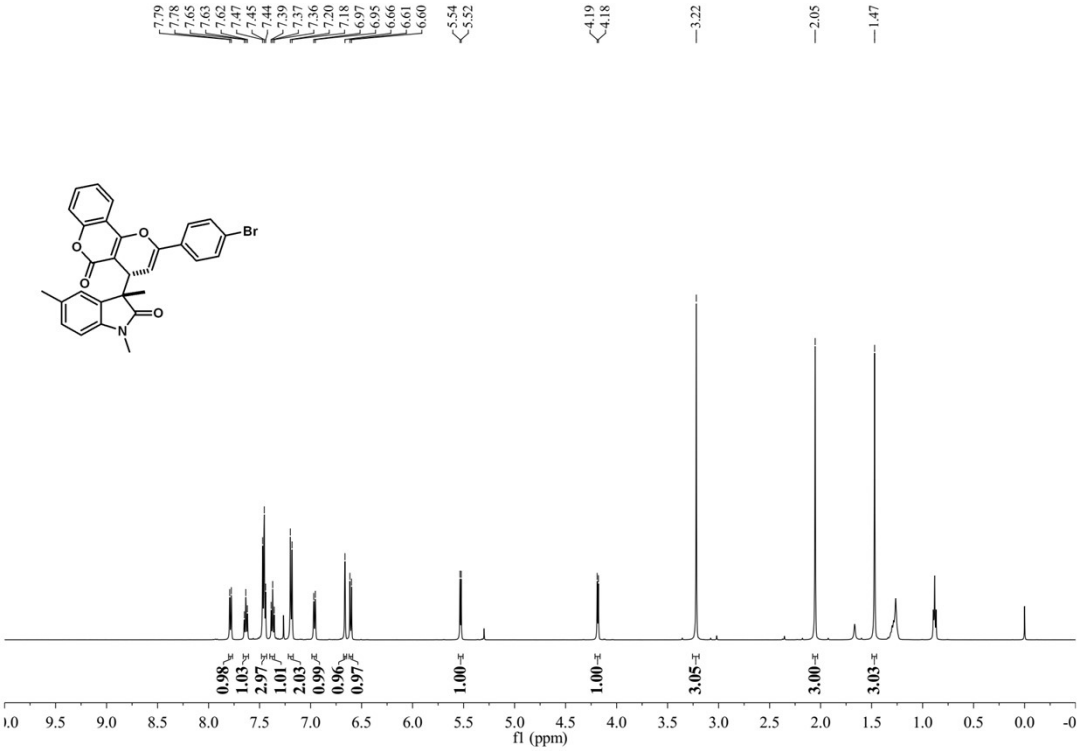


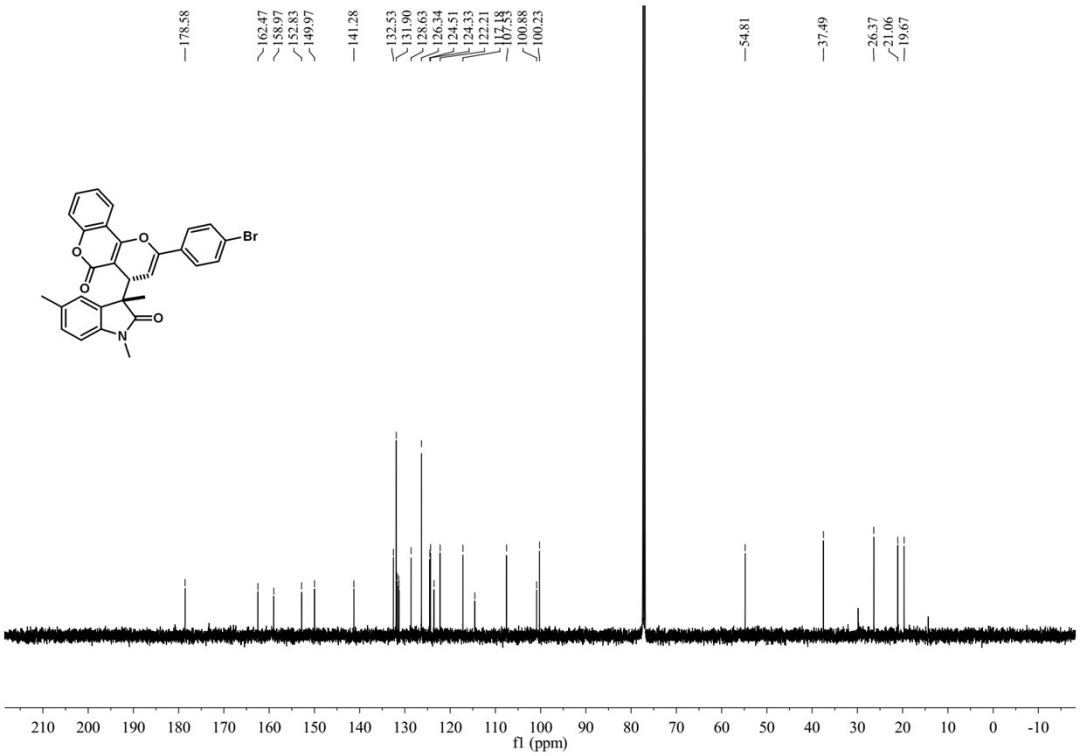
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4cd



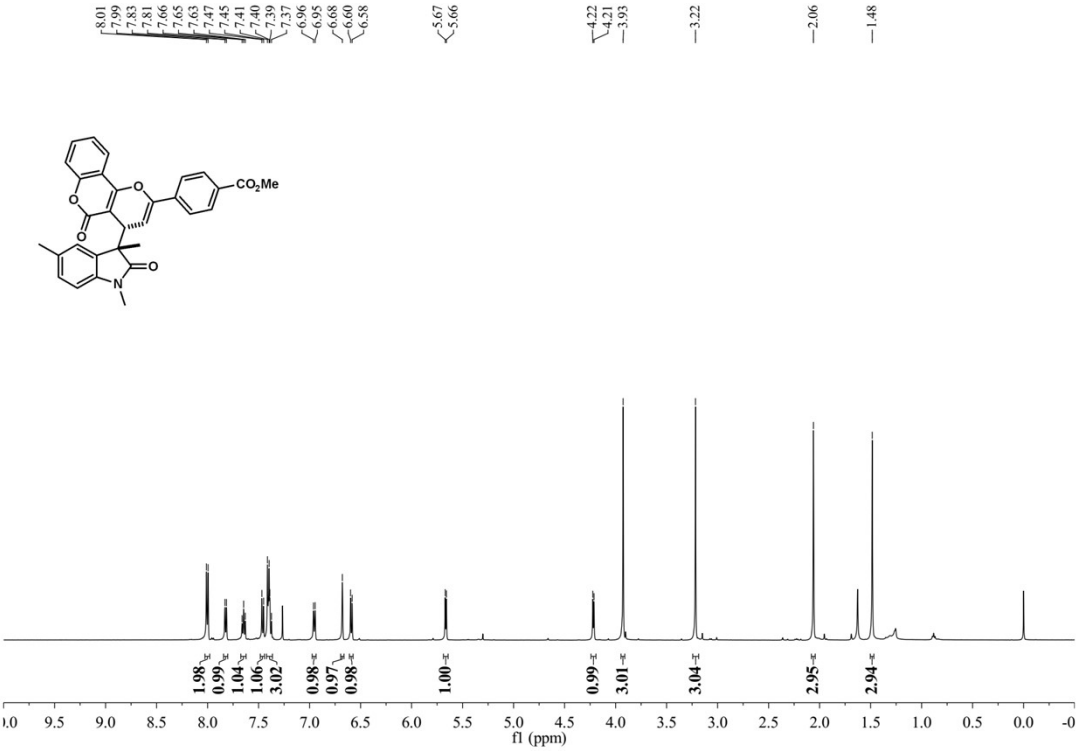


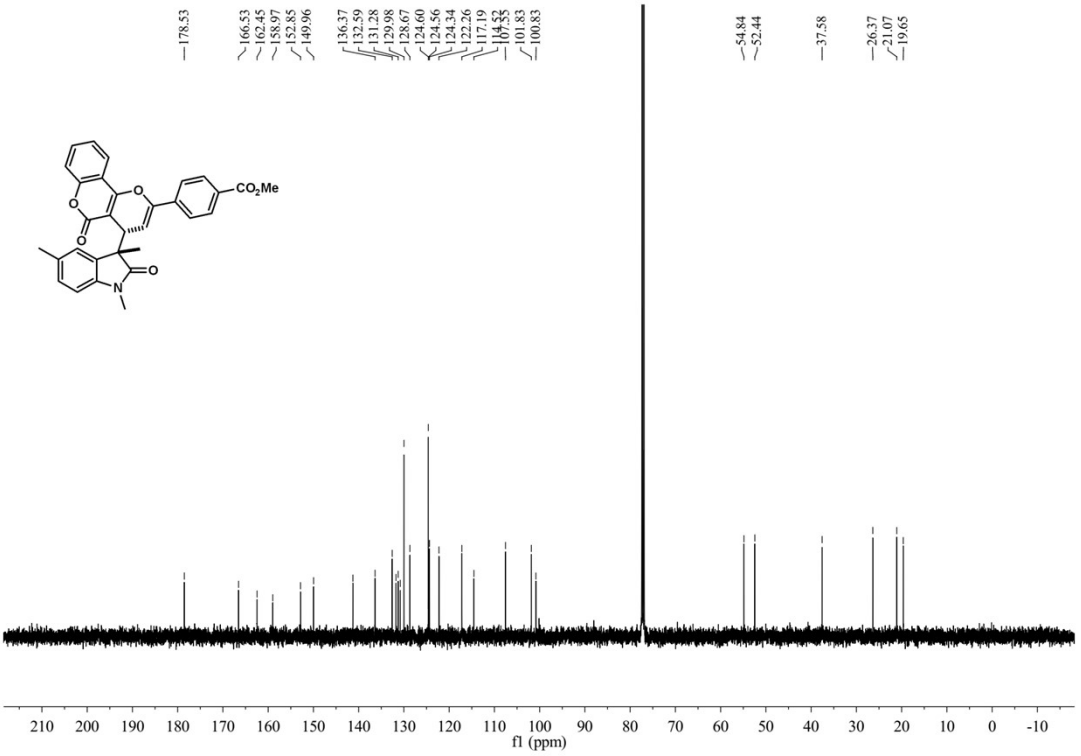
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ce



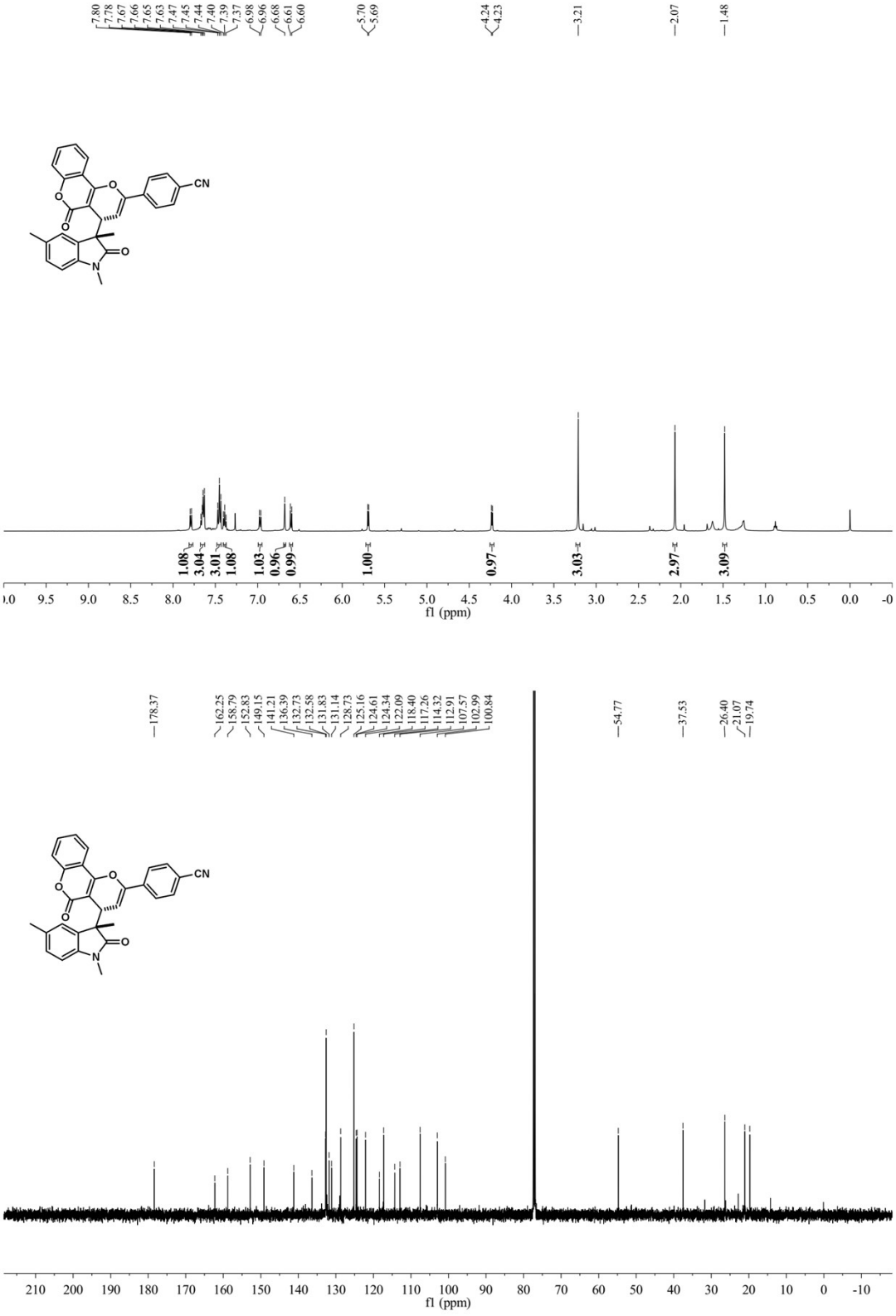


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4cf

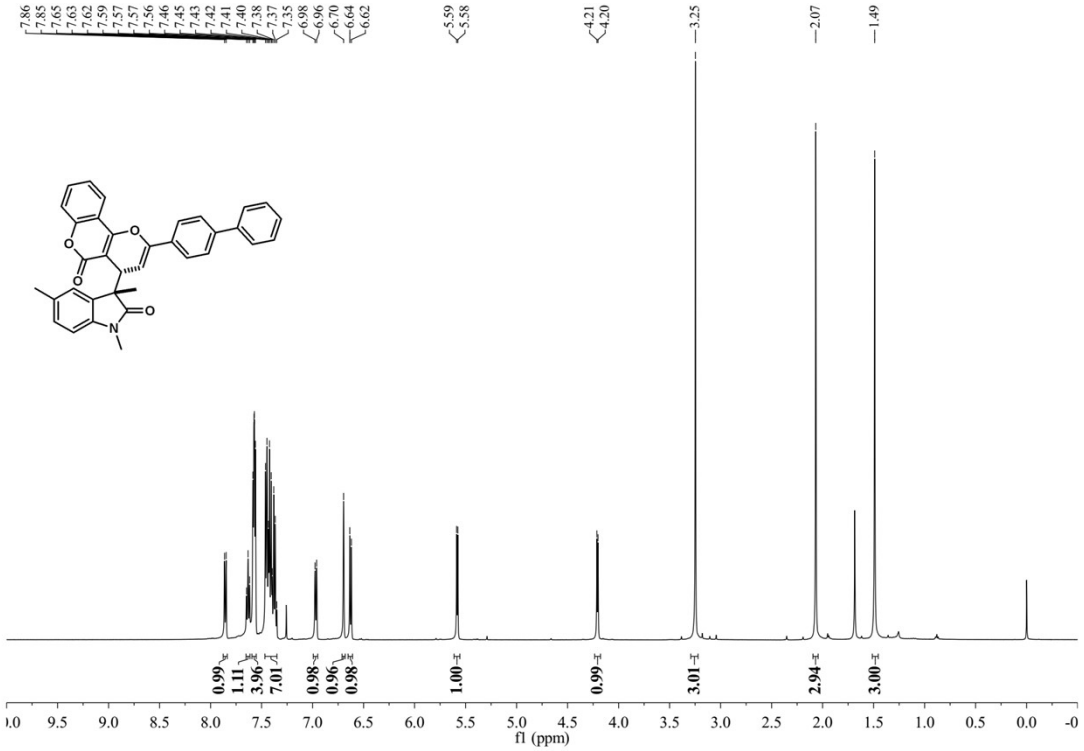


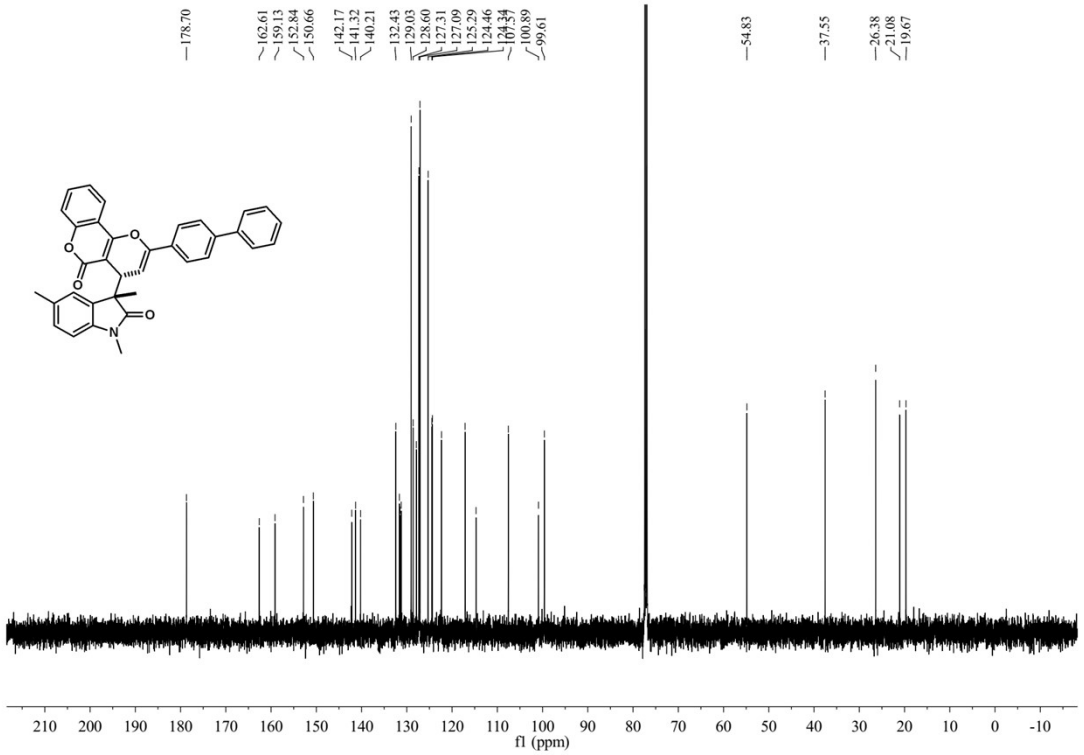


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4cg

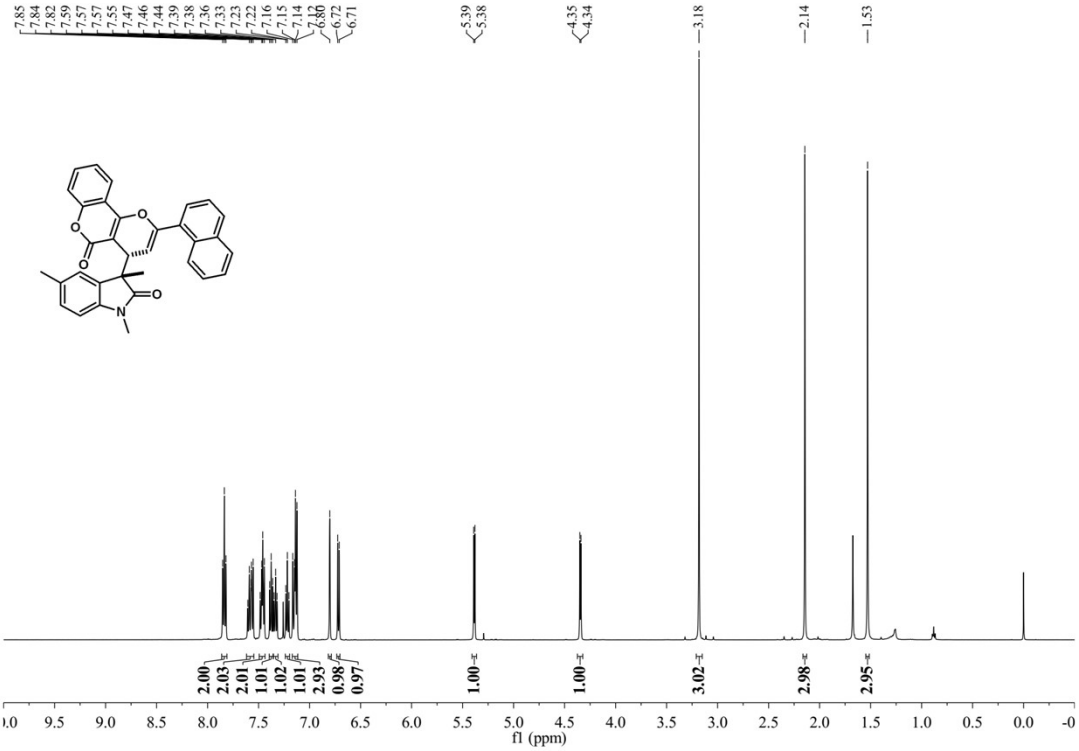


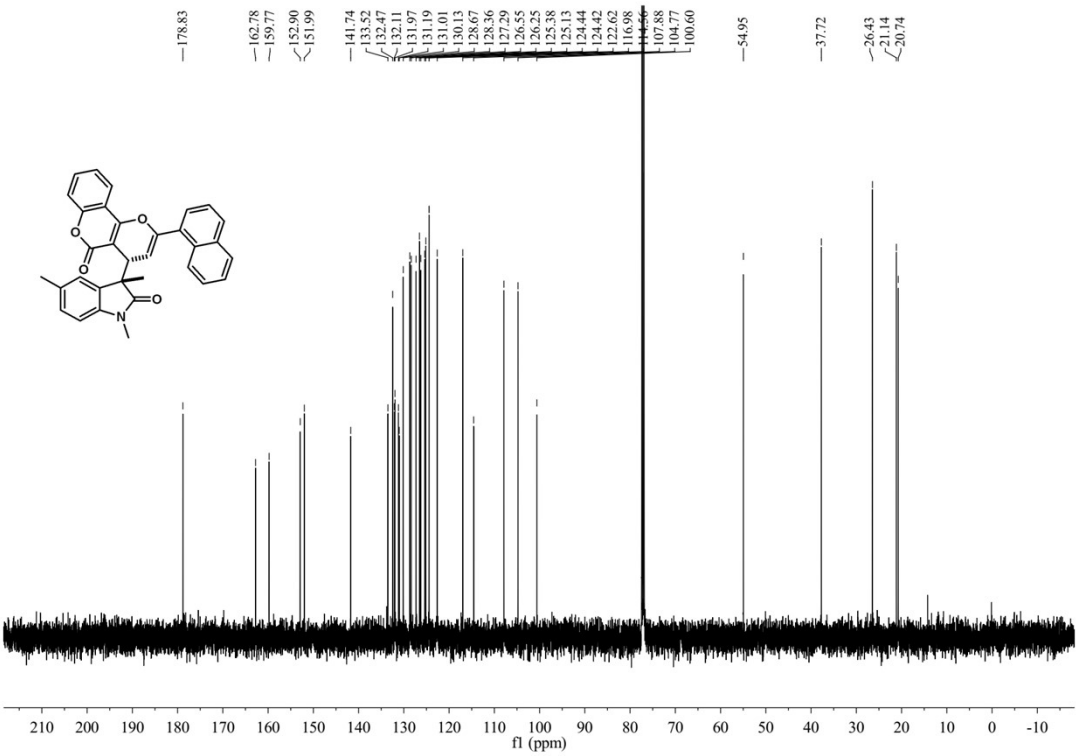
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ch



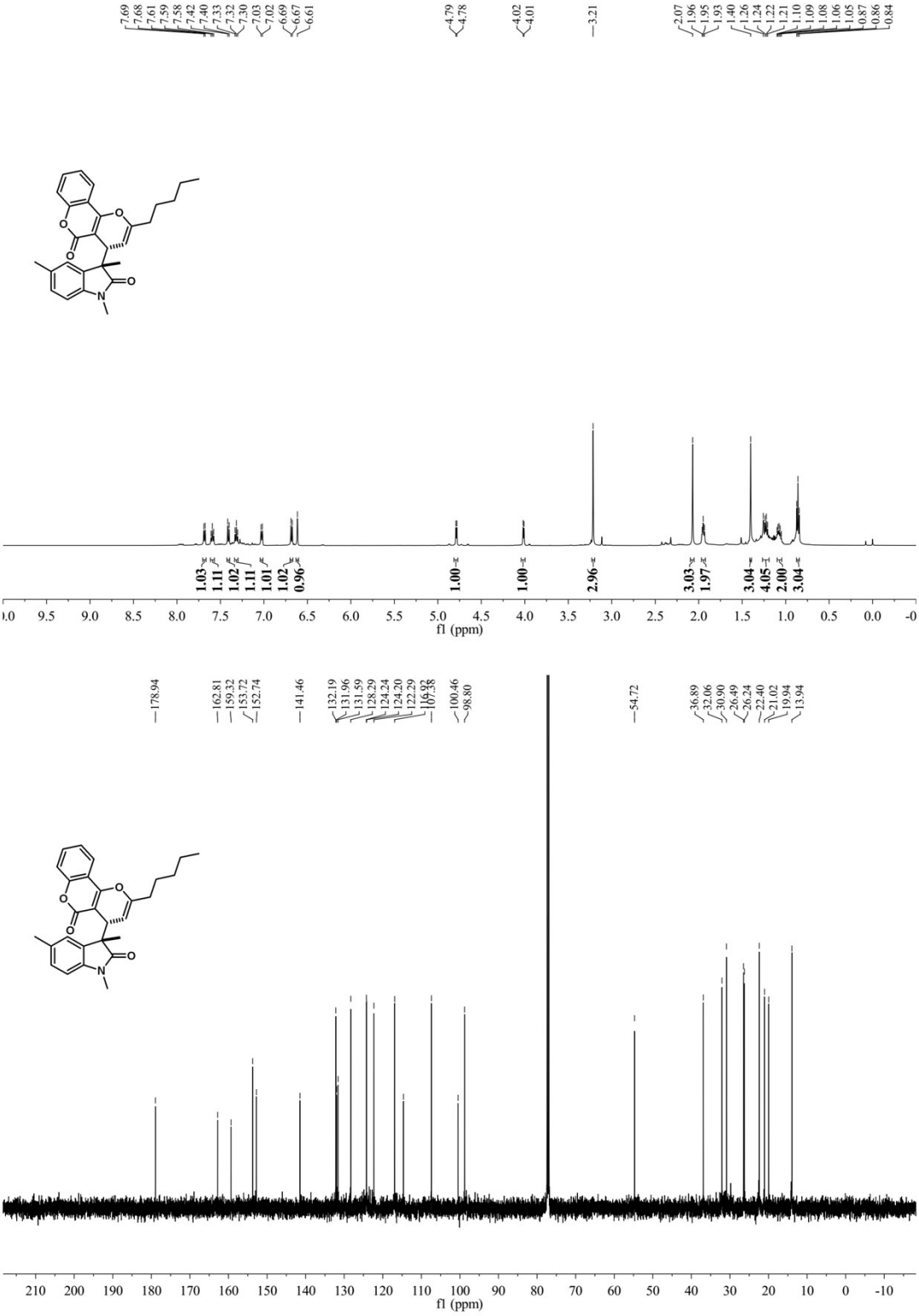


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4ci

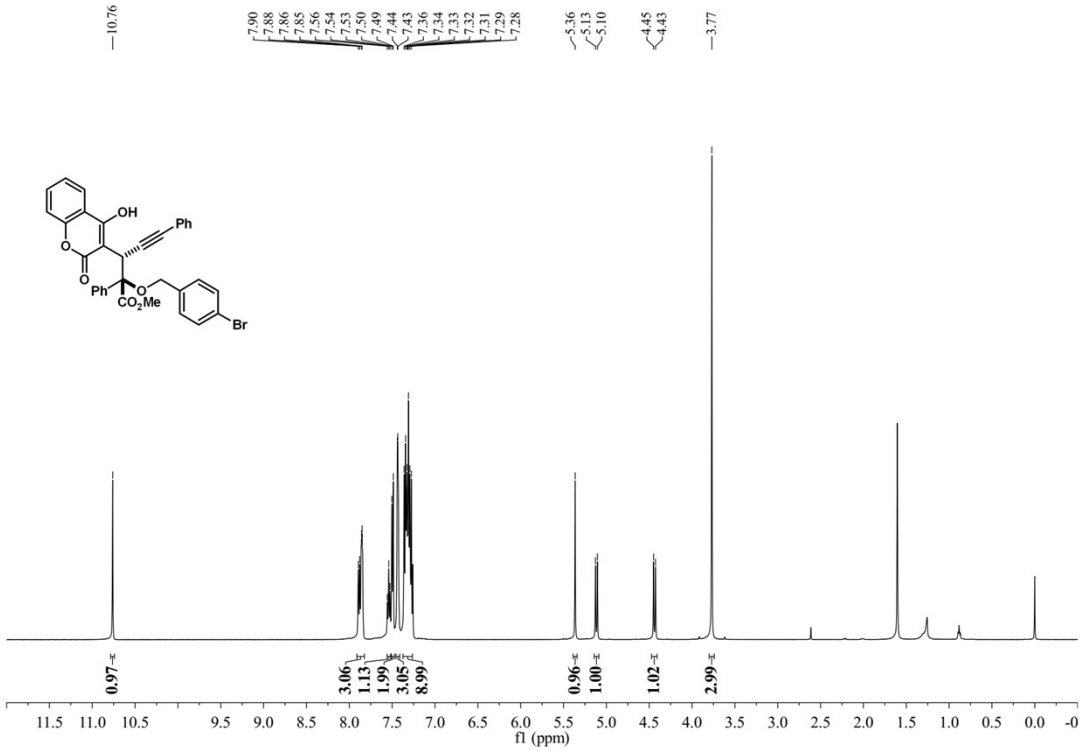


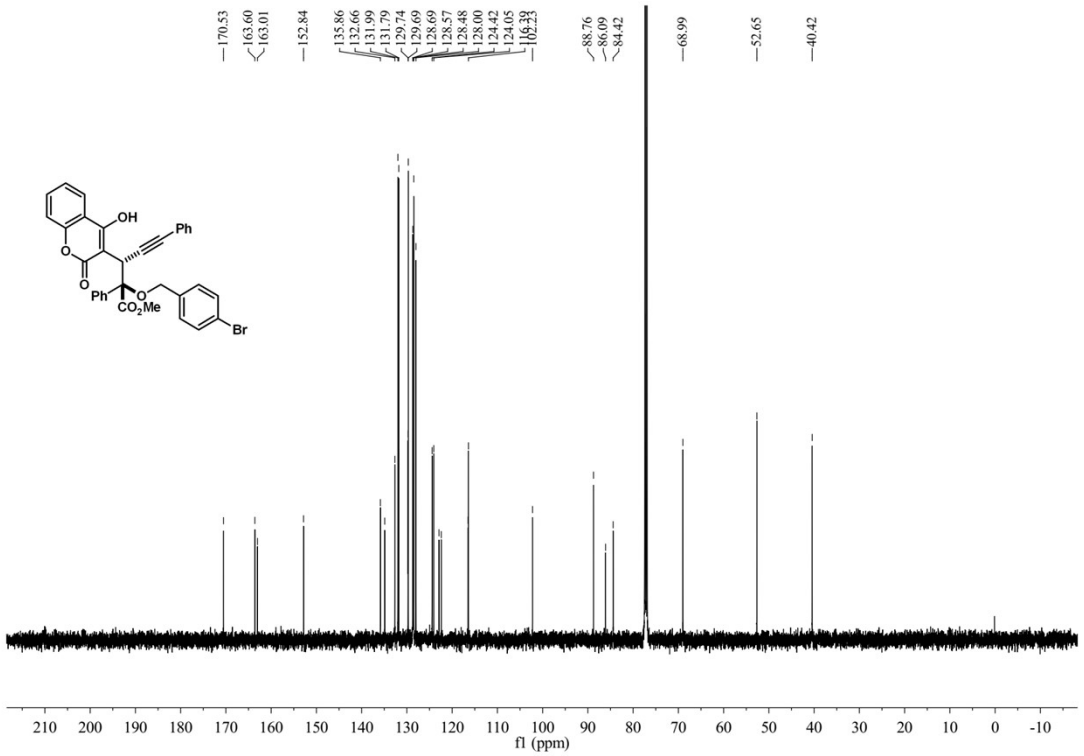


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 4cj

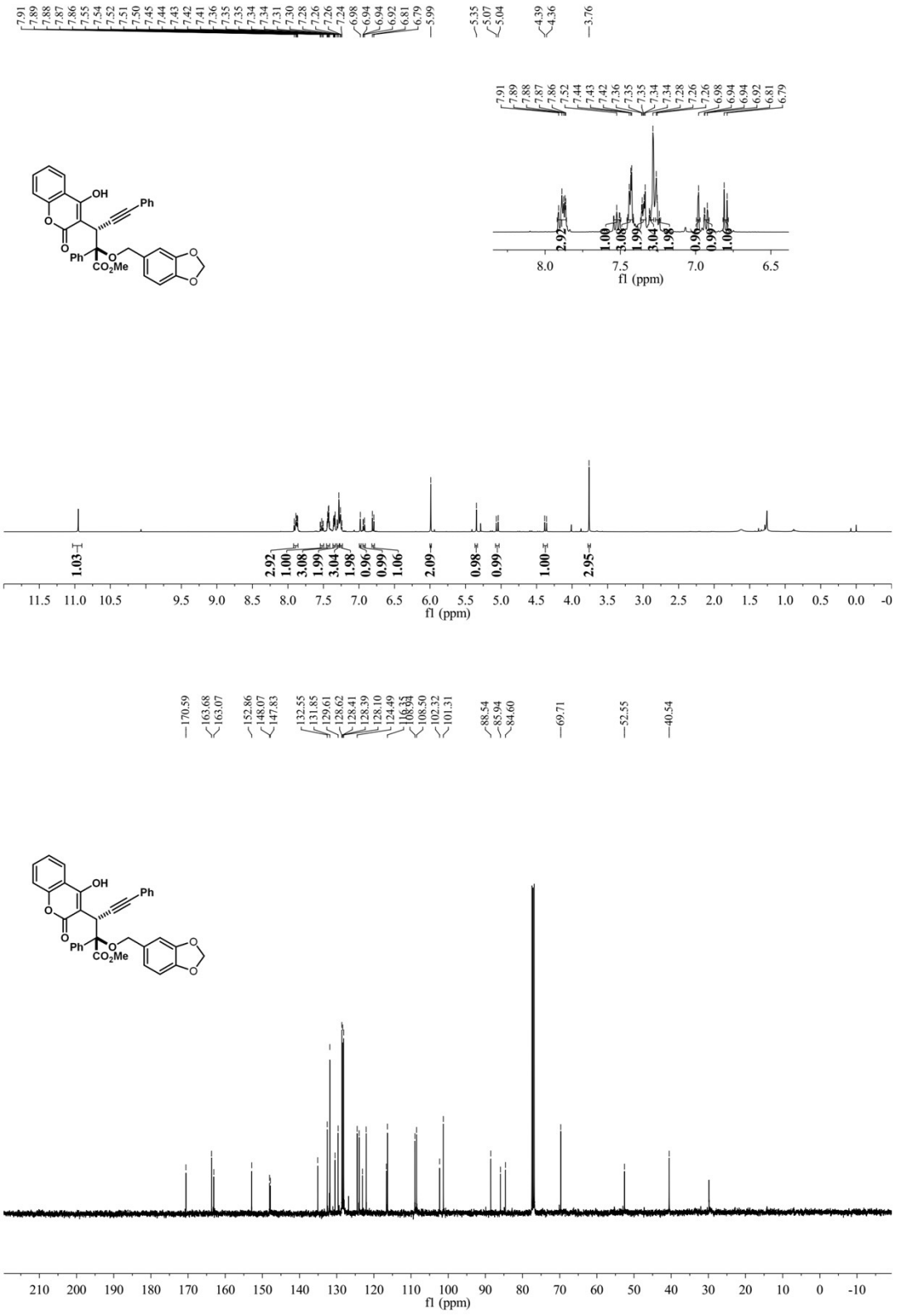


^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 7a

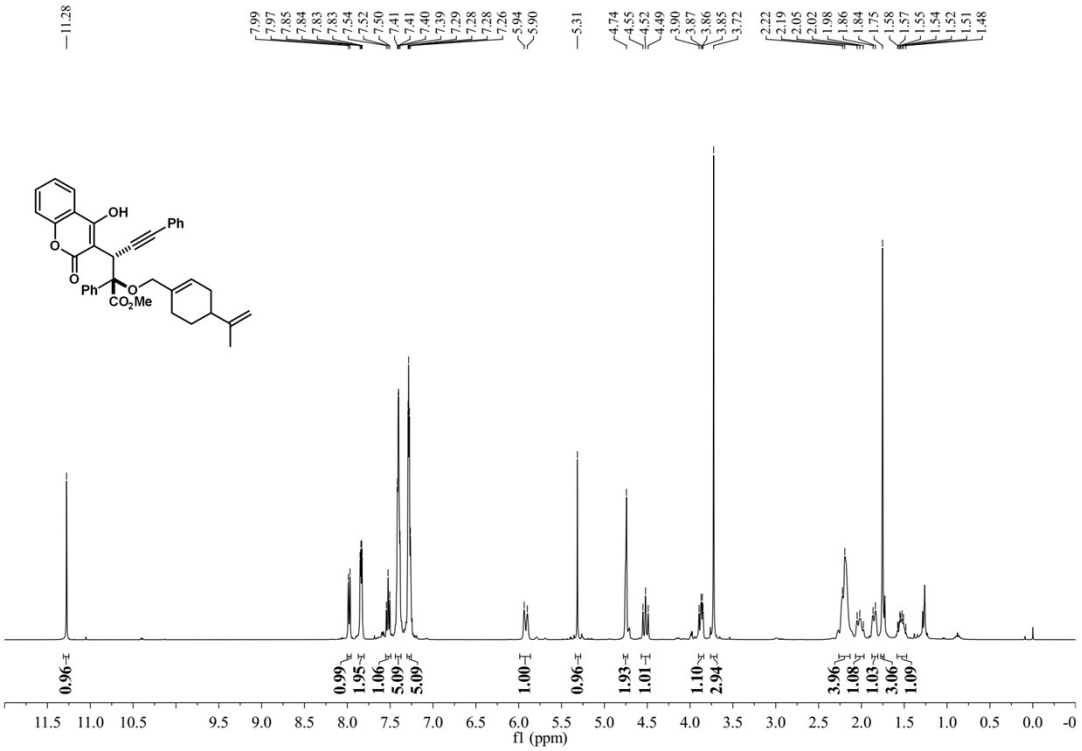


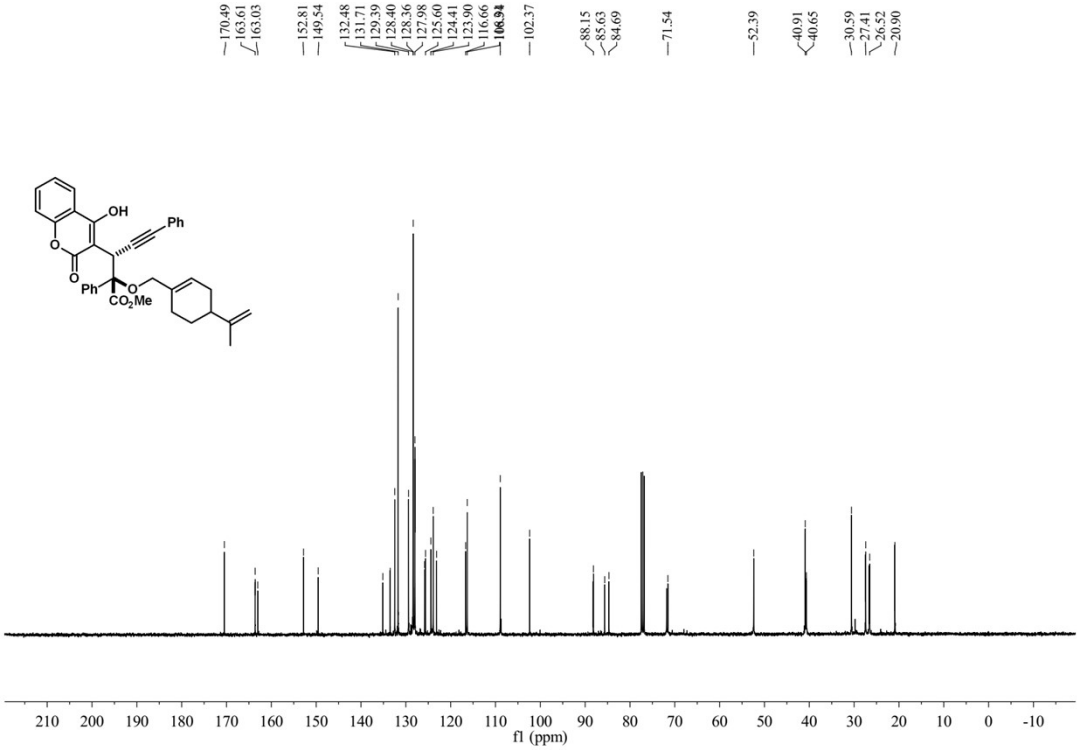


^{1}H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectra for 7b

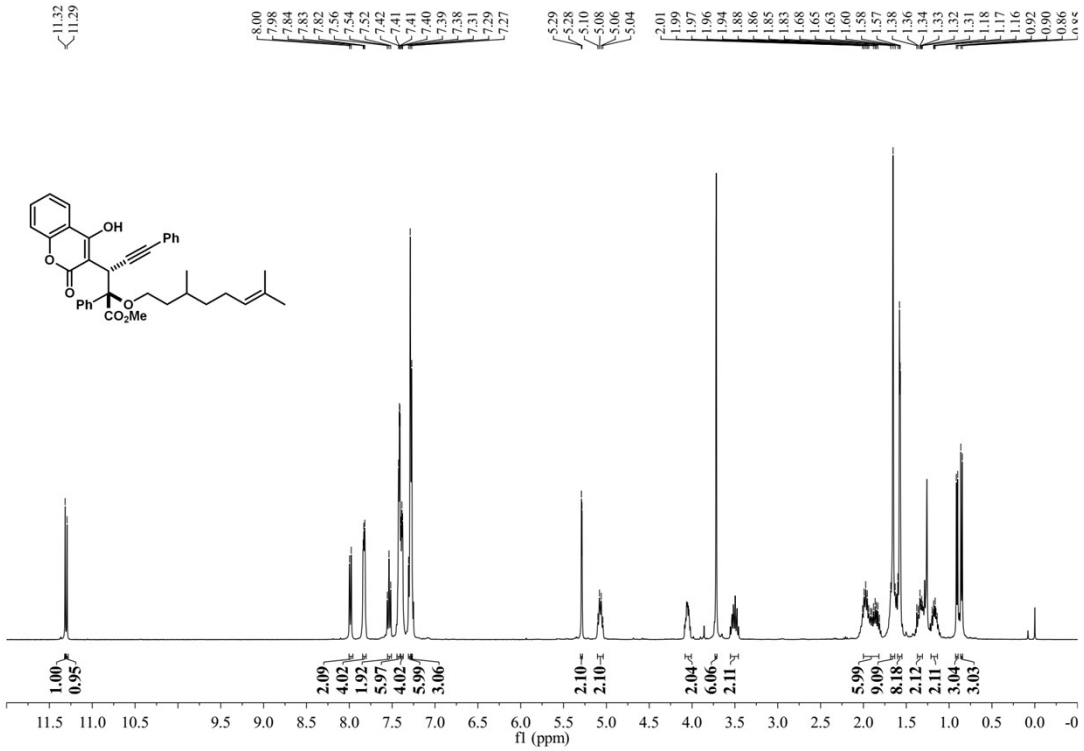


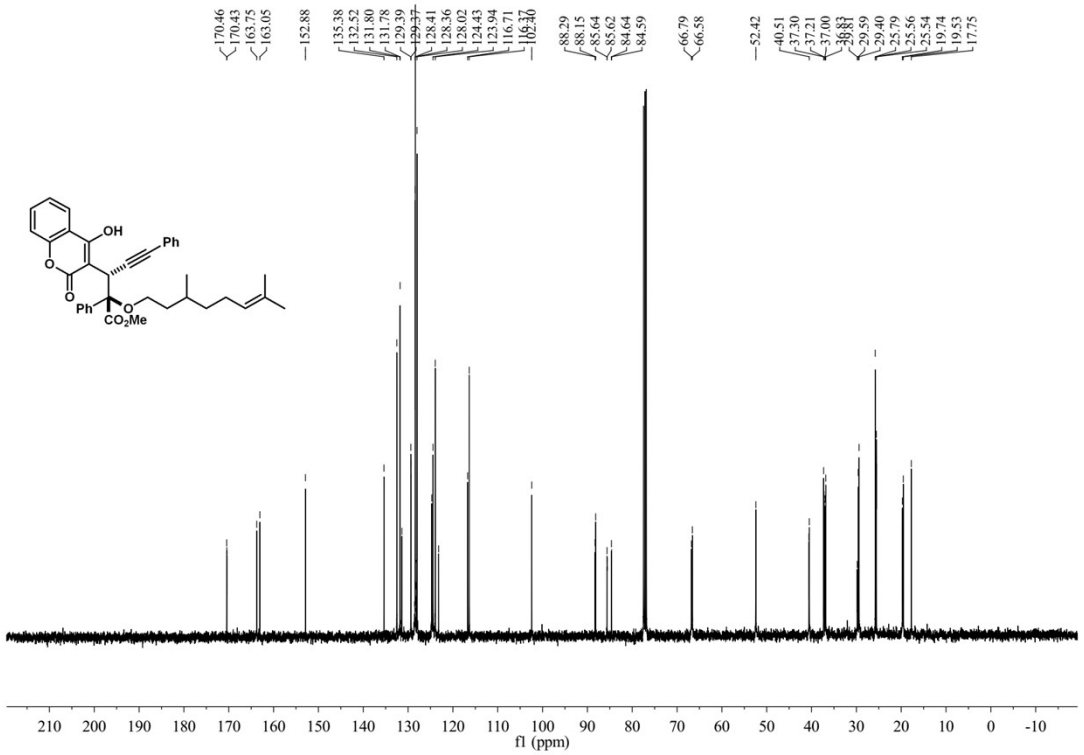
^{1}H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectra for 7c



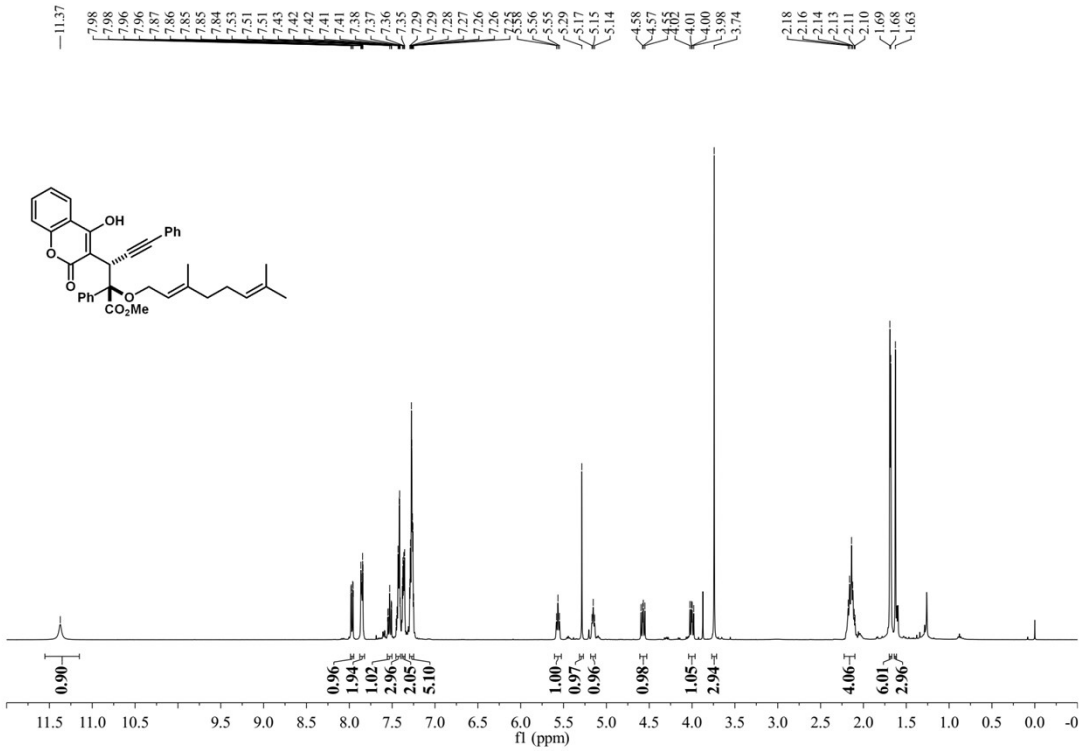


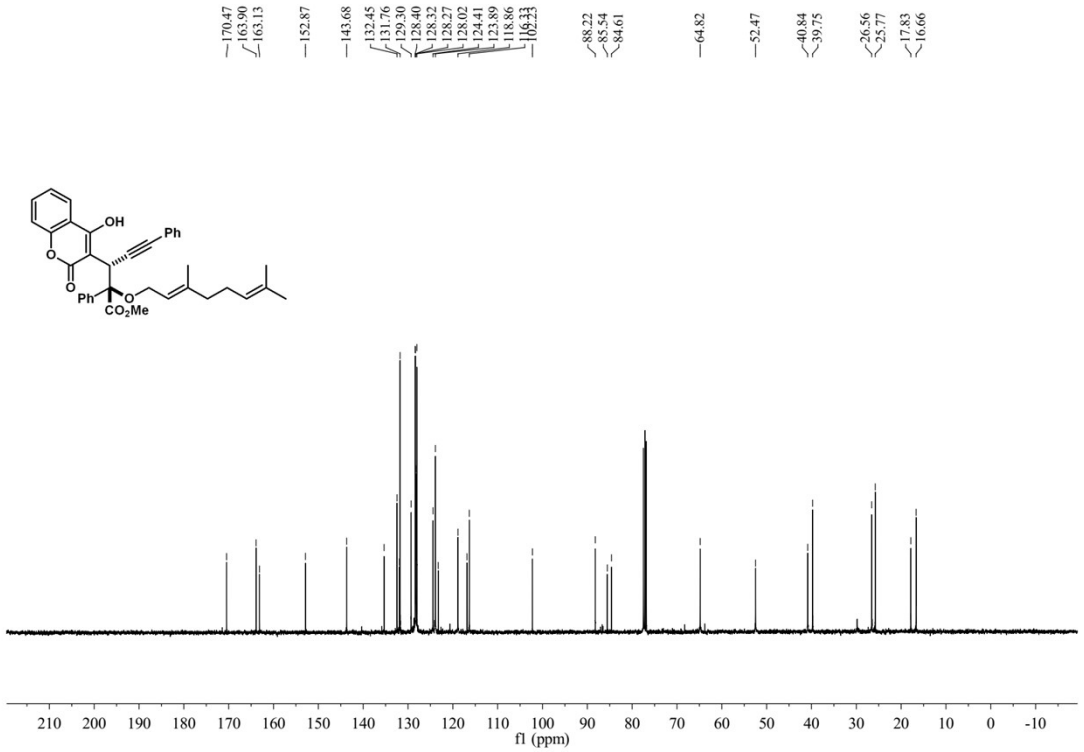
^{1}H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectra for 7d



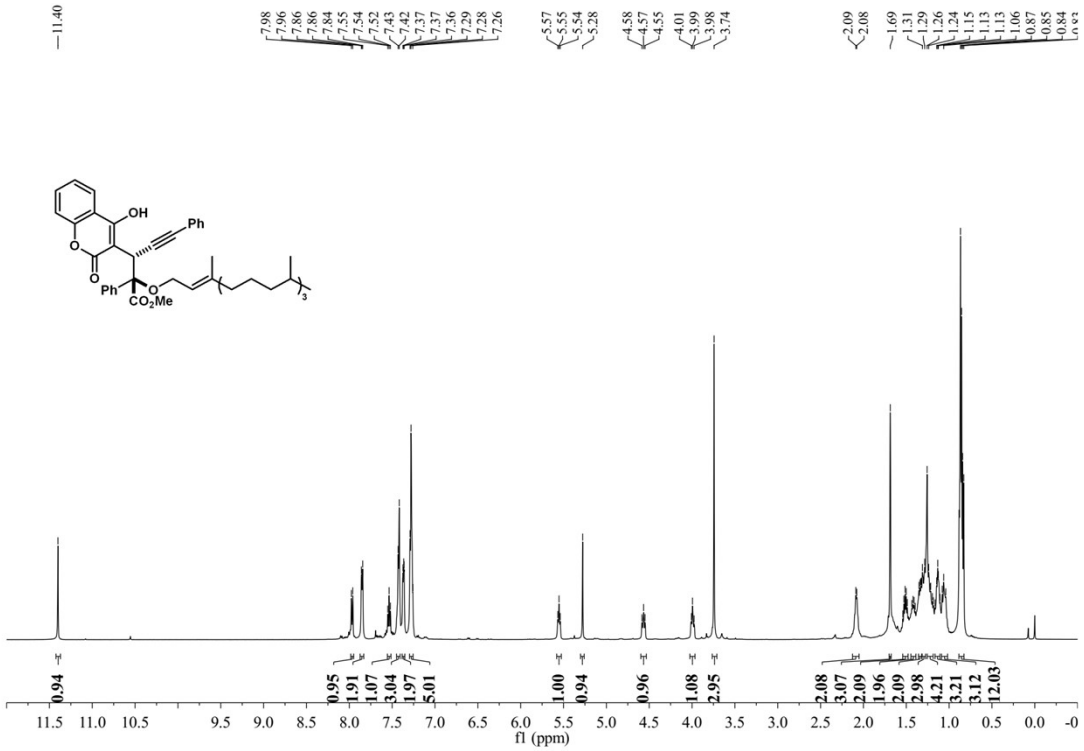


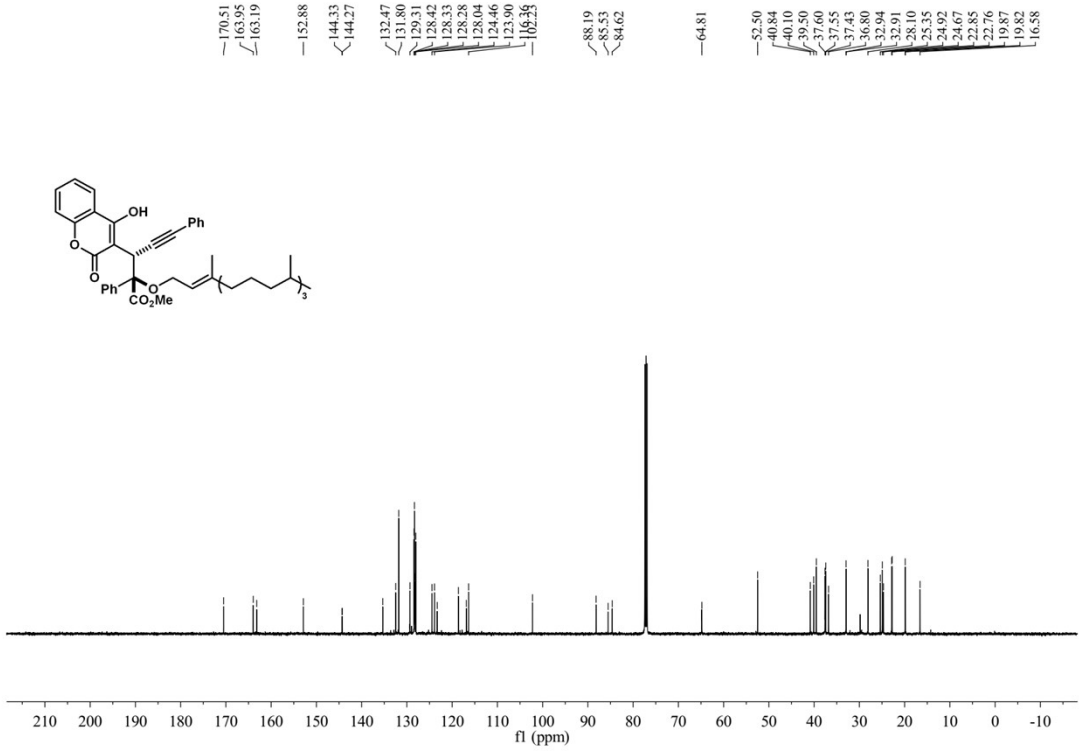
^{1}H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectra for 7e



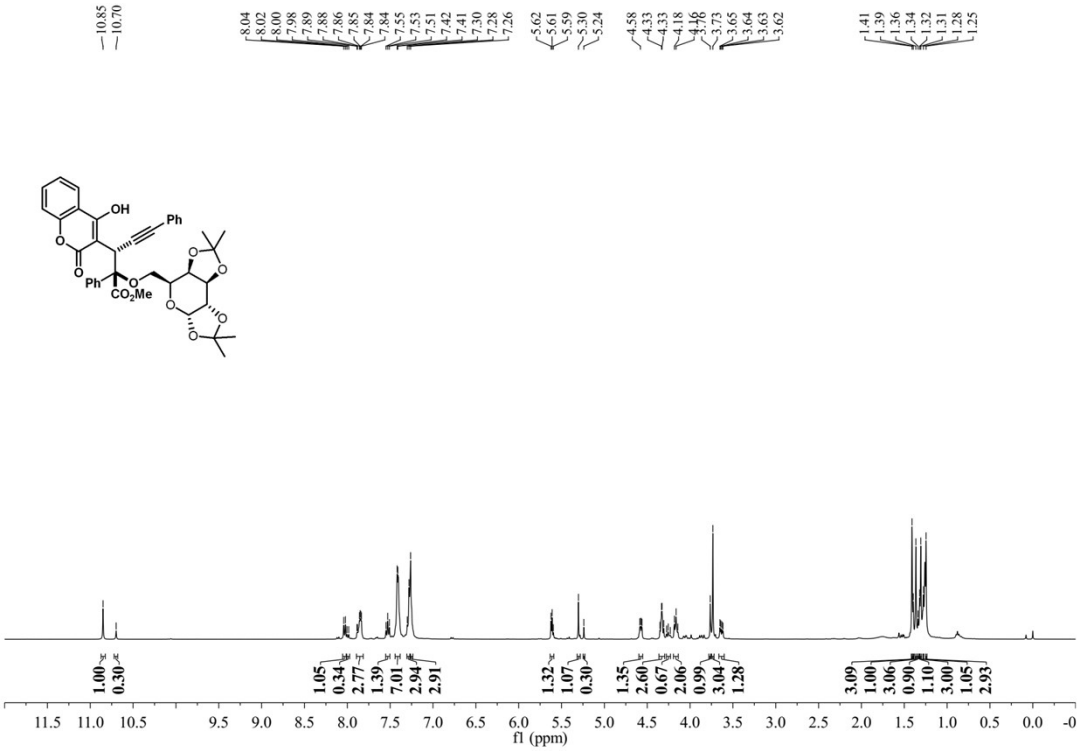


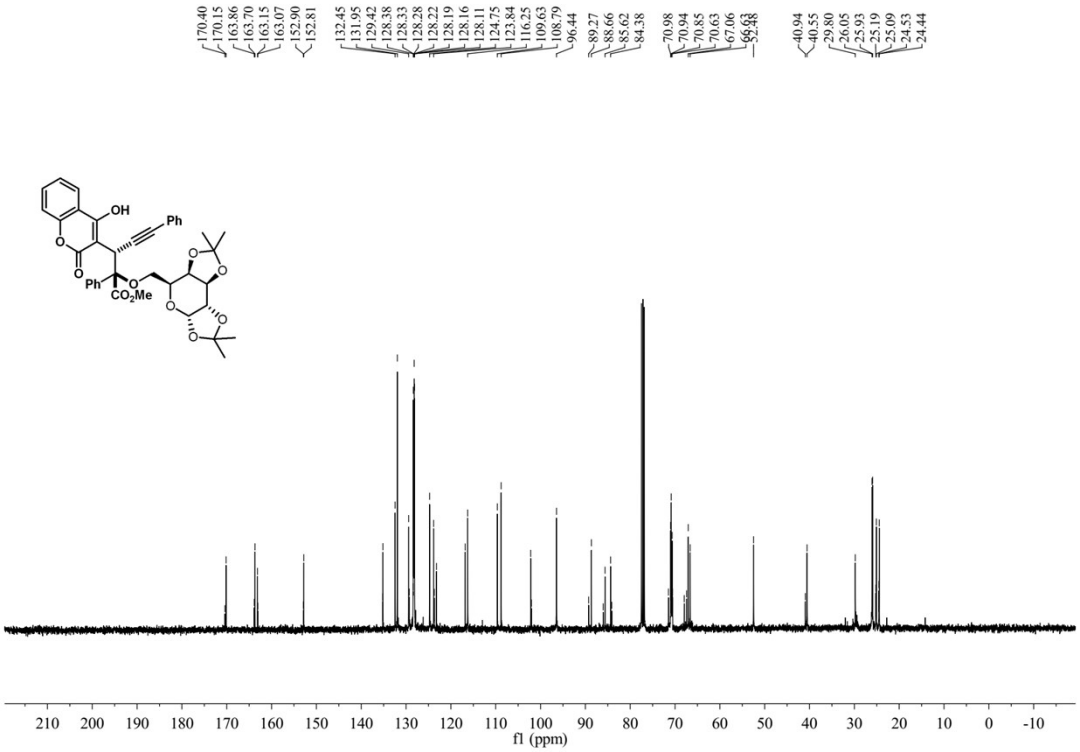
^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 7f



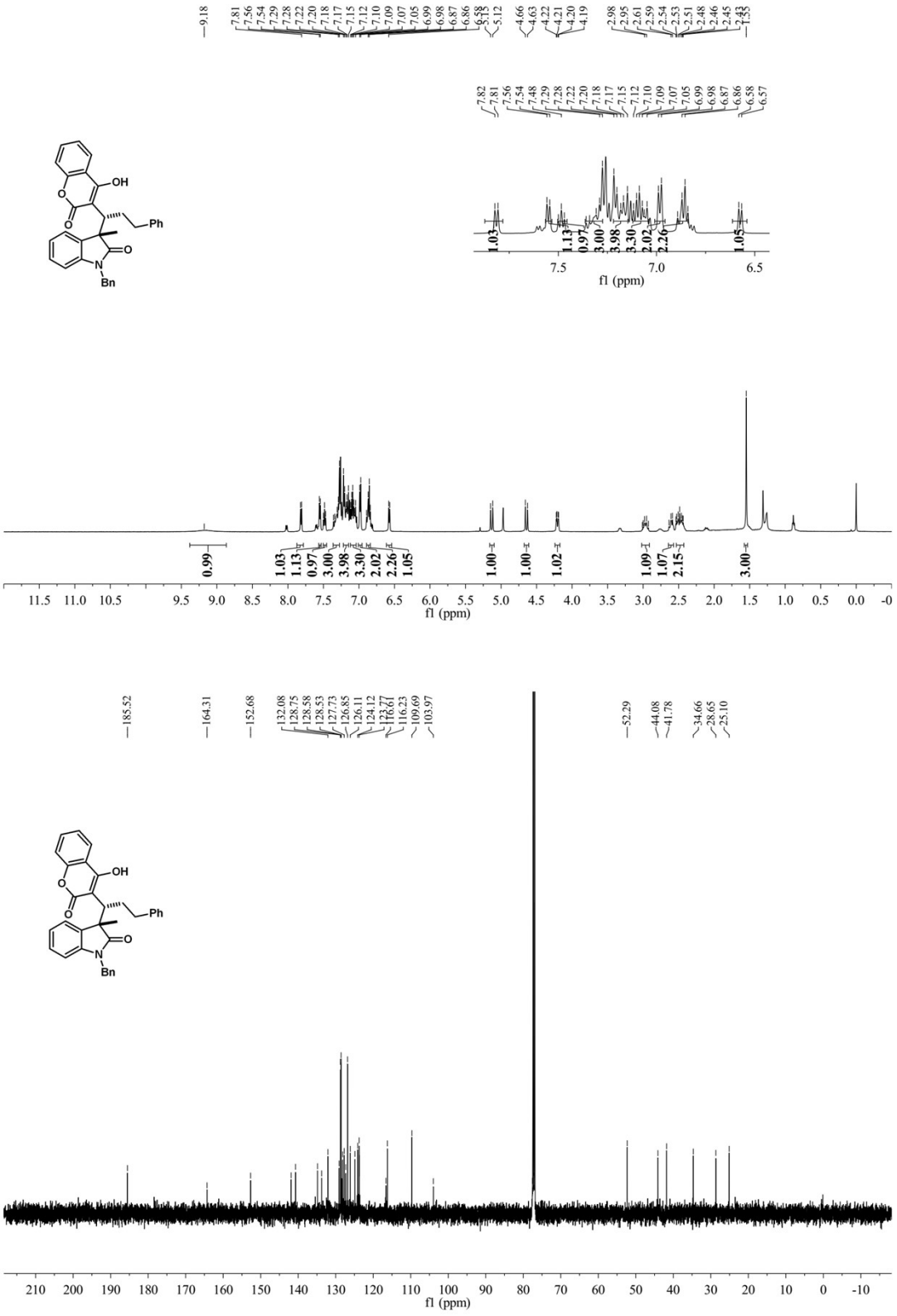


^{1}H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectra for 7g





^{1}H NMR (500 MHz, $CDCl_3$) and ^{13}C NMR (125 MHz, $CDCl_3$) spectra for 8



^{1}H NMR (400 MHz, DMSO) and ^{13}C NMR (100 MHz, DMSO) spectra for 9