Supporting Information

Tandem Oxidative Ring Expansion for Synthesis of Dibenzocyclooctaphenanthrenes

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Contents

1. General Information

^{1}H NMR and ^{13}C NMR spectra were recorded on JEOL JNM AL 400 (400 MHz) and JEOL JNM AL 600 (600 MHz) spectrometers. ^{1}H NMR spectra are reported as follows: chemical shift in ppm (δ) relative to the chemical shift of $CDCl_3$ at 7.26 ppm, multiplicities (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, and br = broadened), and coupling constants (Hz). ^{13}C NMR spectra were recorded on JEOL JNM AL 400 (100 MHz) and JEOL JNM AL 600 (150 MHz) spectrometers with complete proton decoupling, and chemical shift reported in ppm (δ) relative to the central line for $CDCl_3$ at 77 ppm. High resolution mass spectra were obtained on a BRUKER APEXIII spectrometer and JEOL JMS-700 MStation operator. UV/Vis absorption spectra were recorded on a JASCO V-650DS spectrometer. Fluorescence spectra and absolute fluorescence quantum yields were measured by a photon-counting method using an integration sphere on a Hamamatsu Photons C9920-02 spectrometer. Flash column chromatography was performed on silica gel 60N (spherical, neutral, 40-50 μm; Kanto Chemical Co., Inc.). Analytical thin-layer chromatography (TLC) was performed on 0.2 mm precoated plate Kieselgel 60 F254 (Merck).

Materials: Materials were purchased from Wako Pure Chemical Industries, Ltd., Tokyo Chemical Industry Co., LTD., Aldrich Inc., and Kanto Chemical Co., Inc. and used as received. In general, the starting substrates **1** was prepared following the reported literatures.[1,2] **1h**,[3,4] **1l**,[5] and **1m**[6] were synthesized following related literatures. Compounds **4b**,[7] **4e**,[7] and **7b**[8] were synthesized following the reported literatures. The structure of **2b** was confirmed by means of X-ray crystallography. CCDC 1994572 contains the supplementary crystallography data of **2b**. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre. The structures of new starting substrates and products **1-7** were determined by ^{1}H, ^{13}C NMR, and high-resolution mass.

References

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7. (a) Chen, C.-T.; Wei, Y.; Lin, J.-S.; Moturu, M. V. R. K.; Chao, W.-S.; Tao, Y.-T.; Chien, C.-H. *J. Am. Chem. Soc*. **2006**, *128*, 10992-10993. (b) Hahn, S.; Koser, S.; Hodecker, M.; Seete, P.; Rominger, F.; Miljanić, O. Š.; Dreuw, A.; Bunz, U. H. F. *Chem. Eur. J*. **2018**, *24*, 6968-6974.
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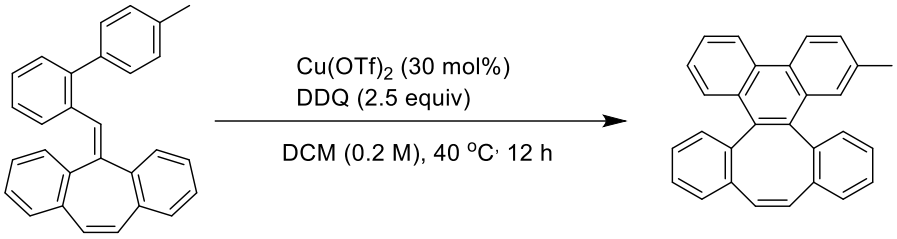
2. Experimental Procedure

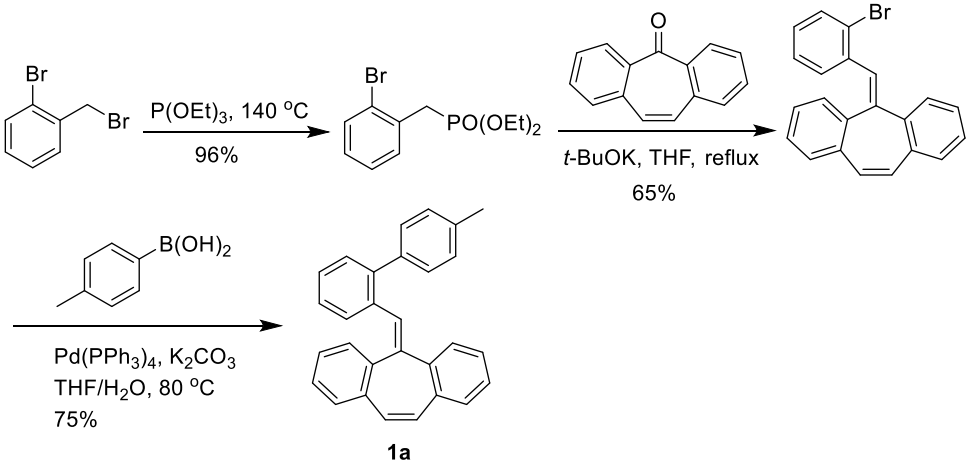
2.1 General procedure for synthesis of (*Z*)-3-methyldibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2a) by oxidative ring expansion



Scheme S1

5-((4'-Methyl-biphenyl-2-yl)methylene)-5*H*-dibenzo[*a,d*][7]annulene (**1a**) (37 mg, 0.1 mmol), DDQ (57 mg, 0.25 mmol), and $Cu(OTf)_2$ (11 mg, 0.3 mmol) was dissolved in dry dichloromethane (DCM, 0.5 mL). The mixture was heated on an aluminum-block at 40 °C for 12 h. After cooling to room temperature, the resulting reaction mixture was quenched by pouring into saturated aqueous $NaHCO_3$ (2 mL). The organic layer was separated and the aqueous layer was extracted with dichloromethane (2 x 1 mL). Combined organic layers were washed with water and brine, dried over anhydrous $MgSO_4$. After concentration of the DCM solvent, the resulting residue was purified by flash silica gel chromatography using a mixture of DCM/hexane (1/5) as eluent, affording the corresponding product (*Z*)-3-methyldibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (**2a**) in 71% yield (26.2 mg) as white solid.

2.2. General synthetic procedure of starting substrates 1



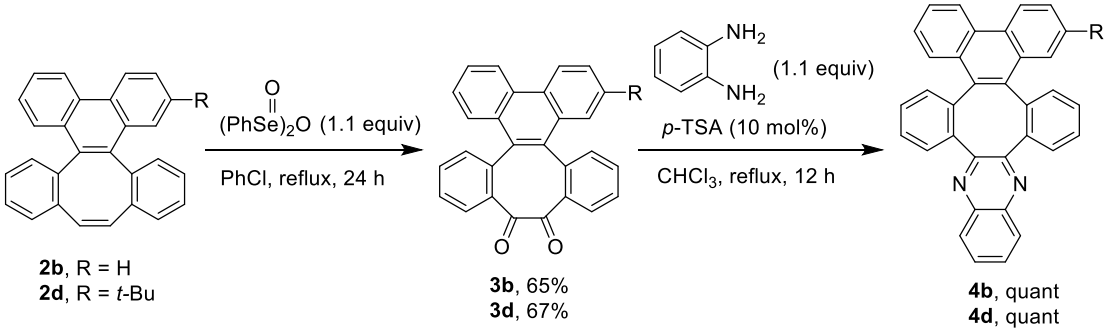
Scheme S2

A mixture of 2-bromomethyl-1-bromobenzene (2.5 g, 10 mmol) and triethyl phosphite (1.7 g, 10.2 mmol) was heated in oil bath at 140 °C for 5 h.[1] The resulting diethyl (2-bromobenzyl)phosphonate was used directly to the next step without isolation. Diethyl (2-bromobenzyl)phosphonate and dibenzosuberenone (10 mmol) were dissolved in 40 mL anhydrous THF under nitrogen. The mixture was refluxed in oil bath under stirring. To this solution, solid potassium *tert*-butoxide (15 mmol) was added in one portion under nitrogen atmosphere. After refluxing for 10 h, THF was removed by rotary evaporation. The residue was purified by column chromatography (silica gel)

using *n*-hexane/ dichloromethane (10 : 1 by volume) as eluent, giving the desired 5-(2-bromobenzylidene)-5*H*-dibenzo[*a,d*][7]annulene as white solid[2] (65% yield, 2.34 g). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 7.8 Hz, 1H), 7.55 (d, *J* = 7.8 Hz, 1H), 7.44-7.48 (m, 1H), 7.31-7.36 (m, 3H), 7.22 (t, *J* = 7.3 Hz, 1H), 7.06-7.12 (m, 1H), 6.87-7.00 (m, 5H), 6.67 (s, 1H), 6.57 (d, *J* = 7.3 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.9, 141.8, 137.5, 137.0, 135.1, 134.3, 132.6, 132.3, 131.6, 131.3, 131.2, 129.5, 129.2, 128.7, 128.6, 128.5, 128.2, 127.7, 127.5, 127.4, 126.7, 124.7. HRMS (FD+): [m/z]: calcd for $C_{22}H_{15}Br$, 358.0357; found, 358.0358. A mixture of 5-(2-bromobenzylidene)-5*H*-dibenzo[*a,d*][7]annulene (719 mg, 2 mmol), *p*-tolylboronic acid (408 mg, 3 mmol), $Pd(PPh_3)_4$ (120 mg, 0.1 mmol), K_2CO_3 (552 mg, 4 mmol), in THF and H_2O (5 mL (4 : 1)) was refluxed in oil bath for 24 h. After cooling to room temperature, the mixture was diluted with DCM. After adding water, the organic phase was separated. The aqueous layer was extracted with DCM and the combined organic phase was dried over $MgSO_4$. After filtration and evaporation of the solvent, the residue was purified by silica gel column chromatography (hexane/DCM, 10:1), giving **1** in 75% yield (556 mg) as white solid.

2.3 Synthetic applications of 2

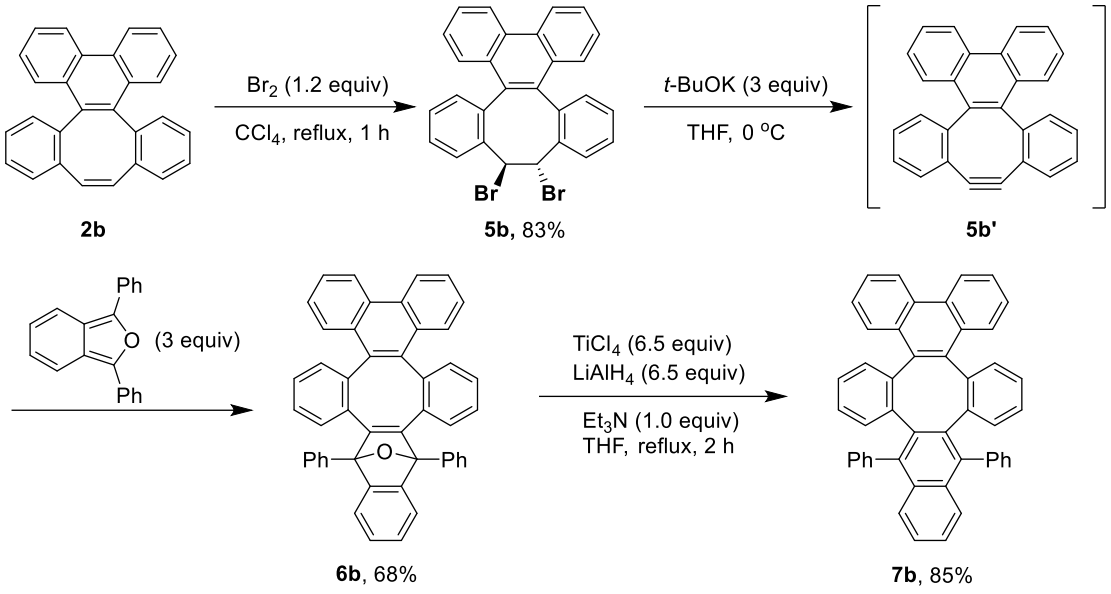
2.3.1 synthesis of 4b and 4d



Scheme S3

To a 5 mL vial was placed a chlorobenzene (1.5 mL) solution of **2b** (71 mg, 0.2 mmol) and benzeneseleninic anhydride (79.3 mg, 0.22 mmol). The resulting mixture was refluxed on an aluminum-block for 18 hours.[7] After cooling to room temperature, the reaction mixture was concentrated under reduced pressure and the crude solid was purified by silica gel column chromatography (hexane/DCM, 1:1), affording **3b** (50.0 mg, 65 %) as a yellowish solid. To a 20 mL, two-necked, round-bottomed flask was placed diketone-**3b** (76.9 mg, 0.2 mmol), 1,2-diaminobenzene (23.8 mg, 0.22 mmol) and 5 mol% *p*-TSA in $CHCl_3$ (3 mL). The reaction mixture was stirred under reflux in oil bath for 12 hours.[7] After cooling to room temperature, the reaction was quenched with saturated aqueous $NaHCO_3$ (3 mL) and the mixture was extracted with DCM (3×6 mL). The combined organic layer was dried over $MgSO_4$ and filtered, After concentration, the residue was purified by silica gel column chromatography (hexane/DCM, 1:3), giving the desired **4b** in quantitative yield (91.3 mg, 0.2 mmol) as white solid.

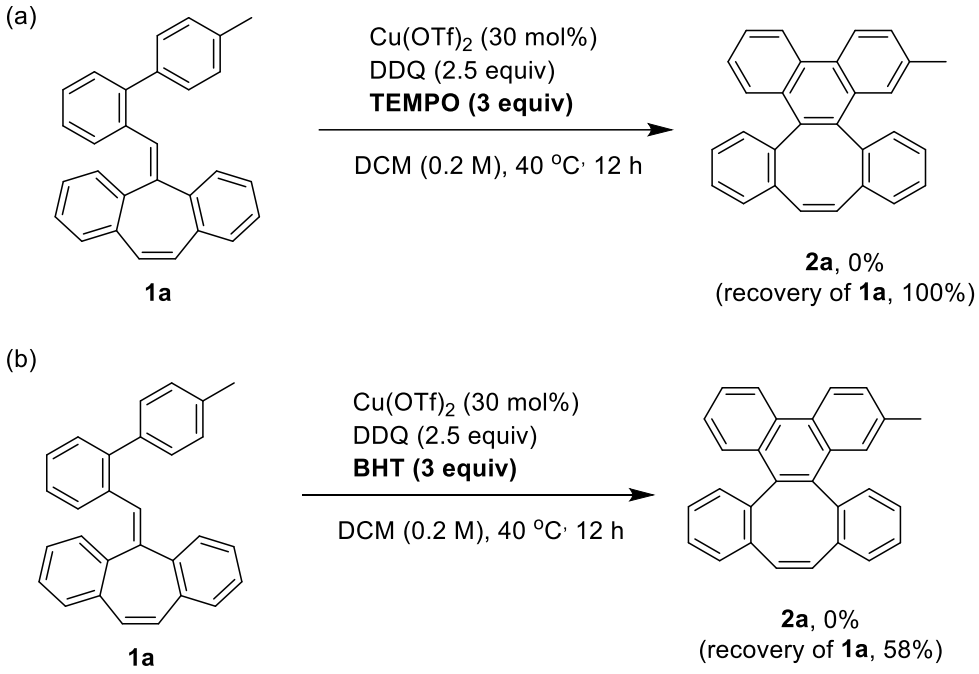
2.3.2 Synthesis of 7b



Scheme S4

To a CCl_4 (3 mL) solution of **2b** (71mg, 0.2 mmol), Br_2 (12.4 µL) in CCl_4 (2 mL) was added in dropwise. The mixture was then subjected to a pre-heated oil bath (80 °C) for 1 h. After completion, the resulted mixture was washed with $Na_2S_2O_4$. The combined organic layers were dried ($MgSO_4$), filtered, and evaporated. The residue was purified by silica gel column chromatography (hexane/DCM, 5:1) giving **5b** (85 mg, 0.166 mmol) in 83% yield as white solid.[8] To a THF (20 mL) solution of 1,3-diphenylisobenzofuran (162.2 mg, 0.6 mmol) was added 9,10-dibromo-9,10-dihydrodibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (**5b**) (102.3 mg, 0.2 mmol) under nitrogen at 0 °C. To this mixture, a suspension of potassium *tert*-butoxide in THF (6 mL. 0.1M) was added dropwise. After stirring for 1 h, hydrochloric acid (2 N, 5 mL) was added and subsequently the reaction mixture was extracted with followed chloroform (3 X 5 mL).[8] The organic layer was dried over anhydrous magnesium sulfate and evaporated. Chromatography on silica gel (2:1 hexanes/DCM eluent) gave a white solid of 13,18-diphenyl-13,18-dihydro-13,18-epoxytribenzo[*a*,*c*,*n*]tetraphenylene (**6b**) in 68% yield (84.7 mg). To a reaction flask containing THF (0.50 mL) were added titanium tetrachloride (71 µL, 0.65 mmol), a solution of lithium aluminum hydride (9.9 mg, 0.26 mmol) in THF (1.0 mL), and triethylamine (14 µL, 0.10 mmol). The mixture was stirred at room temperature for 10 min, and then at reflux for 30 min. After cooling to room temperature, a solution of **6** (62.3 mg, 0.10 mmol) in THF (0.50 mL) was added, and the resulting mixture was reflux for 2 h.[8] The reaction was quenched with sat. aq. K_2CO_3 at 0 °C, and the reaction mixture was extracted with DCM. The organic layer was washed with brine, dried over Na_2SO_4 and evaporated. The residue was purified by silica-gel column chromatography (hexane/DCM = 1:1) , providing **7b** in 85% yield (51.6 mg) with white solid.

3. Additional control experiments for mechanistic study



Scheme S5. Reactions of **1a** under the standard conditions using radical scavengers; the reaction were completely hampered by radical scavengers.

4. Optical properties of 2b

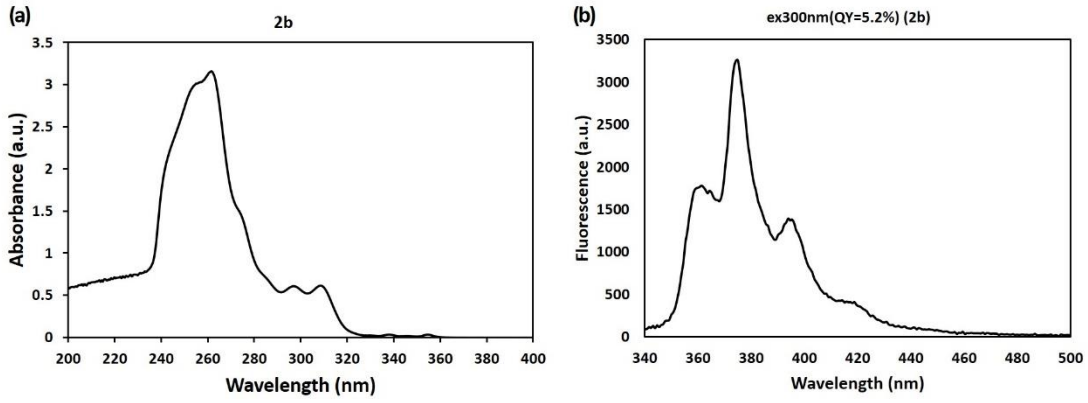


Figure S1. UV-vis absorption (a) and fluorescence spectra (b) of **2b** in diluted chloroform. λ_{abs} = 261 nm, 297 nm, 308 nm; λ_{em} = 361 nm, 375 nm, 395 nm at excited wavelength of 300 nm; fluorescence quantum yield = 5.2%

5. DFT calculation

(a) Study of HOMO of 1b

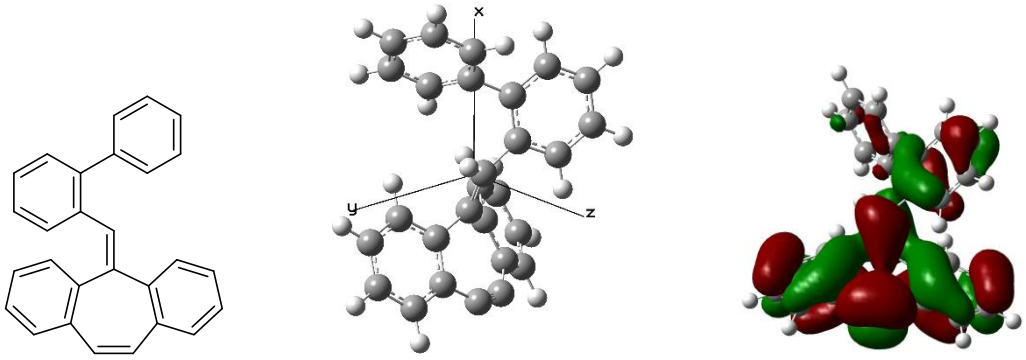


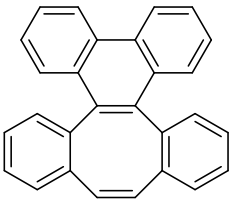
Figure S2. DFT calculation of the HOMO of **1b**. The ground-state geometries and their molecular orbitals were calculated using the Gaussian09 B3LYP/6-31G(d,p). C: gray; H: white

Table S1. Standard orientation: C: 6; H: 1

Center Number	Atomic Number	Atomic Type	Coordinates (Angstroms)		
			X	Y	Z
1	6	0	-1.401507	2.842227	0.021793
2	6	0	-1.386558	1.426006	-0.049021
3	6	0	-2.629483	0.727383	-0.019442
4	6	0	-3.824879	1.482647	0.035489
5	6	0	-3.810638	2.863051	0.082678
6	6	0	-2.585366	3.549931	0.085948
7	1	0	-4.782305	0.975602	0.048717
8	1	0	-4.746318	3.412660	0.126711
9	1	0	-2.566372	4.634353	0.141578
10	6	0	-0.138626	-0.686448	-0.135676
11	6	0	-1.386607	-1.426036	-0.049018
12	6	0	-1.401588	-2.842253	0.021903
13	6	0	-2.585491	-3.549897	0.086117
14	6	0	-3.810738	-2.862996	0.082801
15	6	0	-3.824936	-1.482592	0.035534
16	6	0	-2.629510	-0.727377	-0.019428
17	1	0	-0.460389	-3.377567	0.030658
18	1	0	-2.566526	-4.634319	0.141841
19	1	0	-4.746429	-3.412579	0.126873
20	1	0	-4.782343	-0.975508	0.048716
21	6	0	2.516615	3.032386	-1.499482
22	6	0	1.391377	2.218771	-1.397143
23	6	0	1.140328	1.459060	-0.242910
24	6	0	2.064571	1.510886	0.821870
25	6	0	3.173574	2.367697	0.721139

26	6	0	3.405713	3.119667	-0.426509
27	1	0	2.691334	3.604622	-2.405866
28	1	0	0.681061	2.172442	-2.217450
29	1	0	3.872400	2.419162	1.551871
30	1	0	4.278233	3.763585	-0.486993
31	6	0	3.173574	-2.367797	0.720985
32	6	0	3.405751	-3.119631	-0.426743
33	6	0	2.516698	-3.032206	-1.499744
34	6	0	1.391444	-2.218622	-1.397337
35	6	0	1.140317	-1.459103	-0.242993
36	6	0	2.064557	-1.511012	0.821785
37	1	0	3.872393	-2.419331	1.551719
38	1	0	4.278284	-3.763525	-0.487284
39	1	0	2.691465	-3.604311	-2.406202
40	1	0	0.681174	-2.172174	-2.217677
41	6	0	1.933859	0.670713	2.037521
42	6	0	1.933858	-0.670908	2.037484
43	6	0	-0.138611	0.686405	-0.135649
44	1	0	-0.460252	3.377442	0.030525
45	1	0	1.939217	-1.189829	2.995242
46	1	0	1.939206	1.189578	2.995310

(b) Study of aromaticity of 2b



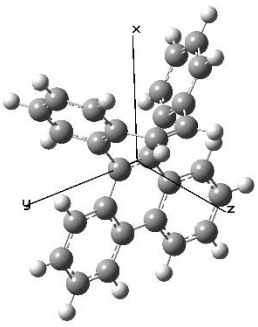


Figure S3. DFT calculation of aromaticity of **2b**. The ground-state geometries and their molecular orbitals were calculated using the Gaussian09 B3LYP/6-31G(d,p). C: gray; H: white

Table S2. Standard orientation: C: 6; H: 1

Center Number	Atomic Number	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	6	0	-1.401507	2.842227	0.021793
2	6	0	-1.386558	1.426006	-0.049021
3	6	0	-2.629483	0.727383	-0.019442
4	6	0	-3.824879	1.482647	0.035489

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6	6	0	-2.585366	3.549931	0.085948
7	1	0	-4.782305	0.975602	0.048717
8	1	0	-4.746318	3.412660	0.126711
9	1	0	-2.566372	4.634353	0.141578
10	6	0	-0.138626	-0.686448	-0.135676
11	6	0	-1.386607	-1.426036	-0.049018
12	6	0	-1.401588	-2.842253	0.021903
13	6	0	-2.585491	-3.549897	0.086117
14	6	0	-3.810738	-2.862996	0.082801
15	6	0	-3.824936	-1.482592	0.035534
16	6	0	-2.629510	-0.727377	-0.019428
17	1	0	-0.460389	-3.377567	0.030658
18	1	0	-2.566526	-4.634319	0.141841
19	1	0	-4.746429	-3.412579	0.126873
20	1	0	-4.782343	-0.975508	0.048716
21	6	0	2.516615	3.032386	-1.499482
22	6	0	1.391377	2.218771	-1.397143
23	6	0	1.140328	1.459060	-0.242910
24	6	0	2.064571	1.510886	0.821870
25	6	0	3.173574	2.367697	0.721139
26	6	0	3.405713	3.119667	-0.426509
27	1	0	2.691334	3.604622	-2.405866
28	1	0	0.681061	2.172442	-2.217450
29	1	0	3.872400	2.419162	1.551871
30	1	0	4.278233	3.763585	-0.486993
31	6	0	3.173574	-2.367797	0.720985
32	6	0	3.405751	-3.119631	-0.426743
33	6	0	2.516698	-3.032206	-1.499744
34	6	0	1.391444	-2.218622	-1.397337
35	6	0	1.140317	-1.459103	-0.242993
36	6	0	2.064557	-1.511012	0.821785
37	1	0	3.872393	-2.419331	1.551719
38	1	0	4.278284	-3.763525	-0.487284
39	1	0	2.691465	-3.604311	-2.406202
40	1	0	0.681174	-2.172174	-2.217677
41	6	0	1.933859	0.670713	2.037521
42	6	0	1.933858	-0.670908	2.037484
43	6	0	-0.138611	0.686405	-0.135649
44	1	0	-0.460252	3.377442	0.030525
45	1	0	1.939217	-1.189829	2.995242
46	1	0	1.939206	1.189578	2.995310

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6. Summary of Single crystal 2b

The single crystal of **2b** was prepared by slow diffusion of hexane into a toluene solution of **2b** at room temperature.

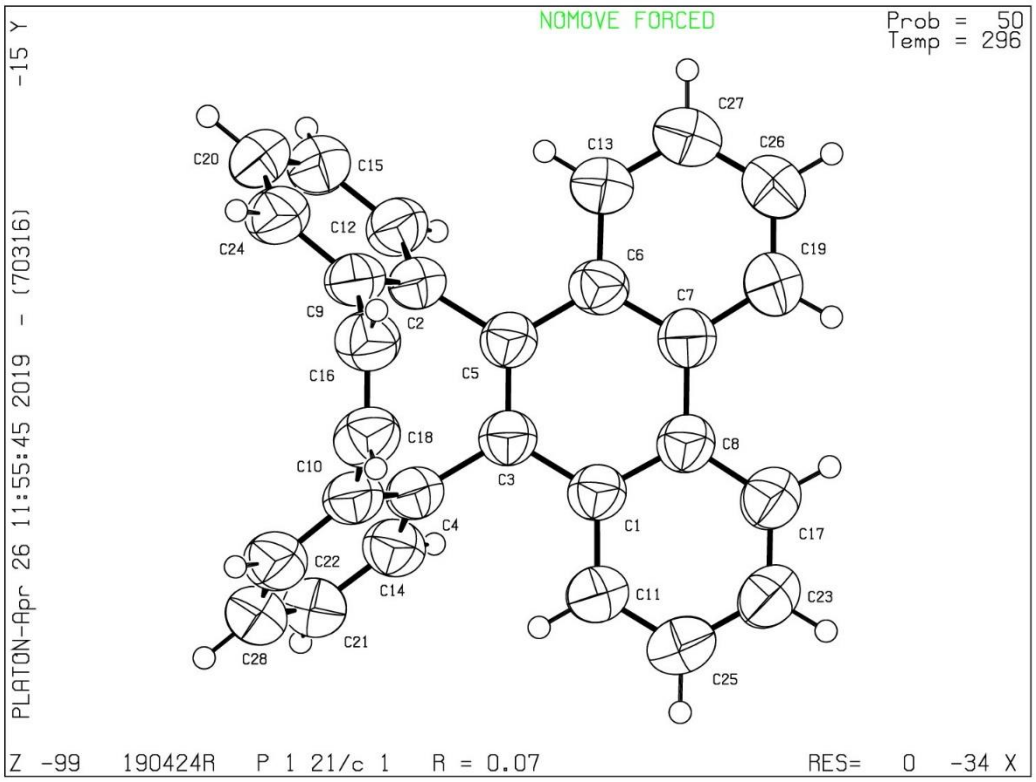


Figure S4. ORTEP drawing of the dbCOTP **2b**. Thermal ellipsoids are shown at 50% probability.

A colorless prism crystal of C28H18 having approximate dimensions of 0.200 x 0.200 x 0.100 mm was mounted on a glass fiber. All measurements were made on a Rigaku R-AXIS RAPID diffractometer using multi-layer mirror monochromated Cu-K α radiation.

Table S3. Summary of crystal structure of **2b** and refinement data

A. Crystal Data

Empirical Formula	$C_{28}H_{18}$
Formula Weight	354.45
Crystal Color, Habit	colorless, prism
Crystal Dimensions	0.200 X 0.200 X 0.100 mm
Crystal System	monoclinic
Lattice Type	Primitive
Lattice Parameters	a = 9.5683(5) Å
	b = 35.080(2) Å
	c = 5.8336(4) Å
	β = 107.439(8) ^{o}

	V = 1868.1(2) Å^3
Space Group	$P2_1/c$ (#14)
Z value	4
D_{calc}	1.260 g/cm^3
F_{000}	744.00
μ(CuKα)	5.418 cm^{-1}

B. Intensity Measurements

Diffractometer	R-AXIS RAPID
Radiation	CuK α (l = 1.54187 Å) multi-layer mirror monochromated
Voltage, Current	40kV, 30mA
Temperature	23.0°C
Detector Aperture	460.0 x 256.0 mm
Data Images	60 exposures
ω oscillation Range (χ=54.0, ϕ=0.0)	80.0 - 260.0°
Exposure Rate	32.0 sec./°
ωoscillation Range (c=54.0, ϕ=90.0)	80.0 - 260.0°
Exposure Rate	32.0 sec./°
ω oscillation Range (χ=54.0, ϕ=180.0)	80.0 - 260.0°
Exposure Rate	32.0 sec./°
ωoscillation Range (χ=54.0, ϕ=270.0)	80.0 - 260.0°
Exposure Rate	32.0 sec./°
ω oscillation Range (χ=0.0, ϕ=0.0)	80.0 - 260.0°
Exposure Rate	32.0 sec./°
Detector Position	127.40 mm
Pixel Size	0.100 mm
2θmax	136.5°
No. of Reflections Measured	Total: 20141 Unique: 3407 (R_{int} = 0.1312)
Corrections	Lorentz-polarization Absorption (trans. factors: 0.436 - 0.947)

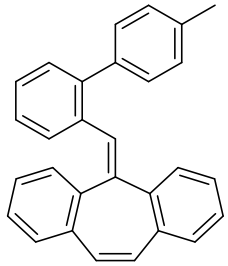
C. Structure Solution and Refinement

Structure Solution	Direct Methods (SHELXT Version 2014/4)
Refinement	Full-matrix least-squares on F^2
Function Minimized	$\sum w (Fo^2 - Fc^2)^2$
Least Squares Weights	$w = 1/ [\sigma^2(Fo^2) + (0.0865 \cdot P)^2$

	+ 0.0000 . P] where P = (Max(Fo^2,0) + 2Fc^2)/3
$2\theta_{max}$ cutoff	136.5°
Anomalous Dispersion	All non-hydrogen atoms
No. Observations (All reflections)	3407
No. Variables	253
Reflection/Parameter Ratio	13.47
Residuals: R1 (I>2.00σ(I))	0.0701
Residuals: R (All reflections)	0.0900
Residuals: wR2 (All reflections)	0.2163
Goodness of Fit Indicator	1.046
Max Shift/Error in Final Cycle	0.000
Maximum peak in Final Diff. Map	0.21 $e^-/Å^3$
Minimum peak in Final Diff. Map	-0.18 $e^-/Å^3$

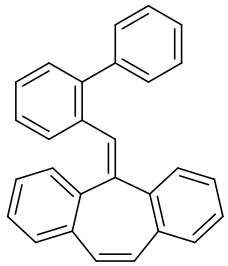
7. Analytical Data

5-((4'-Methyl-biphenyl-2-yl)methylene)-5*H*-dibenzo[*a*,*d*][7]annulene (1a)



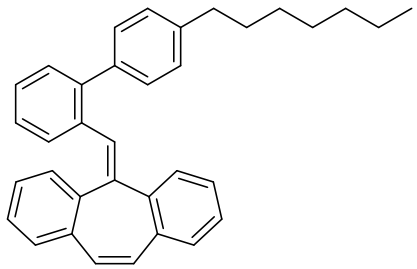
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1a** as a white solid (1.5 mmol, 556.0 mg, 75% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 8.2 Hz, 2H), 7.29-7.37 (m, 6H), 7.22-7.26 (m, 3H), 7.15-7.19 (m, 3H), 6.94-6.96 (m, 1H), 6.93 (d, *J* = 11.9 Hz, 1H), 6.88 (d, *J* = 11.9 Hz, 1H), 6.69 (d, *J* = 7.8 Hz, 1H), 6.42 (s, 1H), 2.49 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ142.4, 141.6, 140.86, 138.3, 137.7, 136.9, 135.3, 135.0, 134.4, 133.3, 131.4, 131.2, 130.1, 129.6, 129.5, 129.3, 128.8, 128.5, 128.5, 128.3, 127.0, 127.0, 126.9, 126.3, 21.3, two sp^2 carbon peaks are not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{29}H_{22}$, 370.1722; found 370.1721.

5-(Biphenyl-2-ylmethylene)-5*H*-dibenzo[*a*,*d*][7]annulene (1b)



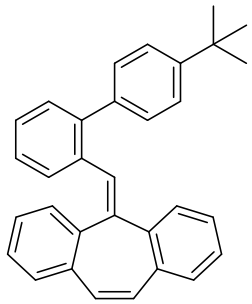
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1b** as a white solid (1.5 mmol, 556.0 mg, 78% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (d, *J* = 6.9 Hz, 2H), 7.55 (t, *J* = 7.3 Hz, 2H), 7.47 (t, *J* = 7.1 Hz, 1H), 7.34-7.40 (m, 4H), 7.19-7.29 (m, 6H), 7.01 (t, *J* = 7.6 Hz, 1H), 6.96 (d, *J* = 11.9 Hz, 1H), 6.91 (d, *J* = 11.9 Hz, 1H), 6.76 (d, *J* = 7.8 Hz, 1H), 6.45 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.3, 141.6, 141.2, 141.0, 137.5, 135.3, 135.1, 134.4, 133.1, 131.3, 131.2, 130.1, 129.6, 129.3, 128.9, 128.8, 128.5, 128.3, 128.1, 127.3, 127.0, 126.9, 126.9, 126.5, two sp^2 carbon peaks are not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{28}H_{20}$, 356.1559; found 356.1559.

5-((4'-Heptyl-biphenyl-2-yl)methylene)-5H-dibenzo[*a*,*d*][7]annulene (1c)



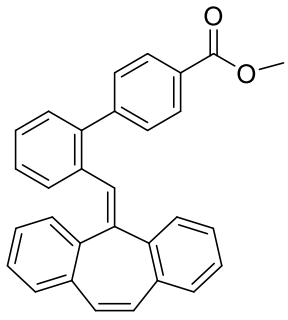
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1c** as a white solid (1.6 mmol, 728.0 mg, 80% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.8 Hz, 2H), 7.31-7.38 (m, 6H), 7.24-7.28 (m, 3H), 7.15-7.22 (m, 3H), 6.98 (t, *J* = 7.8 Hz, 1H), 6.95 (d, *J* = 11.9 Hz, 1H), 6.90 (d, J = 11.9 Hz, 1H), 6.73 (d, *J* = 7.3 Hz, 1H), 6.45 (s, 1H), 2.73-2.78 (m, 2H), 1.73-1.80 (m, 2H), 1.37-1.44 (m, 8H), 0.96 (t, *J* = 6.6 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 142.4, 141.9, 141.7, 140.7, 138.5, 137.6, 135.3, 135.1, 134.4, 134.3, 133.4, 131.4, 131.2, 130.1, 129.5, 129.4, 129.3, 128.8, 128.7, 128.5, 128.3, 128.1, 127.0, 126.8, 126.8, 126.3, 35.7, 31.9, 31.5, 29.3, 29.3, 22.7, 14.2; HRMS (MALDI): [m/z]: calcd. for $C_{35}H_{34}$, 454.2655; found 454.2655.

5-((4'-*Tert*-butyl-biphenyl-2-yl)methylene)-5*H*-dibenzo[*a*,*d*][7]annulene (1d)



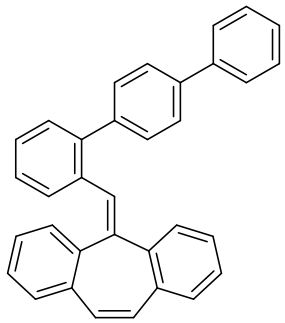
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1d** as a white solid (1.64 mmol, 677.0 mg, 82% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48-7.56 (m, 4H), 7.31-7.36 (m, 4H), 7.26 (dd, *J* = 6.6, 2.5 Hz, 3H), 7.16-7.21 (m, 2H), 6.98 (t, *J* = 7.3 Hz, 1H), 6.92 (d, *J* = 11.7 Hz, 1H), 6.87 (d, *J* = 11.7 Hz, 1H), 6.73 (d, *J* = 7.8 Hz, 1H), 6.44 (s, 1H), 1.46 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.1, 142.4, 141.6, 140.7, 138.2, 137.6, 135.3, 135.1, 134.5, 133.4, 131.3, 131.3, 130.0, 129.5, 129.2, 128.8, 128.7, 128.5, 128.3, 127.1, 127.0, 126.8, 126.3, 125.0, 34.6, 31.5, two sp^2 carbon peaks are not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{32}H_{28}$, 412.2191; found 412.2191.

Methyl 2'-((5*H*-dibenzo[*a*,d][7]annulen-5-ylidene)methyl)-biphenyl-4-carboxylate (1e)



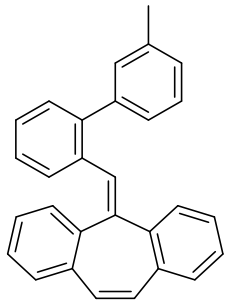
Purified by flash column chromatography (silica gel), [Hexane /DCM = 5:1 to 2:1 (v/v)] to give **1e** as a White solid (1.28 mmol, 531.0 mg, 64% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.2 Hz, 2H), 7.56 (d, *J* = 8.2 Hz, 2H), 7.16-7.35 (m, 8H), 7.08-7.15 (m, 2H), 7.01 (t, *J* = 7.6 Hz, 1H), 6.86 (d, *J* = 11.9 Hz, 1H), 6.81 (d, *J* = 11.9 Hz, 1H), 6.76 (d, *J* = 7.8 Hz, 1H), 6.37 (s, 1H), 3.99 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.0 (C=O), 146.0, 142.0 (2C), 140.4, 137.3, 135.2, 135.1, 134.3, 132.3, 131.2, 131.1, 130.3, 129.5, 129.4, 129.1, 128.9, 128.8, 128.4, 128.3, 127.2, 127.0, 127.0, 126.8, 52.1, three sp^2 carbon peaks are not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{30}H_{22}O_2$, 414.1614; found 414.1614.

5-([1,1':4',1''-Terphenyl]-2-ylmethylene)-5*H*-dibenzo[*a*,*d*][7]annulene (1f)



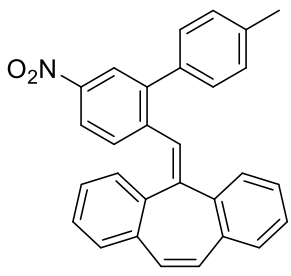
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1f** as a white solid (1.6 mmol, 692.0 mg, 80% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.73 (d, *J* = 8.2 Hz, 4H), 7.61 (d, *J* = 8.2 Hz, 2H), 7.53 (t, *J* = 7.6 Hz, 2H), 7.42 (t, *J* = 7.6 Hz, 1H), 7.38 (d, *J* = 7.6 Hz, 1H), 7.31-7.35 (m, 3H), 7.20-7.26 (m, 4H), 7.15-7.18 (m, 2H), 7.01 (t, *J* = 7.6 Hz, 1H), 6.88 (d, *J* = 11.7 Hz, 1H), 6.86 (d, *J* = 11.7 Hz, 1H), 6.78 (d, *J* = 7.6 Hz, 1H), 6.49 (s, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 142.3, 141.3, 141.2, 140.9, 140.3, 140.0, 137.6, 135.3, 135.2, 134.5, 133.0, 131.2, 130.2, 130.0, 129.6, 129.3, 128.9, 128.8, 128.4, 128.3, 127.4, 127.1, 127.0, 126.9, 126.9, 126.8, 126.6, three sp^2 carbon peaks are not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{34}H_{24}$, 432.1878, found 432.1877.

5-((3'-Methyl-biphenyl-2-yl)methylene)-5*H*-dibenzo[*a*,*d*][7]annulene (1g)



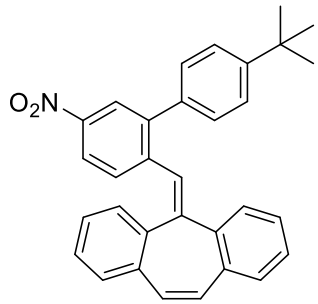
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1g** as a white solid (1.52 mmol, 563.0 mg, 76% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.40 (m, 5H), 7.23-7.27 (m, 6H), 7.14-7.17 (m, 3H), 6.94 (t, *J* = 7.6 Hz, 1H), 6.89 (d, *J* = 11.9 Hz, 1H), 6.85 (d, *J* = 11.9 Hz, 1H), 6.69 (d, *J* = 7.8 Hz, 1H), 6.39 (s, 1H), 2.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.4, 141.7, 141.1, 140.8, 137.6, 135.3, 135.0, 134.5, 133.2, 131.3, 130.3, 130.1, 129.5, 129.3, 128.9, 128.8, 128.5, 128.3, 128.0, 127.9, 127.0, 126.8, 126.7, 126.4, 21.6, four sp^2 carbon peaks are not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{29}H_{22}$, 370.1716; found 370.1716.

5-((4'-Methyl-5-nitro-biphenyl-2-yl)methylene)-5*H*-dibenzo[*a*,*d*][7]annulene (1h)



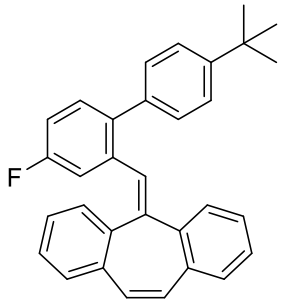
Purified by flash column chromatography (silica gel), [Hexane /DCM = 5:1 to 2:1 (v/v)] to give **1h** as a yellow solid (1.2 mmol, 499.0 mg, 60% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 2.1 Hz, 1H), 7.77 (dd, *J* = 8.9, 2.1 Hz, 1H), 7.49 (d, *J* = 7.6 Hz, 2H), 7.35-7.42 (m, 4H), 7.29-7.34 (m, 4H), 7.17-7.20 (m, 1H), 7.11 (d, *J* = 7.6 Hz, 1H), 6.97 (d, *J* = 11.7 Hz, 1H), 6.92 (d, *J* = 11.7 Hz, 1H), 6.77 (d, *J* = 8.9 Hz, 1H), 6.40 (s, 1H), 2.52 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 146.2, 144.2, 142.7, 142.2, 141.4, 138.3, 136.5, 136.0, 135.1, 134.2, 131.4, 131.3, 130.9, 129.2, 129.1, 129.0, 128.9, 128.8, 128.5, 127.7, 127.3, 126.6, 124.6, 121.0, 21.3, two sp^2 carbon peaks are not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{29}H_{21}NO_2$, 415.1572; found 415.1573.

5-((4'-*Tert*-butyl-5-nitro-biphenyl-2-yl)methylene)-5*H*-dibenzo[*a,d*][7]annulene (1i)



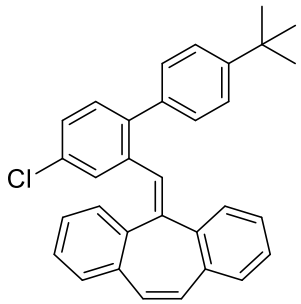
Purified by flash column chromatography (silica gel), [Hexane /DCM = 5:1 to 2:1 (v/v)] to give **1i** as a yellow solid (1.26 mmol, 577.0 mg, 63% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.18 (d, *J* = 2.1 Hz, 1H), 7.78 (dd, *J* = 8.6, 2.4 Hz, 1H), 7.50-7.59 (m, 4H), 7.38 (d, *J* = 8.2 Hz, 1H), 7.28-7.35 (m, 5H), 7.16-7.18 (m, 1H), 7.08 (d, *J* = 7.6 Hz, 1H), 6.93 (d, *J* = 11.7 Hz, 1H), 6.89 (d, *J* = 11.7 Hz, 1H), 6.79 (d, *J* = 8.2 Hz, 1H), 6.41 (s, 1H), 1.45 (s, 9H); ^{13}C-NMR (150 MHz, $CDCl_3$) δ 151.5, 146.3, 144.1, 142.7, 142.4, 141.5, 136.5, 136.0, 135.1, 134.2, 131.4, 131.4, 131.0, 130.9, 129.1, 129.1, 128.9, 128.9, 128.8, 128.5, 127.7, 127.3, 126.8, 125.4, 124.6, 121.1, 34.8, 31.4; HRMS (FD+): [m/z]: calcd. for $C_{32}H_{27}NO_2$, 457.2041; found 457.2040.

5-((4'-*Tert*-butyl-4-fluoro-biphenyl-2-yl)methylene)-5*H*-dibenzo[*a,d*][7]annulene (1j)



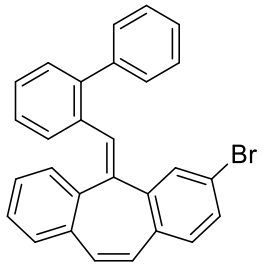
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1j** as a white solid (1.4 mmol, 603.0 mg, 70% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.43-7.48 (m, 3H), 7.37 (d, *J* = 7.6 Hz, 1H), 7.17-7.33 (m, 9H), 6.93 (d, *J* = 11.7 Hz, 1H), 6.86-6.89 (m, 2H), 6.32-6.36 (m, 2H), 1.42 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.3 (d, J_F = 245.4 Hz), 150.9, 142.1, 142.0, 140.0, 138.5, 137.1 (d, J_F = 8.6 Hz), 136.9, 135.1, 134.3, 132.0, 131.3, 131.2, 131.1 (d, J_F = 8.6 Hz), 129.0 (d, J_F = 4.8 Hz), 128.7 (d, J_F = 5.8 Hz), 128.4, 127.9, 127.4, 127.0, 126.9, 126.8, 126.5, 124.6, 116.2 (d, J_F = 22.0 Hz), 113.8 (d, J_F = 22.0 Hz), 34.8, 31.5; HRMS (MALDI): [m/z]: calcd. for $C_{32}H_{27}F$, 430.2091; found 430.2092.

5-((4'-*Tert*-butyl-4-chloro-biphenyl-2-yl)methylene)-5*H*-dibenzo[*a*,*d*][7]nnulene (1k)



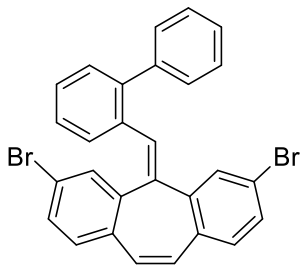
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1k** as a white solid (1.42 mmol, 635.0 mg, 71% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.54 (d, *J* = 8.2 Hz, 2H), 7.46 (d, *J* = 8.2Hz, 2H), 7.34 (d, *J* = 7.6 Hz, 1H), 7.30 (t, *J* = 2.1 Hz, 3H), 7.24-7.27 (m, 3H), 7.18 (td, *J* = 7.6, 1.4 Hz, 1H), 7.13 (d, *J* = 6.9 Hz, 1H), 6.92-6.93 (m, 1H), 6.90 (d, *J* = 11.7 Hz, 1H), 6.86 (d, *J* = 11.7 Hz, 1H), 6.61 (d, *J* = 8.2 Hz, 1H), 6.34 (s, 1H), 1.44 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 150.8, 143.2, 142.1, 141.5, 137.2, 137.0, 135.2, 134.4, 133.7, 132.3, 132.1, 131.3, 131.2, 131.1, 129.4, 129.1, 129.0, 128.9, 128.7, 128.6, 128.4, 127.2, 127.0, 126.4, 125.1, 34.7, 31.4, one sp^2 carbon peak is not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{32}H_{27}Cl$, 446.1796; found 446.1796.

(*E*)-5-(Biphenyl-2-ylmethylene)-3-bromo-5*H*-dibenzo[*a*,*d*][7]annulene (1l)



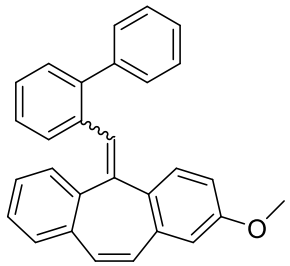
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1l** as a white solid (1.24 mmol, 540.0 mg, 62% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.49 (d, *J* = 4.8 Hz, 4H), 7.42 (td, *J* = 8.8, 4.6 Hz, 1H), 7.22-7.35 (m, 8H), 7.17 (d, *J* = 8.2 Hz, 1H), 7.03-7.06 (m, 1H), 6.86 (d, *J* = 11.7 Hz, 1H), 6.75-6.80 (m, 2H), 6.46 (s, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 141.9, 141.8, 141.1, 139.7, 139.2, 134.4, 134.3, 134.3, 133.9, 131.9, 131.8, 130.3, 130.0, 129.9, 129.8, 129.7, 129.6, 129.1, 128.4, 128.1, 127.3, 127.3, 127.1, 126.8, 122.3, one sp^2 carbon peak is not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{28}H_{19}Br$, 434.0670; found 434.0670.

5-(Biphenyl]-2-ylmethylene)-3,7-dibromo-5*H*-dibenzo[*a*,*d*][7]annulene (1m)



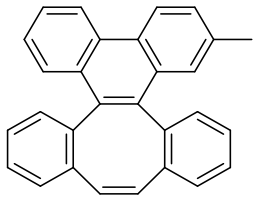
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1m** as a white solid (1.2 mmol, 617.0 mg, 60% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.42-7.52 (m, 6H), 7.33-7.37 (m, 3H), 7.24 (d, *J* = 6.9 Hz, 1H), 7.18 (d, *J* = 2.1 Hz, 1H), 7.15 (d, *J* = 8.2 Hz, 1H), 7.08 (d, *J* = 8.2 Hz, 1H), 7.03-7.07 (m, 1H), 6.74-6.77 (m, 3H), 6.46 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.3, 141.8, 140.9, 138.6, 138.0, 134.7, 134.1, 133.9, 133.3, 131.8, 130.6, 130.6, 130.4, 130.2, 130.1, 130.0, 129.8, 129.6, 129.5, 128.2, 127.6, 127.5, 126.8, 123.0, 122.5, one sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{28}H_{19}Br$, 511.9774; found 511.9775.

5-([1,1'-biphenyl]-2-ylmethylene)-2-methoxy-5*H*-dibenzo[*a*,*d*][7]annulene (1n)



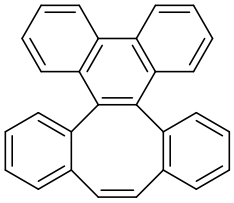
Purified by flash column chromatography (silica gel), [Hexane /DCM = 20:1 to 10:1 (v/v)] to give **1n** as a white solid (2.1 mmol, 823.0 mg, 72% yield); *Z*/*E* mixture (1: 1.1): ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.55 (dd, J = 8.2, 1.4 Hz, 2H), 7.51 (t, J = 7.6 Hz, 2H), 7.41-7.44 (m, 1H), 7.29-7.34 (m, 2H), 7.21-7.25 (m, 2H), 7.14-7.20 (m, 2H), 7.07-7.08 (m, 1H), 6.98 (m, 1H), 6.69-6.92 (m, 5H), 6.37 (s, 1H), 3.81 (s, 3H) [3.79 (s, 3H), for isomer]; ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.5, 158.4 (for isomer), 142.6, 141.5, 141.4, 141.2, 141.1 (7), 140.6, 140.5 (6), 137.8, 136.4, 135.5, 135.2, 135.1 (9) (for isomer), 135.1, 134.2, 132.6, 132.5, 131.7, 131.5, 131.1, 131.0, 130.6, 130.4, 130.1, 130.0, 129.5, 129.2, 128.9, 128.7, 128.4, 128.1, 128.0, 127.1, 126.8, 126.7 (4), 126.7 (1), 126.6, 126.5, 126.4, 114.8 (for isomer), 114.7, 113.1, 112.8 (for isomer), 55.0 (for isomer), 54.9; HRMS (FD+): [m/z]: calcd. for $C_{29}H_{22}O$, 386.1670; found 386.1670.

(*Z*)-3-Methyldibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2a)



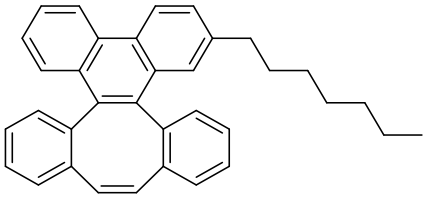
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2a** as a white solid (0.071 mmol, 26.2 mg, 71% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.76 (d, *J* = 8.2 Hz, 1H), 8.69 (d, *J* = 8.2 Hz, 1H), 7.63 (t, *J* = 7.6 Hz, 1H), 7.49 (d, *J* = 8.7 Hz, 1H), 7.44 (d, *J* = 6.9 Hz, 1H), 7.39 (d, *J* = 8.2 Hz, 1H), 7.27 (m, 6H), 7.20 (m, 3H), 6.84 (d, *J* = 11.7 Hz, 1H), 6.81 (d, *J* = 11.7 Hz, 1H), 2.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.3, 139.2, 138.3, 138.2, 136.4, 136.2, 136.1, 133.0, 131.4, 131.0, 130.6, 130.2, 128.0, 127.9, 127.5, 127.3, 126.9, 126.7, 126.2, 126.0, 122.4, 122.2, 21.8, six sp^2 carbon peaks are not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{29}H_{20}$, 368.1559; found 368.1559.

(*Z*)-Dibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2b)



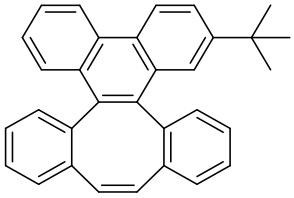
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2b** as a white solid (0.057 mmol, 23.0 mg, 57% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.77 (d, *J* = 8.2 Hz, 2H), 7.60-7.65 (m, 2H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.36 (dd, *J* = 8.2, 1.4 Hz, 2H), 7.24-7.26 (m, 6H), 7.16-7.18 (m, 2H), 6.78 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.1, 138.3, 136.4, 133.0, 131.4, 130.6, 130.2, 127.5, 127.4, 126.8, 126.5, 126.2, 126.2, 122.4; HRMS (FD+): [m/z]: calcd. for $C_{28}H_{18}$, 354.1408; found 354.1408.

(*Z*)-3-Heptyldibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2c)



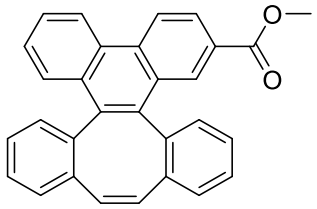
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2c** as a white solid (0.068 mmol, 30.8 mg, 68% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.74 (d, *J* = 8.2 Hz, 1H), 8.69 (d, *J* = 8.2 Hz, 1H), 7.58-7.62 (m, 1H), 7.48 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.41 (t, *J* = 7.6 Hz, 1H), 7.34 (d, *J* = 8.2 Hz, 1H), 7.24-7.29 (m, 6H), 7.17-7.19 (m, 2H), 7.14 (d, *J* = 1.4 Hz, 1H), 6.81 (d, *J* = 11.7 Hz, 2H), 6.79 (d, *J* = 11.7 Hz, 1H), 2.65 (t, *J* = 7.6 Hz, 2H), 1.57-1.61 (m, 2H), 1.24-1.31 (m, 8H), 0.88 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 141.2, 139.3, 138.3, 138.3, 136.4, 136.3, 133.1, 133.0, 131.4, 131.1, 130.7, 130.6, 130.3, 128.3, 127.5, 127.4, 127.3, 127.2, 126.7, 126.5, 126.2, 126.1, 126.0, 125.9, 122.4, 122.3, 35.9, 31.8, 31.3, 29.1, 22.6, 14.1, two sp^2 carbon peaks and one sp^3 carbon peak are not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{35}H_{32}$, 452.2498; found 452.2498.

(*Z*)-3-(*Tert*-butyl)dibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2d)



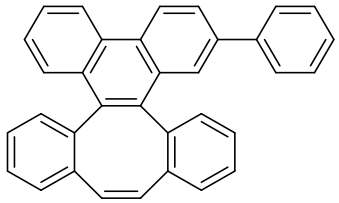
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2d** as a white solid (0.08 mmol, 32.8 mg, 80% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.76 (d, *J* = 8.7 Hz, 1H), 8.72 (d, *J* = 8.7 Hz, 1H), 7.73 (d, *J* = 8.7 Hz, 1H), 7.62 (t, *J* = 7.3 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.37 (d, *J* = 7.8 Hz, 2H), 7.27 (m, 6H), 7.21 (m, 2H), 6.84 (d, *J* = 11.9 Hz, 1H), 6.81 (d, *J* = 11.4 Hz, 1H), 1.30 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.1, 139.3, 139.2, 138.3, 138.2, 136.6, 136.3, 133.1, 132.9, 131.2, 131.1, 130.7, 130.1, 128.0, 127.6, 127.5, 127.3, 126.7, 126.6, 126.1, 126.0, 125.9, 125.8, 124.4, 123.2, 122.3, 122.2, 34.8, 31.2, one sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{32}H_{26}$, 410.2035; found 410.2035.

Methyl (*Z*)-dibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene-3-carboxylate (2e)



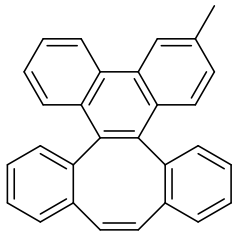
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2e** as a white solid (0.038 mmol, 15.7 mg, 38% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ8.82 (d, *J* = 8.2 Hz, 1H), 8.80 (d, *J* = 8.2 Hz, 1H), 8.23 (dd, *J* = 8.6, 1.7 Hz, 1H), 8.13 (d, *J* = 1.4 Hz, 1H), 7.65-7.67 (m, 1H), 7.49-7.52 (m, 1H), 7.39 (d, *J* = 8.2 Hz, 1H), 7.23-7.31 (m, 6H), 7.19 (t, *J* = 3.8 Hz, 2H), 6.82 (d, *J* = 11.7 Hz, 1H), 6.80 (d, *J* = 11.7 Hz, 1H), 3.88 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.2 (C=O), 138.7, 138.4, 138.3, 138.2, 137.4, 136.8, 133.2, 133.1, 132.9, 132.3, 130.9, 130.5, 130.4, 129.7, 129.6, 127.9, 127.7, 127.6, 127.5, 127.2, 127.0, 126.6, 126.4, 126.3, 126.1, 123.1, 122.8, 52.1, one sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{30}H_{20}O_2$, 412.1463; found 412.1463.

3-Phenyldibenzo[*g*,*p*]chrysene (2f)



Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2f** as a white solid (0.072 mmol, 31.0 mg, 72% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.82 (d, *J* = 8.2 Hz, 1H), 8.80 (d, *J* = 8.2 Hz, 1H), 7.90 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.62-7.66 (m, 2H), 7.56-7.57 (m, 2H), 7.47 (t, *J* = 7.2 Hz, 1H), 7.38-7.44 (m, 3H), 7.34-7.35 (m, 2H), 7.27-7.29 (m, 5H), 7.19 (m, 2H), 6.82 (d, *J* = 11.7 Hz, 1H), 6.80 (d, *J* = 11.7 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 141.0, 139.1, 139.0, 138.9, 138.4, 138.3, 136.9, 136.6, 133.1, 133.0, 131.8, 131.4, 130.6, 130.0, 129.4, 128.8, 127.7, 127.6, 127.5, 127.2, 126.9, 126.8, 126.5, 126.4, 126.3, 126.2, 125.5, 125.4, 123.1, 122.5, two sp^2 carbon peaks are not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{34}H_{22}$, 430.1716; found 430.1716.

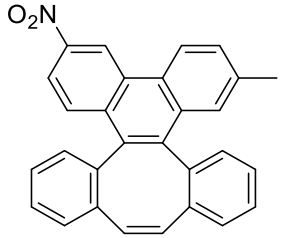
(*Z*)-2-Methyldibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2g)



Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2g** as a white solid (0.037 mmol, 13.6 mg, 37% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.76 (d, *J* = 8.2 Hz, 1H), 8.56 (s, 1H), 7.59-7.62 (m, 1H), 7.41-7.44 (m, 1H), 7.35 (d, *J* = 8.2 Hz, 1H), 7.22-7.27 (m, 8H), 7.16-7.17 (m, 2H), 6.79 (d, *J* = 11.7 Hz, 1H), 6.77 (d, *J* = 11.7 Hz, 1H), 2.60 (s, 3H); ^{13}C-NMR (151

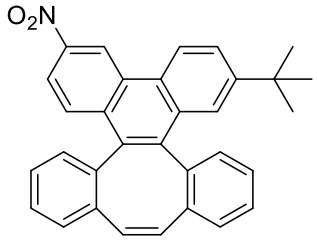
MHz, $CDCl_3$) δ 139.3, 139.2, 138.4, 138.3, 136.3, 135.9, 135.5, 133.0, 132.9, 131.5, 130.7, 130.6, 130.3, 129.9, 129.3, 128.2, 127.5, 127.3, 127.2, 126.7, 126.4, 126.2, 126.1, 126.0, 125.9, 122.4, 122.3, 21.9, one sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{29}H_{20}$, 368.1565; found 368.1565.

(*Z*)-16-methyl-2-nitrodibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2h)



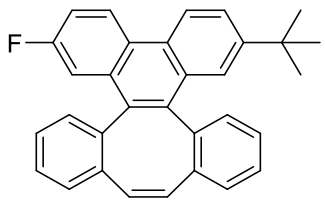
Purified by flash column chromatography (silica gel), [Hexane /DCM = 5:1 to 2:1 (v/v)] to give **2h** as a yellow solid (0.043 mmol, 17.8 mg, 43% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 9.64 (d, *J* = 2.1 Hz, 1H), 8.72 (d, *J* = 8.2 Hz, 1H), 8.17 (dd, *J* = 9.3, 2.4 Hz, 1H), 7.57 (dd, J = 8.2, 1.4 Hz, 1H), 7.46 (d, J = 8.9 Hz, 1H), 7.24-7.32 (m, 5H), 7.20 (t, J = 8.6 Hz, 4H), 6.81 (d, *J* = 11.0 Hz, 1H), 6.78 (d, *J* = 11.0 Hz, 1H), 2.44 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 145.5, 140.5, 138.4, 138.3, 138.2, 137.9, 136.0, 134.7, 133.0, 132.8, 132.0, 130.3, 130.2, 130.0, 129.2, 128.7, 128.1, 127.8, 127.7, 127.4, 127.3, 127.2, 126.6, 126.4, 122.7, 119.6, 118.6, 21.8, one sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{29}H_{19}NO_2$, 413.1415; found 413.1415.

(*Z*)-16-(*Tert*-butyl)-2-nitrodibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2i)



Purified by flash column chromatography (silica gel), [Hexane /DCM = 5:1 to 2:1 (v/v)] to give **2i** as a yellow solid (0.055 mmol, 25.1 mg, 55% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 9.65 (d, *J* = 2.1 Hz, 1H), 8.76 (d, *J* = 8.2 Hz, 1H), 8.17 (dd, *J* = 8.9, 2.1 Hz, 1H), 7.81 (dd, *J* = 8.9, 2.1 Hz, 1H), 7.19-7.47 (m, 10H), 6.84 (d, *J* = 11.0 Hz, 1H), 6.81 (d, *J* = 11.0 Hz, 1H), 1.30 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 150.9, 145.5, 141.0, 138.3, 138.2, 137.9, 135.8, 134.9, 133.1, 132.8, 131.8, 130.4, 130.2, 129.9, 128.7, 128.1, 127.8, 127.3, 126.6, 126.1, 125.7, 123.7, 122.5, 119.7, 118.6, 35.0, 31.1, three sp^2 carbon peaks are not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{32}H_{25}NO_2$, 455.1885; found 455.1885.

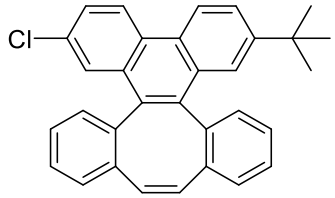
(*Z*)-3-(*Tert*-butyl)-16-fluorodibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2j)



Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2j**

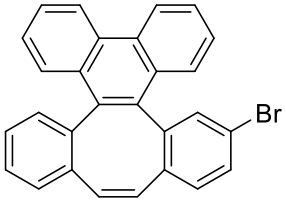
as a White solid (0.08 mmol, 34.3 mg, 80% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.79 (dd, *J* = 9.3, 5.8 Hz, 1H), 8.69 (d, *J* = 2.1 Hz, 1H), 7.53 (dd, *J* = 8.2, 2.1 Hz, 1H), 7.32-7.40 (m, 2H), 7.23-7.29 (m, 6H), 7.17 (d, *J* = 2.1 Hz, 2H), 7.01 (dd, *J* = 11.3, 2.4 Hz, 1H), 6.78 (d, *J* = 11.0 Hz, 1H), 6.76 (d, *J* = 11.7 Hz, 1H), 1.49 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 161.3 (d, J_F = 244.2 Hz), 149.4, 139.0, 138.7, 138.3, 138.1, 137.5, 135.2, 135.1, 133.2 (d, J_F = 8.7 Hz), 133.0 (d, J_F = 10.1 Hz), 130.5 (d, J_F = 8.7 Hz), 129.6, 128.8, 127.7, 127.6, 127.3, 127.0, 126.9, 126.5, 126.2, 124.8, 124.5, 118.0, 114.9 (d, J_F = 23.1 Hz), 111.8 (d, J_F = 21.7 Hz), 35.1, 31.4, two sp^2 carbon peaks are not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{32}H_{25}F$, 428.1935; found 428.1935.

(*Z*)-3-(*Tert*-butyl)-16-chlorodibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2k)



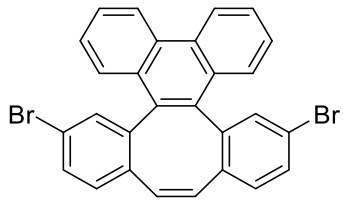
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2k** as a white solid (0.055 mmol, 24.5 mg, 55% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.59-8.69 (m, 2H), 7.72 (d, *J* = 8.7 Hz, 1H), 7.17-7.37 (m, 11H), 6.82 (d, *J* = 12.4 Hz, 1H), 6.79 (d, *J* = 12.4 Hz, 1H), 1.27 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 149.9, 138.9, 138.8, 138.3, 138.2, 137.0, 135.9, 133.2, 132.8, 132.3, 131.6, 131.3, 130.6, 130.5, 129.5, 128.9, 127.7, 127.6, 127.0, 126.9, 126.5, 126.3, 126.0, 124.7, 123.3, 122.3, 121.9, 34.8, 31.1, one sp^2 carbon peak is not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{32}H_{25}Cl$, 444.1639; found 444.1639.

(*Z*)-6-Bromodibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2l)



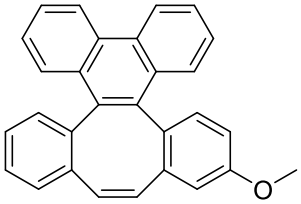
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2l** as a white solid (0.052 mmol, 22.5 mg, 52% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.78 (d, *J* = 8.2 Hz, 2H), 7.62-7.67 (m, 2H), 7.42-7.54 (m, 3H), 7.34-7.40 (m, 3H), 7.27-7.33 (m, 3H), 7.15-7.19 (m, 1H), 7.05 (d, *J* = 8.2 Hz, 1H), 6.80 (d, *J* = 11.4 Hz, 1H), 6.69 (d, *J* = 11.4 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 141.3, 138.8, 137.9, 137.4, 136.7, 135.0, 133.7, 133.2, 131.9, 131.2, 130.9, 130.8, 130.3, 130.2, 130.0, 129.2, 127.6, 127.4, 127.0, 126.8, 126.6, 126.5, 126.4, 126.3, 122.6, 122.5, 120.2, one sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{28}H_{17}Br$, 432.0514; found 432.0514.

(*Z*)-6,13-Dibromodibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2m)



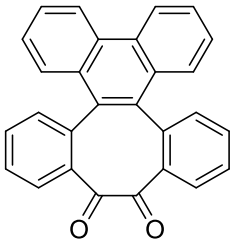
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2m** as a white solid (0.037 mmol, 20.0 mg, 37% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.78 (d, *J* = 8.2 Hz, 2H), 7.67 (t, *J* = 7.6 Hz, 2H), 7.51 (t, *J* = 7.6 Hz, 2H), 7.42-7.44 (m, 4H), 7.36 (d, *J* = 8.2 Hz, 2H), 7.05 (d, *J* = 8.9 Hz, 2H), 6.71 (s, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 140.8, 137.0, 135.3, 133.4, 132.6, 130.8, 130.3, 130.2, 129.2, 127.1, 126.9, 126.7, 122.6, 120.4; HRMS (FD+): [m/z]: calcd. for $C_{28}H_{16}Br_2$, 509.9618; found 509.9618.

(*Z*)-7-methoxydibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (2n)



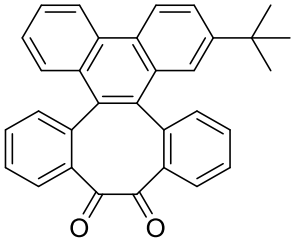
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2n** as a white solid (0.057 mmol, 22.0 mg, 57% yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.78 (d, J = 8.2 Hz, 2H), 7.62-7.65 (m, 2H), 7.43-7.48 (m, 3H), 7.36 (d, J = 8.2 Hz, 1H), 7.26-7.30 (m, 3H), 7.19 (m, 2H), 6.83 (dd, J = 8.2, 2.7 Hz, 1H), 6.80 (d, J = 11.7 Hz, 1H), 6.75 (d, J = 11.7 Hz, 1H), 6.71 (d, J = 2.7 Hz, 1H), 3.81 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.2, 139.5, 139.3, 138.4, 136.6, 136.2, 133.0, 132.9, 131.8, 131.7, 131.6, 131.5, 130.6, 130.2, 130.1, 127.6, 127.4, 127.3, 126.7, 126.5, 126.4, 126.2, 126.1, 126.0, 122.4, 112.6, 112.2, 55.1, one sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{29}H_{20}O$, 384.1514; found 384.1513.

Dibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene-9,10-dione (3b)



Purified by flash column chromatography (silica gel), [Hexane /DCM = 2:1 to 1:1 (v/v)] to give **3b** as a yellowish solid (0.13 mmol, 50.0 mg, 65 % yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.77 (d, *J* = 8.9 Hz, 2H), 7.69 (t, *J* = 7.6 Hz, 2H), 7.42-7.52 (m, 7H), 7.35 (d, *J* = 8.2 Hz, 2H), 7.29 (d, *J* = 7.6 Hz, 2H), 7.25 (s, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.6, 138.7, 136.7, 131.8, 131.0, 130.9, 130.6, 130.5, 128.5, 127.5, 127.4, 127.3, 127.2, 122.7; HRMS (MALDI): [m/z]: calcd. for $C_{28}H_{16}O_2$, 384.1150; found 384.1150.

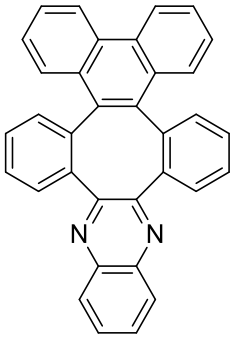
3-(*Tert*-butyl)dibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene-9,10-dione (3d)



Purified by flash column chromatography (silica gel), [Hexane /DCM = 2:1 to 1:1 (v/v)] to give **3d** as

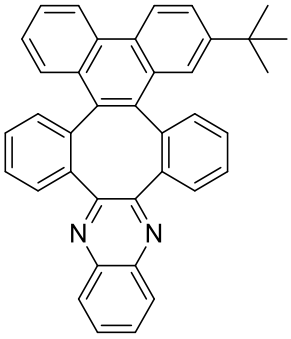
a yellowish solid (0. 13 mmol, 59.0 mg, 67 % yield); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.74 (d, *J* = 8.2 Hz, 1H), 8.70 (d, *J* = 8.2 Hz, 1H), 7.78 (dd, *J* = 8.2, 2.1 Hz, 1H), 7.66-7.69 (m, 1H), 7.43-7.55 (m, 7H), 7.28-7.34 (m, 4H), 1.27 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.7, 192.6, 150.1, 138.8, 138.6, 137.0, 136.9, 132.0, 131.6, 131.0, 130.9, 130.8, 130.6, 130.4, 130.3, 128.7, 128.5, 128.4, 127.6, 127.4, 127.3, 127.2, 126.8, 125.8, 123.0, 122.6, 122.5, 34.8, 31.1, one sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{32}H_{24}O_2$, 440.1776; found 440.1776.

Dibenzo[3,4:7,8]phenanthro[9',10':5,6]cycloocta[1,2-*b*]quinoxaline (4b)



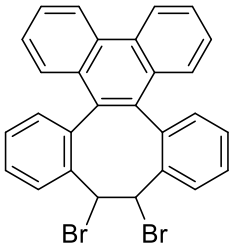
Purified by flash column chromatography (silica gel), [Hexane /DCM = 2:1 to 1:1 (v/v)] to give **4b** as a white solid (0.2 mmol, 91.3 mg, quant.); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.65 (d, *J* = 8.9 Hz, 2H), 8.02 (td, *J* = 6.4, 3.0 Hz, 2H), 7.63 (td, *J* = 6.5, 3.0 Hz, 2H), 7.57-7.60 (m, 4H), 7.44-7.50 (m, 8H), 7.34-7.36 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 155.3, 141.3, 139.6, 138.6, 134.7, 130.8, 130.3, 130.2, 129.7, 129.5, 129.2, 128.5, 128.0, 127.7, 126.8, 126.7, 122.3; HRMS (MALDI): [m/z]: calcd. for $C_{34}H_{20}N_2$, 456.1621; found 456.1621.

2-(*Tert*-butyl)dibenzo[3,4:7,8]phenanthro[9',10':5,6]cycloocta[1,2-*b*]quinoxaline (4d)



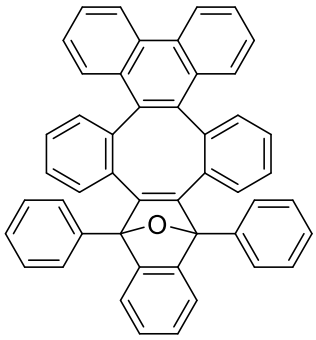
Purified by flash column chromatography (silica gel), [Hexane /DCM = 2:1 to 1:1 (v/v)] to give **4d** as a white solid (0.2 mmol, 102.5 mg, quant.); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.61 (d, *J* = 8.2 Hz, 1H), 8.60 (d, *J* = 8.9 Hz, 1H), 8.03 (m, 2H), 7.68 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.63-7.65 (m, 2H), 7.52-7.58 (m, 3H), 7.43-7.50 (m, 6H), 7.37-7.42 (m, 2H), 7.29 (td, *J* = 6.2, 3.7 Hz, 1H), 1.29 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 155.4, 155.3, 149.7, 141.3, 141.3, 139.8, 139.6, 138.9, 138.6, 134.8, 134.7, 130.6, 130.5, 130.3, 130.2, 129.7, 129.6, 129.3, 129.2, 128.5, 128.2, 128.0, 127.9, 127.7, 126.6, 126.4, 125.0, 123.3, 122.2, 122.1, 34.9, 31.2, two sp^2 carbon peaks are not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{38}H_{28}N_2$, 512.2253; found 512.2253.

9,10-Dibromo-9,10-dihydrodibenzo[3,4:7,8]cycloocta[1,2-*l*]phenanthrene (5b)



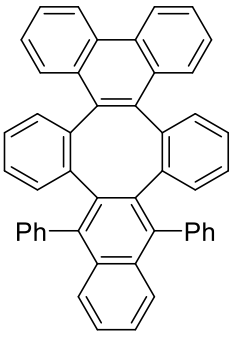
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **5b** as a white solid (0.17 mmol, 85.0 mg, 83%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.86 (d, *J* = 8.2 Hz, 1H), 8.83 (d, *J* = 8.2 Hz, 1H), 7.51-7.83 (m, 8H), 7.32 (td, *J* = 7.6, 1.4 Hz, 1H), 7.14-7.25 (m, 4H), 7.08 (m, 1H), 6.99 (m, 1H), 5.46 (d, *J* = 9.2 Hz, 1H), 5.39 (d, *J* = 8.7 Hz, 1H); ^{13}C-NMR (100 MHz, $CDCl_3$) δ 139.6, 139.1, 137.9, 137.7, 137.4, 134.7, 132.9, 130.8, 130.6, 130.5, 129.6, 129.3, 128.5, 128.4, 127.9, 127.8, 127.6, 127.5, 127.2, 127.0, 126.8, 122.8, 122.4, 62.8, 58.5, three sp^2 carbon peak is not shown due to superimposition; HRMS (MALDI): [m/z]: calcd. for $C_{28}H_{18}Br_2$, 511.9770; found 511.9770.

13,18-Diphenyl-13,18-dihydro-13,18-epoxytribenzo[*a*,*c*,*n*]tetraphenylene (6b)



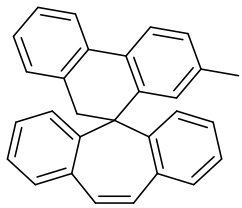
Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **2l** as a white solid (0.14 mmol, 84.7 mg, 68%); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.61 (d, *J* = 8.2 Hz, 2H), 7.62 (t, *J* = 7.6 Hz, 2H), 7.53 (t, *J* = 7.2 Hz, 2H), 7.40-7.45 (m, 8H), 7.34-7.37 (m, 2H), 7.30 (t, *J* = 7.2 Hz, 4H), 7.24 (dd, *J* = 7.6, 1.4 Hz, 2H), 7.07 (td, *J* = 7.6, 1.4 Hz, 2H), 6.55 (d, *J* = 8.2 Hz, 2H), 5.93 (q, J = 2.7 Hz, 2H), 5.72 (q, J = 2.7 Hz, 2H); ^{13}C-NMR (150 MHz, $CDCl_3$) δ 154.4, 149.5, 139.7, 135.3, 134.7, 134.0, 131.8, 130.3, 130.2, 130.1, 127.9, 127.3, 127.1, 126.8, 126.4, 126.3, 126.1, 125.8, 123.2, 122.5, 117.4, 93.2, two sp^2 carbon peak is not shown due to superimposition; HRMS (FD+): [m/z]: calcd. for $C_{48}H_{30}O$, 622.2296; found 622.2295.

13,18-Diphenyltribenzo[*a*,*c*,*n*]tetraphenylene (7b)



Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **7b** as a white solid (0.085 mmol, 51.6 mg, 85%); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.76 (d, *J* = 8.2 Hz, 2H), 7.66-7.70 (m, 4H), 7.59 (t, *J* = 7.6 Hz, 2H), 7.52 (d, *J* = 7.6 Hz, 2H), 7.41 (t, *J* = 7.6 Hz, 2H), 7.34-7.36 (m, 2H), 7.27 (t, *J* = 8.2 Hz, 4H), 7.16-7.21 (m, 4H), 7.08 (d, *J* = 6.9 Hz, 2H), 7.01-7.03 (m, 2H), 6.98 (d, *J* = 6.9 Hz, 2H), 6.92-6.95 (m, 2H), 6.55 (d, *J* = 7.6 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 141.3, 139.5, 139.3, 138.7, 137.3, 136.6, 132.0, 131.6, 131.3, 130.4, 130.3, 129.4, 128.3, 127.7, 127.0, 126.7, 126.7, 126.4, 126.2, 126.1, 125.9, 125.5, 122.6, one sp^2 carbon peak is not shown due to superimposition. HRMS (FD+): [m/z]: calcd. for $C_{48}H_{30}$, 606.2347; found 606.2345.

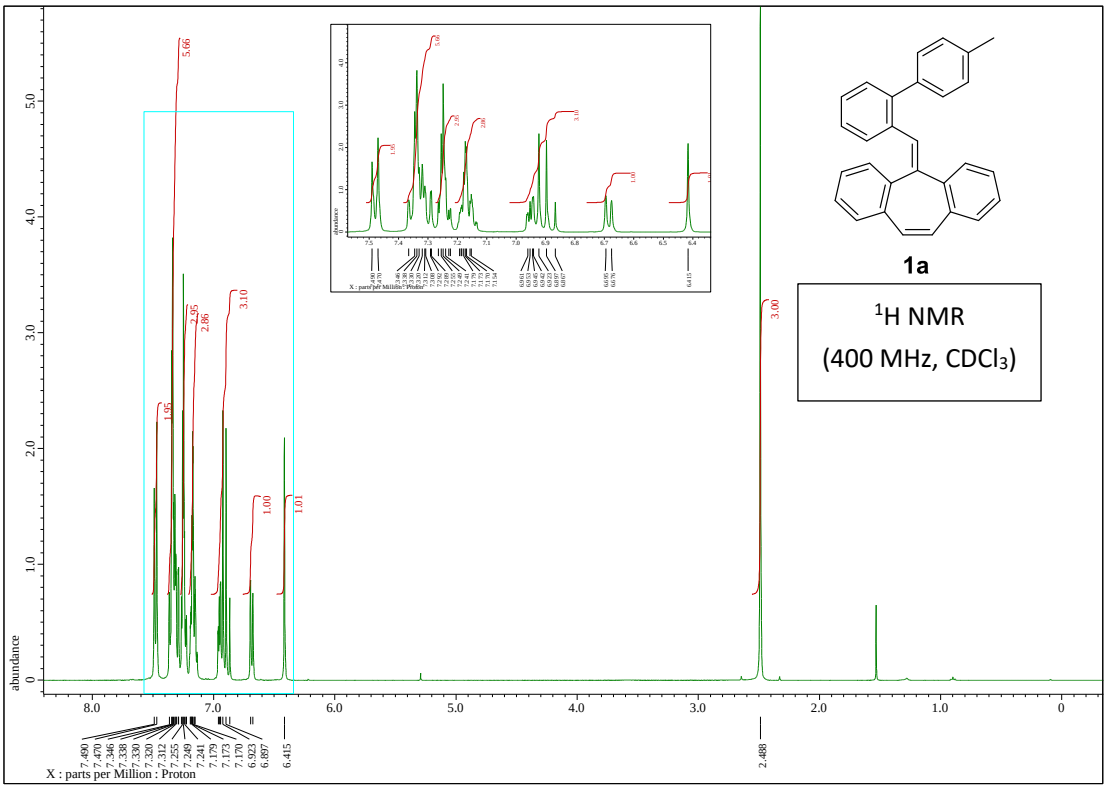
7'-Methyl-10'*H*-spiro[dibenzo[*a*,*d*][7]annulene-5,9'-phenanthrene] (1a')

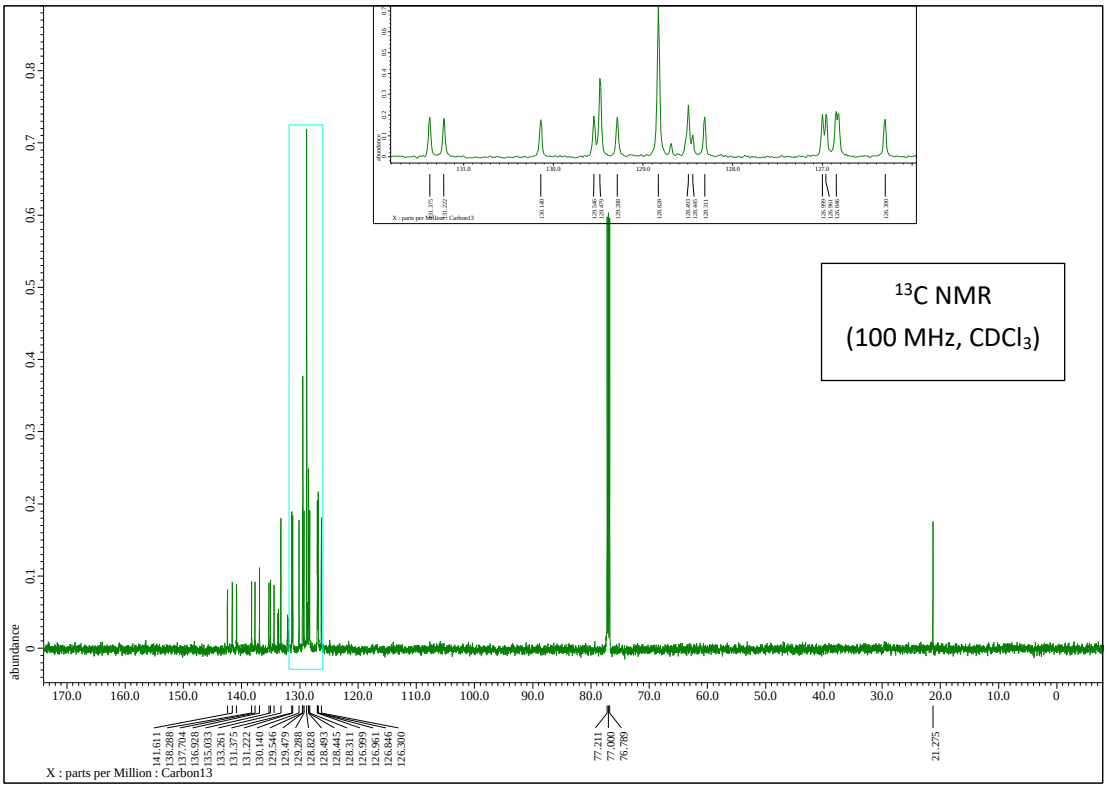


Purified by flash column chromatography (silica gel), [Hexane /DCM = 10:1 to 5:1 (v/v)] to give **1a'** as a White solid (0.12 mmol, 44.5 mg, 60%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 7.6 Hz, 2H), 7.07-7.47 (m, 13H), 6.95 (s, 2H), 3.94 (s, 2H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.8, 137.3, 136.1, 135.9, 135.0, 134.3, 132.7, 132.1, 131.6, 130.0, 128.5, 127.7, 127.6, 127.5, 127.1, 126.7, 125.9, 125.3, 122.6, 50.3, 39.6, 21.6; HRMS (FD+): [m/z]: calcd. for $C_{29}H_{22}$, 370.1721; found 370.1721.

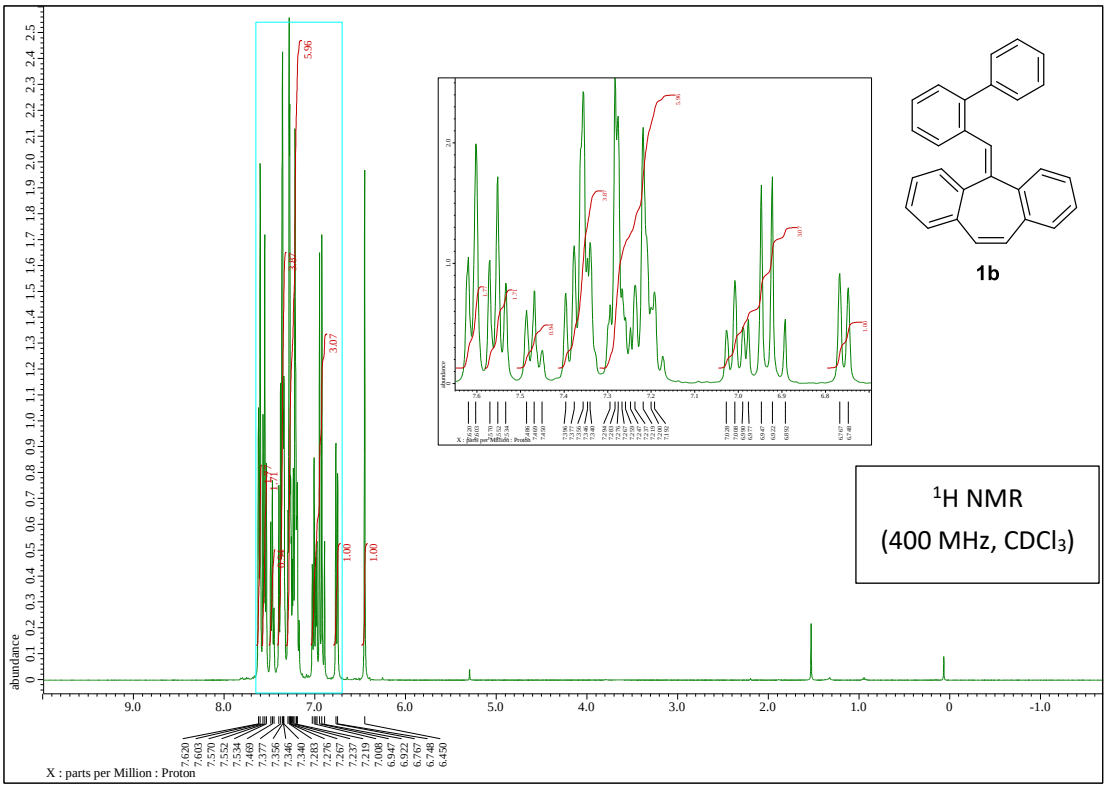
8. ^{1}H NMR and ^{13}C NMR spectra

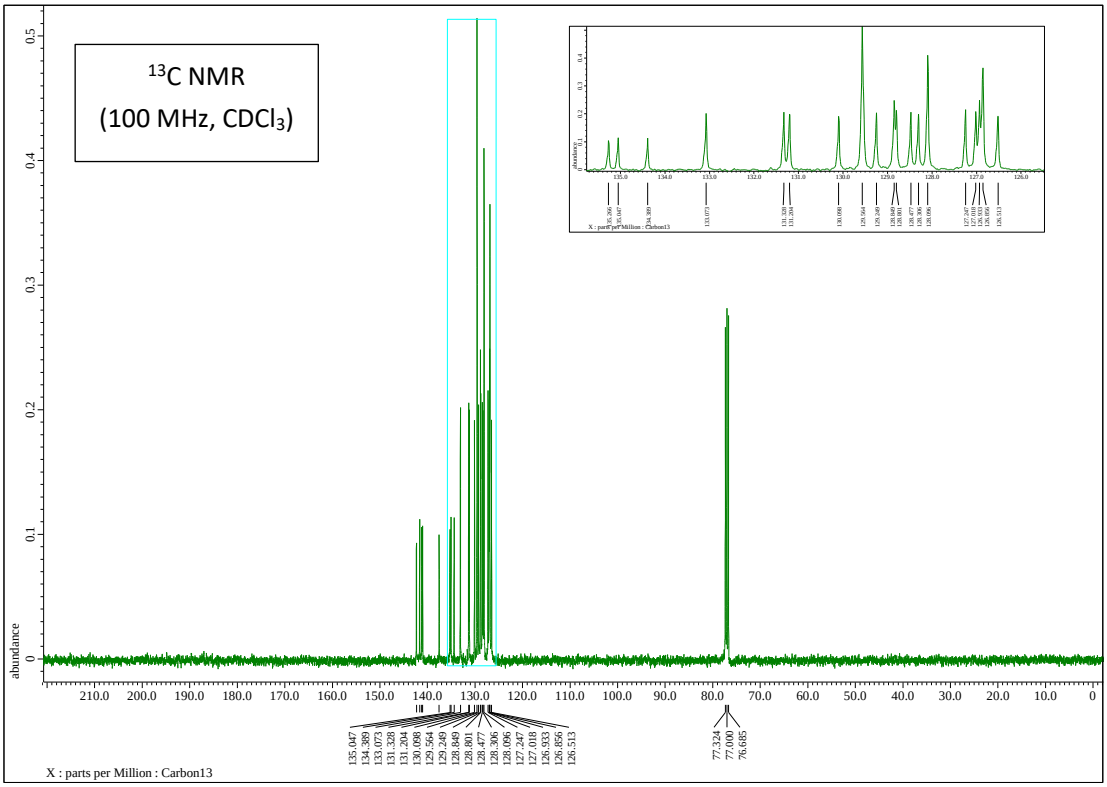
^{1}H and ^{13}C NMR Spectra of **1a**



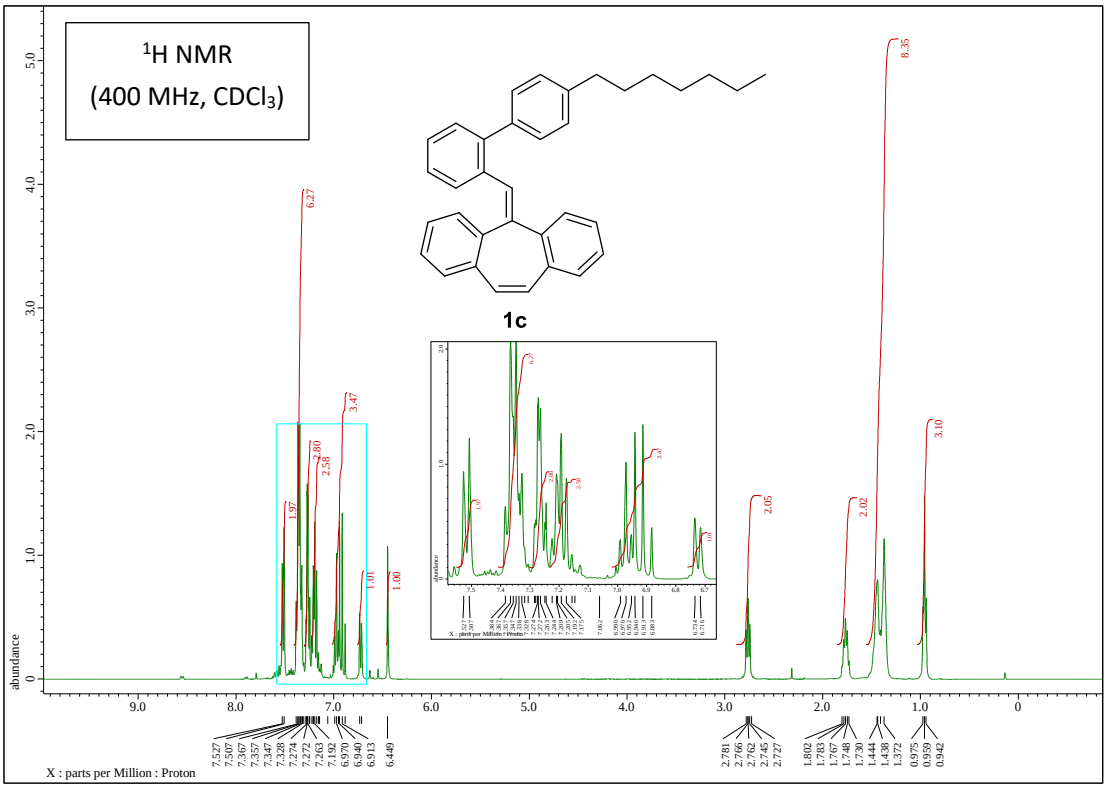


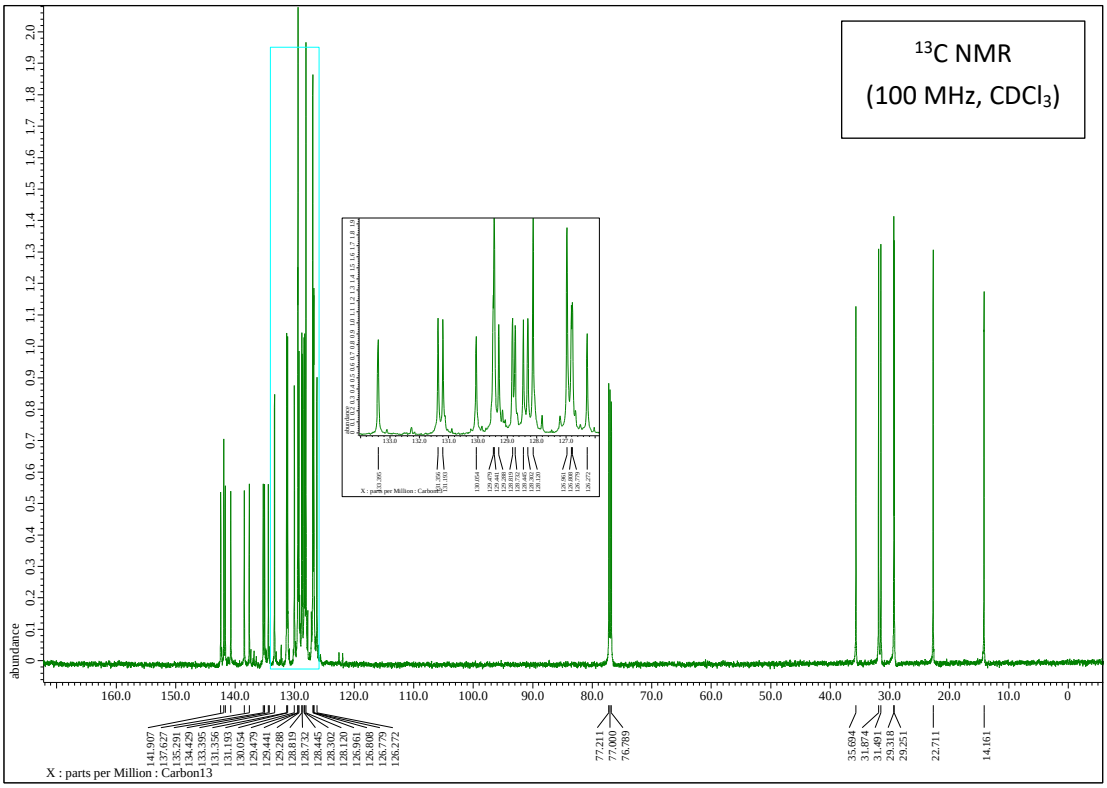
^{1}H and ^{13}C NMR Spectra of **1b**



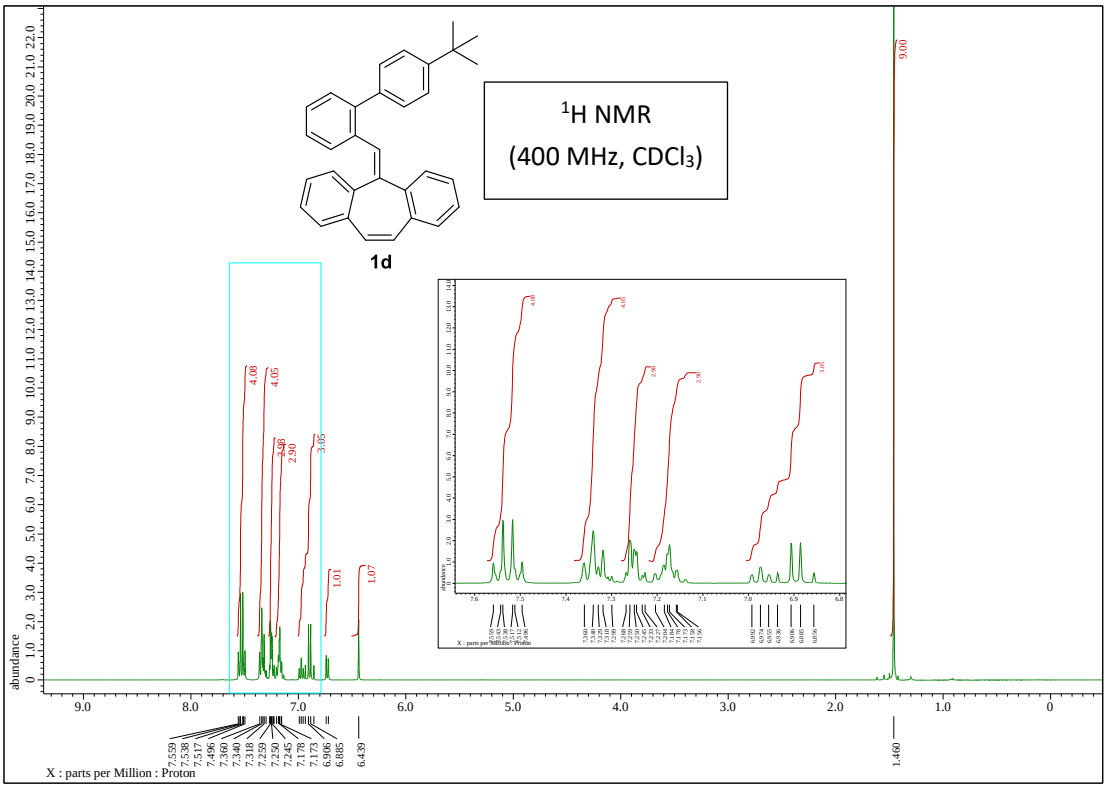


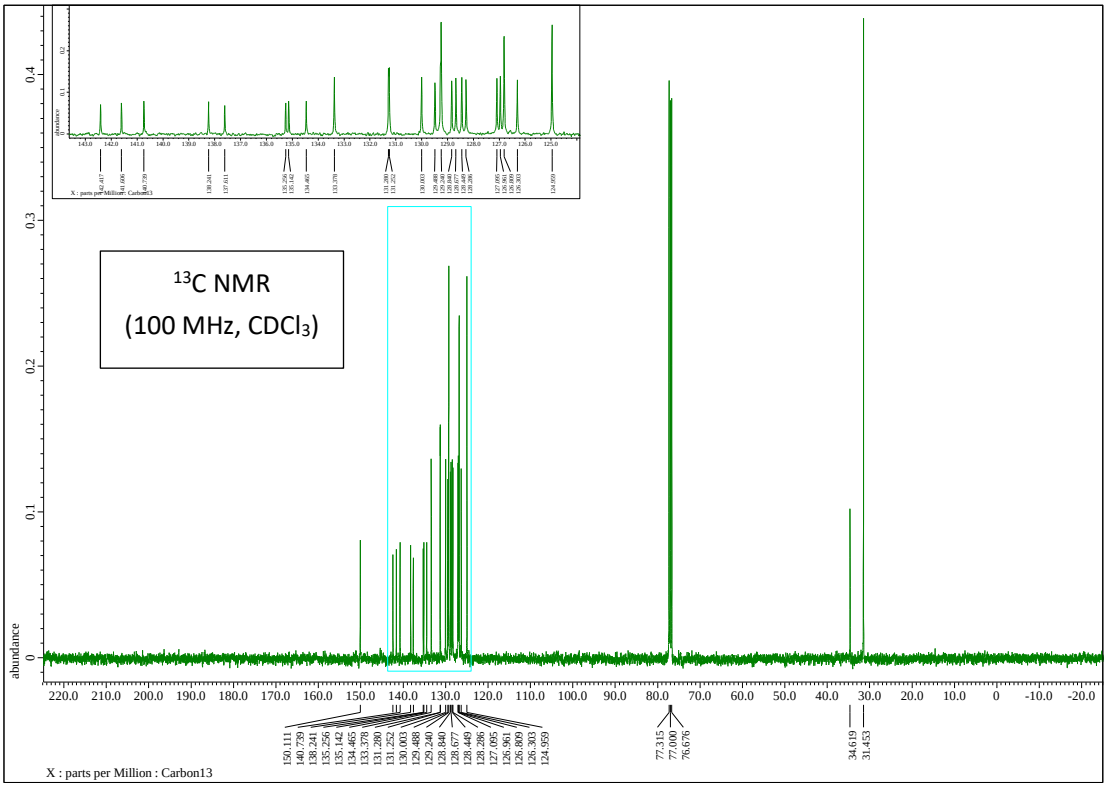
^{1}H and ^{13}C NMR Spectra of **1c**



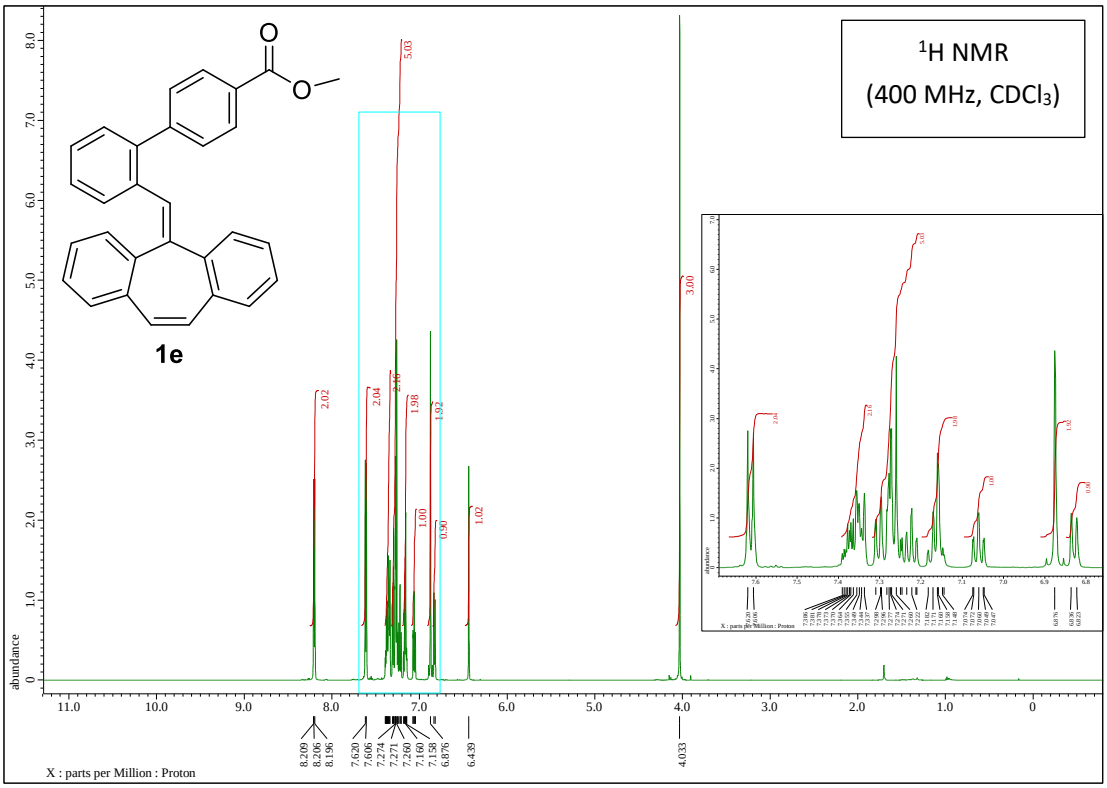


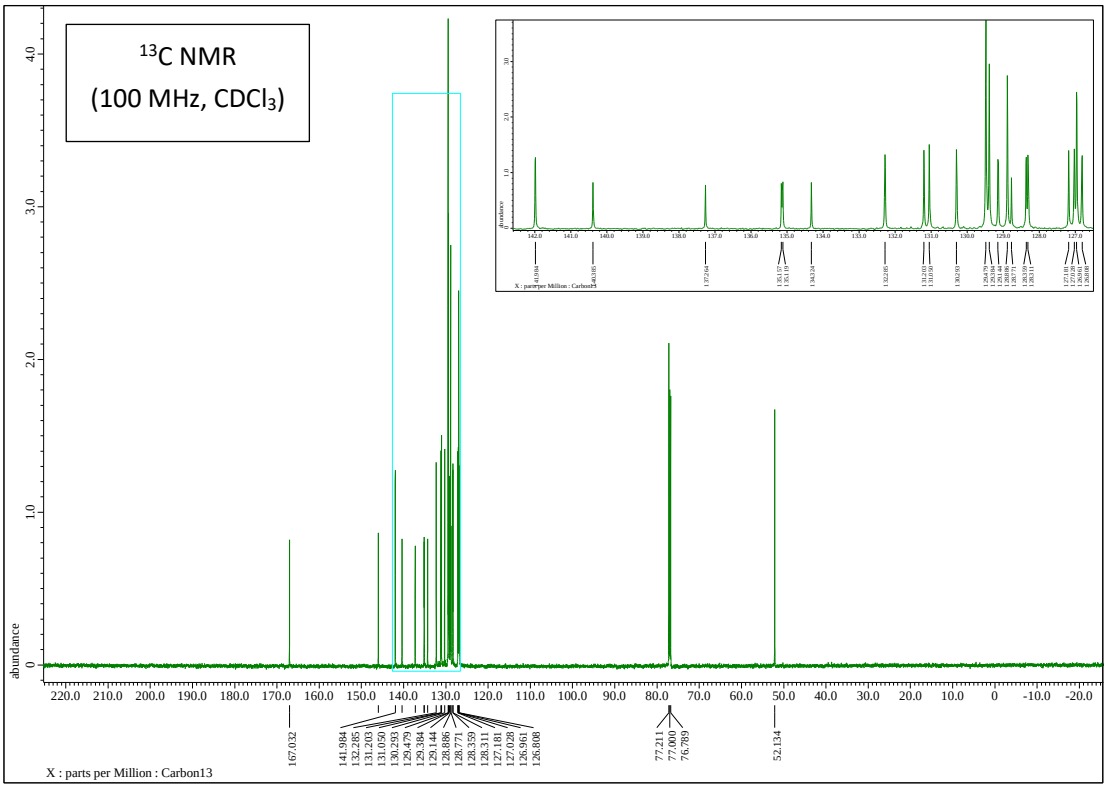
^{1}H and ^{13}C NMR Spectra of **1d**



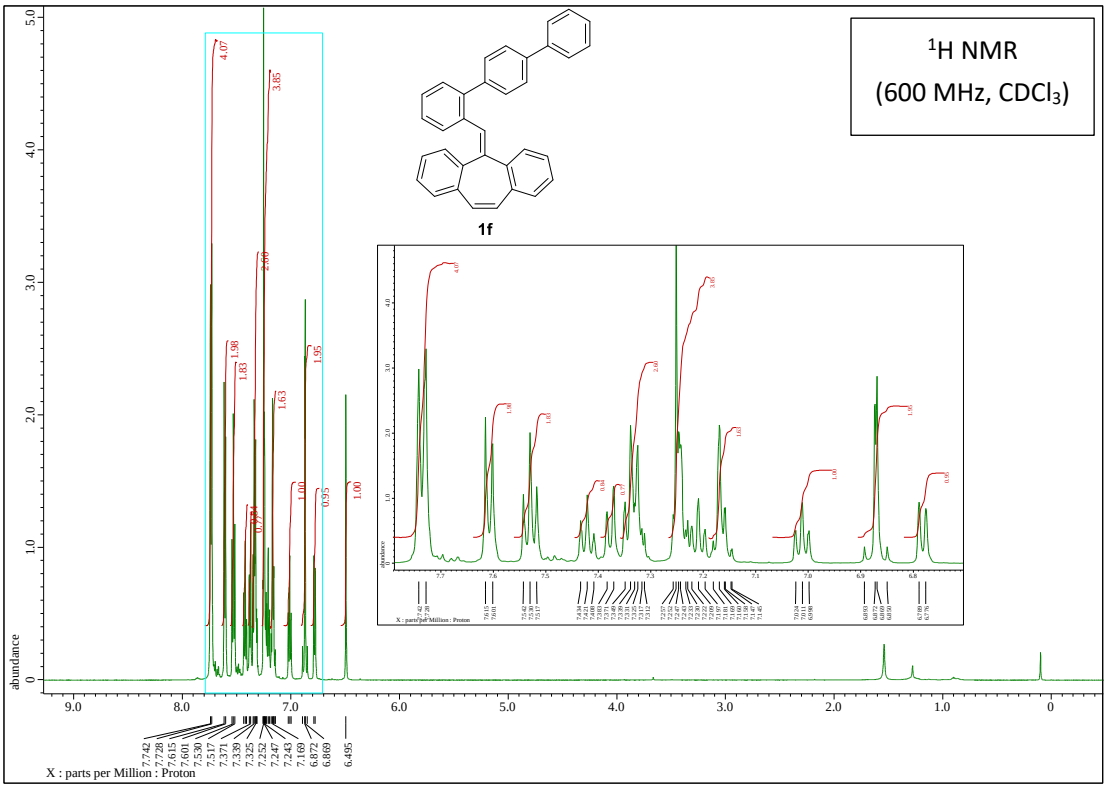


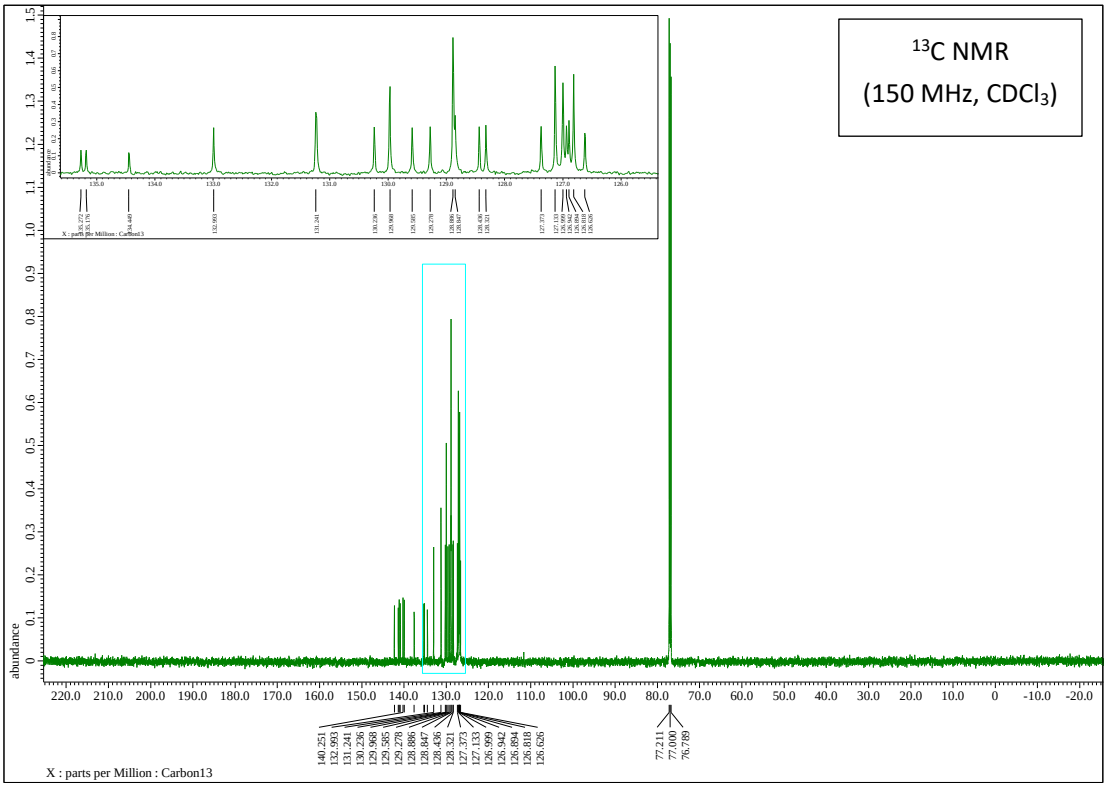
^{1}H and ^{13}C NMR Spectra of **1e**



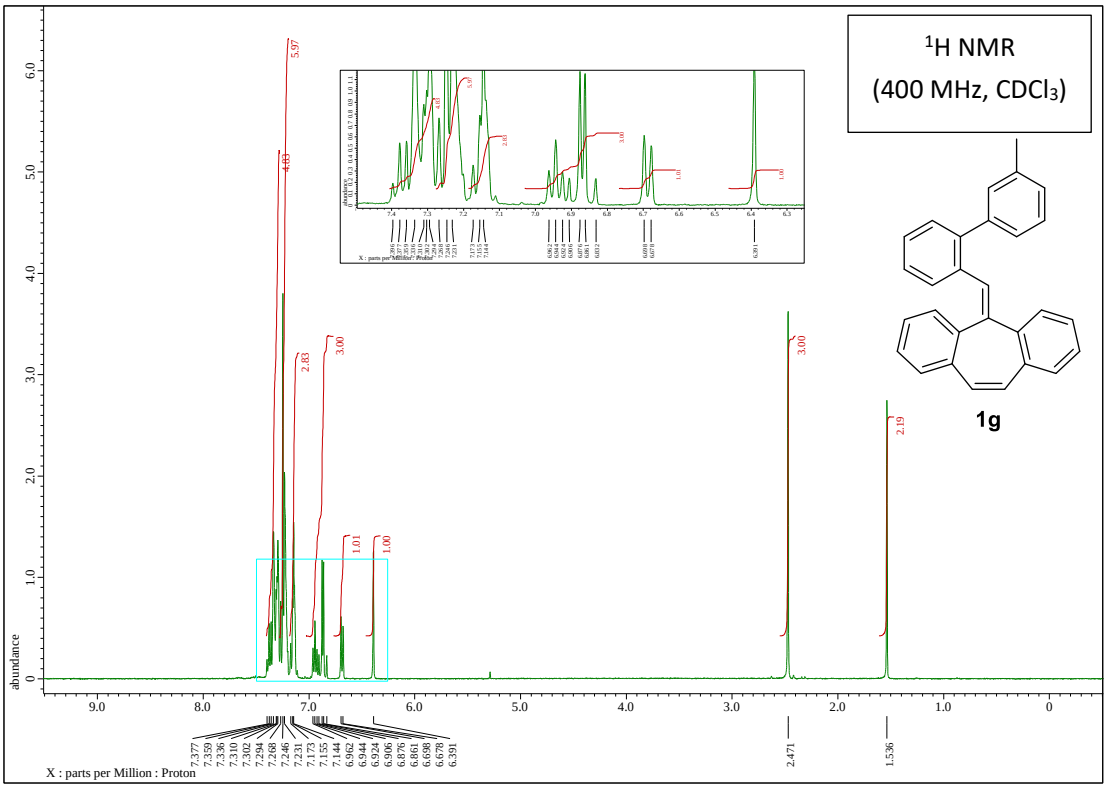


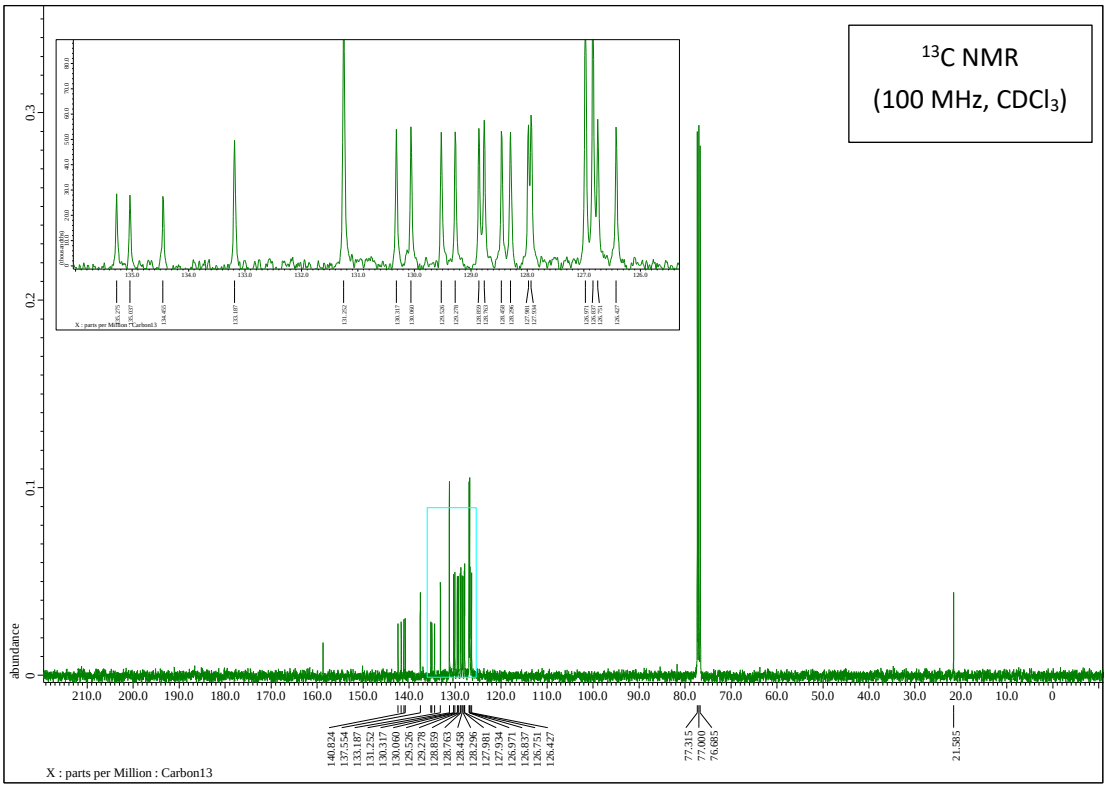
^{1}H and ^{13}C NMR Spectra of **1f**



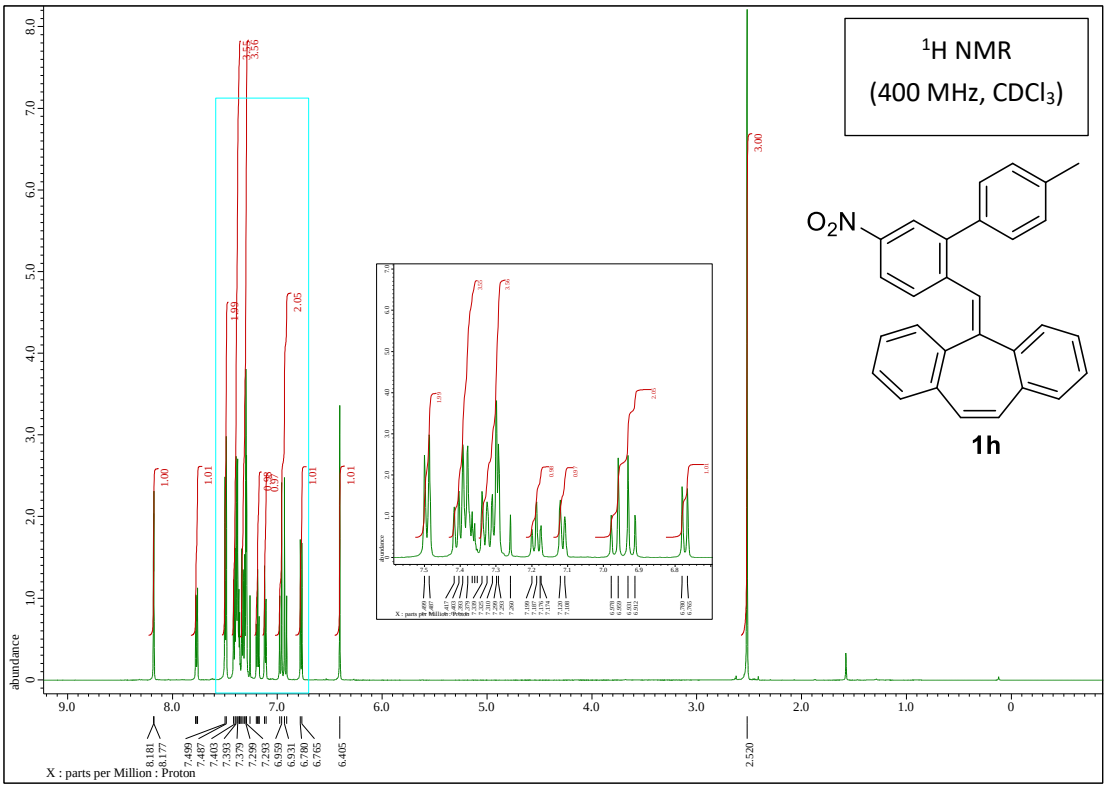


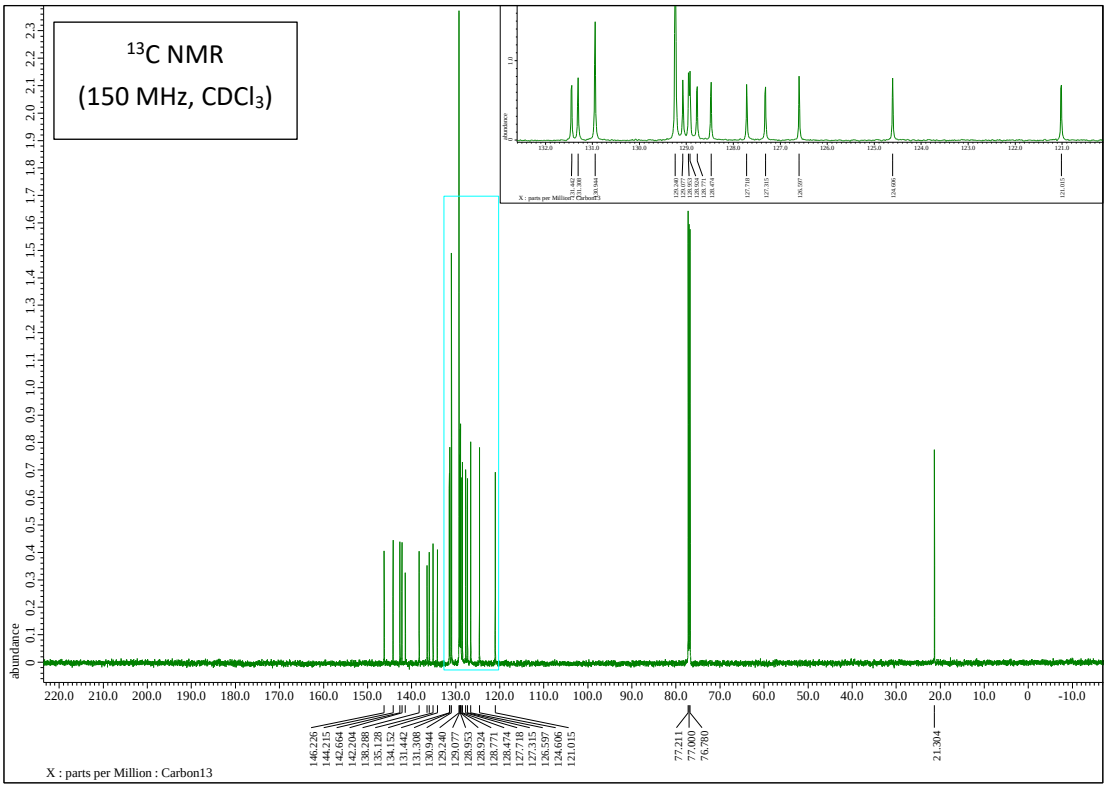
^{1}H and ^{13}C NMR Spectra of **1g**



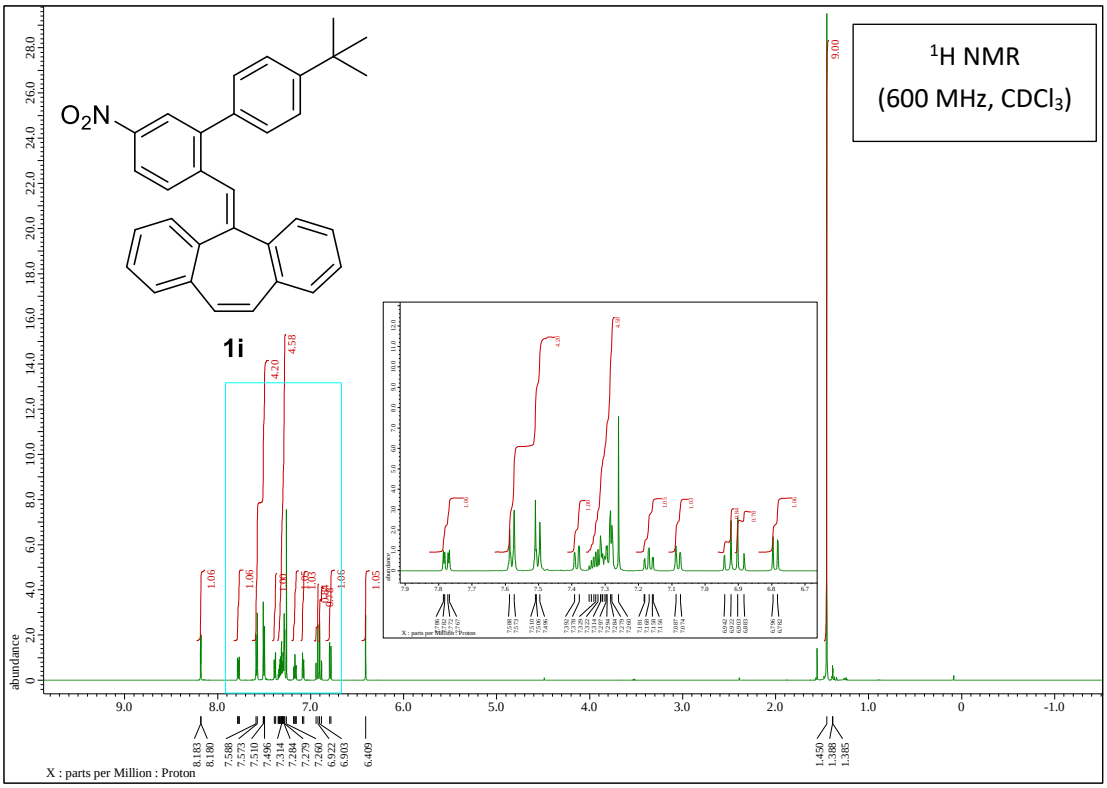


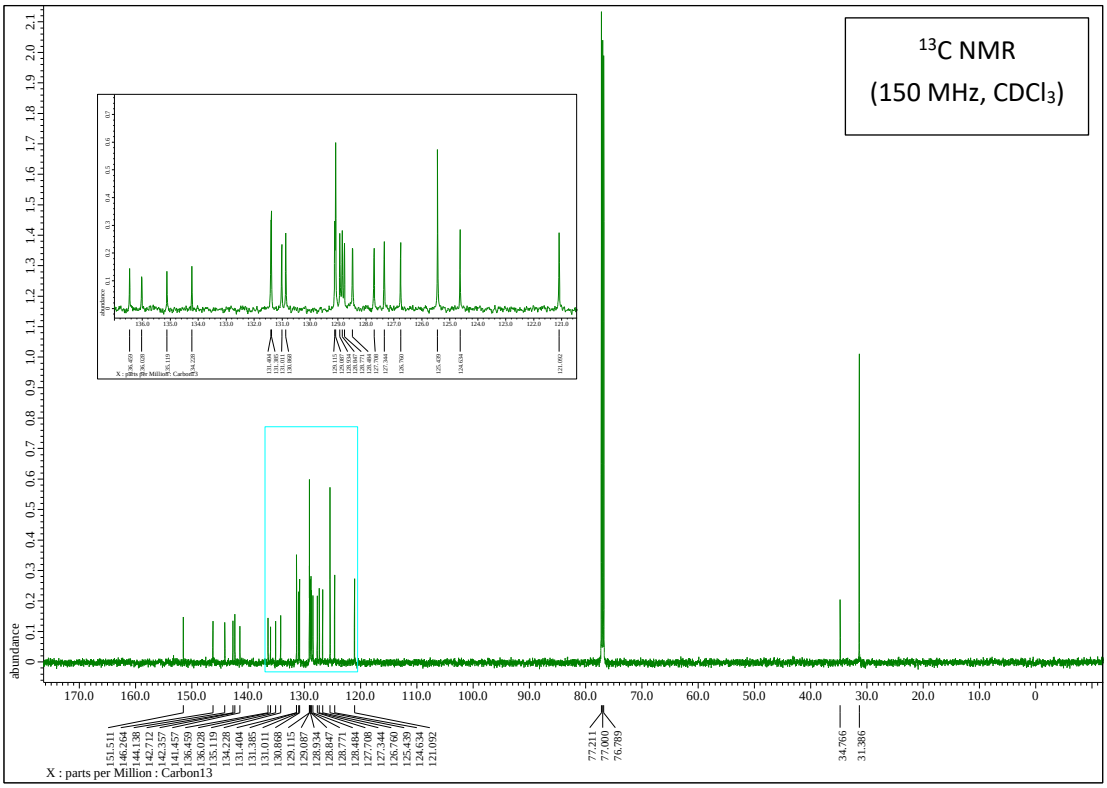
^{1}H and ^{13}C NMR Spectra of **1h**



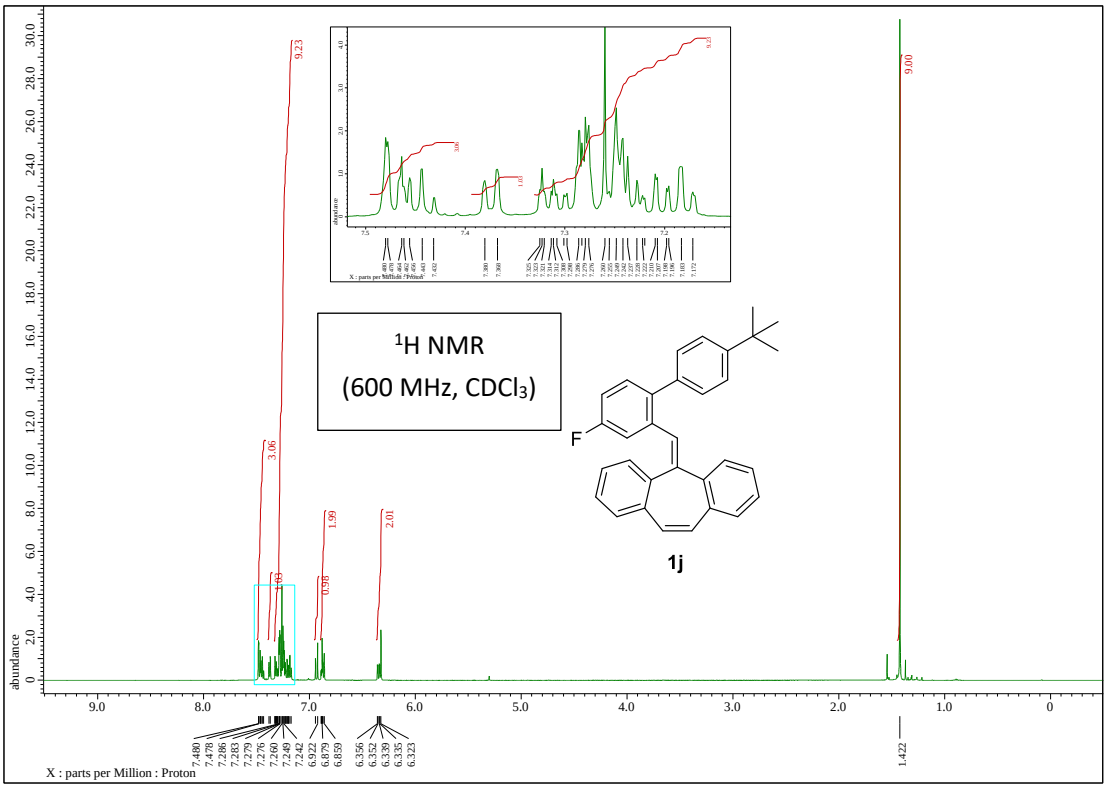


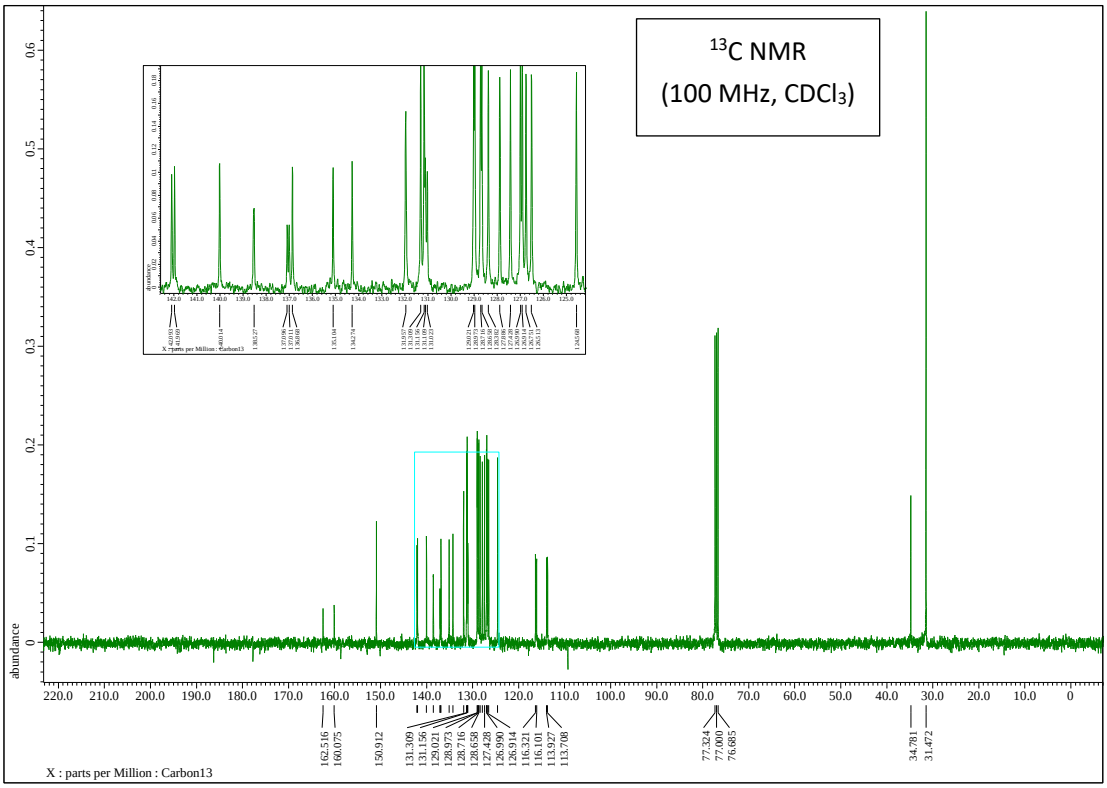
^{1}H and ^{13}C NMR Spectra of **1i**



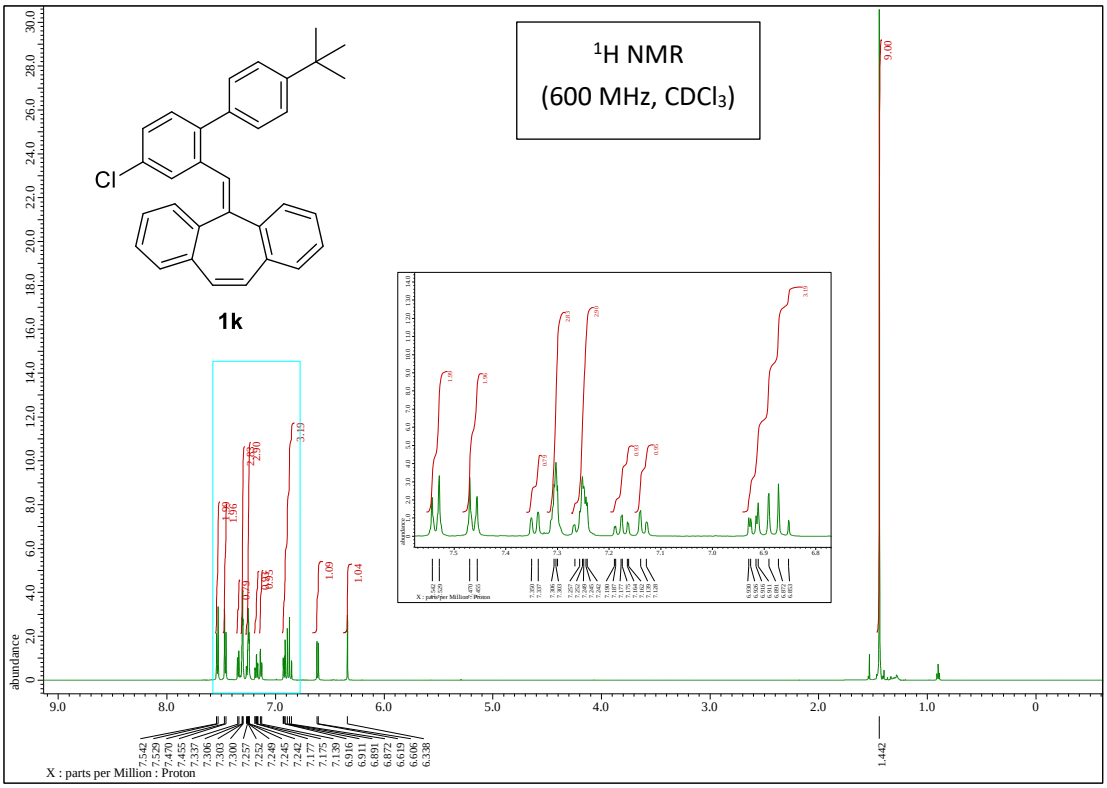


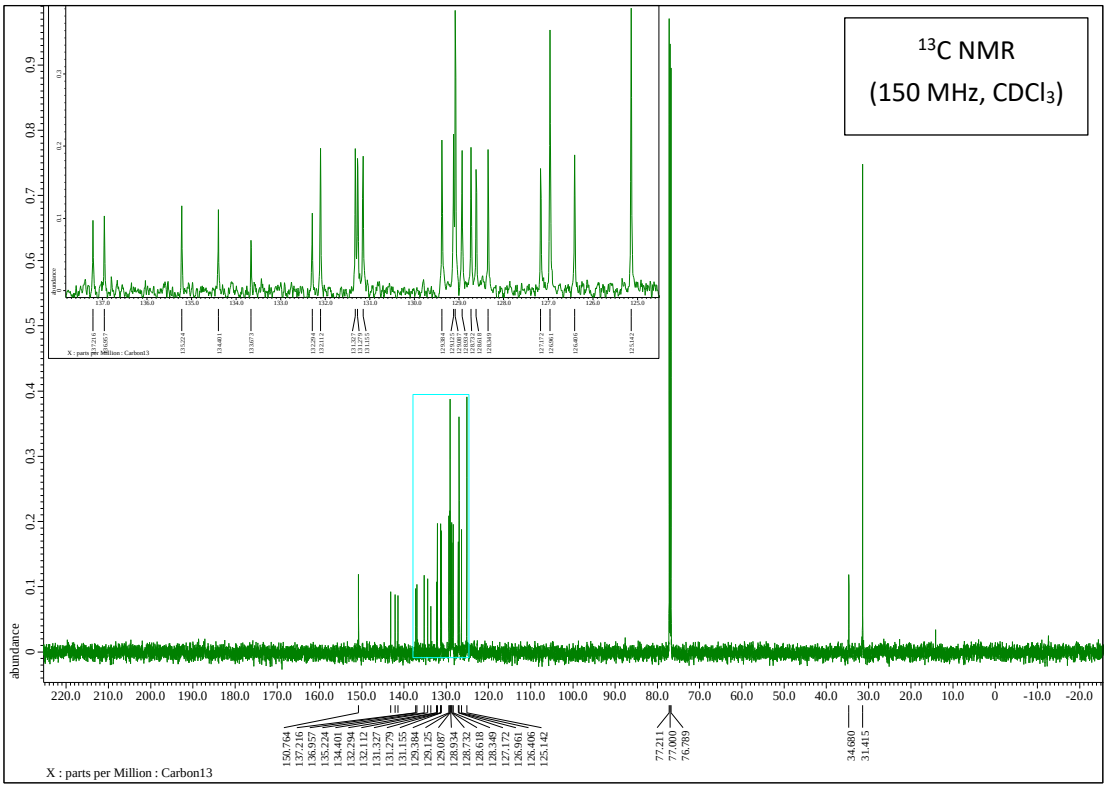
^{1}H and ^{13}C NMR Spectra of **1j**



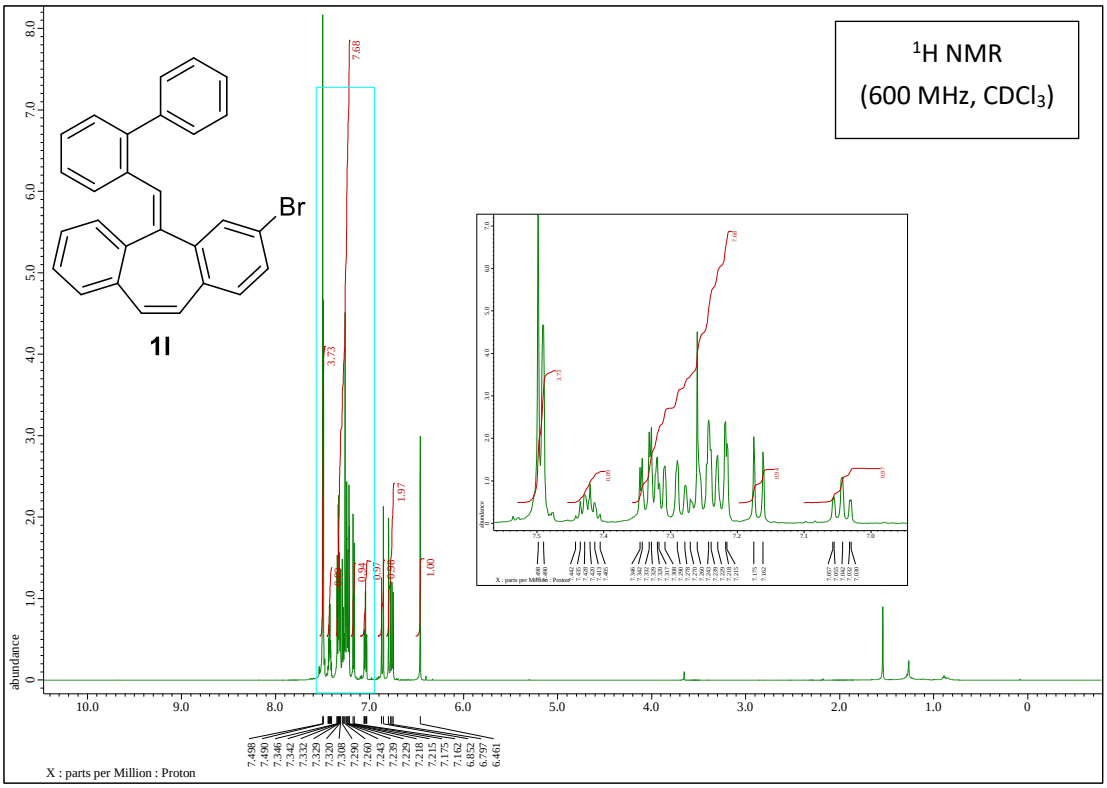


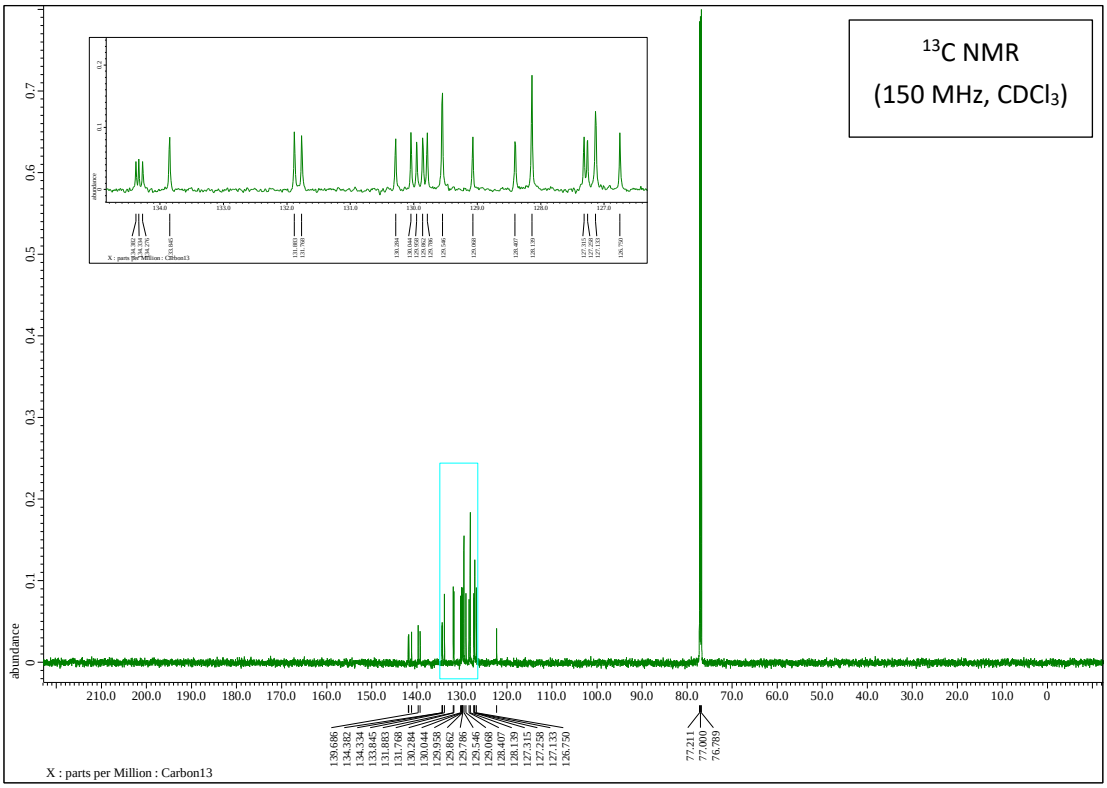
^{1}H and ^{13}C NMR Spectra of **1k**



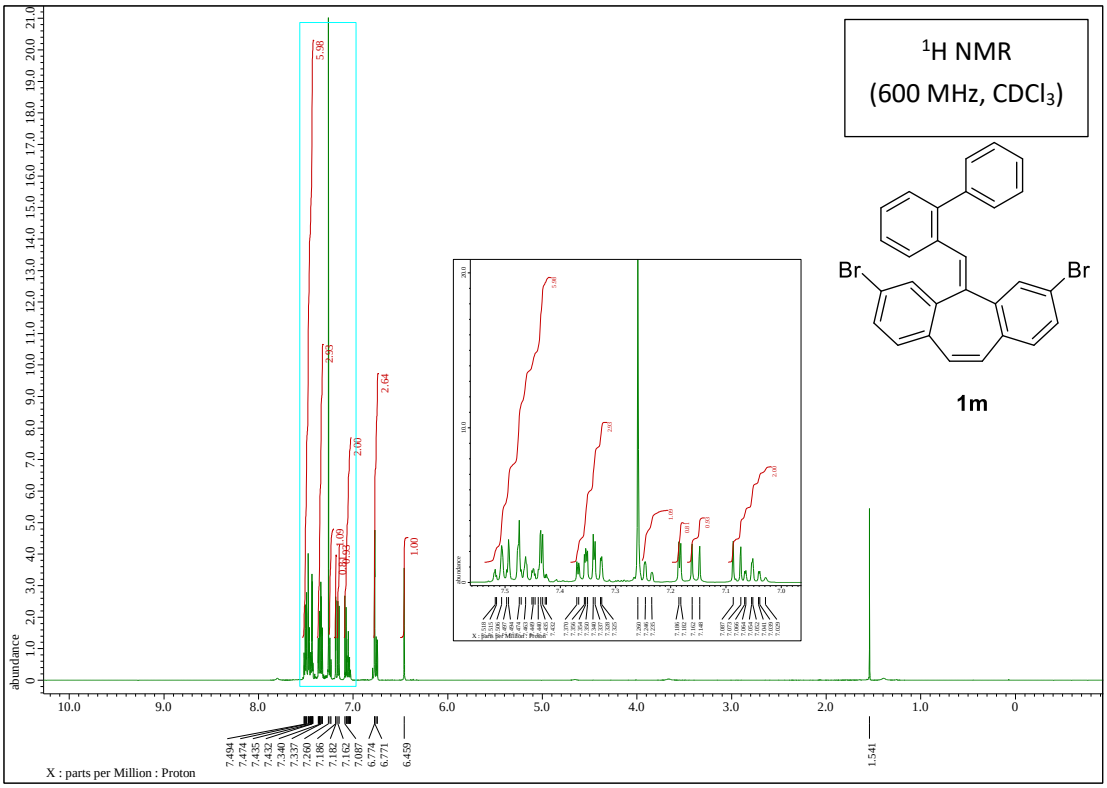


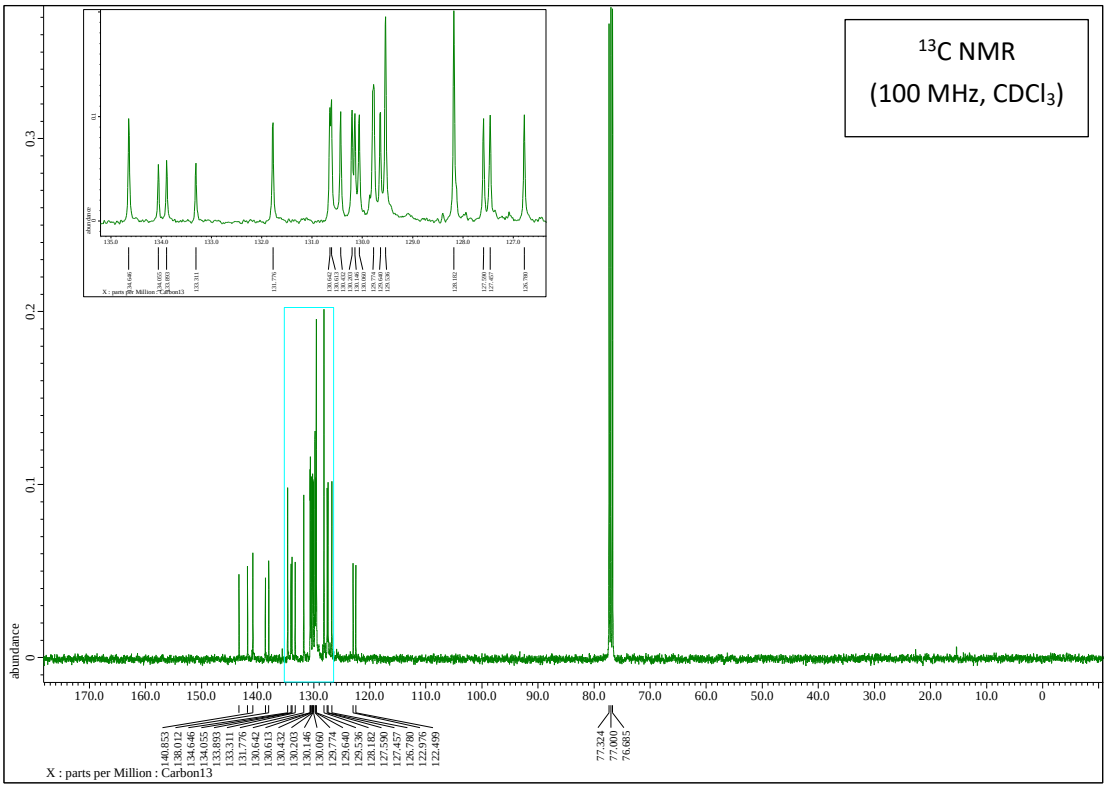
^{1}H and ^{13}C NMR Spectra of **1l**



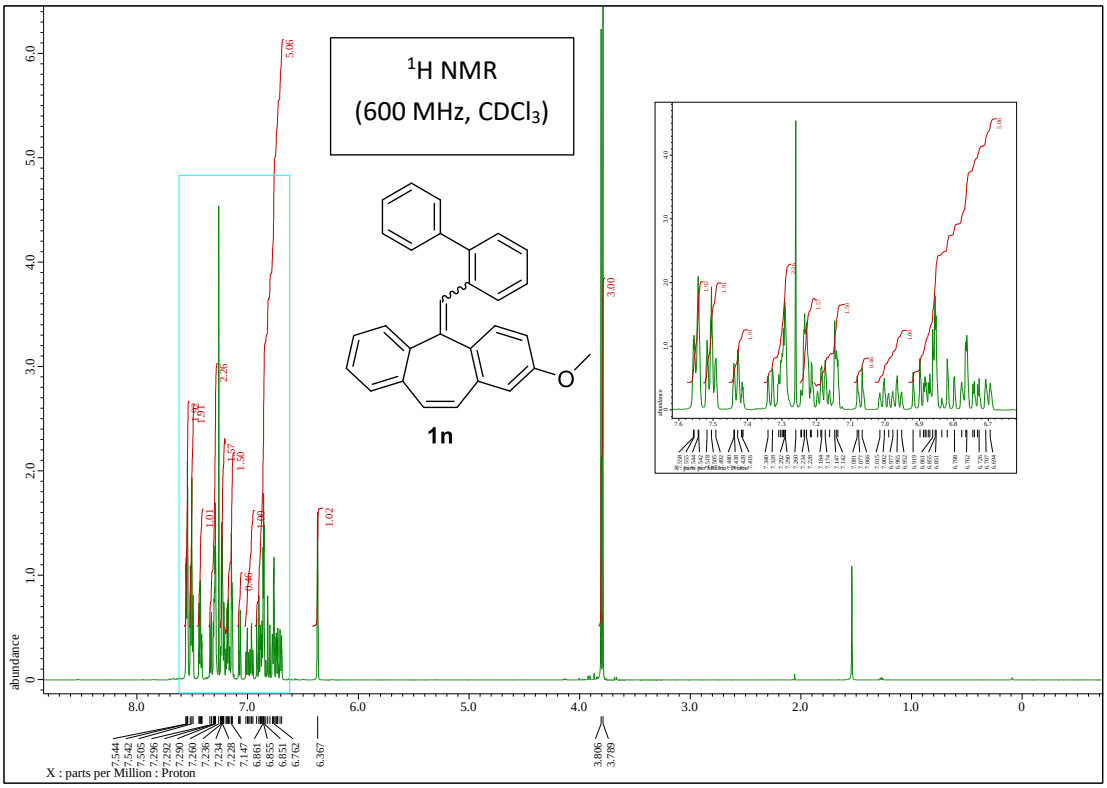


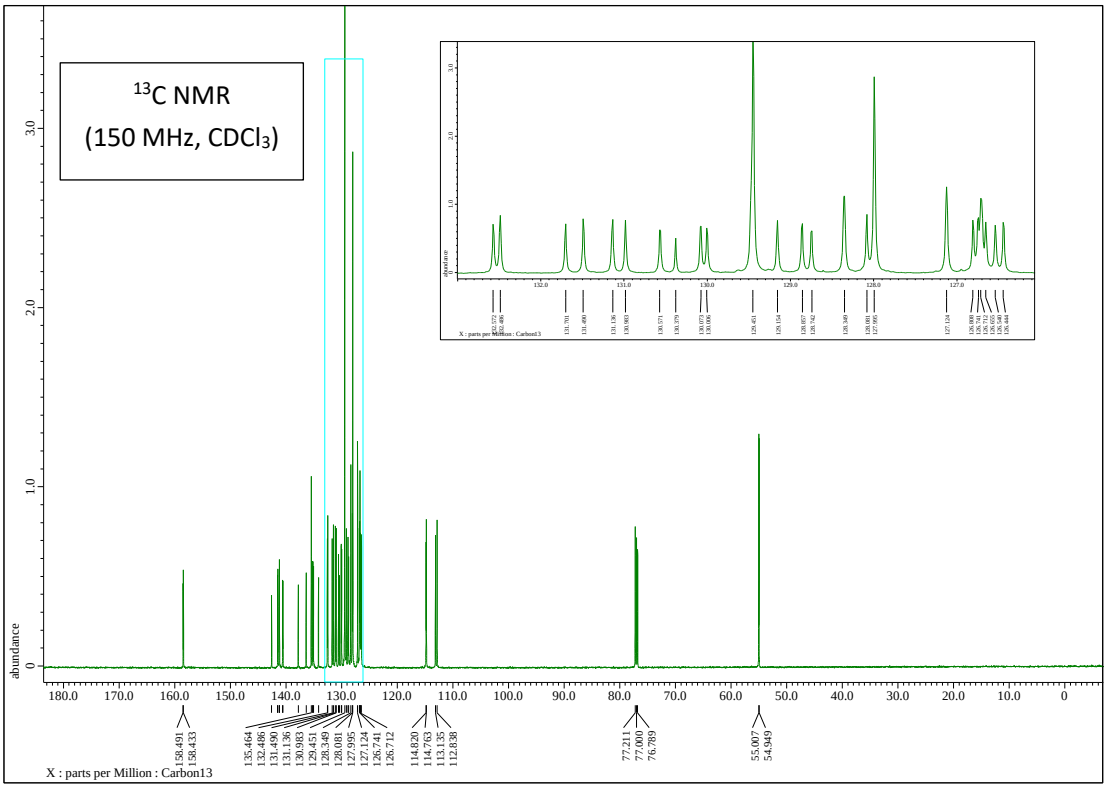
^{1}H and ^{13}C NMR Spectra of **1m**



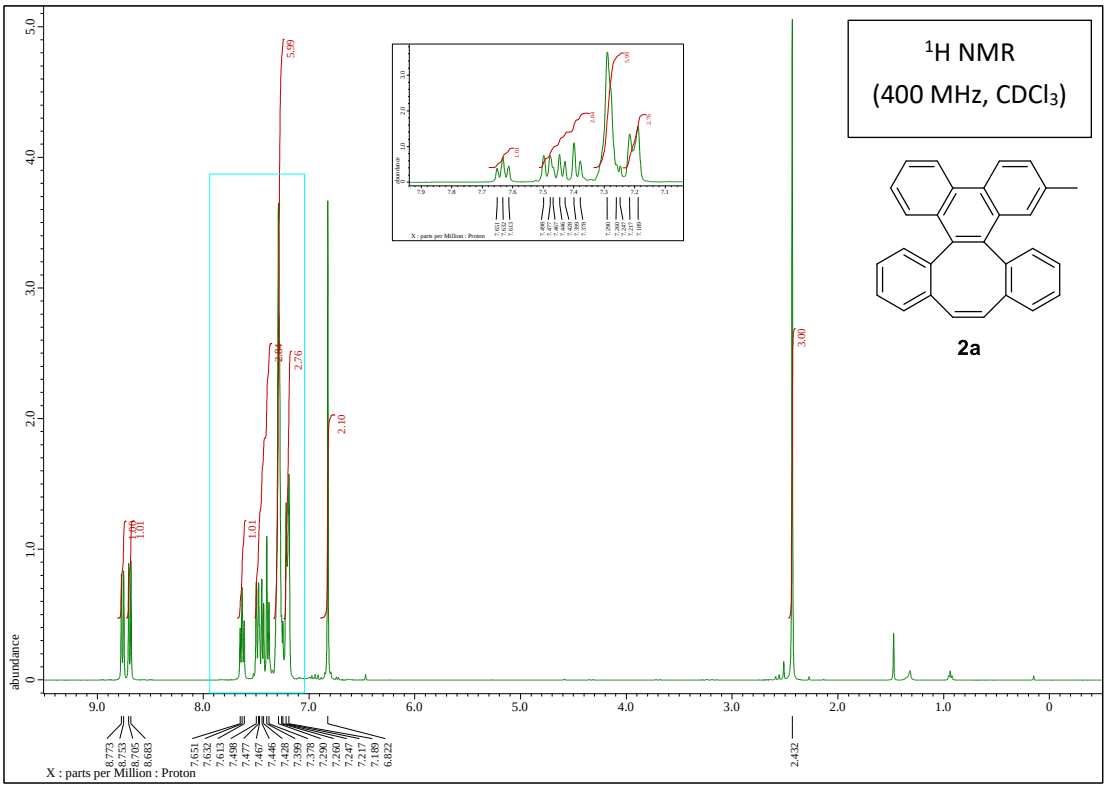


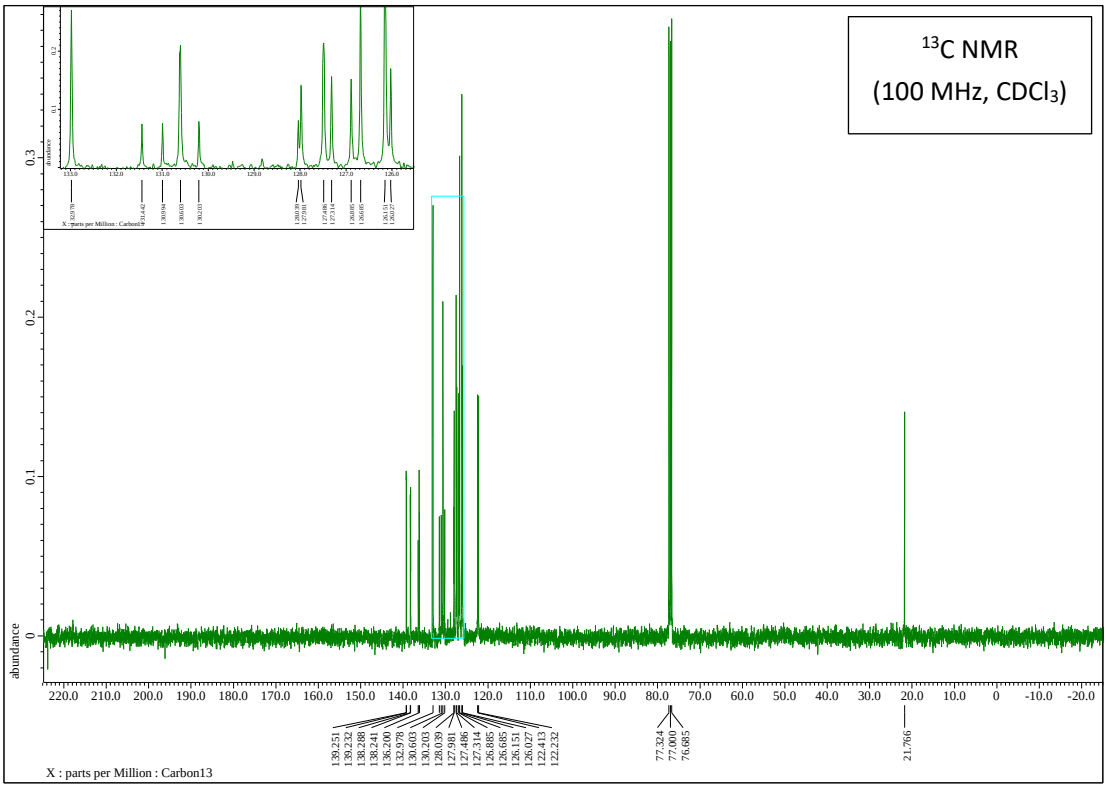
^{1}H and ^{13}C NMR Spectra of **1n**



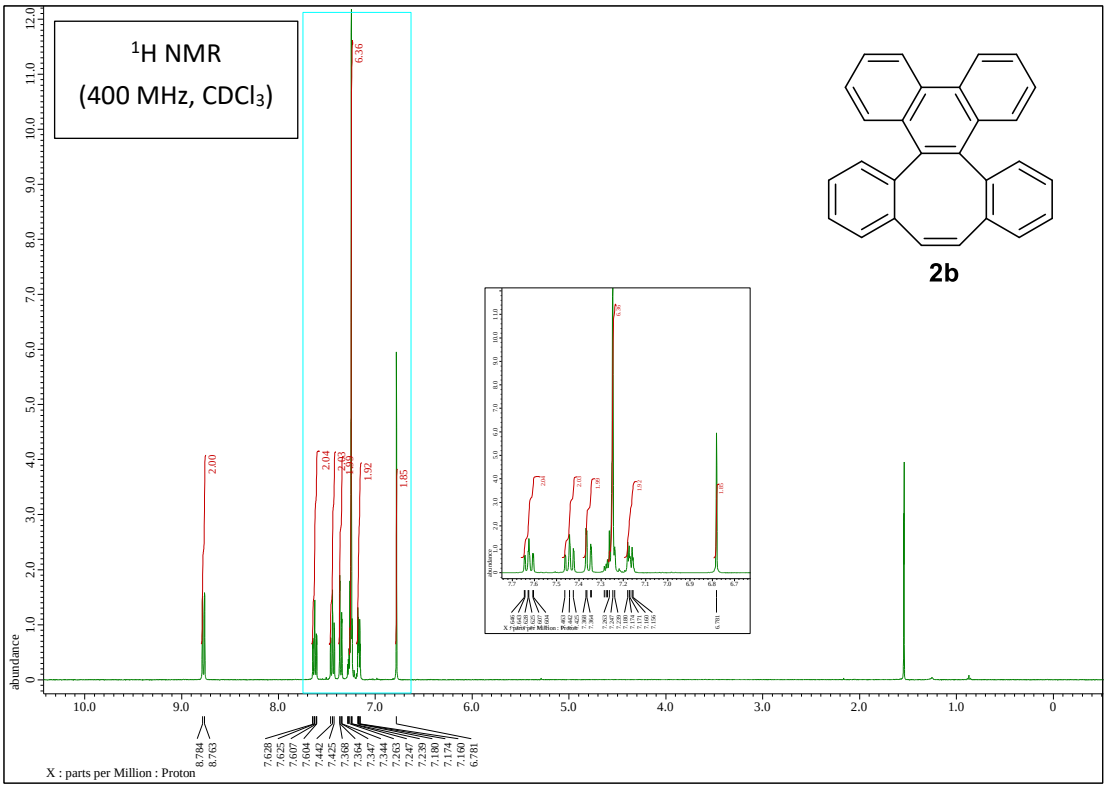


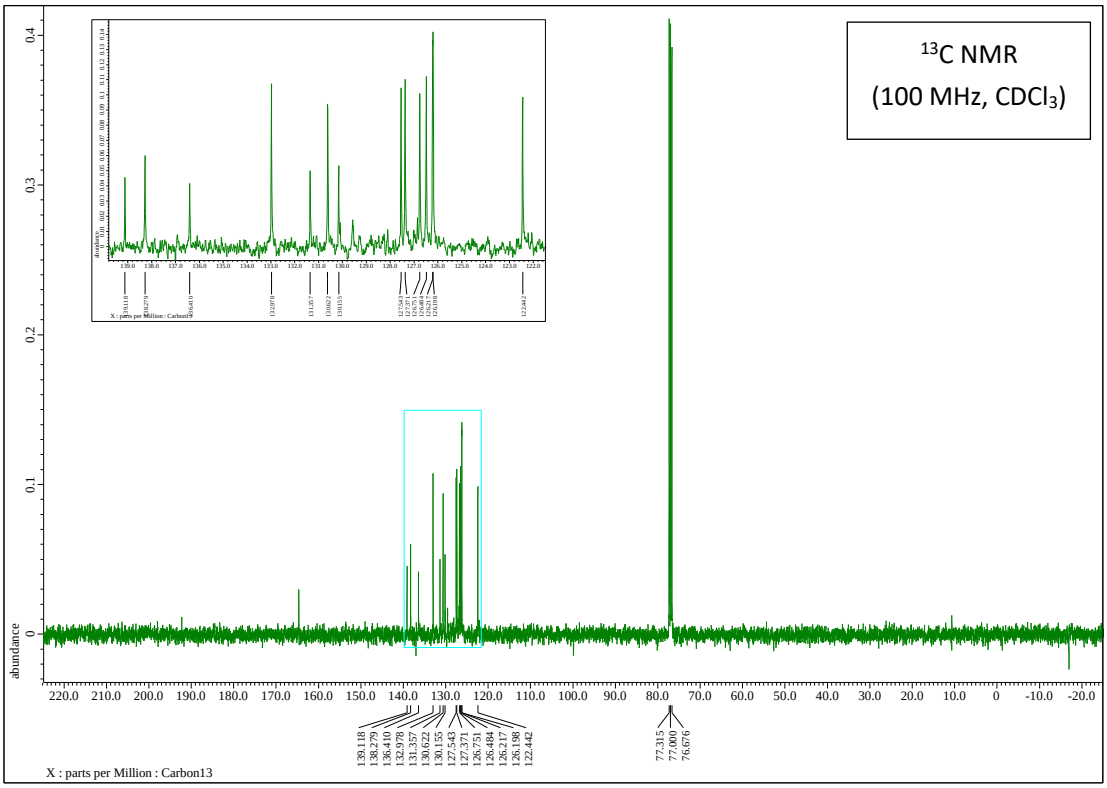
^{1}H and ^{13}C NMR Spectra of **2a**



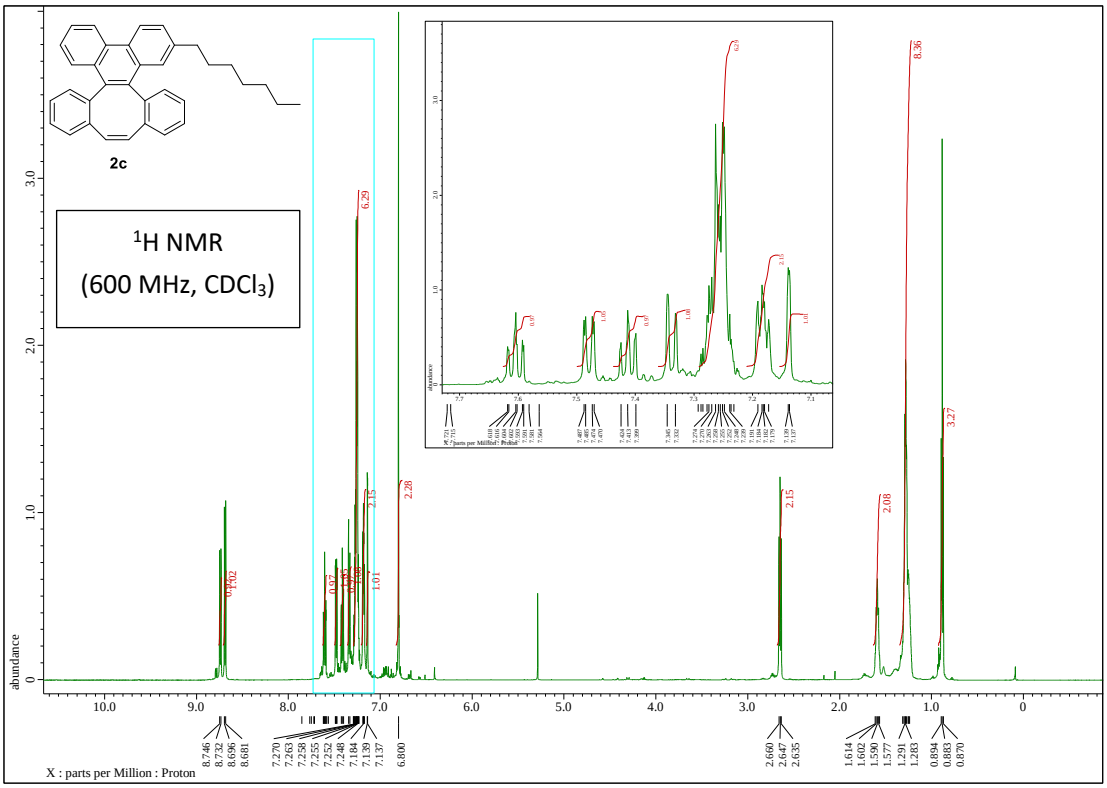


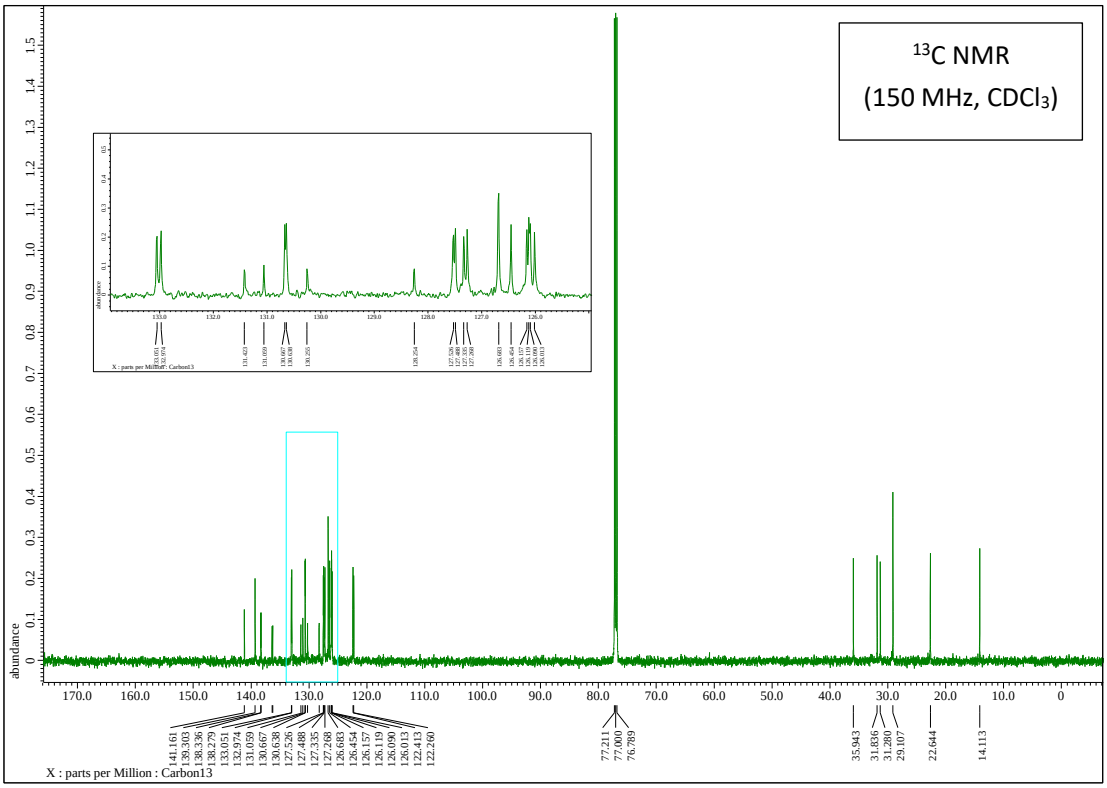
^{1}H and ^{13}C NMR Spectra of **2b**



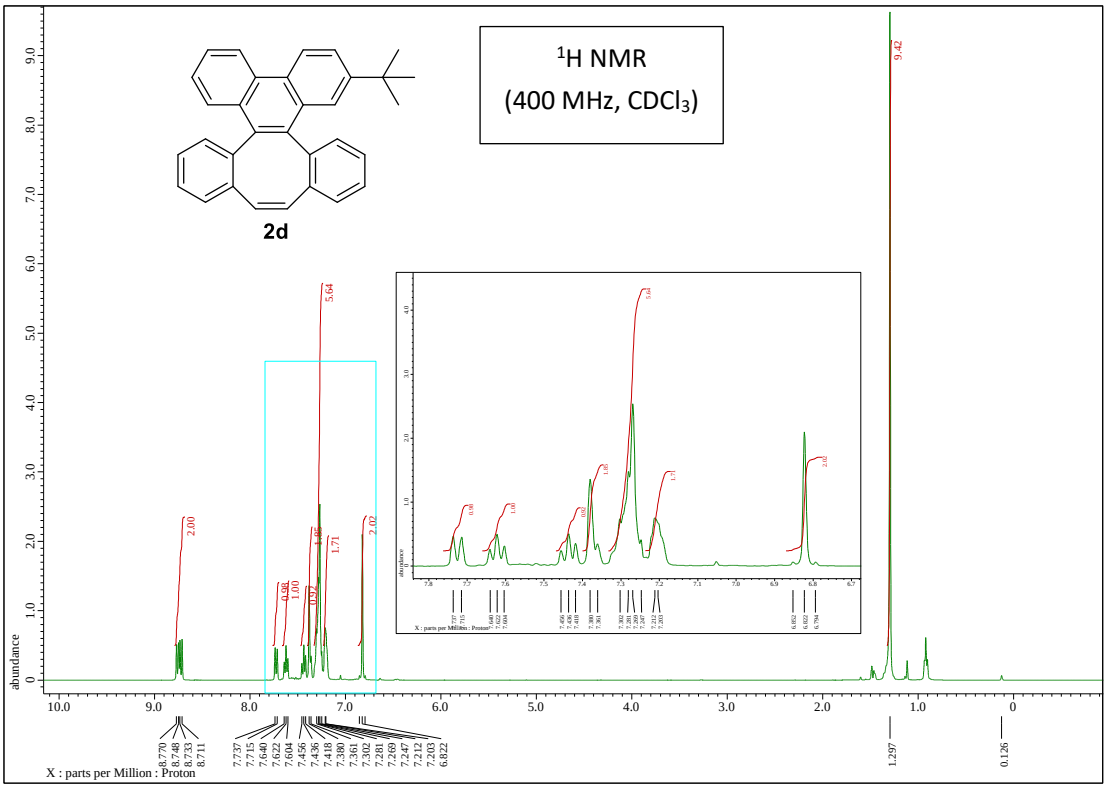


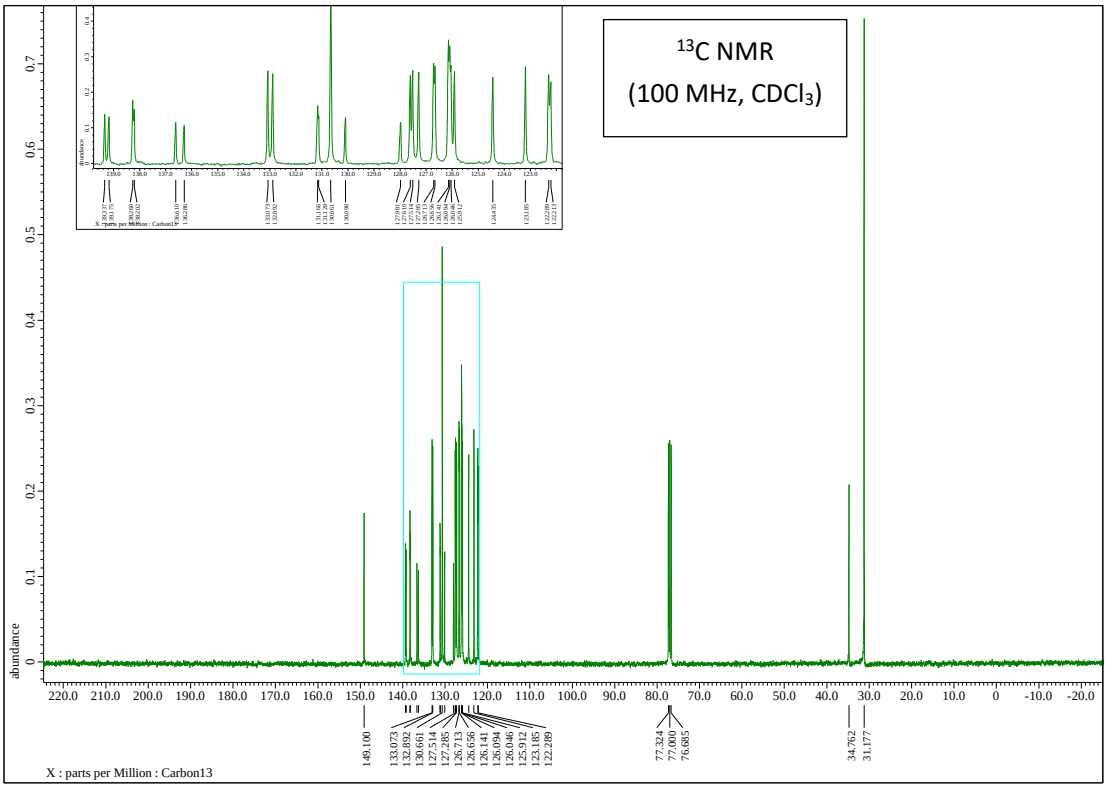
^{1}H and ^{13}C NMR Spectra of **2c**



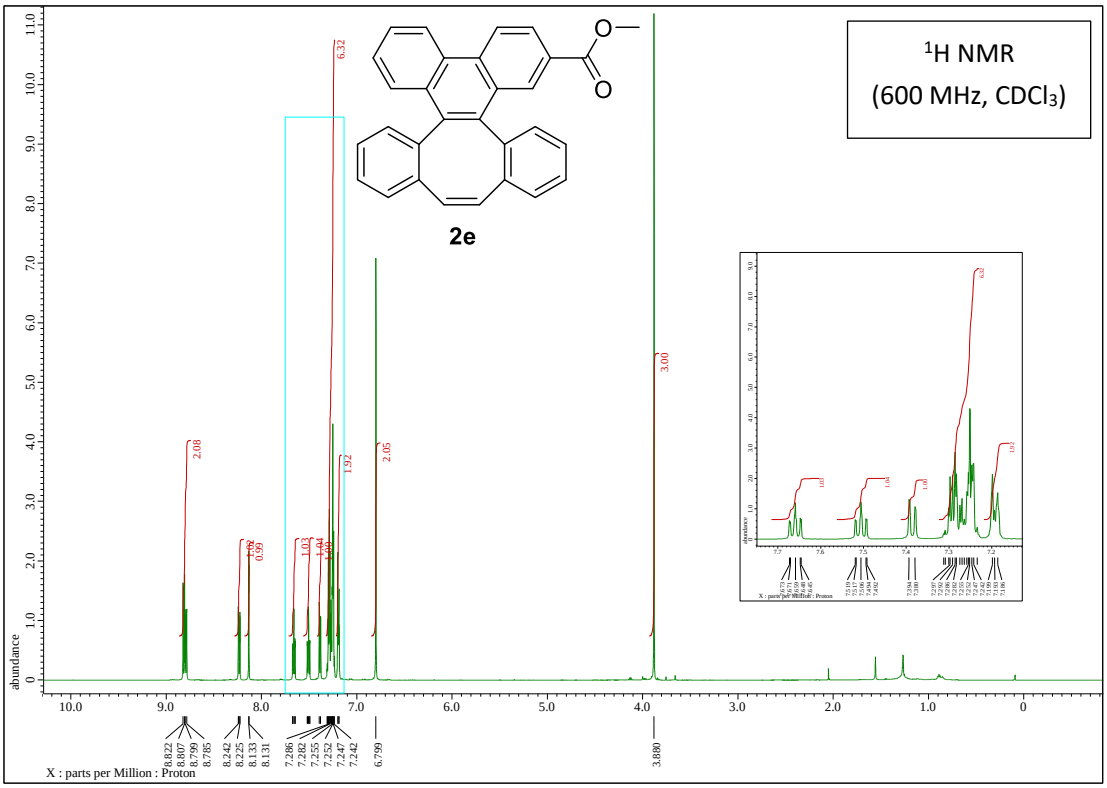


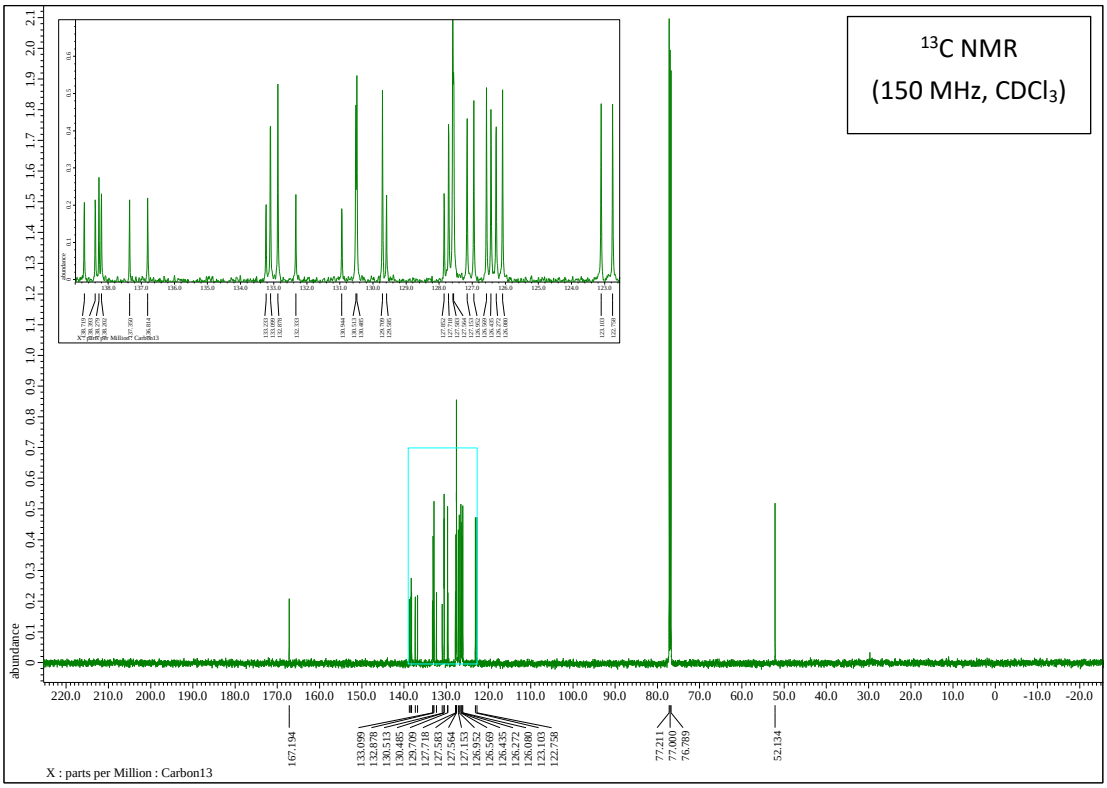
^{1}H and ^{13}C NMR Spectra of **2d**



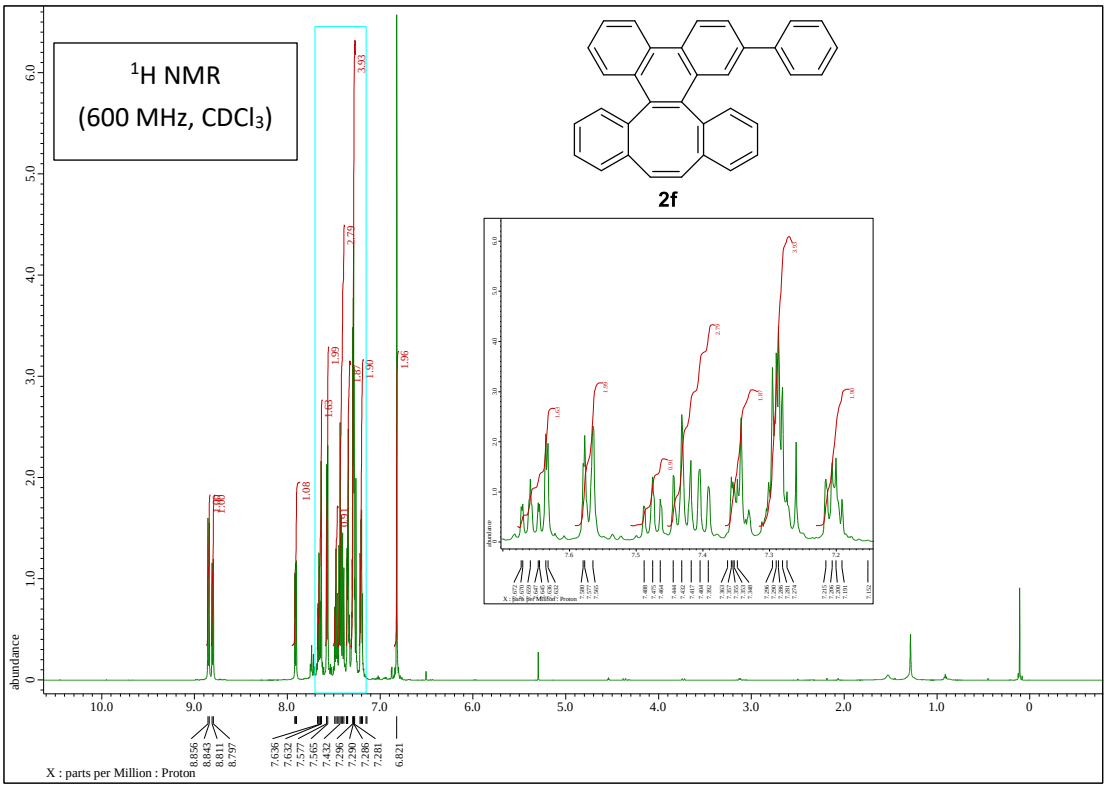


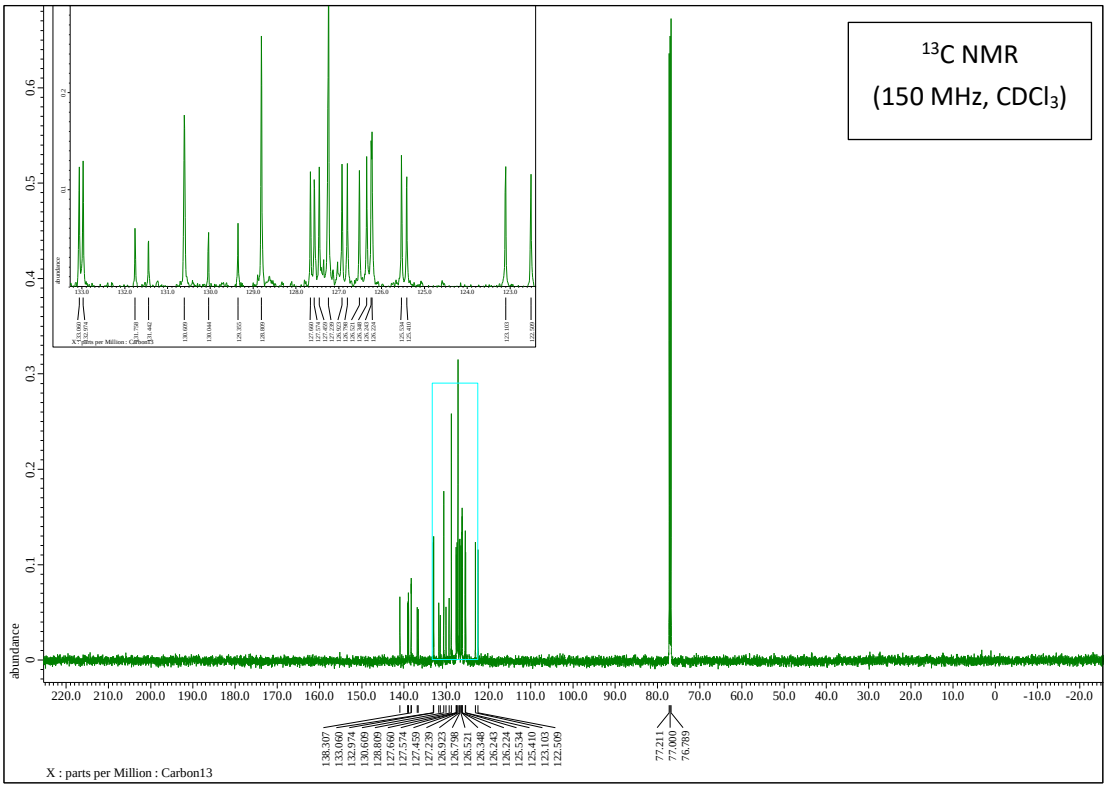
^{1}H and ^{13}C NMR Spectra of **2e**



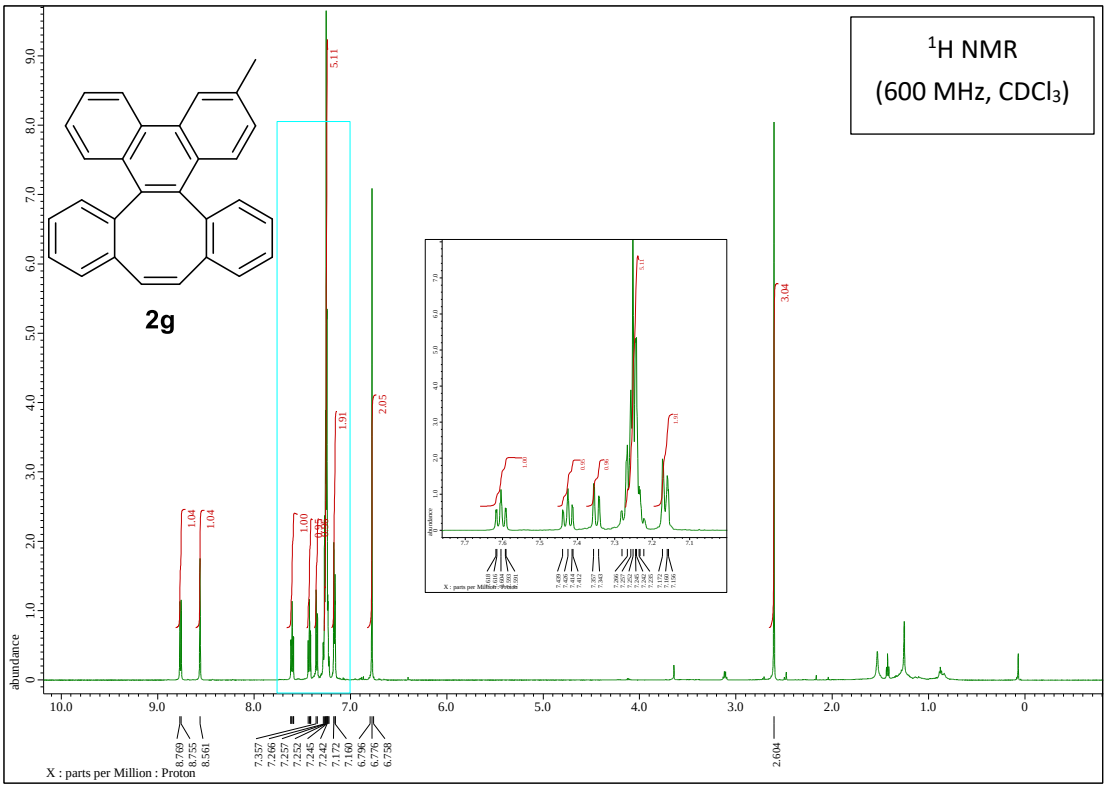


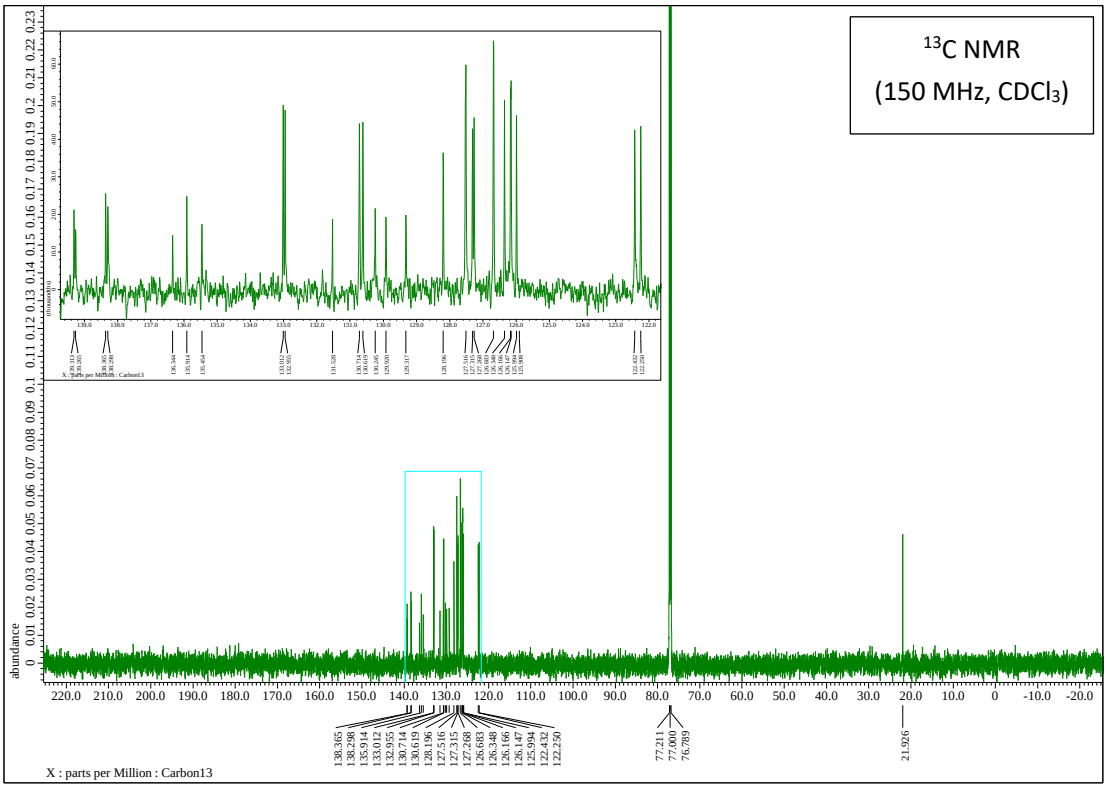
^{1}H and ^{13}C NMR Spectra of **2f**



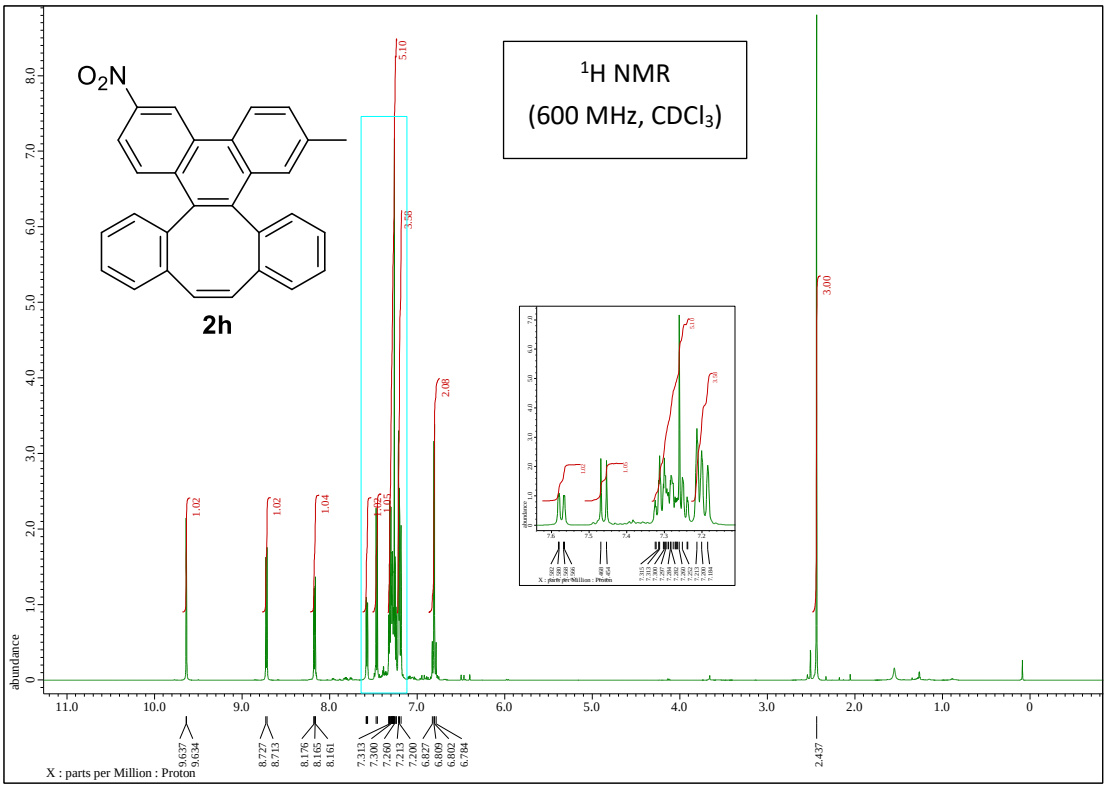


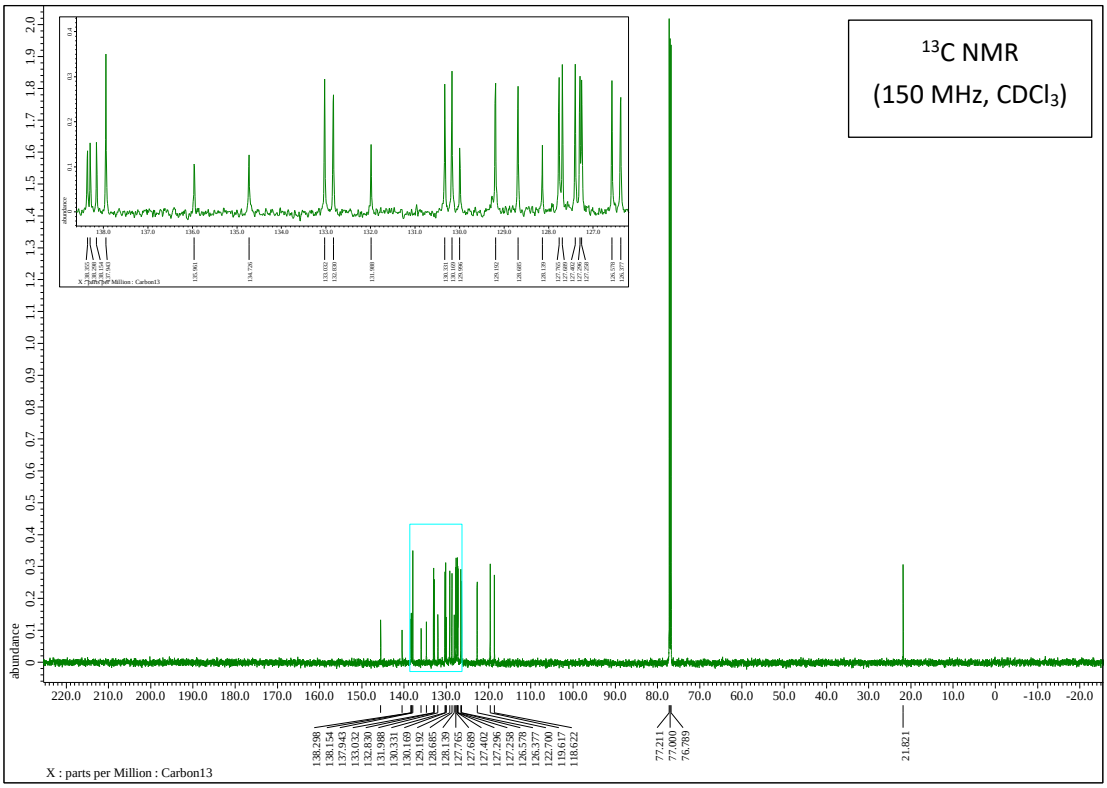
^{1}H and ^{13}C NMR Spectra of **2g**



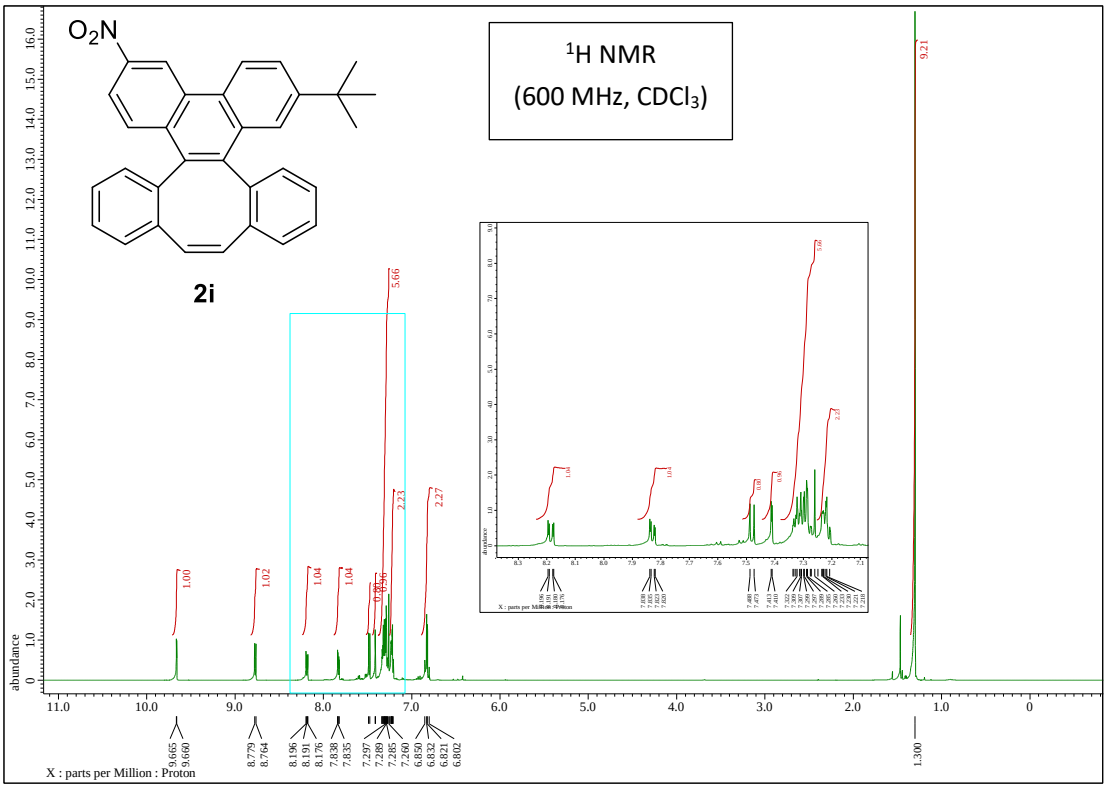


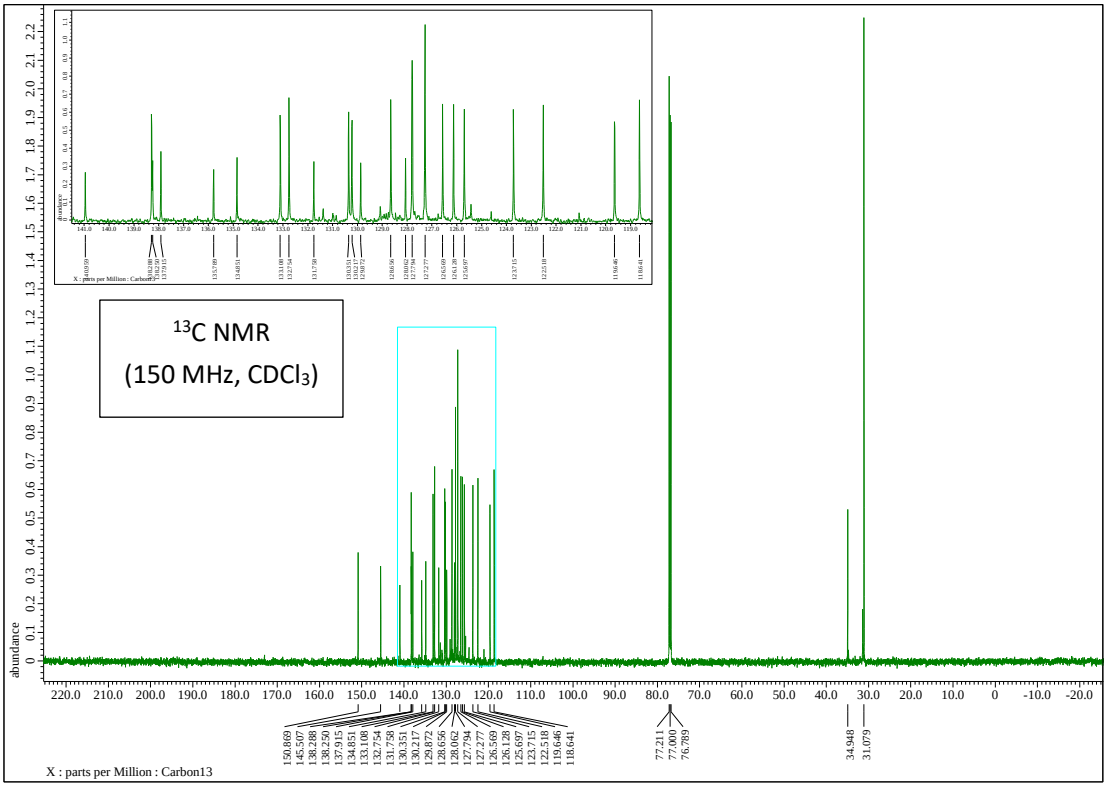
^{1}H and ^{13}C NMR Spectra of **2h**



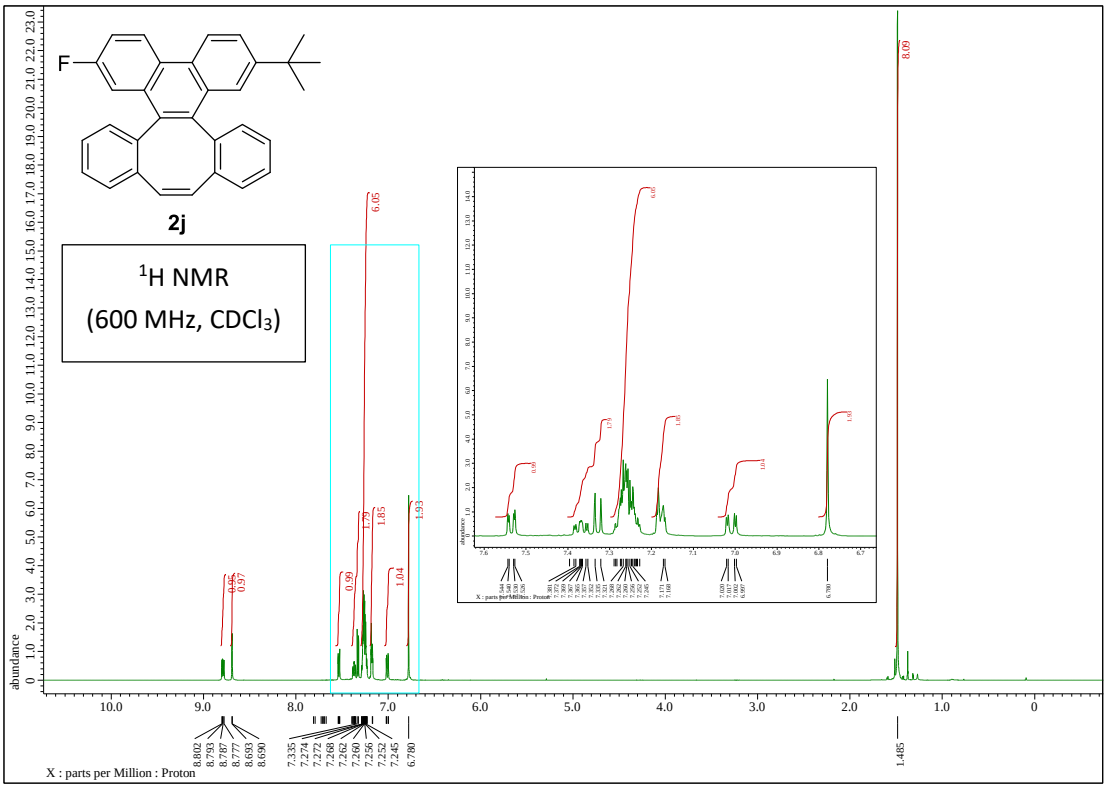


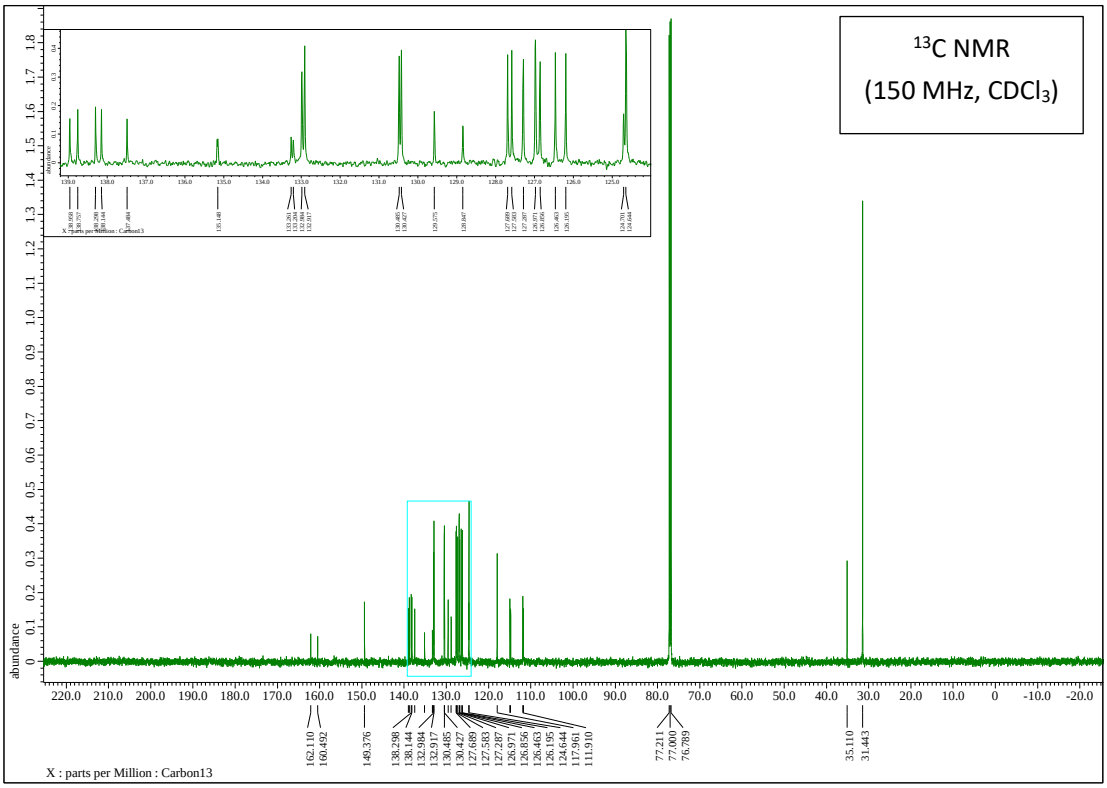
^{1}H and ^{13}C NMR Spectra of **2i**



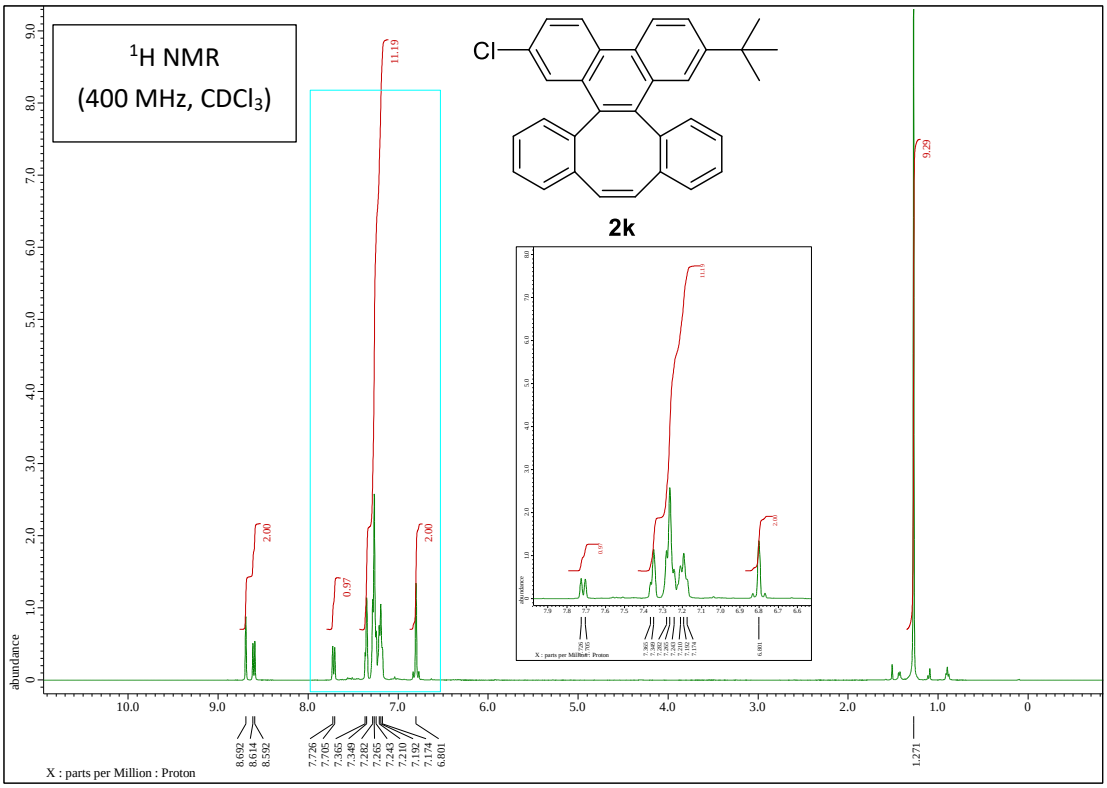


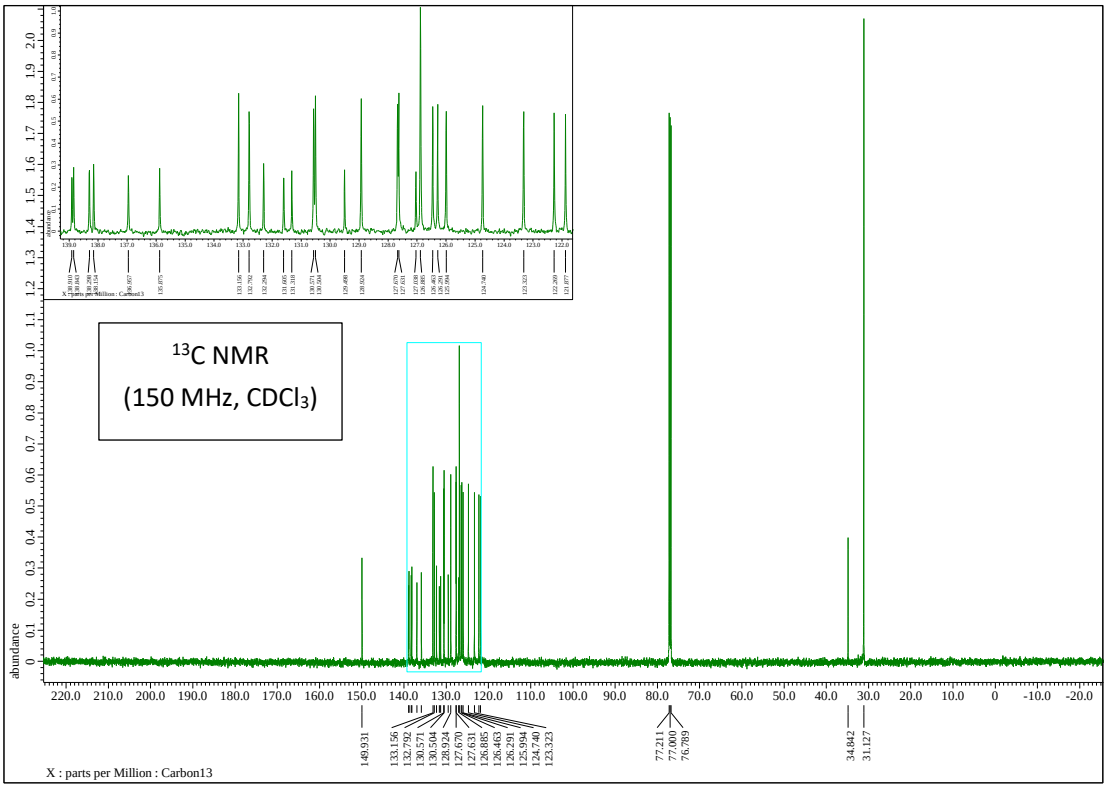
^{1}H and ^{13}C NMR Spectra of **2j**



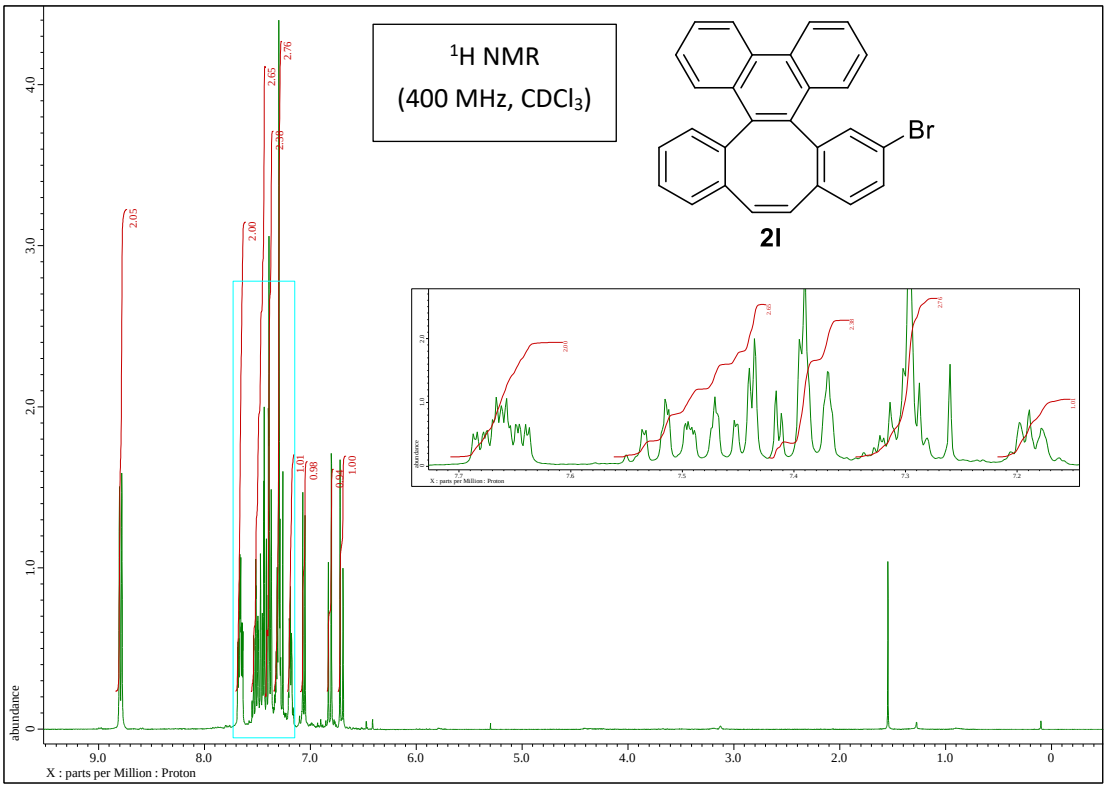


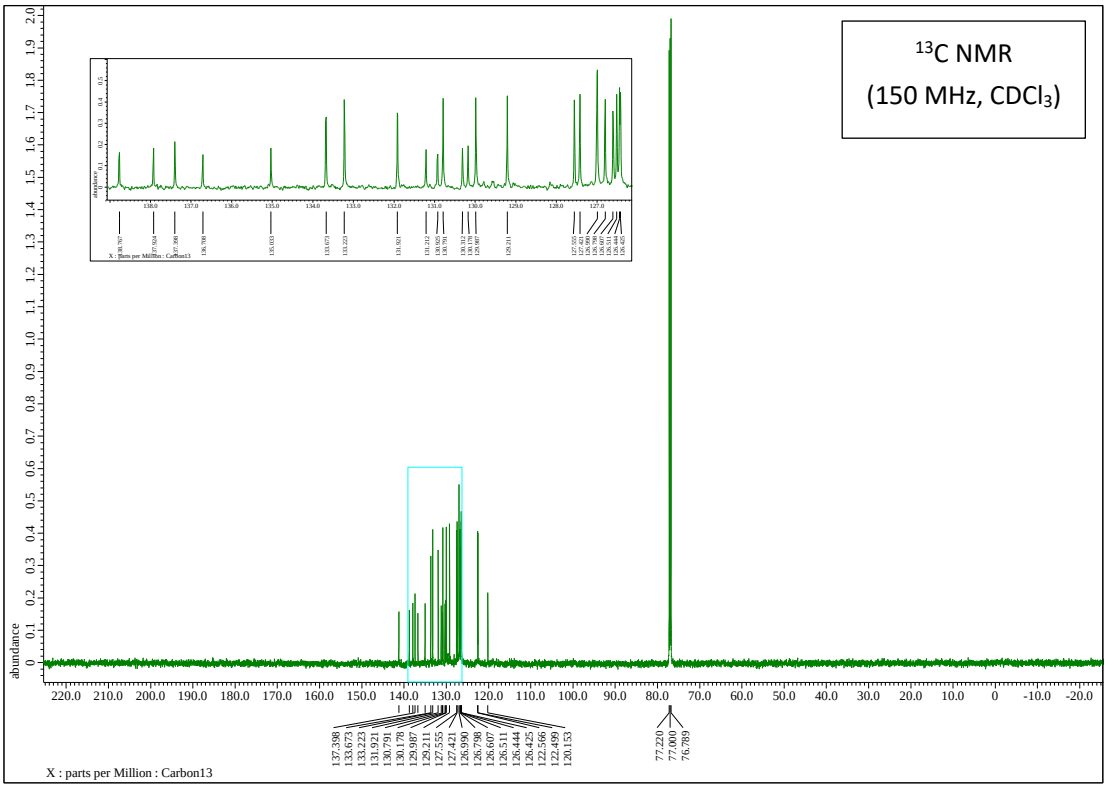
^{1}H and ^{13}C NMR Spectra of **2k**



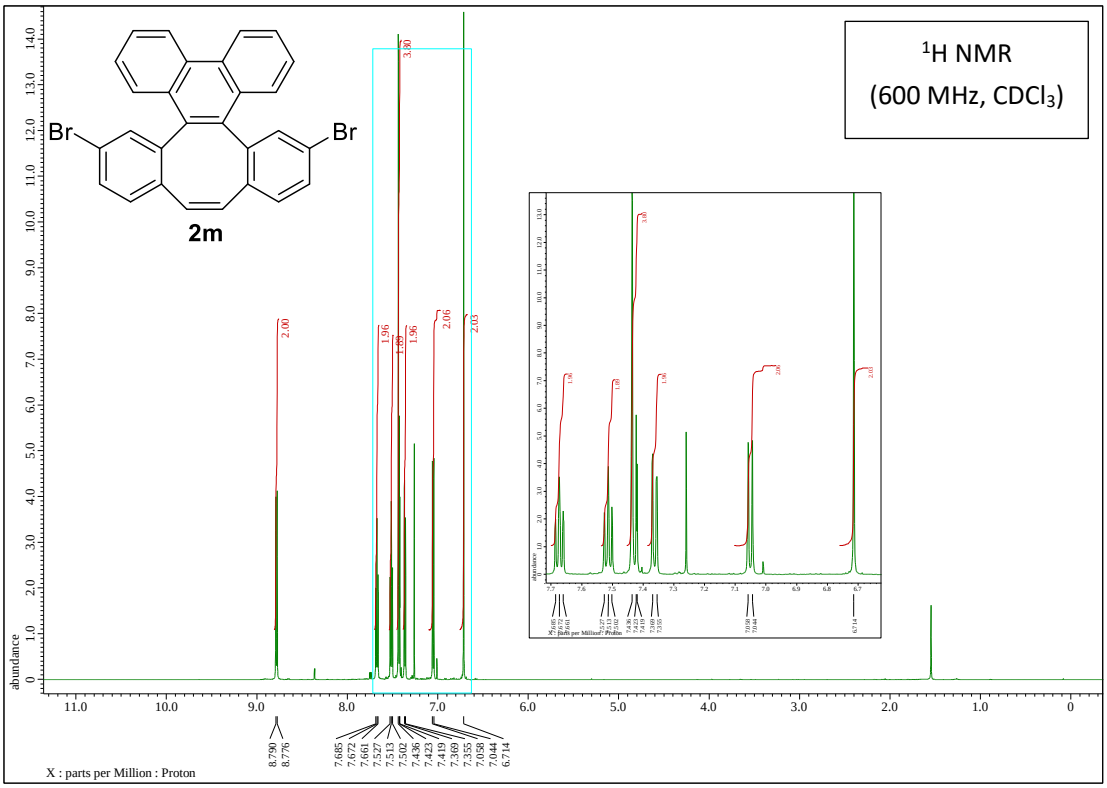


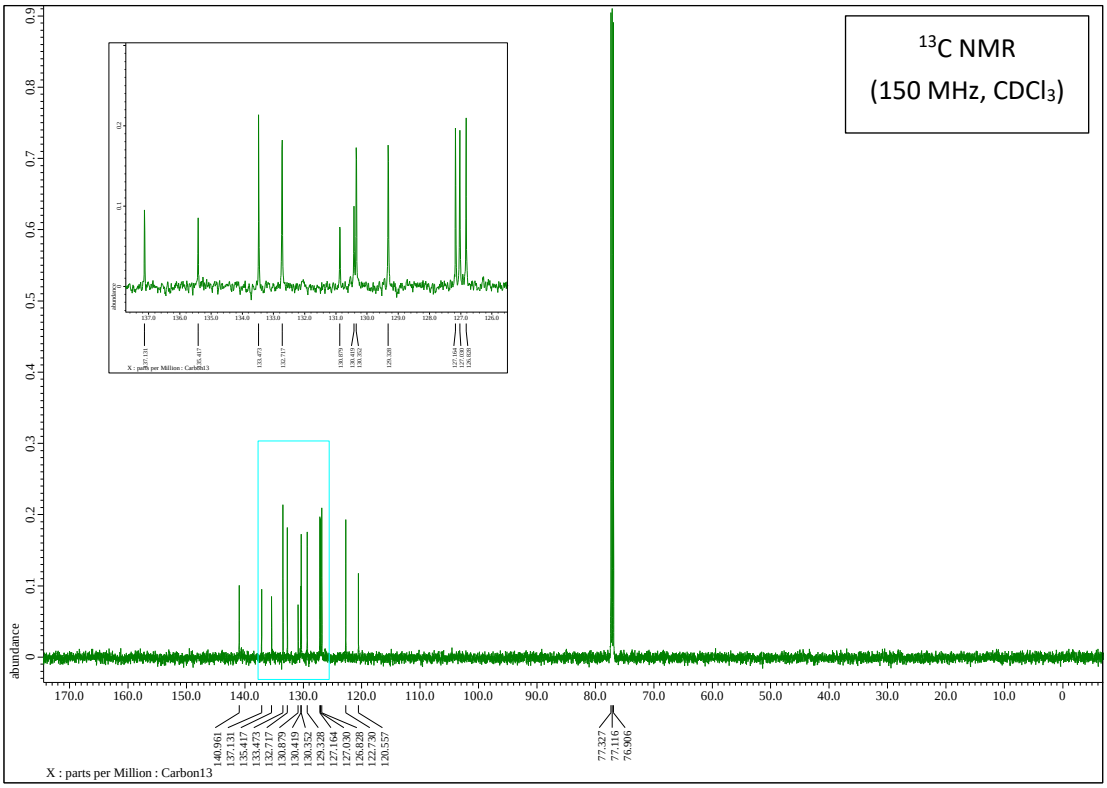
^{1}H and ^{13}C NMR Spectra of **2l**



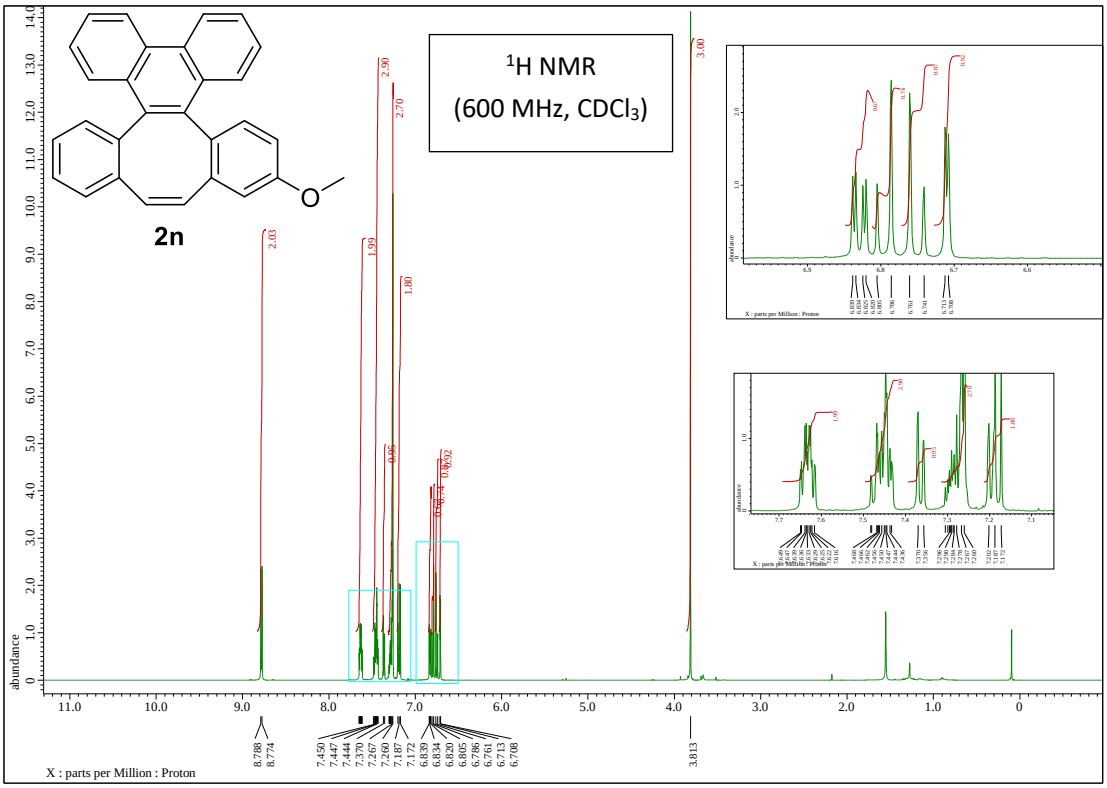


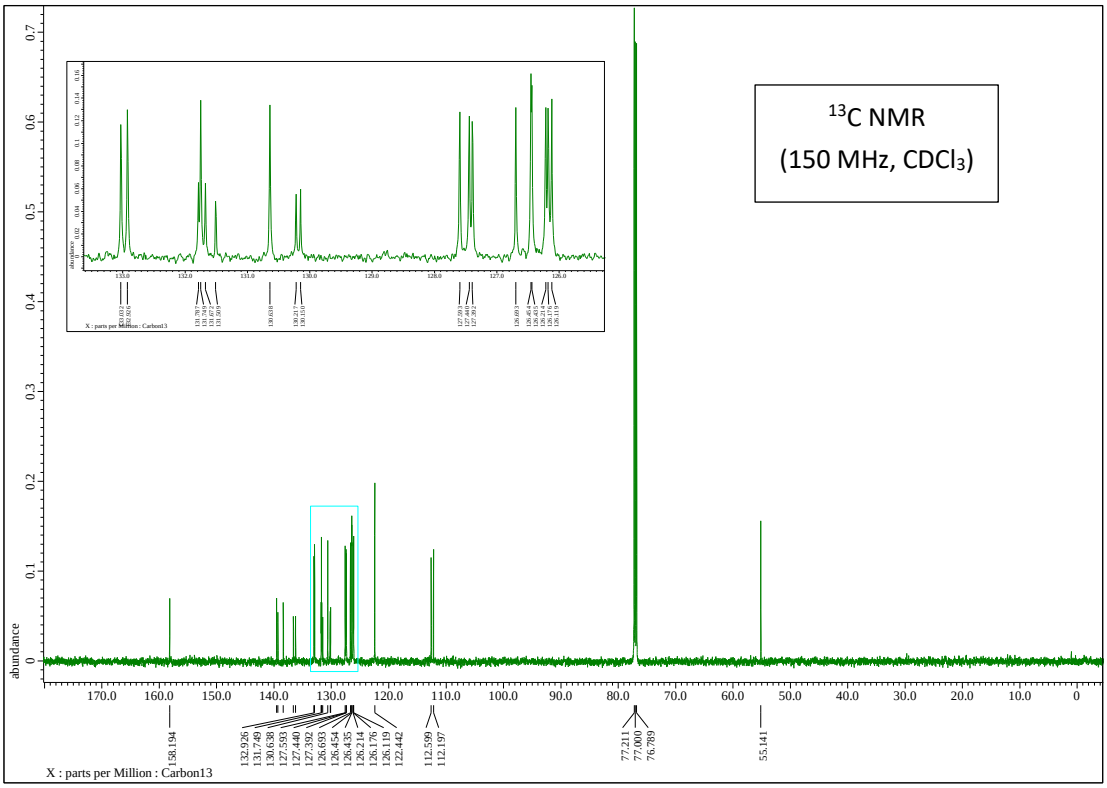
^{1}H and ^{13}C NMR Spectra of **2m**



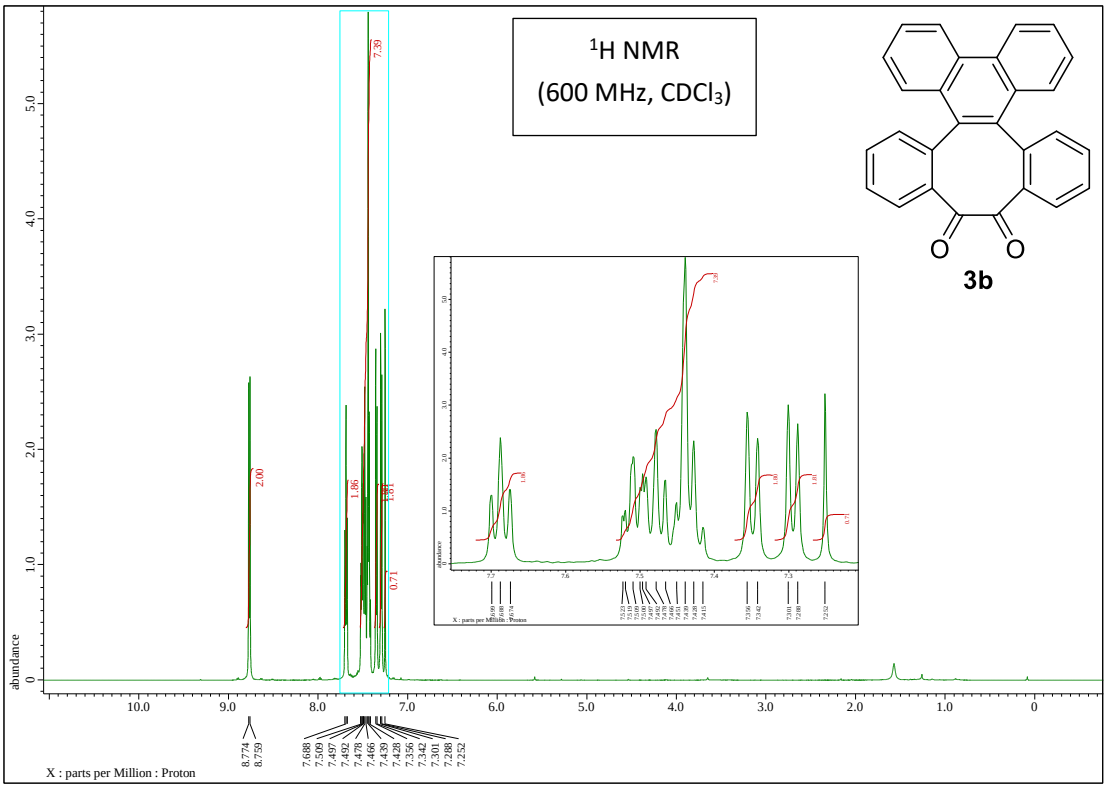


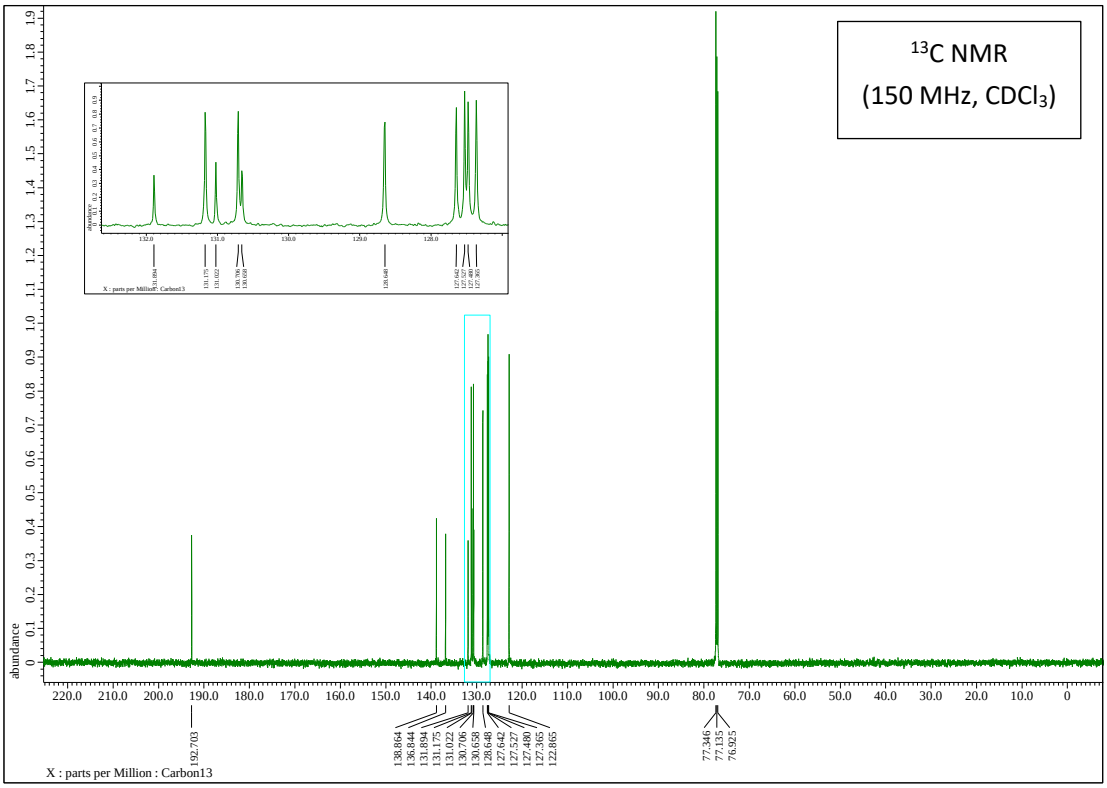
^{1}H and ^{13}C NMR Spectra of **2n**



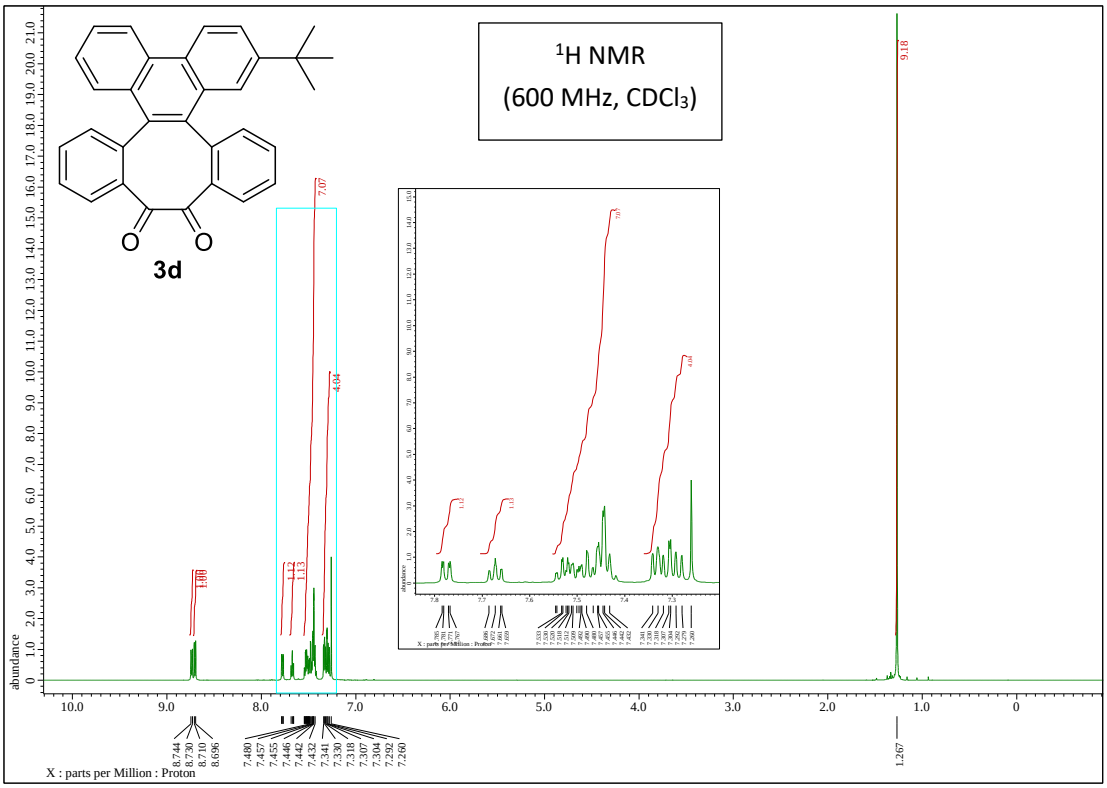


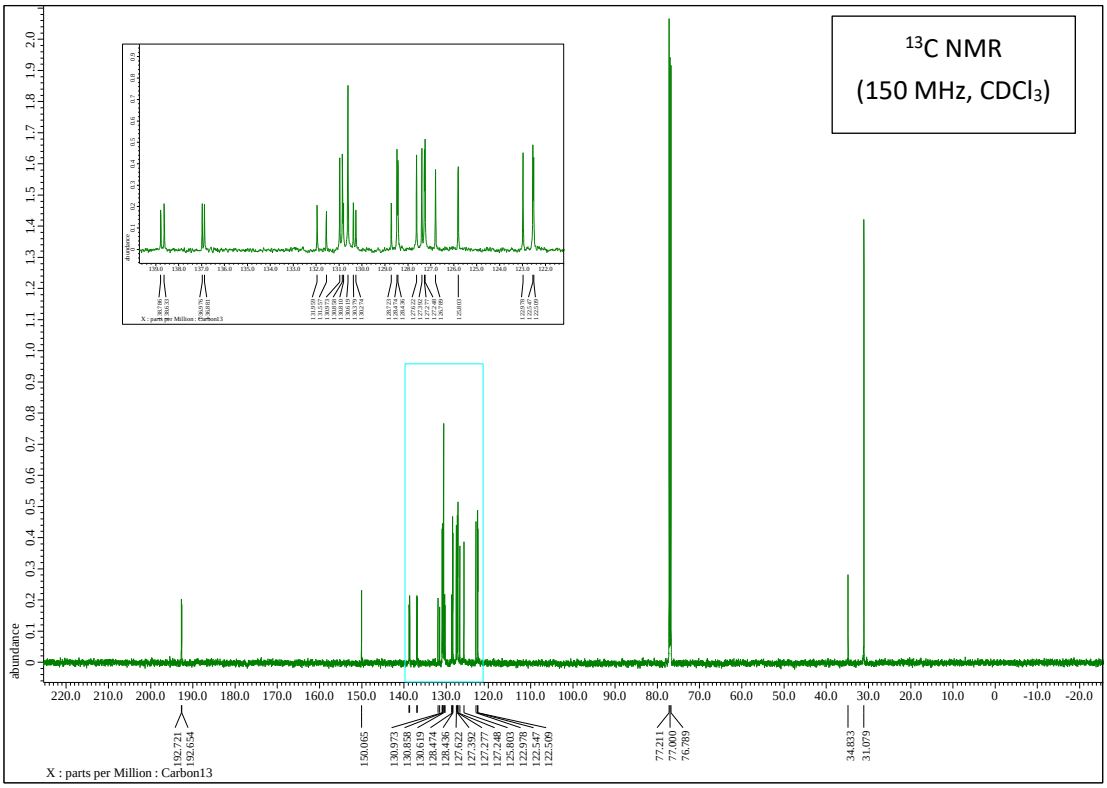
^{1}H and ^{13}C NMR Spectra of **3b**



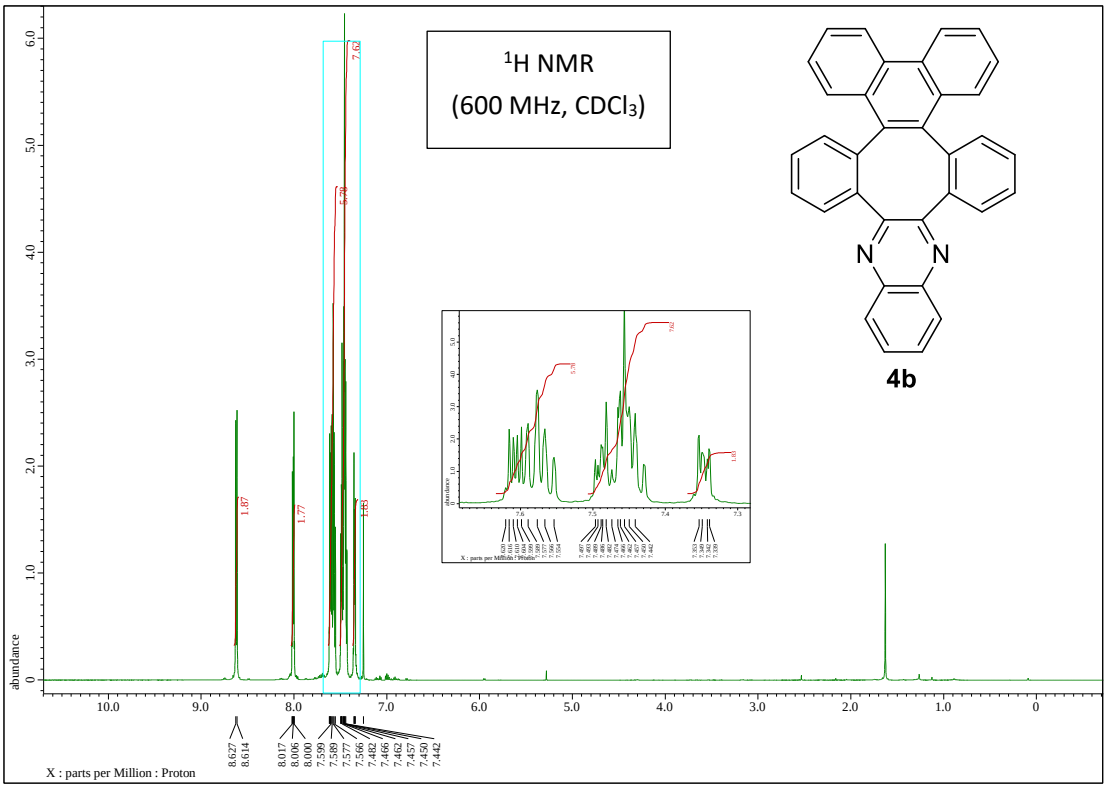


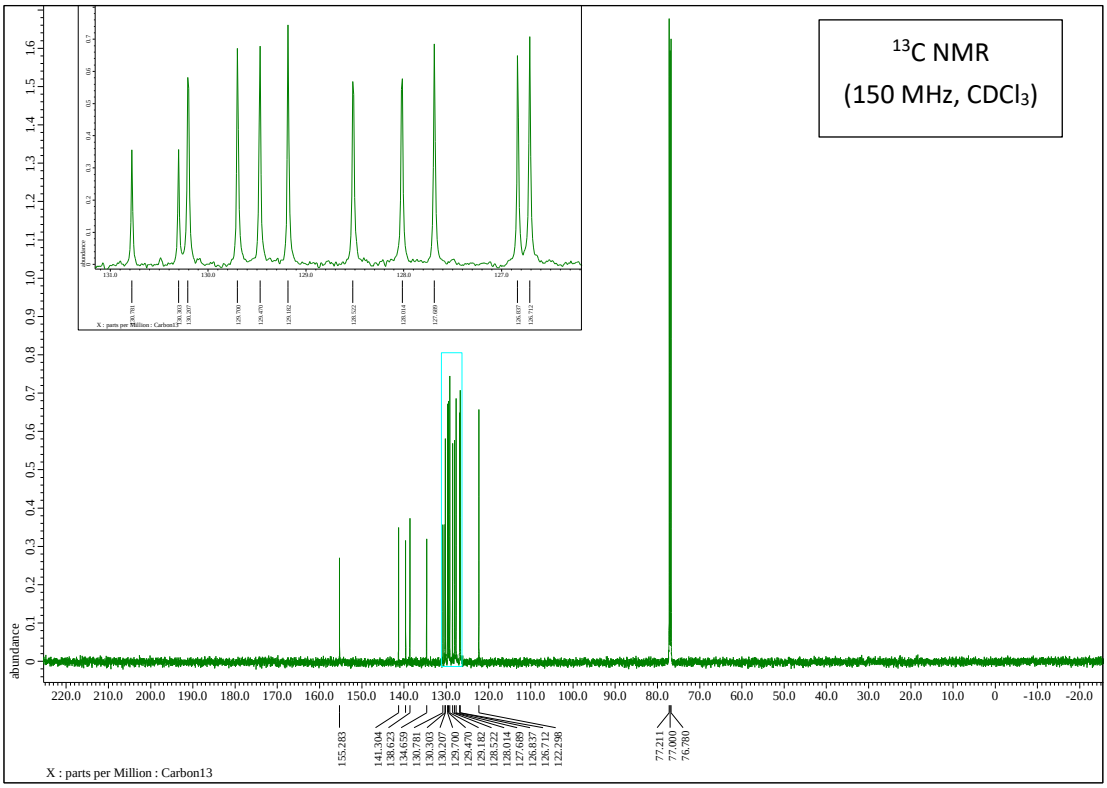
^{1}H and ^{13}C NMR Spectra of **3d**



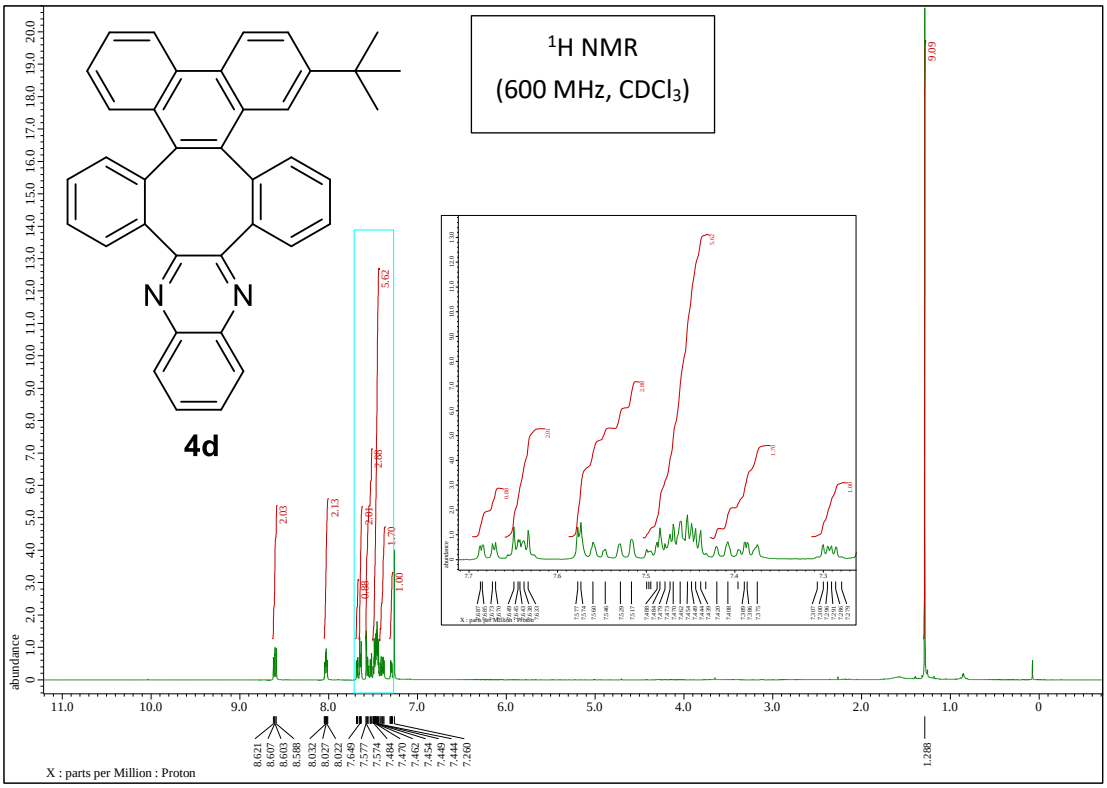


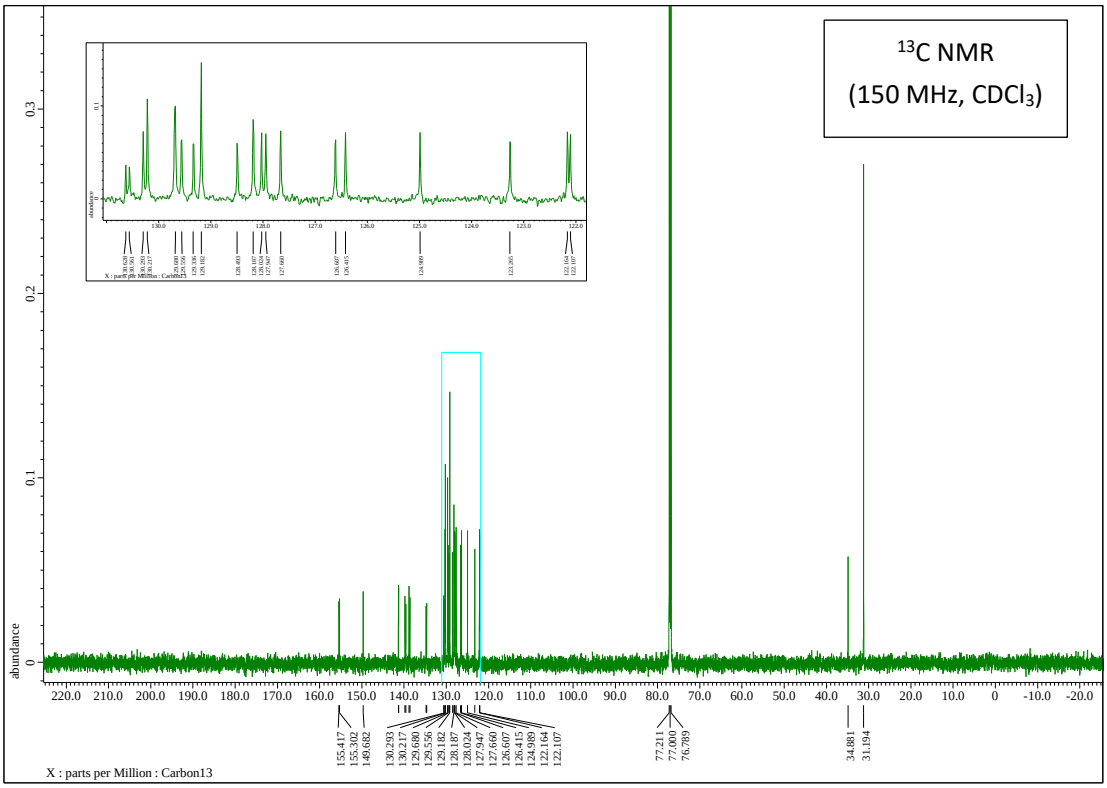
^{1}H and ^{13}C NMR Spectra of **4b**



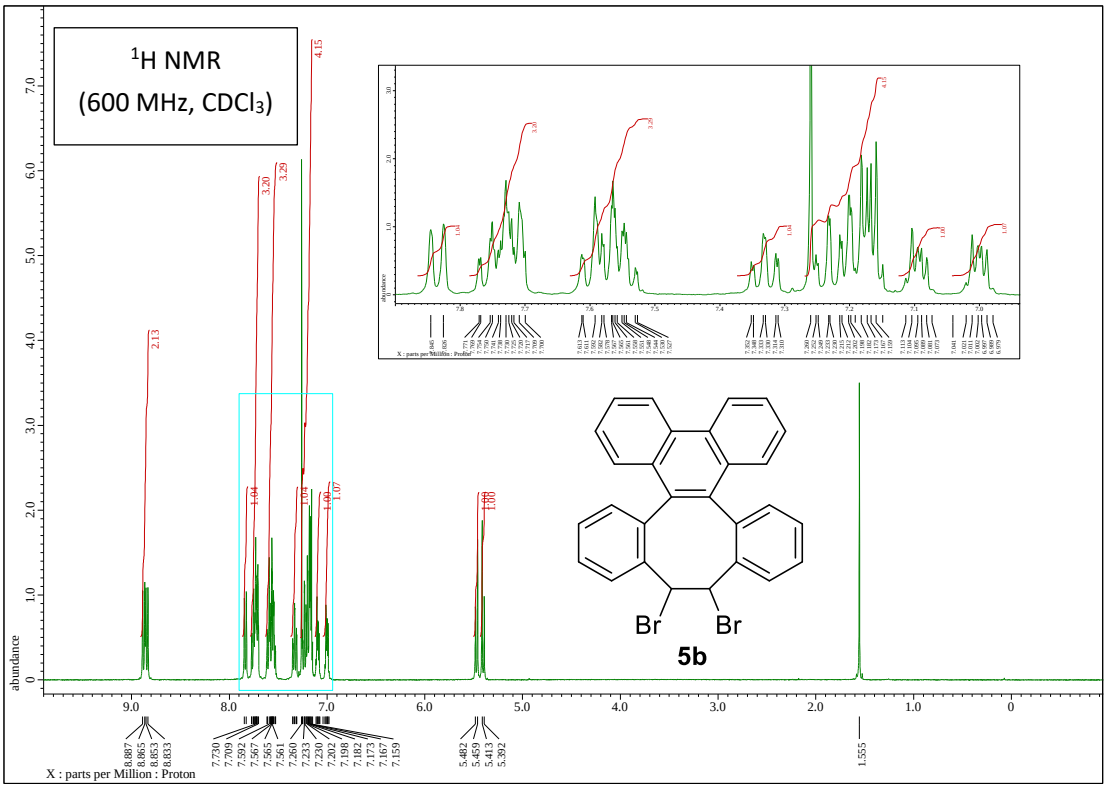


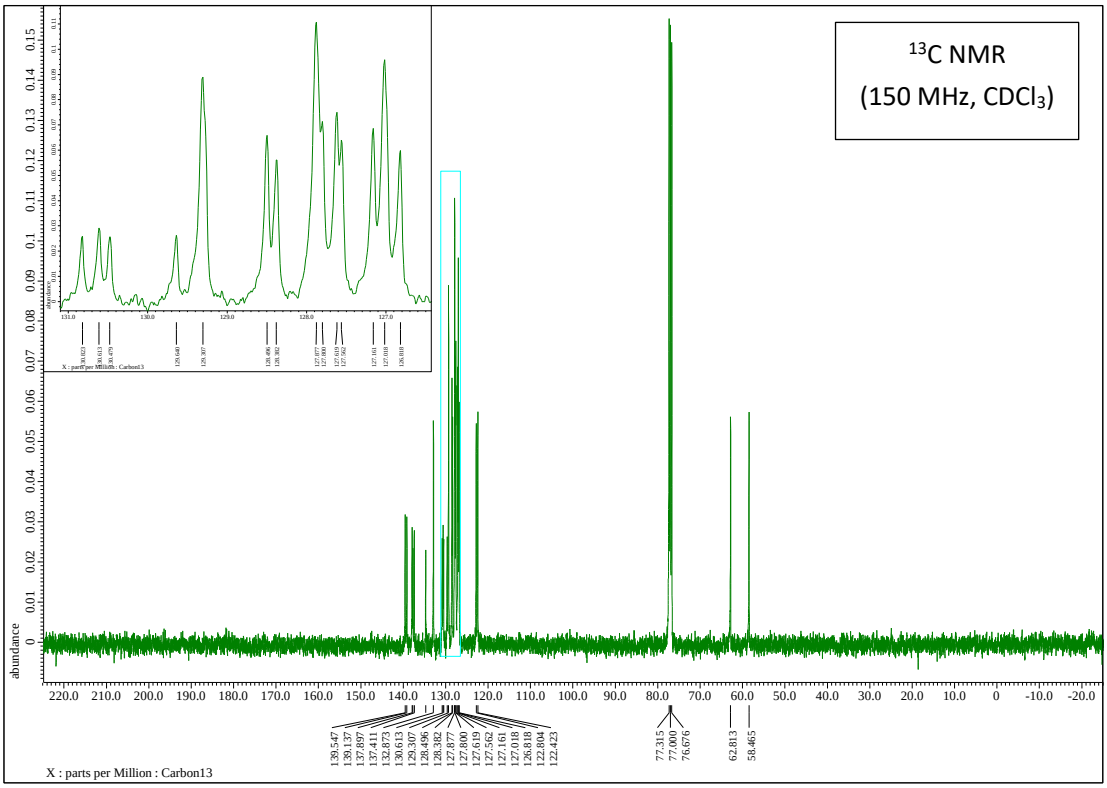
^{1}H and ^{13}C NMR Spectra of **4d**



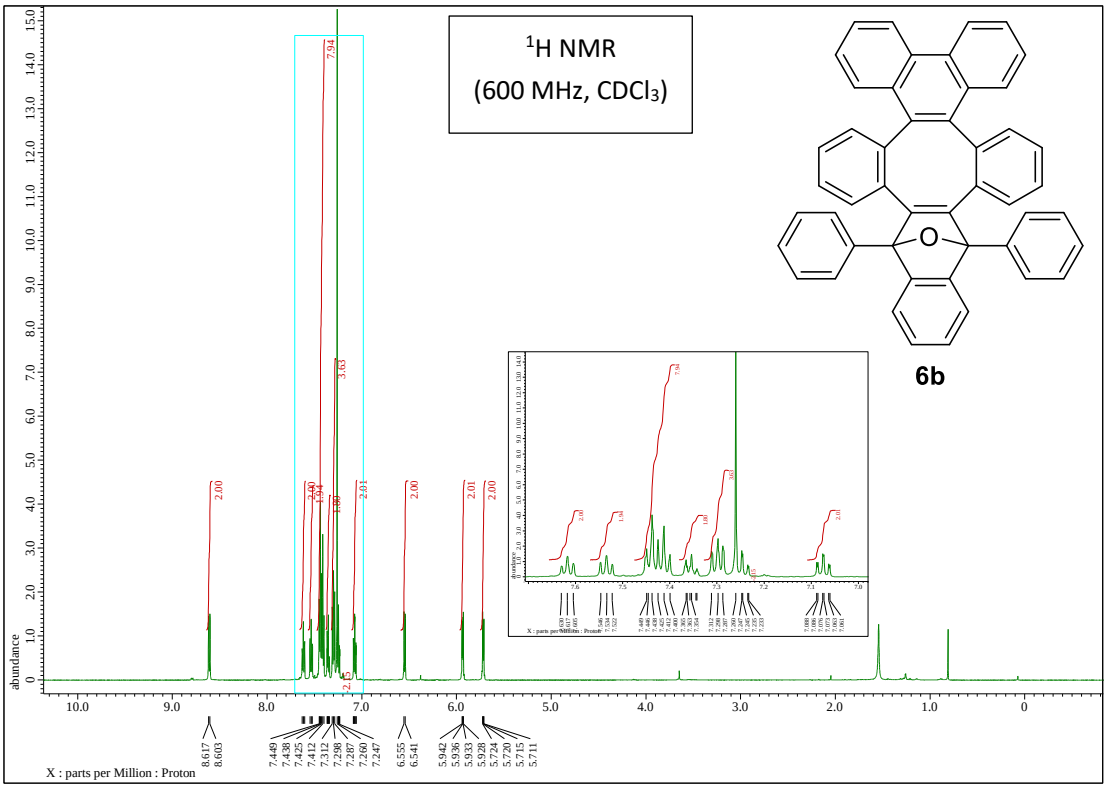


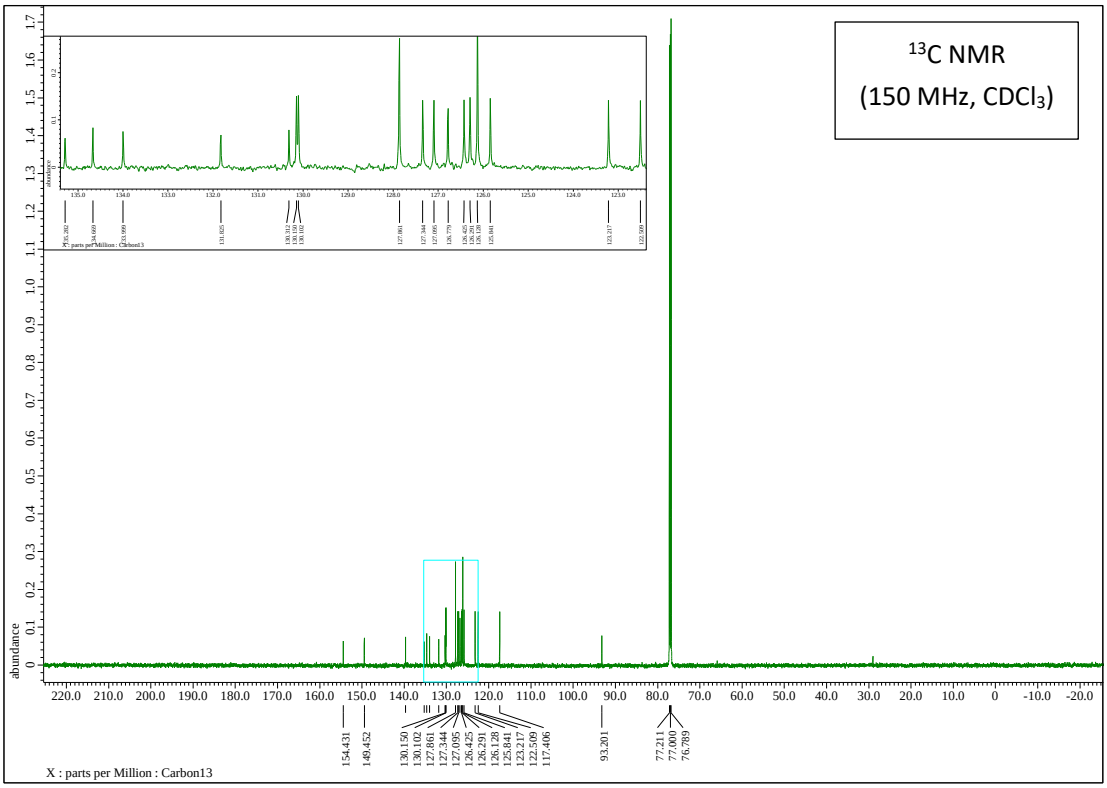
^{1}H and ^{13}C NMR Spectra of **5b**



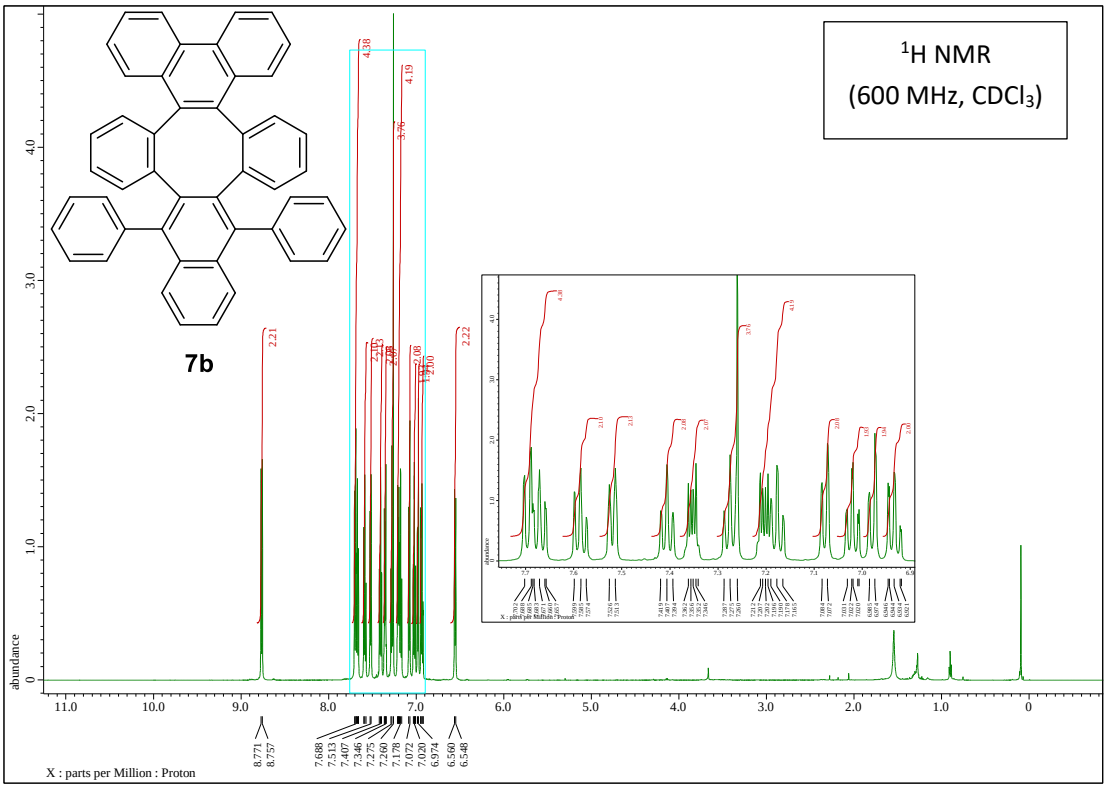


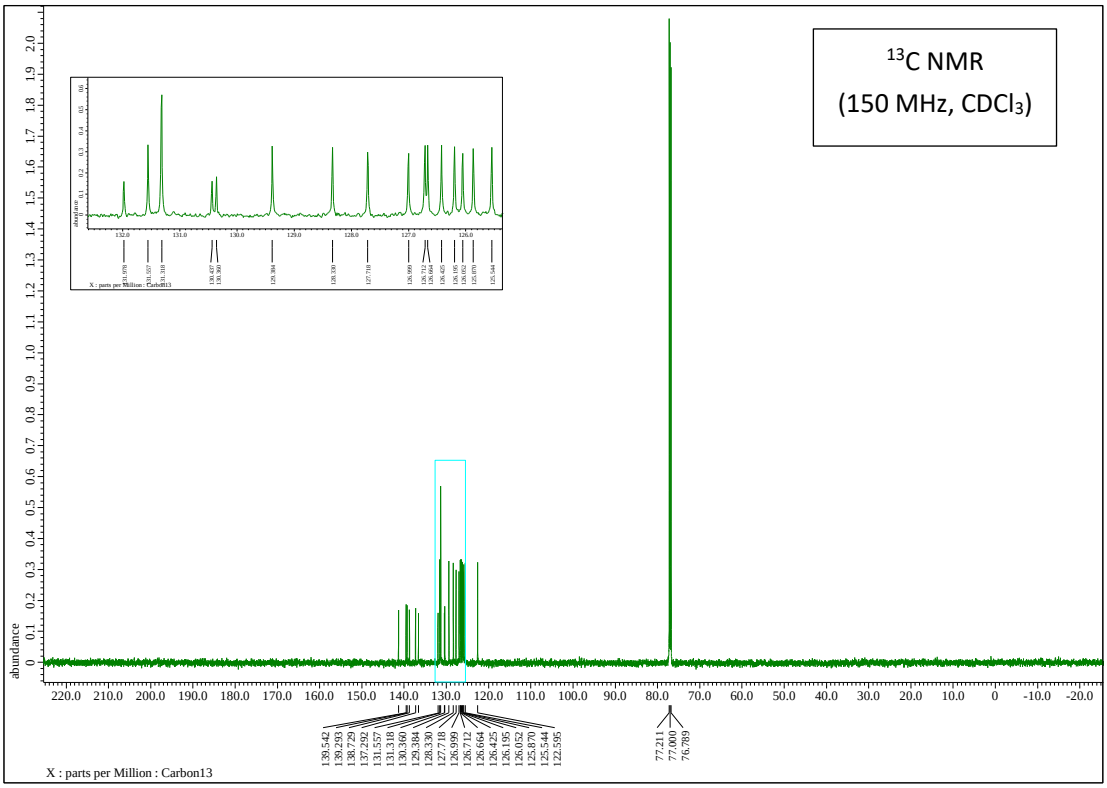
^{1}H and ^{13}C NMR Spectra of **6b**





^{1}H and ^{13}C NMR Spectra of **7b**





^{1}H and ^{13}C NMR Spectra of **1a'**