Supporting Information

for

Palladium-Catalyzed C-H Bond Activation for the Assembly of N-Aryl Carbazoles with Aromatic Amines as Nitrogen Sources

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1. General information

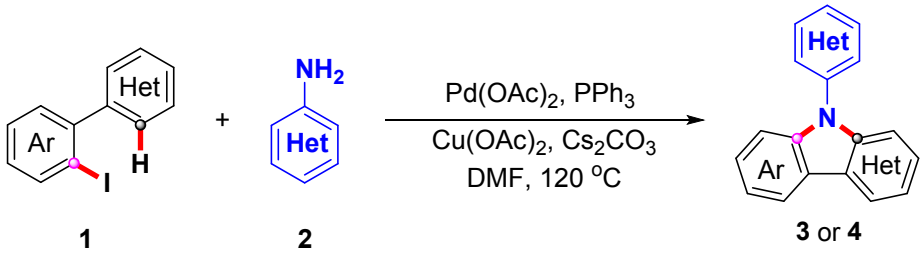
All chemicals were purchased from Adamas Reagent, Ltd, Energy chemical company, J&K Scientific Ltd, Alfa Aesa chemical company and so forth. Unless otherwise stated, all experiments were conducted in a seal tube under air atmosphere. Reactions were monitored by TLC or GC-MS analysis. Flash column chromatography was performed over silica gel (200-300 mesh).

^{1}H-NMR and ^{13}C-NMR spectra were recorded in $CDCl_3$ on a Bruker Avance 500 spectrometer (500 MHz ^{1}H, 125 MHz ^{13}C) at room temperature. Chemical shifts were reported in ppm on the scale relative to CDC_{l3} (δ = 7.26 for ^{1}H-NMR , δ = 77.00 for ^{13}C-NMR) or DMSO-d6 (δ = 2.50 for ^{1}H-NMR, δ = 39.60 for ^{13}C-NMR) as an internal reference. High resolution mass spectra were recorded using Q-TOF time-of-flight mass spectrometer. Coupling constants (J) were reported in Hertz (Hz).

The starting materials 2-iodobiphenyl and arylamine were purchased from commercial suppliers. Other 2-iodobiaryl were synthetized according to methods reported by previous literatures.[1]

1. C. Shao, B. Zhou, Z. Wu, X. Ji and Y. Zhang, *Adv. Synth. Catal.* 2018, **5**, 887.

2. General procedure for the synthesis of 3 and 4

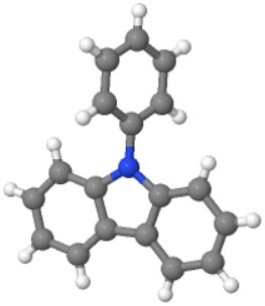


1 **2** **3** or **4**

A dry sealed tube equipped with a magnetic stir bar was charged with **1** (0.2 mmol), aniline **2** (0.24 mmol, 1.2 equiv), $Pd(OAc)_2$ (2.2 mg, 5 mol%), PPh_3 (5.2 mg, 10 mol%), $Cu(OAc)_2$ (0.2 mol, 1.0 equiv), Cs_2CO_3 (0.2 mmol, 1.0 equiv) and DMF (2 mL). Upon completion of the reaction, Upon completion of the reaction, ethyl acetate was added to the mixture, and then washed with saturated brine. The combined water layers were extracted with ethyl acetate three times. The combined organic layers were dried over anhydrous Na_2SO_4. The solvent was evaporated under reduced pressure and the residue was purified by flash column chromatograph (silica gel, petroleum ether/Ethyl acetate = 100:1) to give the desired product **3** or **4**.

3. Crystal data of 3a and 5

Crystallographic data for compound **3a** (CCDC-1916897) has been deposited with the Cambridge Crystallographic Data Centre, Copies of the data can be obtained, free of charge, on application to CCDC (Email:deposit@ccdc.cam.ac.uk).



ORTEP view with ellipsoids (at the 30% probability level)

Bond precision: C-C = 0.0054 A Wavelength=0.71073

Cell: a=38.272(3) b=12.8163(8) c=10.858(1)
alpha=90 beta=90 gamma=90
Temperature: 293 K

	Calculated	Reported
Volume	5325.9(7)	5325.9(7)
Space group	F d d 2	F d d 2
Hall group	F 2 -2d	F 2 -2d
Moiety formula	C18 H13 N	C18 H13 N
Sum formula	C18 H13 N	C18 H13 N
Mr	243.29	243.29
Dx,g cm-3	1.214	1.214
Z	16	16
Mu (mm-1)	0.071	0.071
F000	2048.0	2048.0
F000'	2048.72	
h,k,lmax	52,17,14	51,17,14
Nref	3622[1901]	2768
Tmin,Tmax	0.992,0.993	0.749,1.000
Tmin'	0.992	

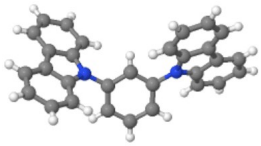
Correction method= # Reported T Limits: Tmin=0.749 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 1.46/0.76 Theta(max)= 29.195

R(reflections)= 0.0508(1751) wR2(reflections)= 0.1077(2768)

S = 1.036 Npar= 172

Crystallographic data for compound **5** (CCDC-1969291) has been deposited with the Cambridge Crystallographic Data Centre, Copies of the data can be obtained, free of charge, on application to CCDC (Email:deposit@ccdc.cam.ac.uk).



ORTEP view with ellipsoids (at the 30% probability level)

```
Bond precision:  C-C = 0.0038 A          Wavelength=0.71073

Cell:             a=9.0542(4)     b=12.4973(6)     c=18.9834(7)
                  alpha=90        beta=90          gamma=90
Temperature:      298 K

                 Calculated                Reported
Volume           2148.03(16)               2148.03(16)
Space group      P 21 21 21                P 21 21 21
Hall group       P 2ac 2ab                 P 2ac 2ab
Moiety formula   C30 H20 N2                C30 H20 N2
Sum formula      C30 H20 N2                C30 H20 N2
Mr               408.48                    408.48
Dx,g cm-3        1.263                     1.263
Z                4                         4
Mu (mm-1)        0.074                     0.074
F000             856.0                     856.0
F000'            856.30
h,k,lmax         12,17,26                  12,17,25
Nref             6004[ 3384]               5185
Tmin,Tmax        0.991,0.993               0.843,1.000
Tmin'            0.991

Correction method= # Reported T Limits: Tmin=0.843 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 1.53/0.86      Theta(max)= 29.530

R(reflections)= 0.0482( 3651)     wR2(reflections)= 0.0913( 5185)

S = 1.041                 Npar= 289
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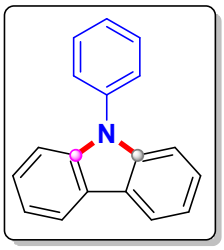
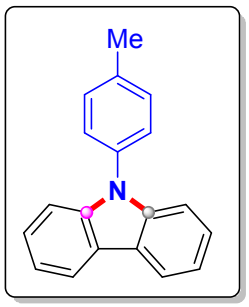
4. Characterization data for products

9-phenyl-9H-carbazole (3a) (CAS Number: 1150-62-5)



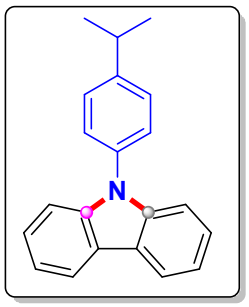
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (43.8 mg, 90%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.24 (d, *J* = 7.8 Hz, 2H), 7.71 – 7.60 (m, 4H), 7.58 – 7.45 (m, 5H), 7.38 (ddd, *J* = 7.9, 5.6, 2.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 140.9, 137.7, 129.8, 127.4, 127.1, 125.9, 123.3, 120.3, 119.9, 109.7.

9-(p-tolyl)-9H-carbazole (3b) (CAS Number: 19264-73-4)



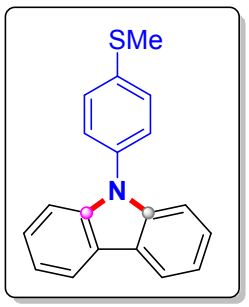
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (36.1 mg, 70%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.17 (d, *J* = 7.8 Hz, 2H), 7.49 – 7.37 (m, 8H), 7.30 (ddd, *J* = 8.0, 6.2, 1.9 Hz, 2H), 2.51 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.1, 137.3, 135.0, 130.4, 127.0, 125.8, 123.2, 120.2, 119.7, 109.8, 21.2. HRMS (ESI, m/z) calcd for $C_{19}H_{16}N$ $[M+H]^+$: 258.1277; found: 258.1272.

9-(4-isopropylphenyl)-9H-carbazole (3c)



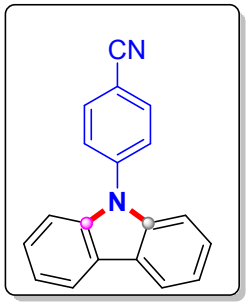
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (46.7 mg, 82%). m.p. 135-137 °C ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (d, *J* = 7.8 Hz, 2H), 7.56 – 7.34 (m, 8H), 7.29 (td, *J* = 6.9, 6.1, 2.5 Hz, 2H), 3.06 (p, *J* = 6.9 Hz, 1H), 1.37 (d, *J* = 6.9 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.2, 141.1, 135.2, 127.8, 127.0, 125.8, 123.2, 120.2, 119.7, 109.9, 33.9, 24.0. HRMS (ESI, m/z) calcd for $C_{21}H_{20}N$ $[M+H]^+$: 286.1590; found: 286.1592.

9-(4-(methylthio)phenyl)-9H-carbazole (3d) (CAS Number: 57103-12-5)



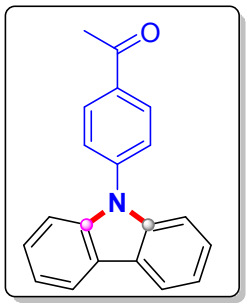
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (22.0 mg, 38%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 (d, *J* = 7.7 Hz, 2H), 7.53 – 7.45 (m, 4H), 7.45 – 7.36 (m, 4H), 7.29 (ddd, *J* = 7.9, 6.6, 1.5 Hz, 2H), 2.59 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 140.9, 137.9, 134.6, 127.7, 127.56, 125.9, 123.3, 120.3, 119.9, 109.7, 15.9.

4-(9H-carbazol-9-yl)benzonitrile (3e) (CAS Number: 57103-17-0)



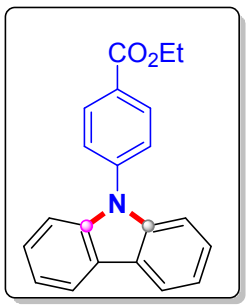
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 50:1, v/v) to give the product as a white solid (35.9 mg, 67%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 (d, *J* = 7.8 Hz, 2H), 7.94 – 7.87 (m, 2H), 7.76 – 7.70 (m, 2H), 7.45 (dd, *J* = 6.1, 1.4 Hz, 4H), 7.35 (ddd, *J* = 8.0, 6.2, 2.0 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 142.0, 139.9, 133.9, 127.1, 126.3, 124.0, 121.0, 120.6, 118.3, 110.4, 109.5.

1-(4-(9H-carbazol-9-yl)phenyl)ethan-1-one (3f) (CAS Number: 142116-85-6)



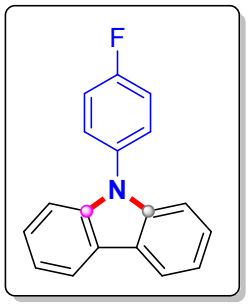
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 60:1, v/v) to give the product as a white solid (20.5 mg, 36%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.25 – 8.19 (m, 2H), 8.17 – 8.13 (m, 2H), 7.74 – 7.69 (m, 2H), 7.49 (d, *J* = 8.2 Hz, 2H), 7.43 (ddd, *J* = 8.2, 7.0, 1.2 Hz, 2H), 7.35 – 7.30 (m, 2H), 2.71 (s, 3H).^{13}C NMR (125 MHz, $CDCl_3$) δ 197.0, 142.2, 140.2, 135.5, 130.1, 126.5, 126.2, 123.8, 120.6, 120.4, 109.7, 26.7.

ethyl 4-(9H-carbazol-9-yl)benzoate (3g) (CAS Number: 717881-64-6)



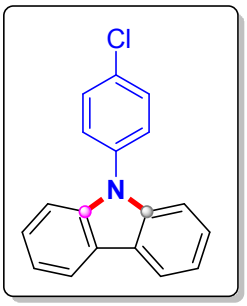
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 30:1, v/v) to give the product as a white solid (39.7 mg, 63%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.38 – 8.25 (m, 2H), 8.16 (dd, *J* = 7.7, 1.1 Hz, 2H), 7.75 – 7.66 (m, 2H), 7.49 (d, *J* = 8.2 Hz, 2H), 7.44 (ddd, *J* = 8.2, 6.9, 1.2 Hz, 2H), 7.33 (td, *J* = 7.4, 6.9, 1.2 Hz, 2H), 4.48 (q, *J* = 7.1 Hz, 2H), 1.47 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.9, 141.9, 140.2, 131.3, 129.0, 126.3, 126.1, 123.7, 120.5, 120.4, 109.7, 61.2, 14.4.

9-(4-fluorophenyl)-9H-carbazole (3h) (CAS Number: 57103-14-7)



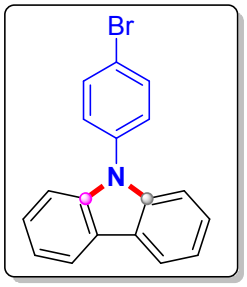
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (48.0 mg, 92%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.17 (d, *J* = 7.8 Hz, 2H), 7.57 – 7.51 (m, 2H), 7.43 (ddd, *J* = 8.3, 7.0, 1.3 Hz, 2H), 7.37 – 7.28 (m, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.6 (d, *J* = 246.3 Hz), 141.0, 133.6 (d, *J* = 3.8 Hz), 129.0 (d, *J* = 8.8 Hz), 126.0, 123.3, 120.3, 120.0, 116.8 (d, *J* = 23.8 Hz), 109.5. ^{19}F NMR (471 MHz, $CDCl_3$) δ -113.7.

9-(4-chlorophenyl)-9H-carbazole (3i) (CAS Number: 19264-71-2)



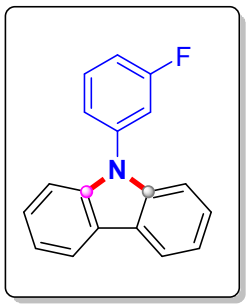
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (45.4 mg, 82%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (d, *J* = 7.7 Hz, 2H), 7.59 (dt, *J* = 7.5, 2.5 Hz, 2H), 7.55 – 7.48 (m, 2H), 7.46 – 7.36 (m, 4H), 7.35 – 7.28 (m, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 140.7, 136.2, 133.0, 130.1, 128.4, 126.1, 123.4, 120.4, 120.2, 109.5.

9-(4-bromophenyl)-9H-carbazole (3j) (CAS Number: 57102-42-8)



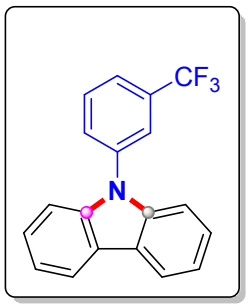
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (30.8 mg, 48%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 (dt, *J* = 7.8, 1.0 Hz, 1H), 7.77 – 7.67 (m, 1H), 7.49 – 7.44 (m, 1H), 7.42 (ddd, *J* = 8.1, 6.8, 1.2 Hz, 1H), 7.38 (dt, *J* = 8.3, 1.1 Hz, 1H), 7.31 (ddd, *J* = 7.9, 6.9, 1.2 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 140.6, 136.8, 133.1, 128.7, 126.1, 123.5, 120.9, 120.4, 120.2, 109.5.

9-(3-fluorophenyl)-9H-carbazole (3k) (CAS Number: 81329-47-7)



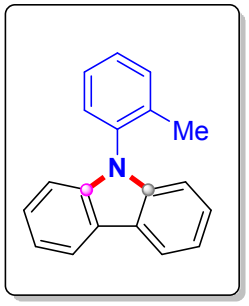
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (45.9 mg, 88%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (dt, *J* = 7.8, 1.0 Hz, 2H), 7.58 (td, *J* = 8.1, 6.3 Hz, 1H), 7.50 – 7.38 (m, 5H), 7.36 – 7.30 (m, 3H), 7.19 (tdd, *J* = 8.3, 2.5, 0.9 Hz, 1H).^{13}C NMR (125 MHz, $CDCl_3$) δ 163.4 (d, *J* = 246.3 Hz), 140.5, 139.3 (d, *J* = 10.0 Hz), 131.0 (d, *J* = 8.8 Hz), 126.1, 123.5, 122.7 (d, *J* = 2.5 Hz), 120.4, 120.3, 114.4 (d, *J* = 21.3 Hz), 114.3 (d, *J* = 23.8 Hz), 109.7. ^{19}F NMR (471 MHz, $CDCl_3$) δ -110.5.

9-(3-(trifluoromethyl)phenyl)-9H-carbazole (3l) (CAS Number: 1241949-50-7)



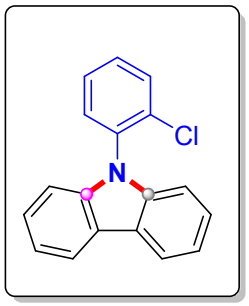
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (56.0 mg, 90%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (dt, *J* = 7.8, 1.0 Hz, 2H), 7.88 (d, *J* = 1.9 Hz, 1H), 7.82 – 7.72 (m, 3H), 7.48 – 7.38 (m, 4H), 7.33 (ddd, *J* = 7.9, 6.9, 1.2 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 140.5, 138.5, 132.6 (q, *J* = 32.5 Hz), 130.6, 130.4, 126.2, 124.1 (q, *J* = 3.8 Hz), 123.9 (q, J = 3.8 Hz), 123.7 (q, *J* = 271.3 Hz), 123.6, 120.5, 120.4, 109.4. ^{19}F NMR (471 MHz, $CDCl_3$) δ -62.7.

9-(o-tolyl)-9H-carbazole (3m) (CAS Number: 19155-50-1)



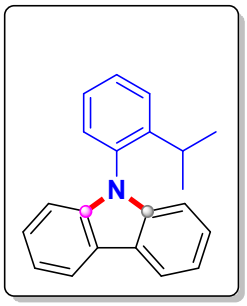
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (45.2 mg, 88%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.18 (dt, *J* = 7.8, 0.9 Hz, 2H), 7.48 (ddd, *J* = 8.4, 7.3, 2.0 Hz, 2H), 7.44 – 7.36 (m, 4H), 7.29 (td, *J* = 7.4, 7.0, 1.0 Hz, 2H), 7.06 (dt, *J* = 8.2, 0.9 Hz, 2H), 1.99 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.2, 137.4, 136.0, 131.5, 129.3, 128.7, 127.3, 125.9, 123.0, 120.3, 119.5, 109.8, 17.6.

9-(2-chlorophenyl)-9H-carbazole (3n) (CAS Number: 19155-51-2)



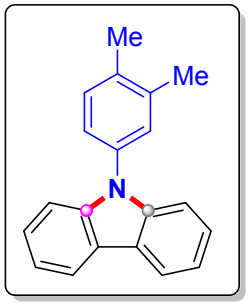
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (30.5 mg, 55%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (dt, *J* = 7.8, 1.0 Hz, 2H), 7.72 – 7.67 (m, 1H), 7.54 – 7.47 (m, 3H), 7.41 (ddd, *J* = 8.2, 7.1, 1.2 Hz, 2H), 7.30 (td, *J* = 7.5, 1.0 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 140.9, 135.1, 133.8, 131.01, 130.9, 129.8, 128.1, 125.9, 123.3, 120.3, 120.0, 110.0.

9-(2-isopropylphenyl)-9H-carbazole (3o)



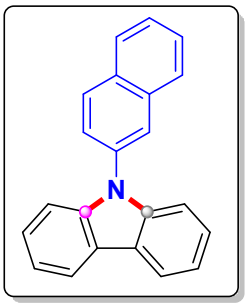
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (42.8 mg, 75%). m.p. 111-113 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.19 (d, *J* = 7.7 Hz, 2H), 7.61 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.56 (td, *J* = 7.6, 1.4 Hz, 1H), 7.41 (ddt, *J* = 9.1, 7.5, 1.6 Hz, 3H), 7.34 – 7.27 (m, 3H), 7.06 (d, *J* = 8.2 Hz, 2H), 2.62 (p, *J* = 6.9 Hz, 1H), 1.08 (d, *J* = 6.9 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.5, 142.0, 134.6, 129.6, 129.4, 127.2, 127.1, 125.9, 122.9, 120.2, 119.4, 109.7, 28.0, 23.9. HRMS (ESI, m/z) calcd for $C_{21}H_{20}N$ $[M+H]^+$: 286.1590; found: 286.1584.

9-(3,4-dimethylphenyl)-9H-carbazole (3p) (CAS Number: 204066-04-6)



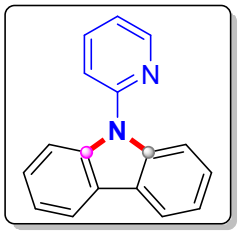
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (47.7 mg, 88%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.17 (d, *J* = 7.7 Hz, 2H), 7.42 (q, *J* = 5.6, 4.2 Hz, 4H), 7.39 – 7.33 (m, 2H), 7.30 (dtd, *J* = 7.9, 5.6, 3.4 Hz, 3H), 2.41 (s, 3H), 2.39 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.1 138.3, 136.0, 135.2, 130.8, 128.1, 125.8, 124.4, 123.2, 120.2, 119.6, 109.8, 19.9, 19.5.

9-(naphthalen-2-yl)-9H-carbazole (3q) (CAS Number: 34292-03-0)



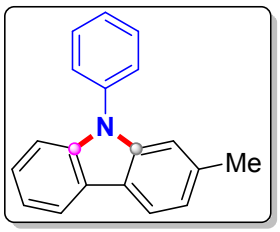
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (25.8 mg, 44%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.20 (d, *J* = 7.8 Hz, 2H), 8.12 – 8.03 (m, 2H), 7.99 (dd, *J* = 6.2, 3.4 Hz, 1H), 7.93 (dd, *J* = 6.2, 3.3 Hz, 1H), 7.69 (dd, *J* = 8.7, 2.2 Hz, 1H), 7.61 (dt, *J* = 6.3, 3.5 Hz, 2H), 7.52 – 7.41 (m, 4H), 7.34 (t, *J* = 7.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.0, 135.1, 134.0, 132.4, 129.8, 127.92, 127.9, 126.8, 126.5, 126.0, 125.4, 125.3, 123.4, 120.3, 120.0, 109.8.

9-(pyridin-2-yl)-9H-carbazole (3r) (CAS Number: 23866-67-3)



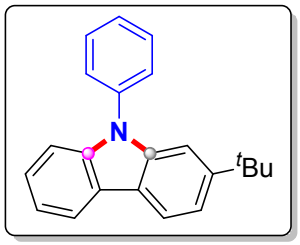
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:EtOAc = 20:1, v/v) to give the product as a white solid (20.1 mg, 41%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.74 (ddd, *J* = 4.9, 2.0, 0.9 Hz, 1H), 8.14 (dt, *J* = 7.8, 1.0 Hz, 2H), 7.93 (ddd, *J* = 8.2, 7.4, 2.0 Hz, 1H), 7.85 (dt, *J* = 8.3, 0.9 Hz, 2H), 7.65 (dt, *J* = 8.1, 1.0 Hz, 1H), 7.46 (ddd, *J* = 8.4, 7.2, 1.3 Hz, 2H), 7.37 – 7.28 (m, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 151.8, 149.6, 139.5, 138.4, 126.2, 124.3, 121.2, 120.9, 120.2, 119.0, 111.1.

2-methyl-9-phenyl-9H-carbazole (4a) (CAS Number: 2080745-13-5)



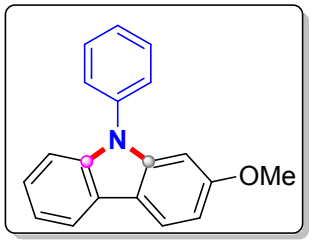
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum) to give the product as a white solid (42.1 mg, 82%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 (dt, *J* = 7.6, 1.0 Hz, 1H), 8.07 (d, *J* = 7.9 Hz, 1H), 7.71 – 7.56 (m, 4H), 7.53 – 7.48 (m, 1H), 7.45 – 7.39 (m, 2H), 7.31 (ddd, *J* = 8.0, 5.4, 2.7 Hz, 1H), 7.26 – 7.22 (m, 1H), 7.16 (dd, *J* = 8.0, 1.4 Hz, 1H), 2.54 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.4, 141.0, 137.8, 136.1, 129.8, 127.4, 127.2, 125.3, 123.5, 121.4, 121.1, 120.0, 119.9, 119.8, 109.8, 109.6, 22.1.

2-(tert-butyl)-9-phenyl-9H-carbazole (4b) (CAS Number: 2080745-14-6)



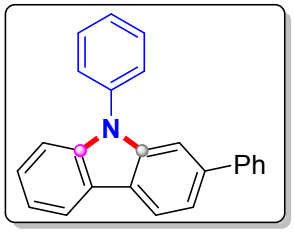
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (37.7 mg, 63%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (dt, *J* = 7.7, 1.0 Hz, 1H), 8.09 (d, *J* = 8.2 Hz, 1H), 7.69 – 7.57 (m, 4H), 7.52 – 7.46 (m, 1H), 7.46 – 7.35 (m, 4H), 7.28 (ddd, *J* = 8.0, 6.2, 1.9 Hz, 1H), 1.41 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 149.7, 141.1, 141.0, 137.8, 129.8, 127.3, 127.1, 125.3, 123.3, 120.9, 120.0, 119.7, 118.0, 109.6, 106.1, 35.2, 31.7.

2-methoxy-9-phenyl-9H-carbazole (4c) (CAS Number: 1357929-88-4)



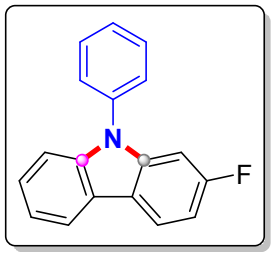
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 50:1, v/v) to give the product as a white solid (43.7 mg, 80%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 (dt, *J* = 7.8, 1.0 Hz, 1H), 8.04 (d, *J* = 8.5 Hz, 1H), 7.66 – 7.61 (m, 2H), 7.61 – 7.57 (m, 2H), 7.52 – 7.47 (m, 1H), 7.40 – 7.34 (m, 2H), 7.29 (ddd, *J* = 8.1, 6.3, 1.9 Hz, 1H), 6.94 (dd, *J* = 8.5, 2.3 Hz, 1H), 6.91 (d, *J* = 2.2 Hz, 1H), 3.86 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.2, 142.2, 141.1, 137.7, 129.9, 127.5, 127.1, 124.6, 123.5, 121.0, 120.0, 119.4, 117.2, 109.5, 108.5, 94.0, 55.6.

2,9-diphenyl-9H-carbazole (4d) (CAS Number: 1187235-30-8)



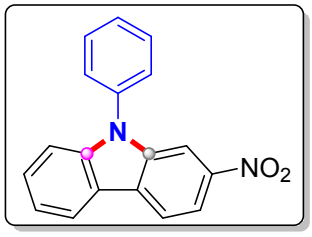
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, pure petroleum ether) to give the product as a white solid (53.0 mg, 83%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (dd, *J* = 8.1, 1.3 Hz, 1H), 8.18 (dq, *J* = 7.8, 1.0 Hz, 1H), 7.69 – 7.63 (m, 3H), 7.63 – 7.59 (m, 4H), 7.56 (dt, *J* = 8.1, 1.5 Hz, 1H), 7.50 (ddt, *J* = 7.6, 6.1, 2.0 Hz, 1H), 7.48 – 7.40 (m, 4H), 7.38 – 7.29 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 142.0, 141.4, 141.4, 139.5, 137.6, 129.9, 128.7, 127.5, 127.2, 127.1, 125.9, 123.1, 122.6, 120.5, 120.3, 120.0, 119.6, 109.8, 108.3.

2-fluoro-9-phenyl-9H-carbazole (4e)



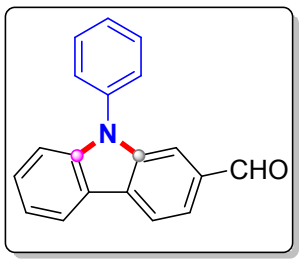
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (47.0 mg, 90%). m.p. 73-75 ^{o}C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.12 (d, *J* = 1.1 Hz, 1H), 8.10 (d, *J* = 1.1 Hz, 1H), 8.07 (dd, *J* = 8.5, 5.4 Hz, 2H), 7.67 – 7.60 (m, 4H), 7.60 – 7.53 (m, 4H), 7.53 – 7.47 (m, 2H), 7.45 – 7.38 (m, 4H), 7.32 (ddd, *J* = 8.0, 4.9, 3.3 Hz, 2H), 7.10 (dd, *J* = 9.9, 2.3 Hz, 2H), 7.04 (ddd, *J* = 9.3, 8.5, 2.3 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.1 (d, *J* = 241.3 Hz), 141.6 (d, *J* = 12.5 Hz), 141.4 (d, *J* = 1.3 Hz), 137.2, 130.0, 127.8, 126.9, 125.5, 123.0, 121.2 (d, *J* = 10.0 Hz), 120.3, 119.9, 119.7, 109.8, 108.0 (d, *J* = 25.0 Hz), 96.7 (d, *J* = 27.5 Hz). ^{19}F NMR (471 MHz, $CDCl_3$) δ -114.9. HRMS (ESI, m/z) calcd for $C_{18}H_{12}FNNa$ $[M+H]^{+}$: 284.0846; found: 284.0838.

9-(4-nitrophenyl)-9H-carbazole (4f) (CAS Number: 1257982-94-7)



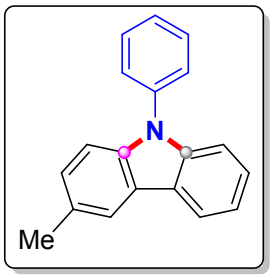
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 5:1, v/v) to give the product as a yellow solid (47.2 mg, 82%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.27 (d, *J* = 1.9 Hz, 1H), 8.24 – 8.15 (m, 3H), 7.67 (dd, *J* = 8.8, 6.7 Hz, 2H), 7.54 (dtd, *J* = 13.1, 7.6, 7.0, 1.3 Hz, 4H), 7.43 (d, *J* = 8.3 Hz, 1H), 7.40 – 7.33 (m, 1H).^{13}C NMR (125 MHz, $CDCl_3$) δ 146.0, 143.2, 139.9, 136.4, 130.3, 128.5, 128.3, 128.2, 127.1, 121.8, 121.4, 121.1, 120.3, 115.2, 110.5, 106.1.

9-phenyl-9H-carbazole-2-carbaldehyde (4g) (CAS Number: 1353684-87-3)



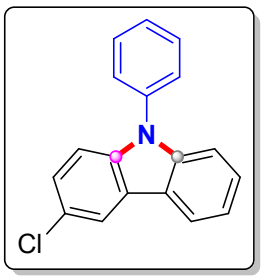
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a yellow solid (47.7 mg, 88%).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.09 (s, 1H), 8.27 (d, *J* = 8.0 Hz, 1H), 8.21 (dt, *J* = 7.8, 1.0 Hz, 1H), 7.92 (d, *J* = 1.2 Hz, 1H), 7.82 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.68 – 7.61 (m, 2H), 7.58 – 7.48 (m, 4H), 7.43 (dd, *J* = 8.3, 0.9 Hz, 1H), 7.35 (ddd, *J* = 8.0, 6.9, 1.0 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 192.5, 142.7, 140.6, 136.9, 134.2, 130.1, 128.4, 128.1, 127.8, 127.2, 122.3, 121.7, 121.3, 120.6, 120.6, 111.4, 110.2.

3-methyl-9-phenyl-9H-carbazole (4h) (CAS Number: 1202362-88-6)



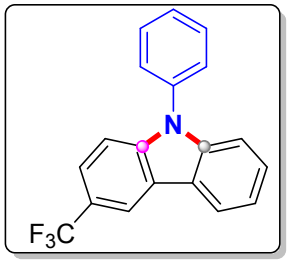
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (38.6 mg, 75%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 (dt, *J* = 7.8, 1.0 Hz, 1H), 8.00 – 7.96 (m, 1H), 7.67 – 7.56 (m, 4H), 7.50 – 7.39 (m, 3H), 7.35 (d, *J* = 8.3 Hz, 1H), 7.30 (ddd, *J* = 7.9, 6.4, 1.7 Hz, 1H), 7.26 (dd, *J* = 8.4, 1.7 Hz, 1H), 2.59 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.0, 139.1, 137.9, 129.8, 129.2, 127.2, 127.0, 125.7, 123.5, 123.2, 120.2, 119.7, 109.7, 109.4, 21.4.

3-chloro-9-phenyl-9H-carbazole (4i) (CAS Number: 193686-61-2)



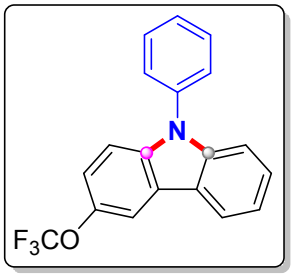
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (51.5 mg, 93%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11 (dd, *J* = 7.2, 1.4 Hz, 2H), 7.65 – 7.58 (m, 2H), 7.56 – 7.52 (m, 2H), 7.52 – 7.47 (m, 1H), 7.45 (ddd, *J* = 8.0, 6.8, 1.2 Hz, 1H), 7.41 (dt, *J* = 8.3, 1.0 Hz, 1H), 7.37 (dd, *J* = 8.7, 2.0 Hz, 1H), 7.35 – 7.28 (m, 2H).^{13}C NMR (125 MHz, $CDCl_3$) δ 141.3, 139.2, 137.3, 129.9, 127.7, 127.0, 126.6, 125.9, 125.3, 124.5, 122.4, 120.4, 120.2, 120.0, 110.8, 110.0.

9-phenyl-3-(trifluoromethyl)-9H-carbazole (4j) (CAS Number: 1417618-06-4)



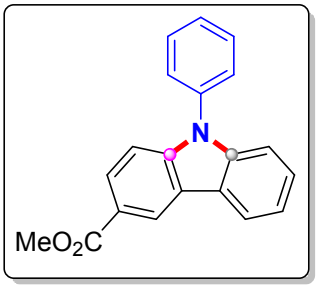
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a white solid (52.9 mg, 85%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.44 (dt, *J* = 1.7, 0.8 Hz, 1H), 8.20 (dt, *J* = 7.8, 1.0 Hz, 1H), 7.70 – 7.61 (m, 3H), 7.58 – 7.51 (m, 3H), 7.51 – 7.41 (m, 3H), 7.37 (ddd, *J* = 8.0, 7.0, 1.1 Hz, 1H).^{13}C NMR (125 MHz, $CDCl_3$) δ 142.3, 141.6, 137.0, 130.1, 128.1, 127.1, 126.9, 125.2 (q, *J* = 270.0 Hz), 123.0, 122.8, 122.7 (q, *J* = 3.8 Hz) , 122.1 (q, *J* = 32.5 Hz)， 120.7, 120.5, 117.9 (q, *J* = 3.8 Hz), 110.2, 109.9. ^{19}F NMR (471 MHz, $CDCl_3$) δ -60.1.

9-phenyl-3-(trifluoromethoxy)-9H-carbazole (4k)



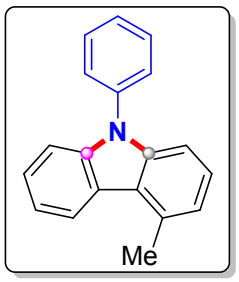
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a pale oil (49.7 mg, 76%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (dt, *J* = 7.7, 1.0 Hz, 1H), 8.00 (dd, *J* = 2.4, 1.2 Hz, 1H), 7.65 – 7.60 (m, 2H), 7.57 – 7.53 (m, 2H), 7.52 – 7.48 (m, 1H), 7.46 (ddd, *J* = 8.2, 6.9, 1.2 Hz, 1H), 7.41 (dt, *J* = 8.3, 1.0 Hz, 1H), 7.37 (d, *J* = 8.8 Hz, 1H), 7.32 (ddd, *J* = 8.0, 6.9, 1.2 Hz, 1H), 7.28 (ddd, *J* = 8.9, 2.4, 0.9 Hz, 1H).^{13}C NMR (125 MHz, $CDCl_3$) δ 142.8 (q, *J* = 2.5 Hz), 141.7, 139.1, 137.2, 130.0, 127.8, 127.1, 126.8, 123.7, 122.7, 120.8 (q, *J* = 253.8 Hz), 120.5, 120.3, 119.6, 113.2, 110.3, 110.1. ^{19}F NMR (471 MHz, $CDCl_3$) δ -58.1. HRMS (ESI, m/z) calcd for $C_{19}H_{13}F_3NO$ $[M+H]^+$: 328.0944; found: 328.0945.

methyl 9-phenyl-9H-carbazole-3-carboxylate (4l)



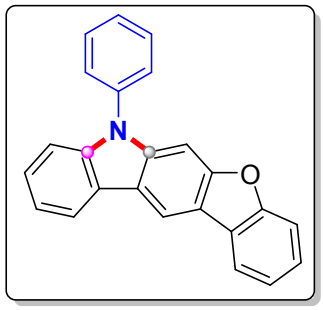
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 30:1, v/v) to give the product as a white solid (45.8 mg, 76%). m.p. 75-77 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.92 – 8.85 (m, 1H), 8.20 (dt, *J* = 7.7, 1.0 Hz, 1H), 8.11 (dd, *J* = 8.7, 1.7 Hz, 1H), 7.68 – 7.59 (m, 2H), 7.58 – 7.54 (m, 2H), 7.54 – 7.49 (m, 1H), 7.45 (ddd, *J* = 8.2, 6.9, 1.2 Hz, 1H), 7.42 – 7.37 (m, 2H), 7.35 (ddd, *J* = 8.0, 7.0, 1.2 Hz, 1H), 3.99 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 167.8, 143.5, 141.6, 137.0, 130.0, 128.0, 127.5, 127.1, 126.6, 123.3, 123.1, 122.9, 121.8, 120.8, 120.6, 110.2, 109.3, 52.0. HRMS (ESI, m/z) calcd for $C_{20}H_{16}NO_2$ $[M+H]^+$: 302.1176; found: 302.1181.

4-methyl-9-phenyl-9H-carbazole (4m)



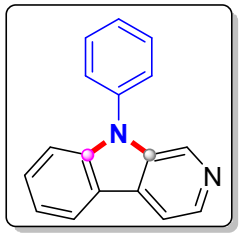
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 100:1, v/v) to give the product as a colourless oil (17.0 mg, 33%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.26 (dt, *J* = 7.9, 1.0 Hz, 1H), 7.64 – 7.58 (m, 2H), 7.58 – 7.53 (m, 2H), 7.48 (ddt, *J* = 7.8, 6.8, 1.4 Hz, 1H), 7.44 – 7.38 (m, 2H), 7.35 – 7.28 (m, 2H), 7.25 (d, *J* = 8.0 Hz, 1H), 7.08 (dt, *J* = 7.1, 0.9 Hz, 1H), 2.95 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.1, 140.9, 137.7, 133.4, 129.8, 127.5, 127.5, 125.6, 125.2, 123.9, 122.6, 121.7, 121.4, 119.8, 109.5, 107.3, 20.9. HRMS (ESI, m/z) calcd for $C_{19}H_{16}N$ $[M+H]^+$: 258.1277; found: 258.1274.

7-phenyl-7H-benzofuro[2,3-b]carbazole (4n) (CAS Number: 1849662-52-7)



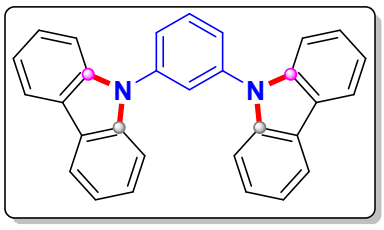
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, PE:EA = 50:1, v/v) to give the product as a white solid 45.3 mg, 68%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.62 (dt, *J* = 7.5, 1.2 Hz, 1H), 8.04 – 7.97 (m, 1H), 7.93 (d, *J* = 8.5 Hz, 1H), 7.78 (dt, *J* = 8.2, 0.9 Hz, 1H), 7.69 – 7.61 (m, 4H), 7.56 – 7.51 (m, 1H), 7.51 – 7.37 (m, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.2, 151.2, 141.4, 140.6, 137.6, 129.9, 127.8, 127.3, 125.7, 125.2, 125.1, 122.8, 122.7, 121.0, 120.6, 119.7, 117.9, 116.4, 111.6, 109.8, 108.6, 105.5.

9-phenyl-9H-pyrido[3,4-b]indole (4o) (CAS Number: 1899836-00-0)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:EtOAc = 20:1, v/v) to give the product as a white solid (22.4 mg, 46%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.86 (s, 1H), 8.63 – 8.39 (m, 1H), 8.20 (d, *J* = 7.8 Hz, 1H), 8.03 (d, *J* = 3.9 Hz, 1H), 7.64 (t, *J* = 7.7 Hz, 2H), 7.61 – 7.56 (m, 2H), 7.56 – 7.46 (m, 3H), 7.39 – 7.33 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.6, 137.0, 136.8, 130.2, 129.1, 129.0, 128.7, 128.1,127.0, 126.9, 121.8, 121.5, 120.7, 111.6, 110.6.

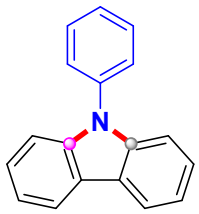
1,3-di(9H-carbazol-9-yl)benzene (5) (CAS Number: 550378-78-4)



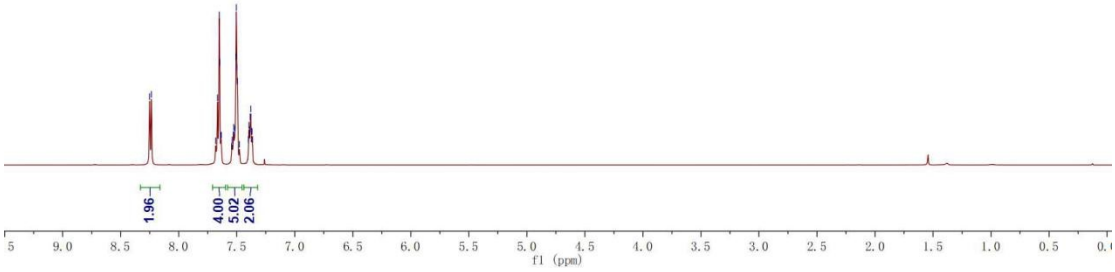
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:EtOAc = 100:1, v/v) to give the product as a white solid (28.6 mg, 70%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.17 (dt, *J* = 7.7, 1.0 Hz, 4H), 7.91 – 7.80 (m, 2H), 7.72 (dd, *J* = 7.9, 2.1 Hz, 2H), 7.56 (dt, *J* = 8.2, 0.9 Hz, 4H), 7.46 (ddd, *J* = 8.3, 7.1, 1.2 Hz, 4H), 7.33 (td, *J* = 7.5, 7.0, 1.0 Hz, 4H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 140.6, 139.4, 131.2, 126.2, 125.9, 125.4, 123.6, 120.4, 120.3, 109.7.

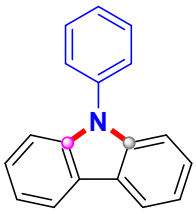
5. NMR spectroscopic data

9-phenyl-9H-carbazole (3a)

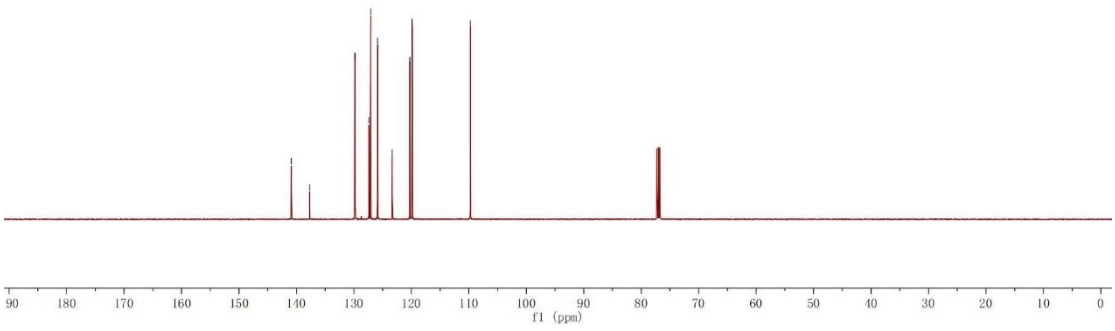


$CDCl_3$ (500 MHz)

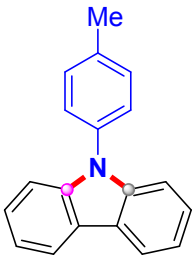




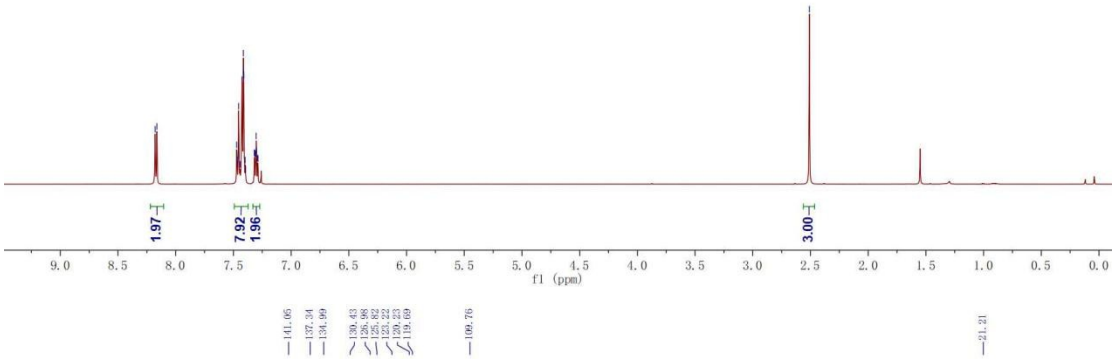
$CDCl_3$ (126 MHz)

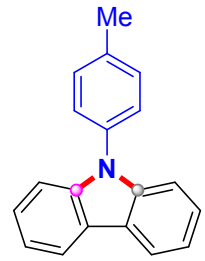


9-(p-tolyl)-9H-carbazole (3b)

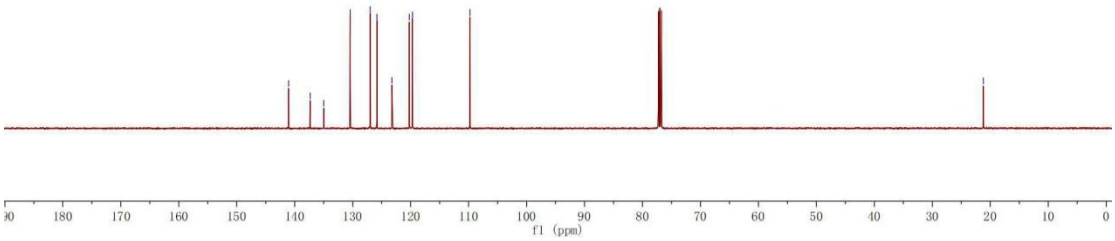


$CDCl_3$ (500 MHz)

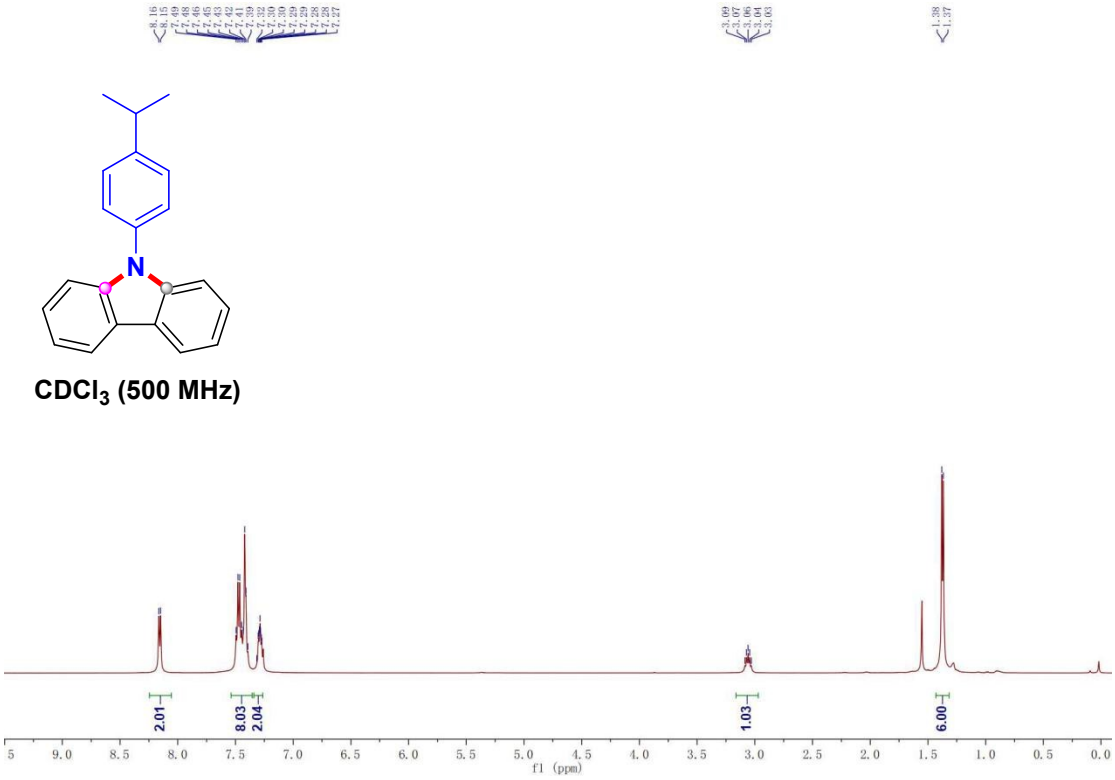


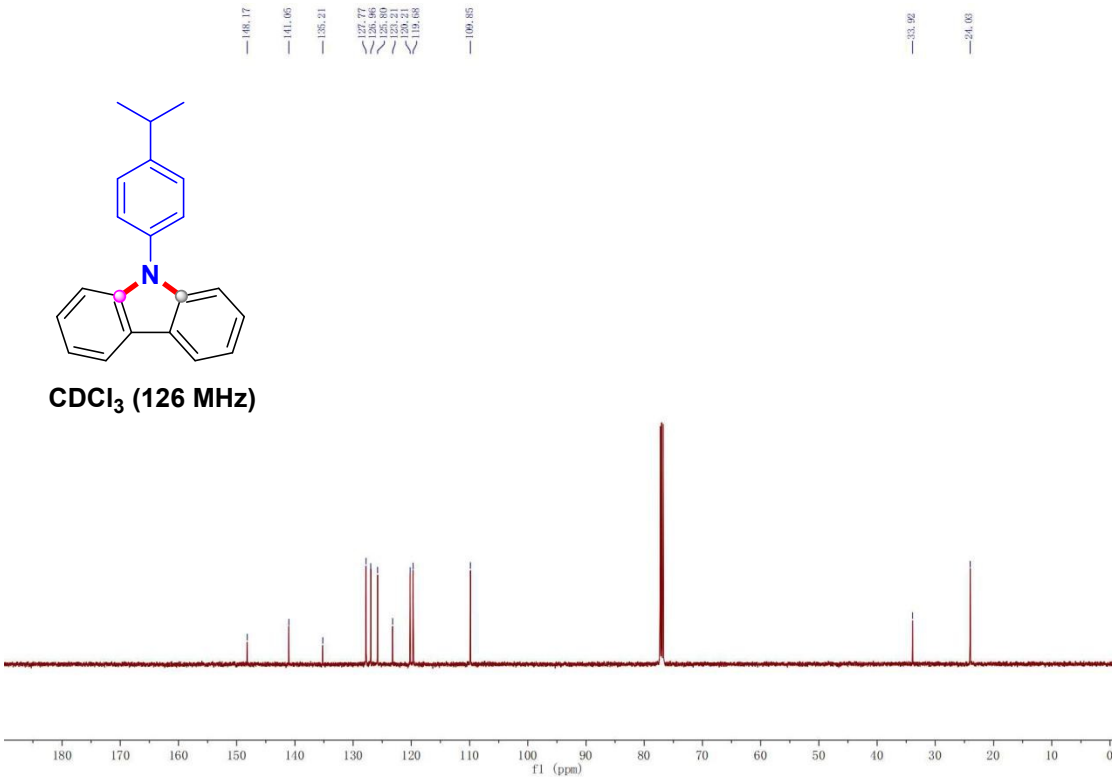


$CDCl_3$ (126 MHz)

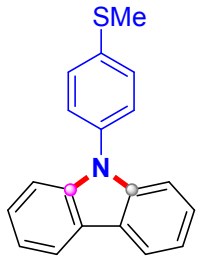


9-(4-isopropylphenyl)-9H-carbazole (3c)

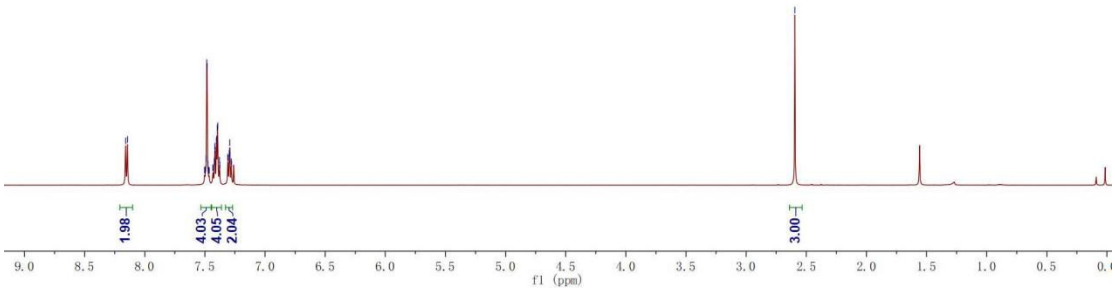


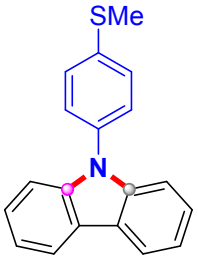


9-(4-(methylthio)phenyl)-9H-carbazole (3d)

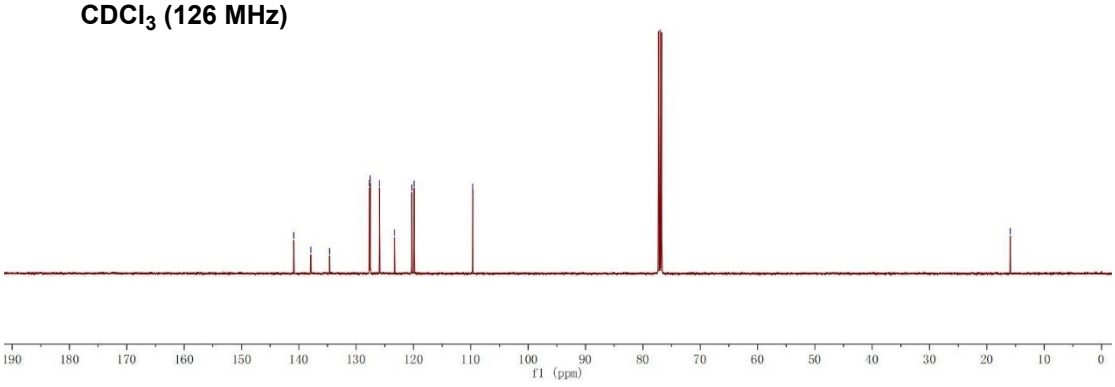


$CDCl_3$ (500 MHz)

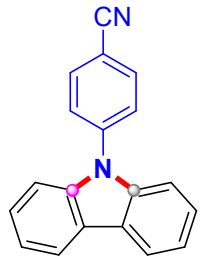




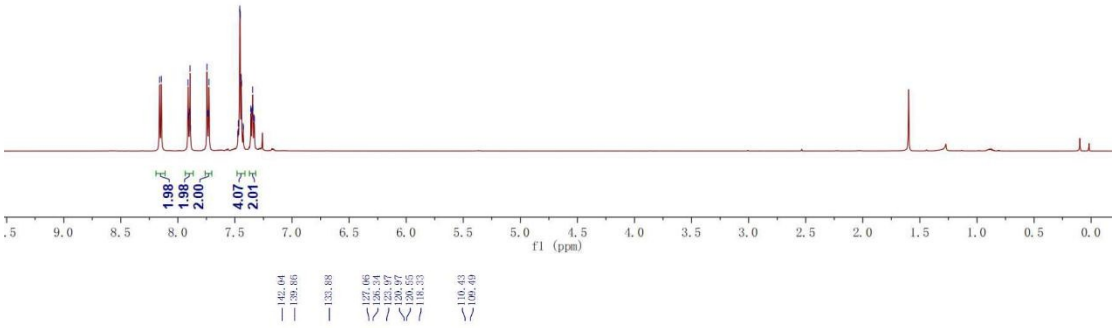
$CDCl_3$ (126 MHz)

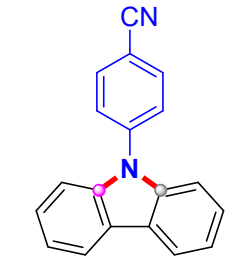


4-(9H-carbazol-9-yl)benzonitrile (3e)

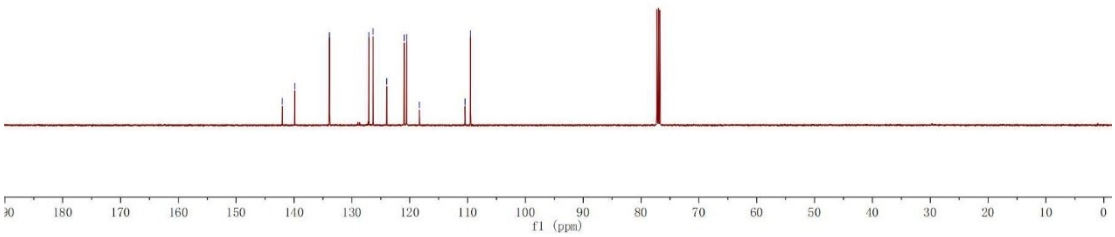


$CDCl_3$ (500 MHz)

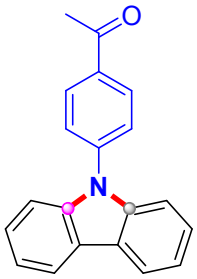




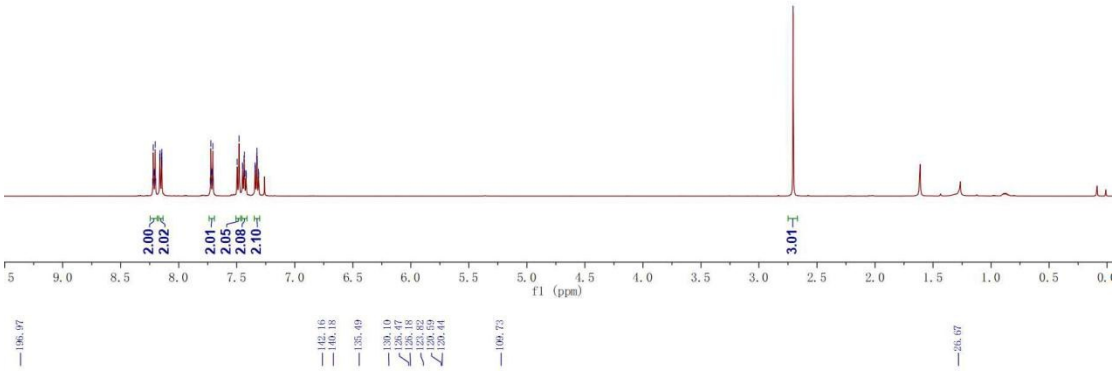
$CDCl_3$ (126 MHz)

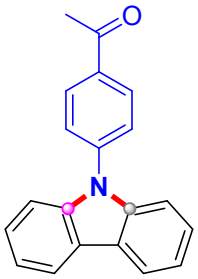


1-(4-(9H-carbazol-9-yl)phenyl)ethan-1-one (3f)

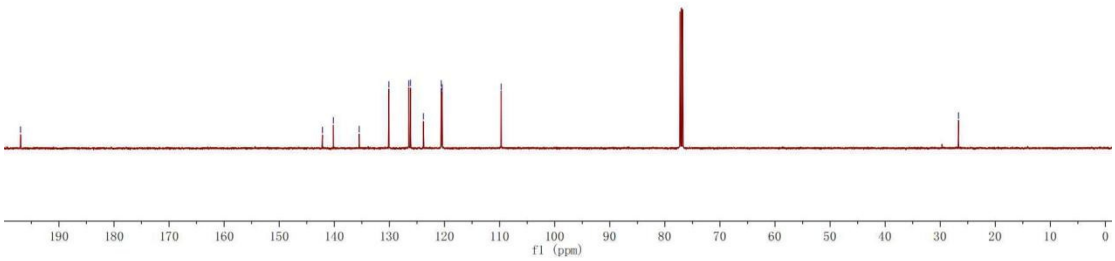


$CDCl_3$ (500 MHz)

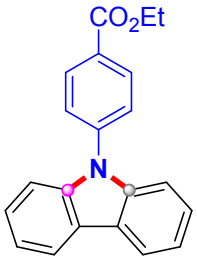




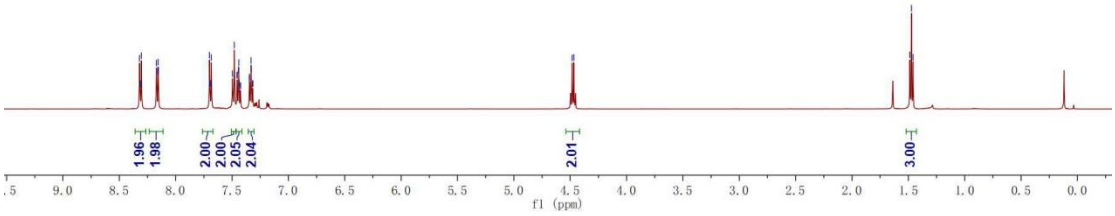
$CDCl_3$ (126 MHz)

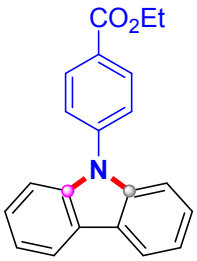


ethyl 4-(9H-carbazol-9-yl)benzoate (3g)

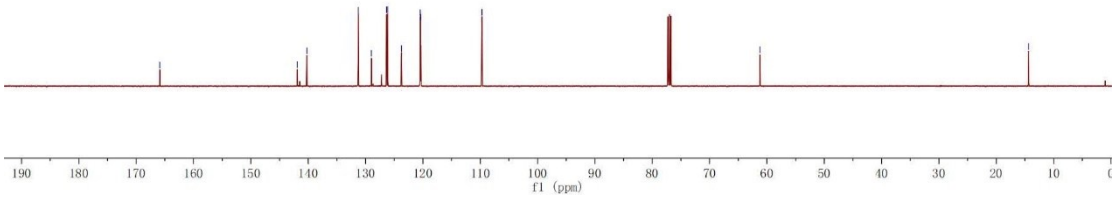


$CDCl_3$ (500 MHz)

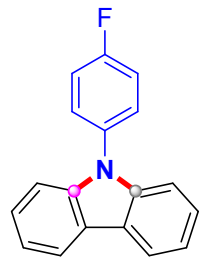




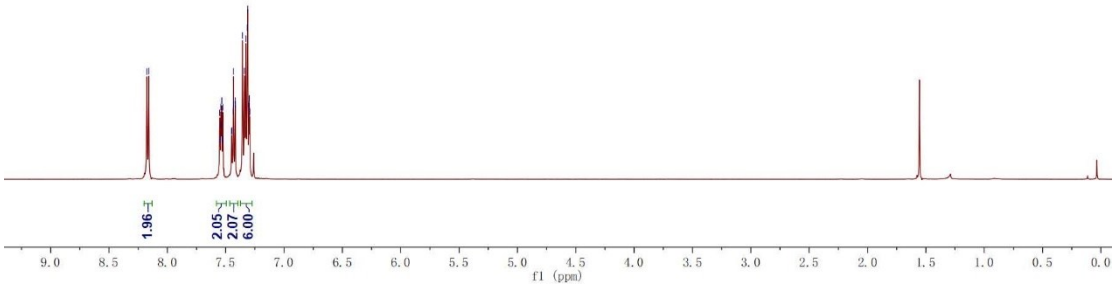
$CDCl_3$ (126 MHz)

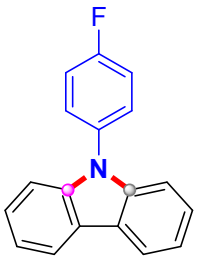


9-(4-fluorophenyl)-9H-carbazole (3h)

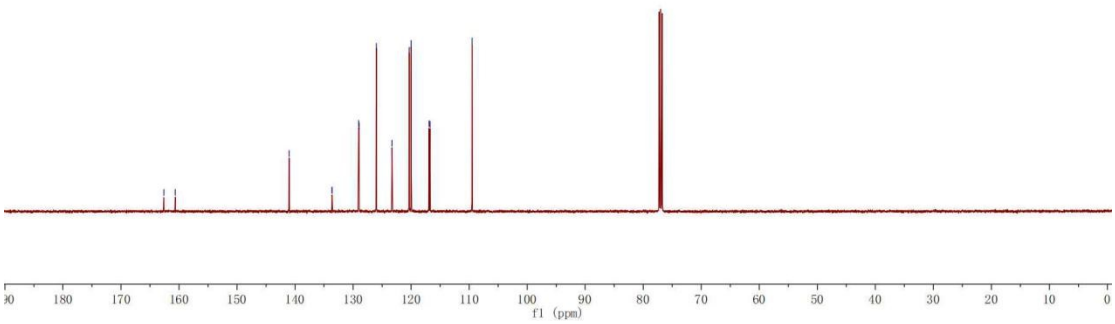


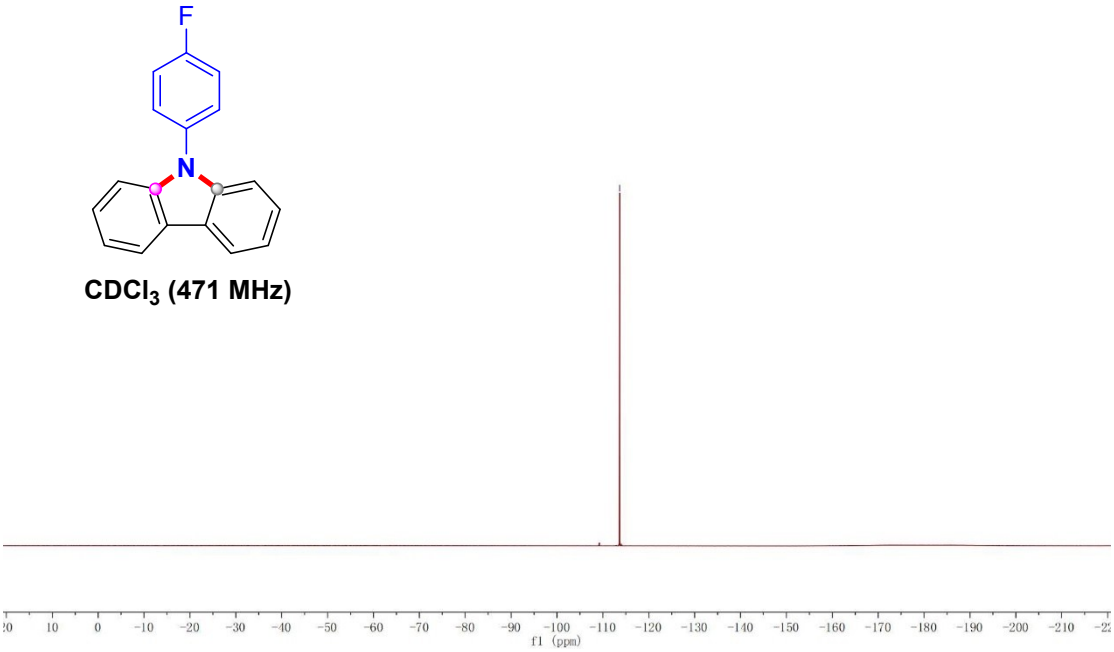
$CDCl_3$ (500 MHz)



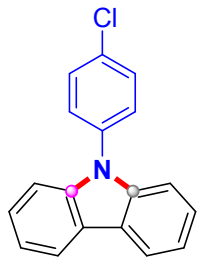


$CDCl_3$ (126 MHz)

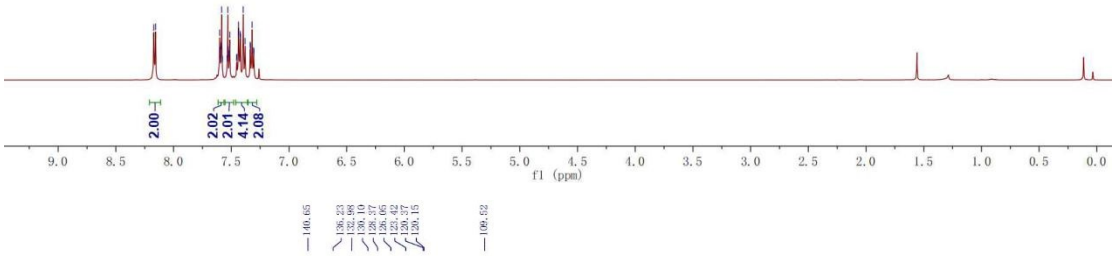


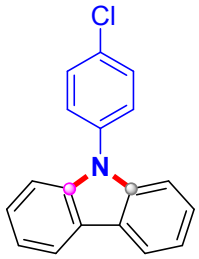

F
N
CDCl3 (471 MHz)
-118.66
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

9-(4-chlorophenyl)-9H-carbazole (3i)

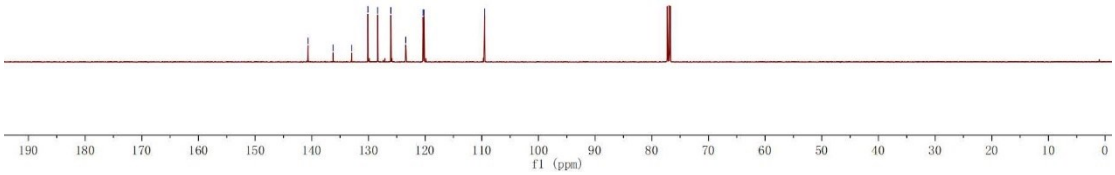


$CDCl_3$ (500 MHz)

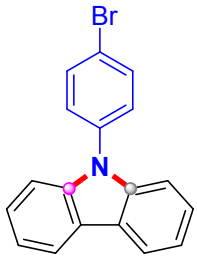




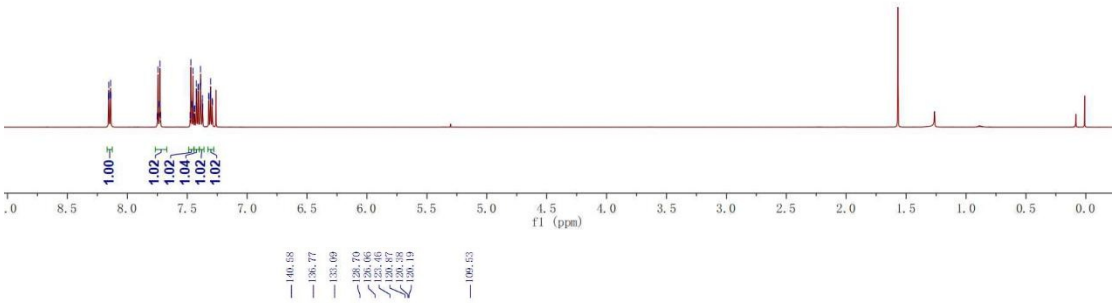
$CDCl_3$ (126 MHz)

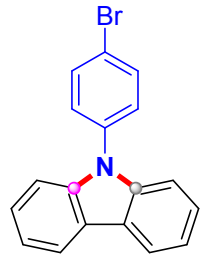


9-(4-bromophenyl)-9H-carbazole (3j)

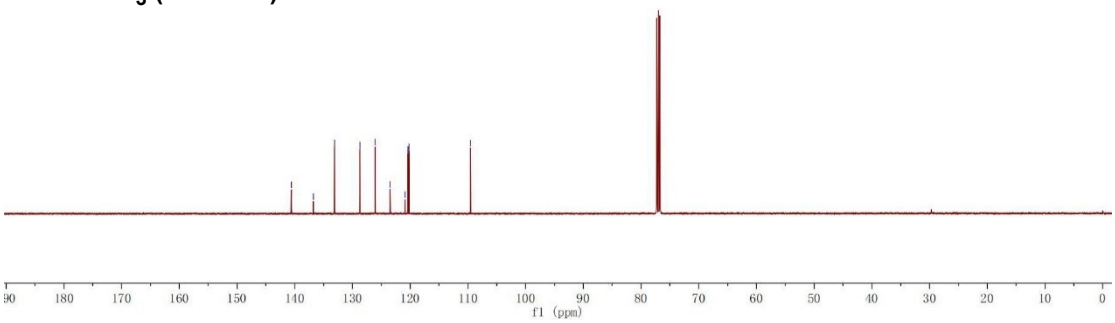


$CDCl_3$ (500 MHz)

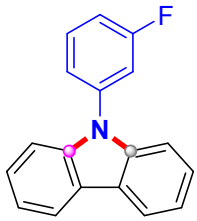




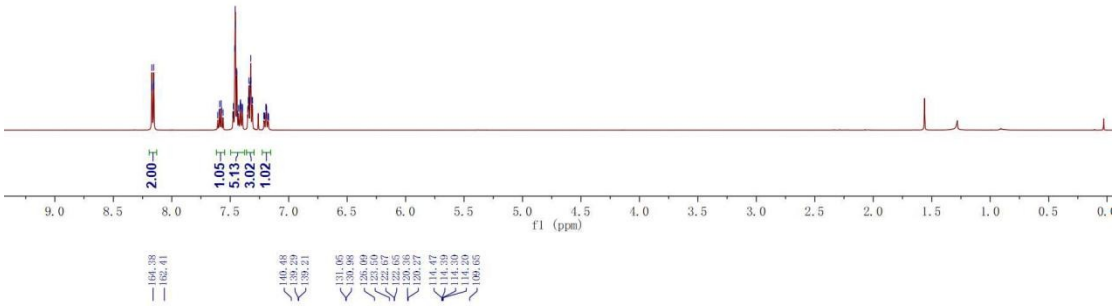
$CDCl_3$ (126 MHz)

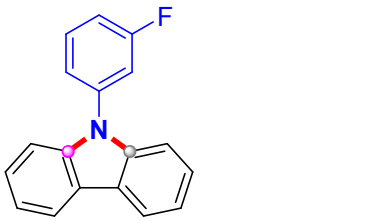


9-(3-fluorophenyl)-9H-carbazole (3k)

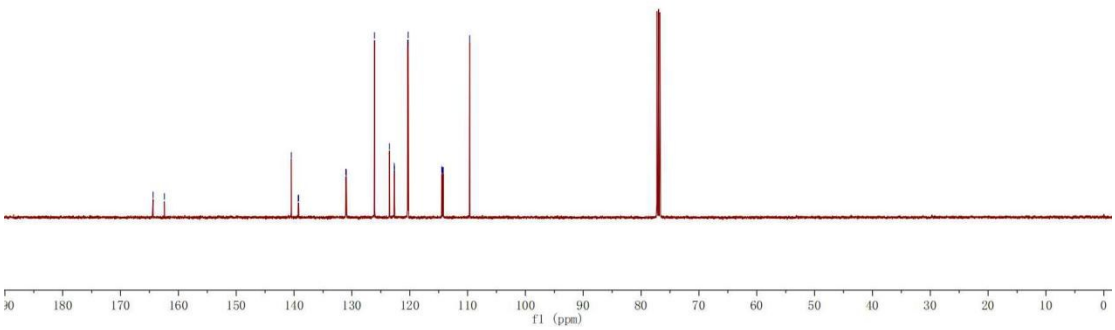


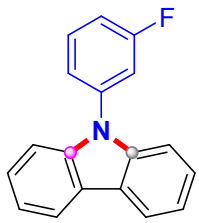
$CDCl_3$ (500 MHz)





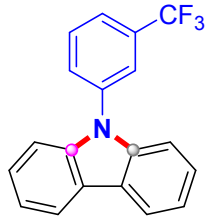
$CDCl_3$ (126 MHz)



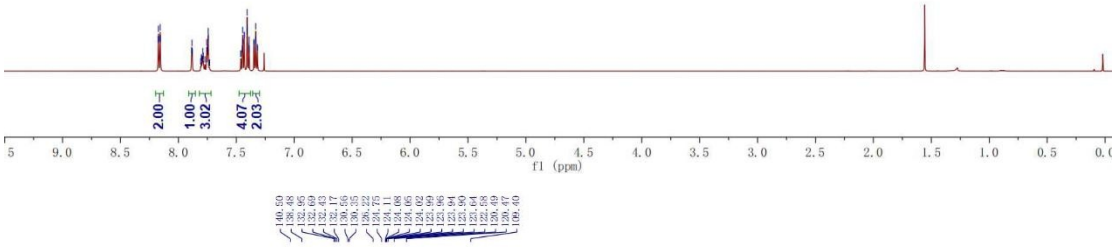


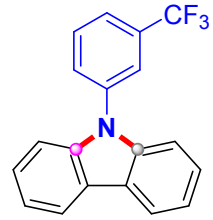
$CDCl_3$ (471 MHz)

9-(3-(trifluoromethyl)phenyl)-9H-carbazole (3l)

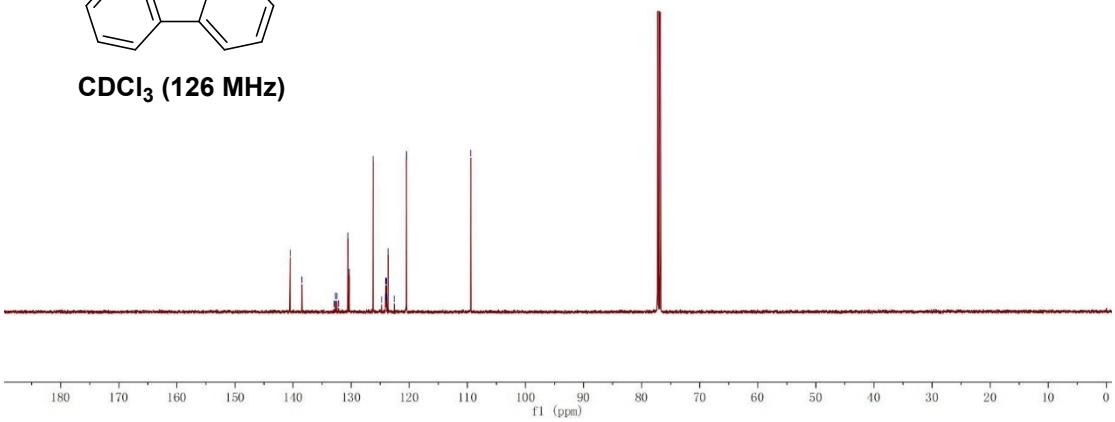


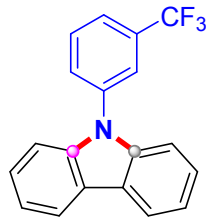
$CDCl_3$ (500 MHz)





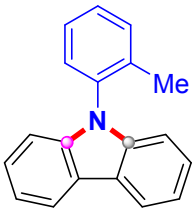
$CDCl_3$ (126 MHz)



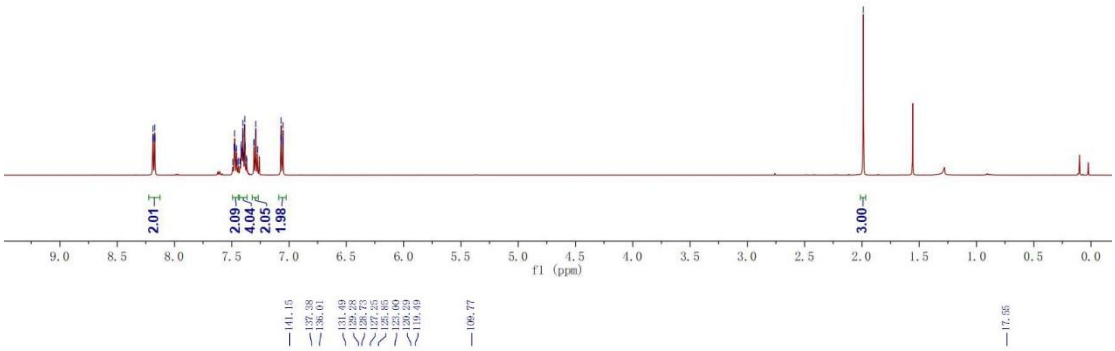


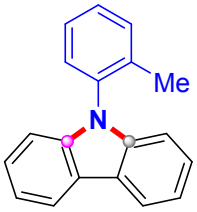
$CDCl_3$ (471 MHz)

9-(o-tolyl)-9H-carbazole (3m)

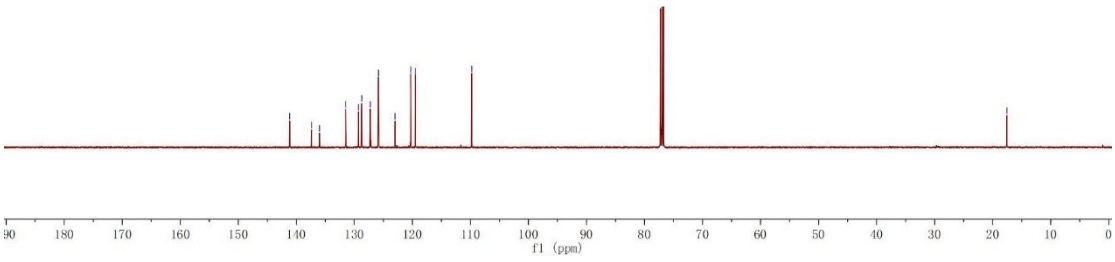


$CDCl_3$ (500 MHz)

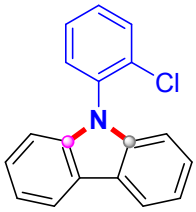




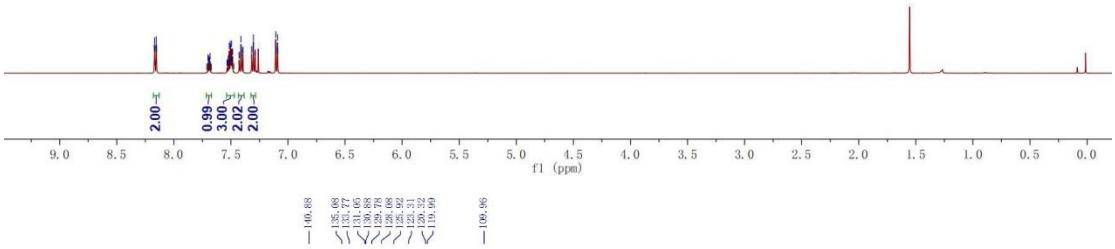
$CDCl_3$ (126 MHz)

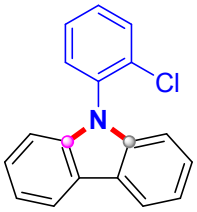


9-(2-chlorophenyl)-9H-carbazole (3n)

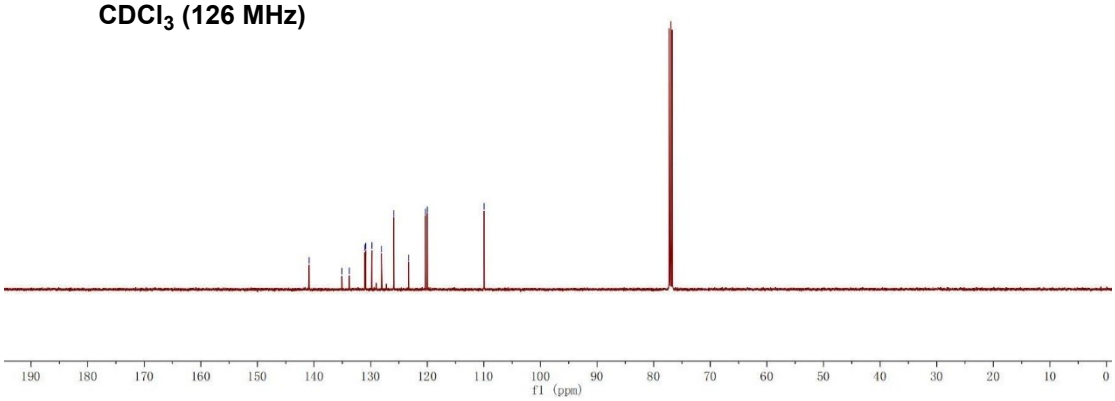


$CDCl_3$ (500 MHz)

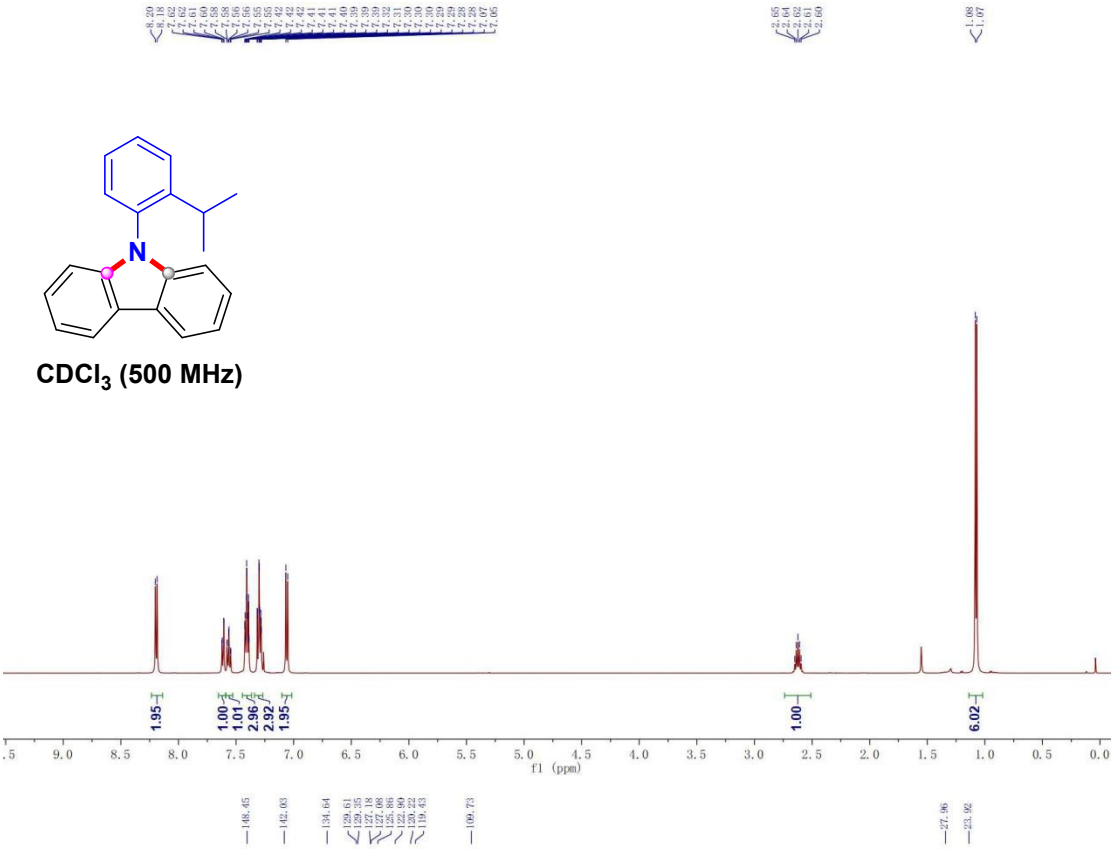




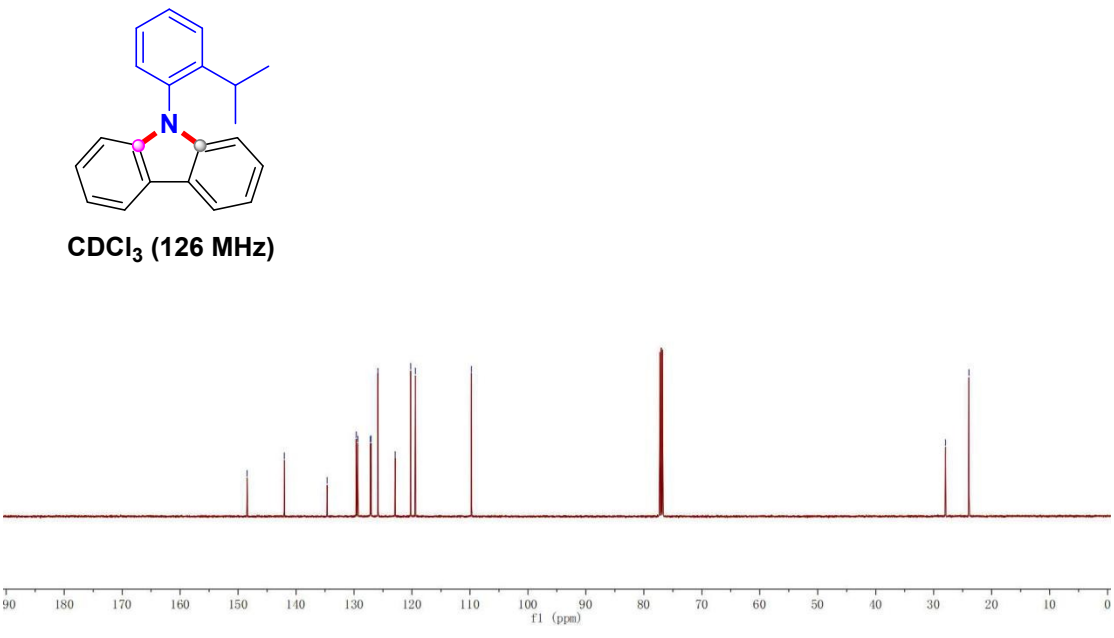
$CDCl_3$ (126 MHz)



9-(2-isopropylphenyl)-9H-carbazole (3o)

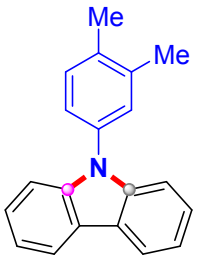


$CDCl_3$ (500 MHz)

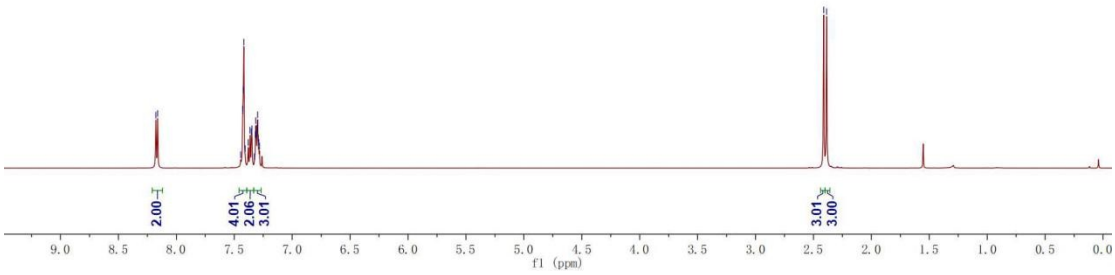


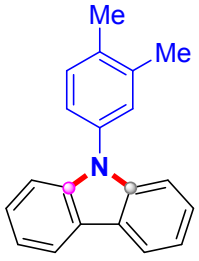
$CDCl_3$ (126 MHz)

9-(3,4-dimethylphenyl)-9H-carbazole (3p)

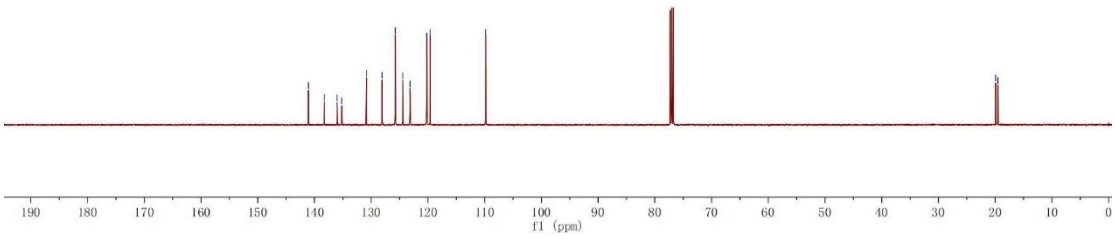


$CDCl_3$ (500 MHz)

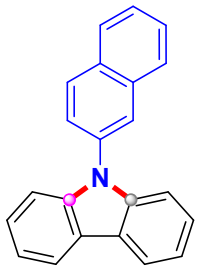




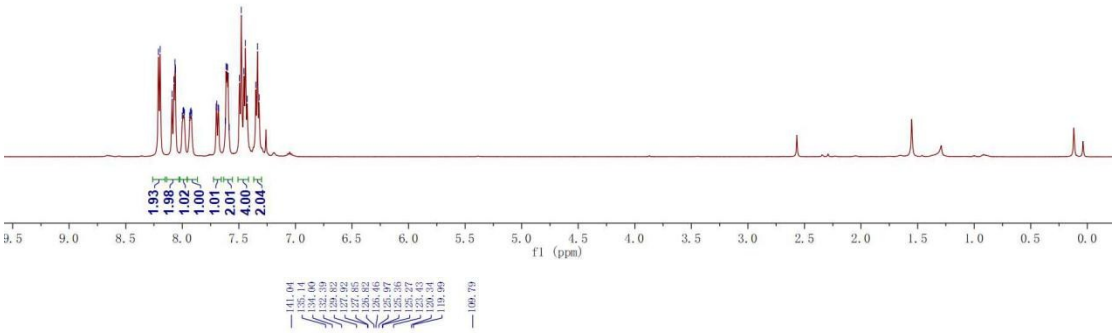
$CDCl_3$ (126 MHz)

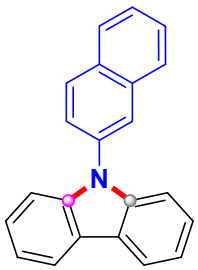


9-(naphthalen-2-yl)-9H-carbazole (3q)

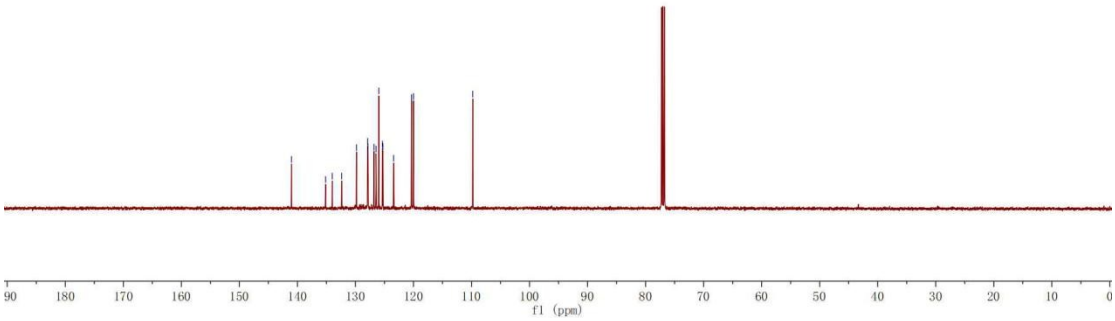


$CDCl_3$ (500 MHz)

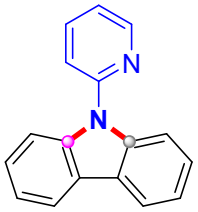




$CDCl_3$ (126 MHz)



9-(pyridin-2-yl)-9H-carbazole (3r)



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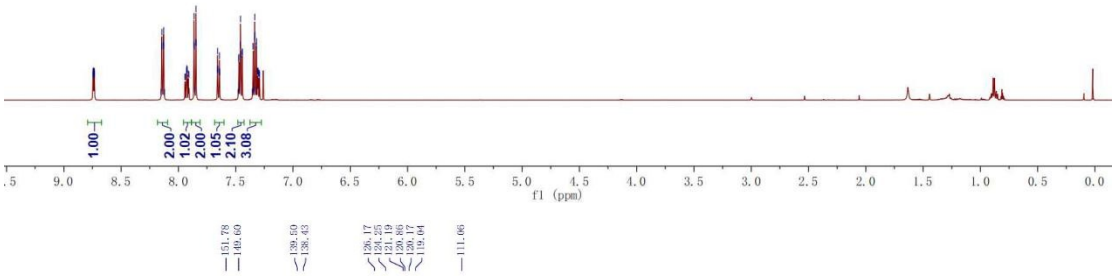
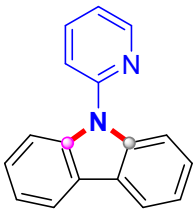
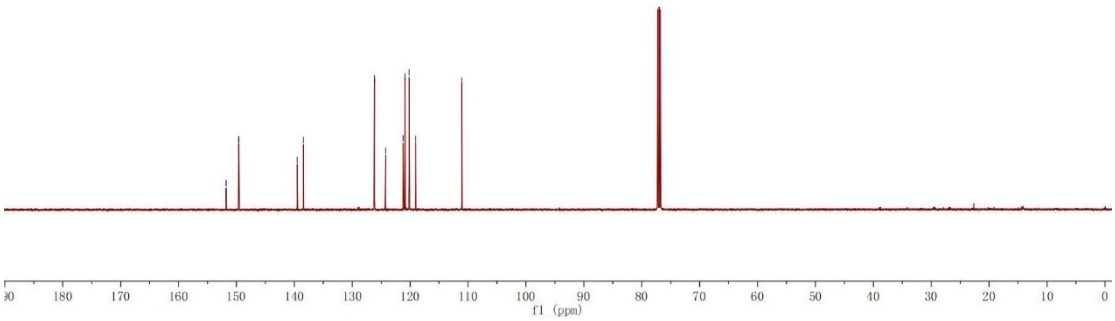
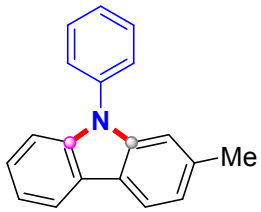




$CDCl_3$ (126 MHz)



2-methyl-9-phenyl-9H-carbazole (4a)



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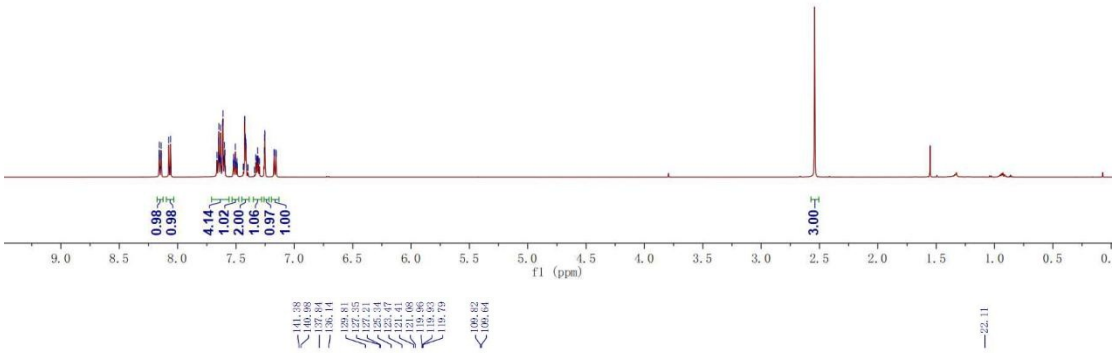
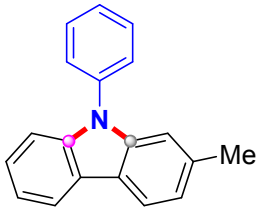
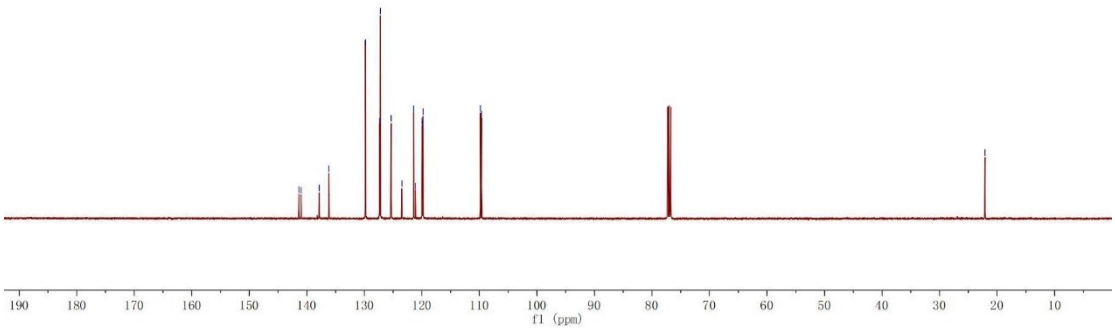
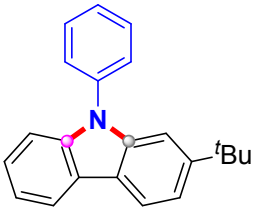




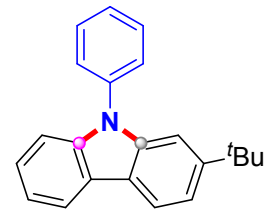
$CDCl_3$ (126 MHz)



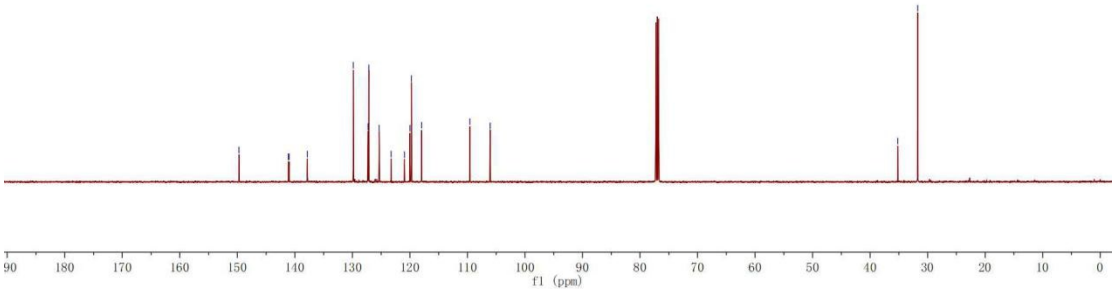
2-(tert-butyl)-9-phenyl-9H-carbazole (4b)



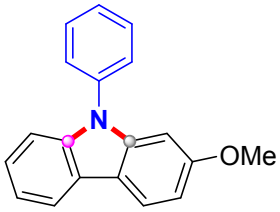
$CDCl_3$ (500 MHz)



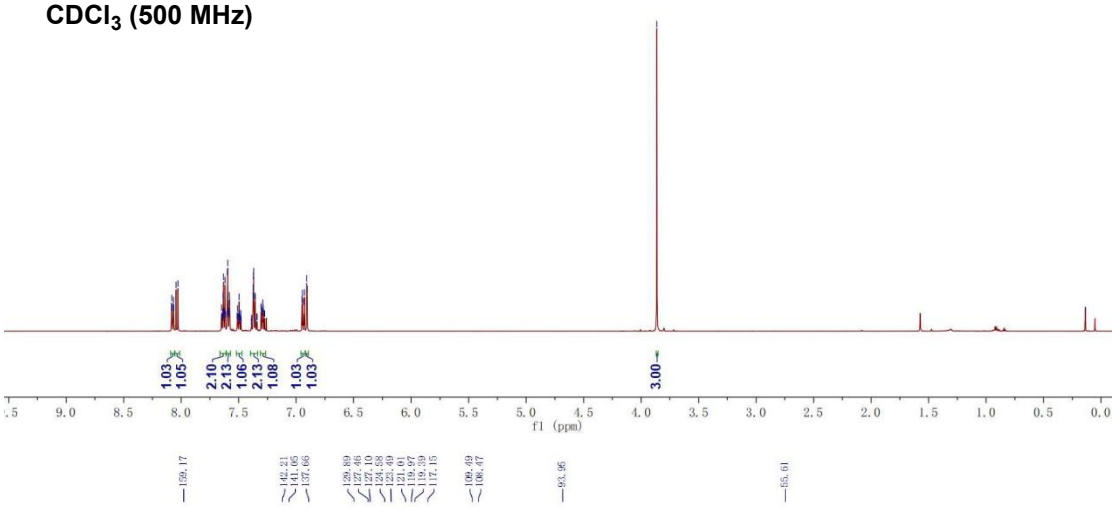
$CDCl_3$ (126 MHz)

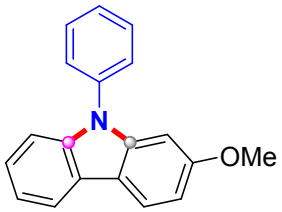


2-methoxy-9-phenyl-9H-carbazole (4c)

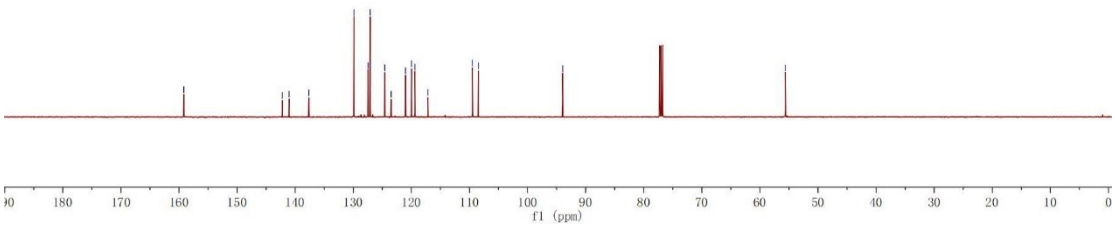


$CDCl_3$ (500 MHz)

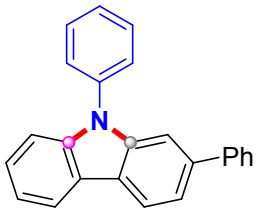




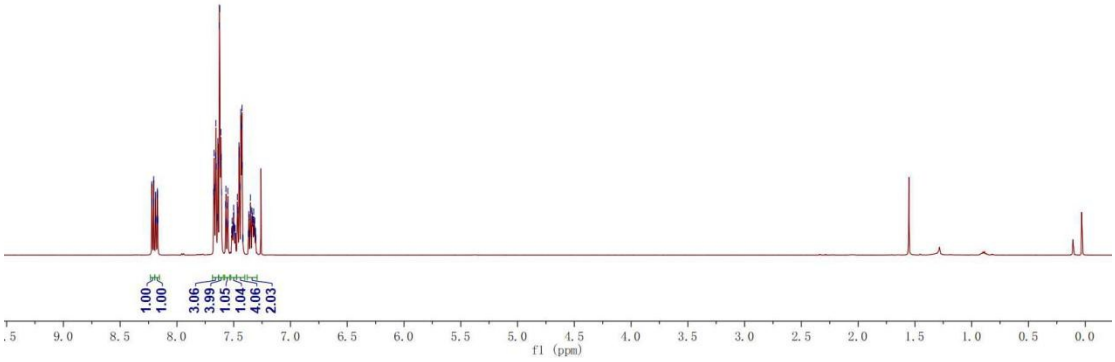
$CDCl_3$ (126 MHz)

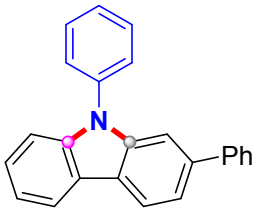


2,9-diphenyl-9H-carbazole (4d)

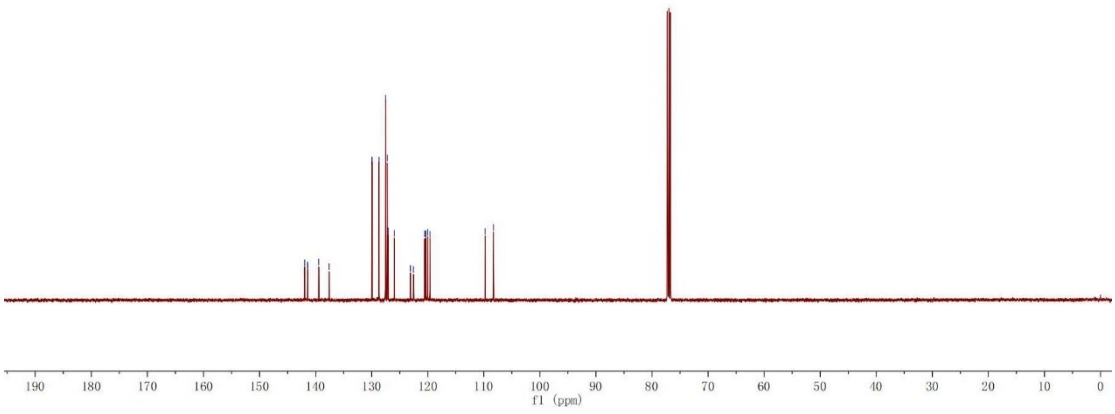


$CDCl_3$ (500 MHz)

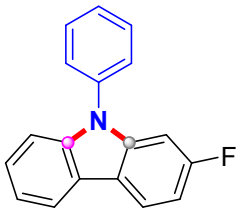




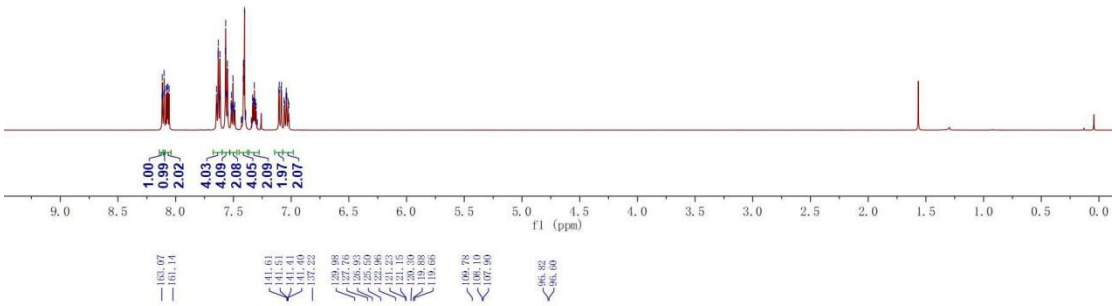
$CDCl_3$ (126 MHz)

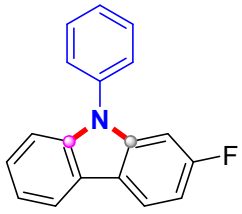


2-fluoro-9-phenyl-9H-carbazole (4e)

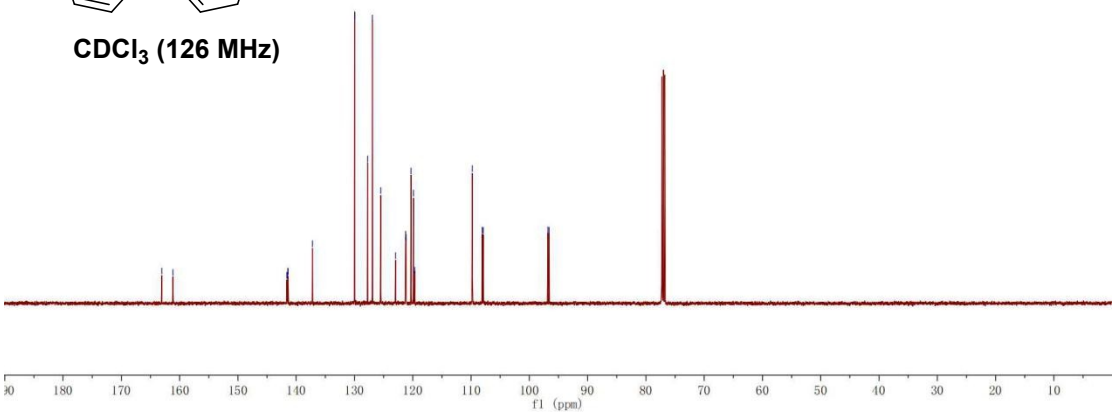


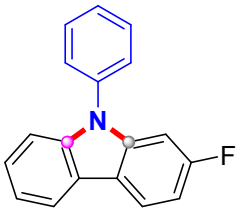
$CDCl_3$ (500 MHz)



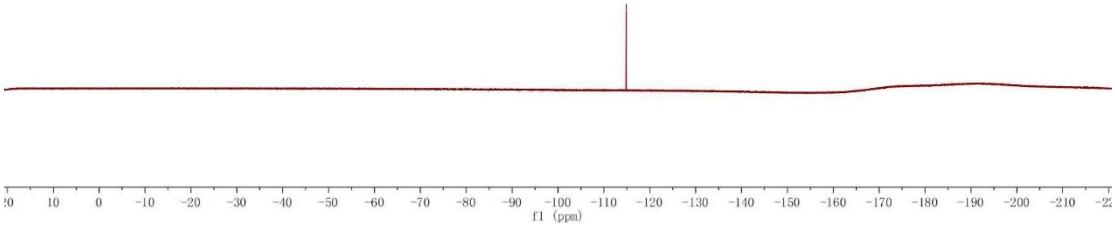


$CDCl_3$ (126 MHz)

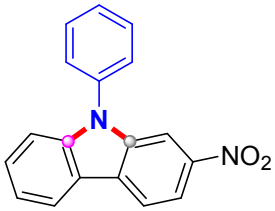




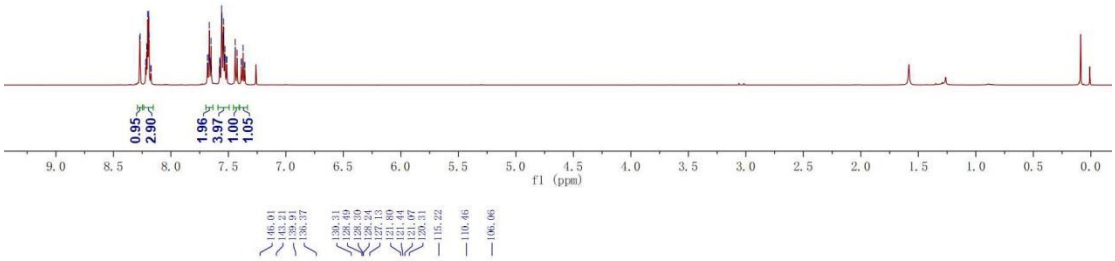
$CDCl_3$ (471 MHz)

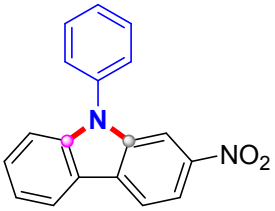


2-nitro-9-phenyl-9H-carbazole (4f)

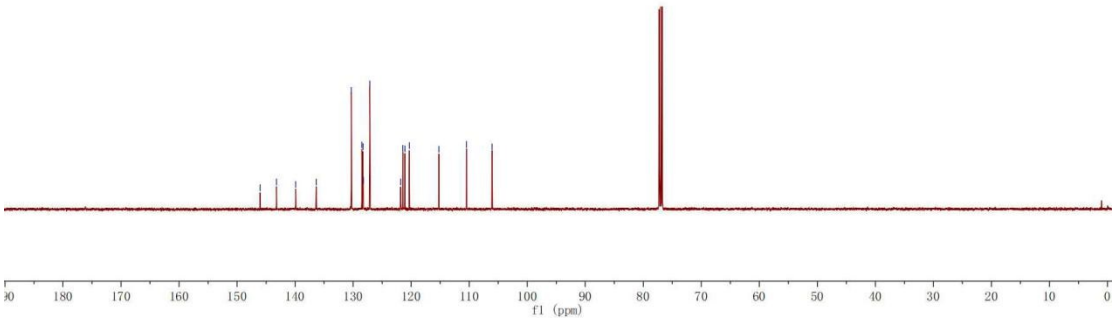


$CDCl_3$ (500 MHz)

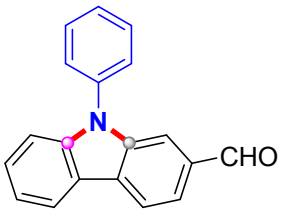




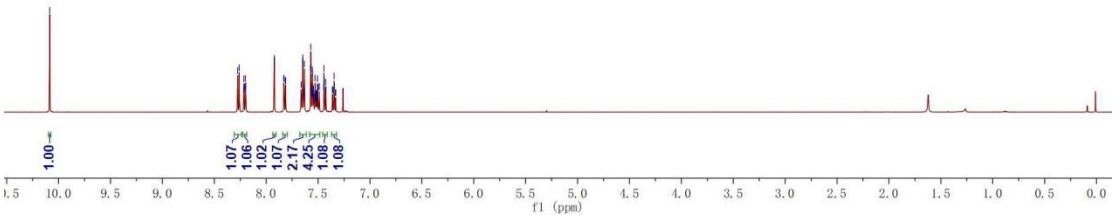
$CDCl_3$ (126 MHz)

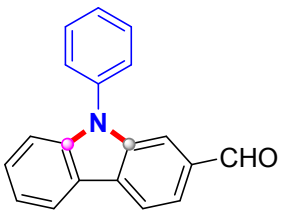


9-phenyl-9H-carbazole-2-carbaldehyde (4g)

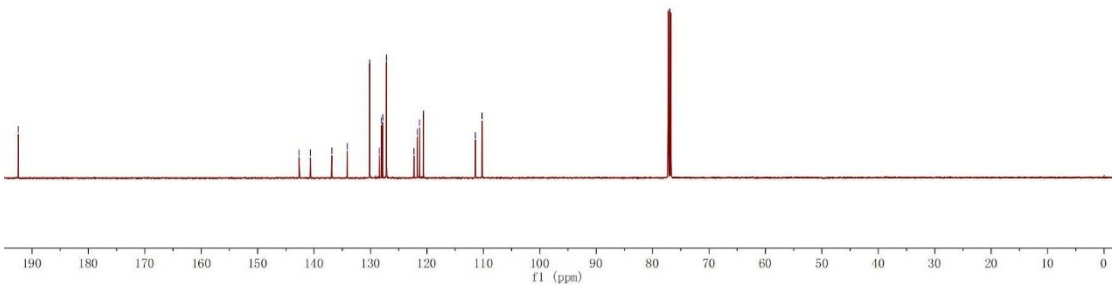


$CDCl_3$ (500 MHz)

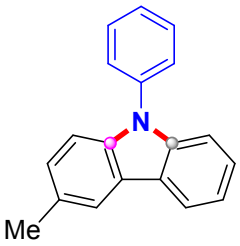




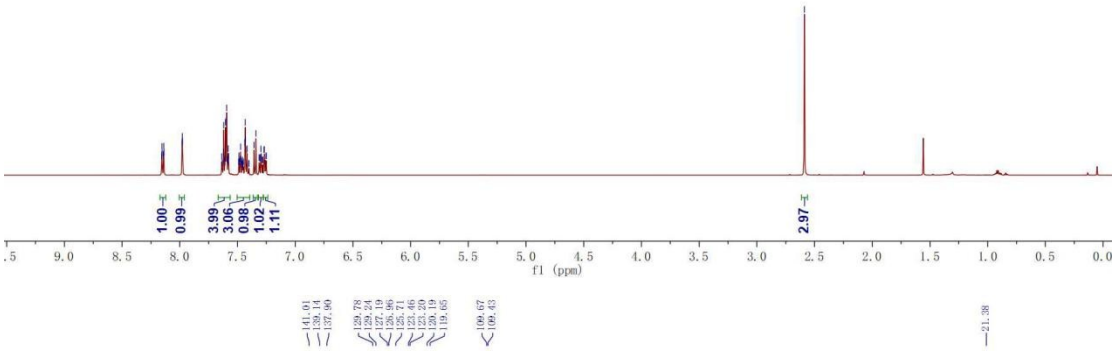
$CDCl_3$ (126 MHz)

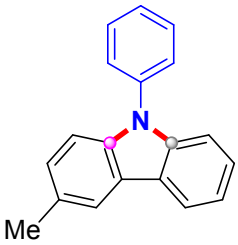


3-methyl-9-phenyl-9H-carbazole (4h)

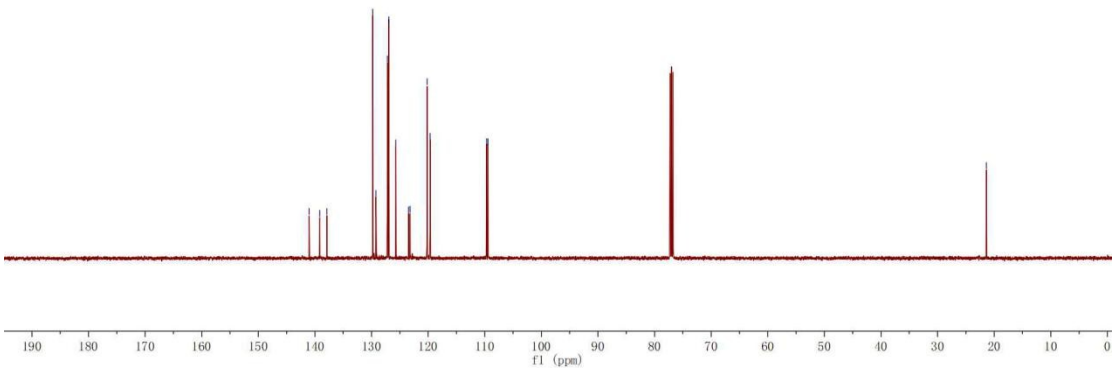


$CDCl_3$ (500 MHz)

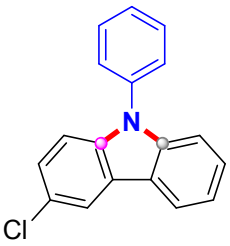




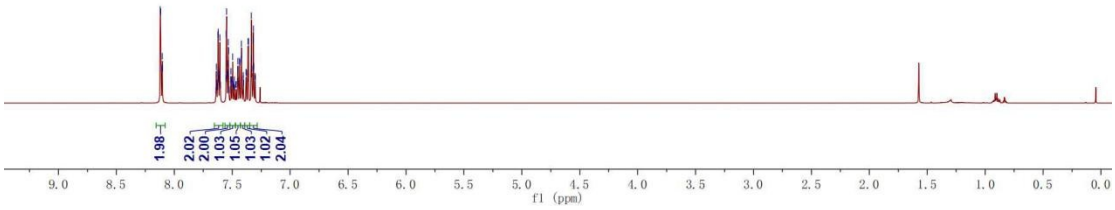
$CDCl_3$ (126 MHz)

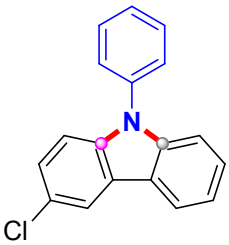


3-chloro-9-phenyl-9H-carbazole (4i)

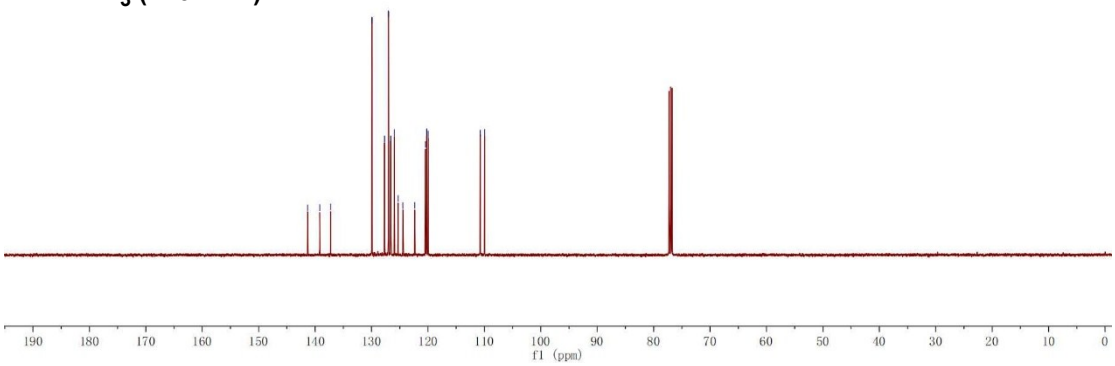


$CDCl_3$ (500 MHz)

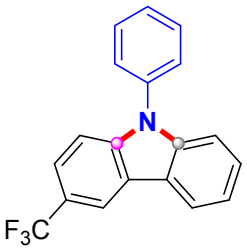




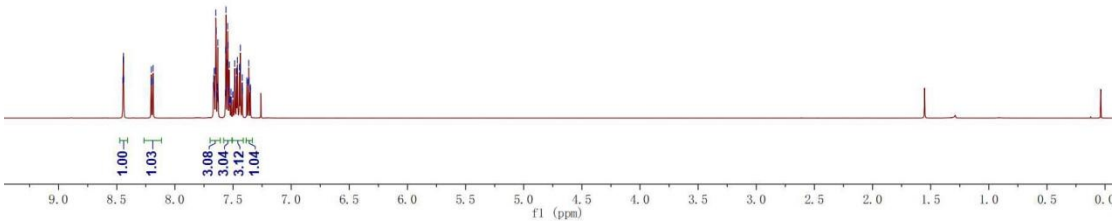
$CDCl_3$ (126 MHz)

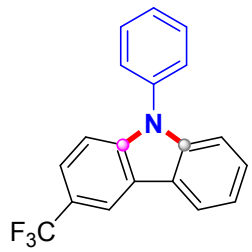


9-phenyl-3-(trifluoromethyl)-9H-carbazole (4j)

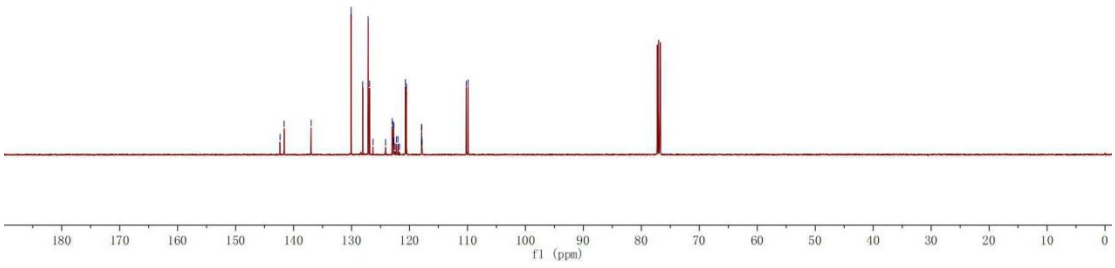


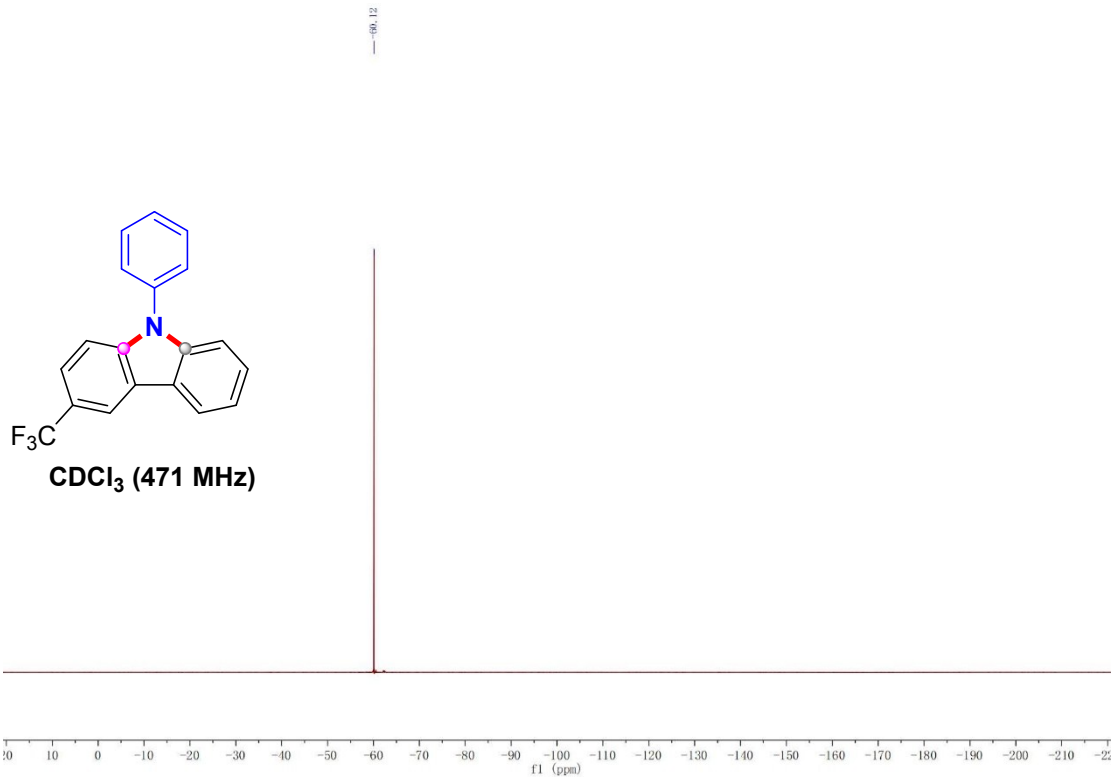
$CDCl_3$ (500 MHz)





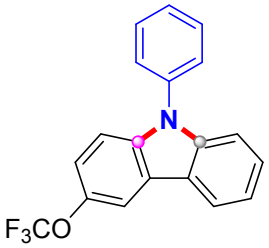
$CDCl_3$ (126 MHz)



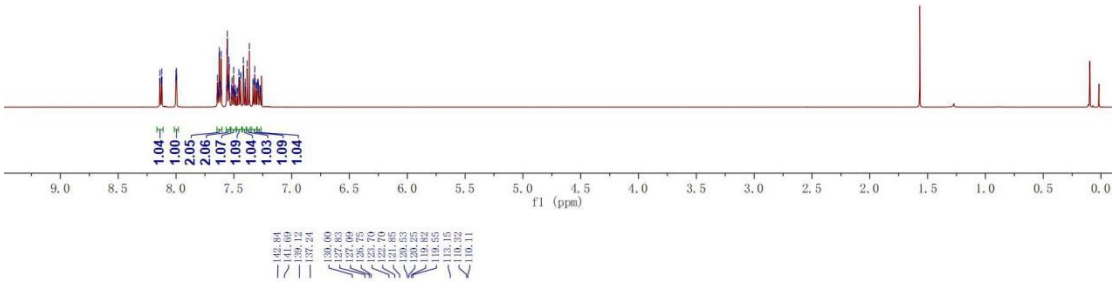


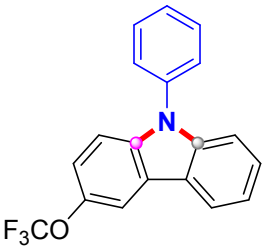
$CDCl_3$ (471 MHz)

9-phenyl-3-(trifluoromethoxy)-9H-carbazole (4k)

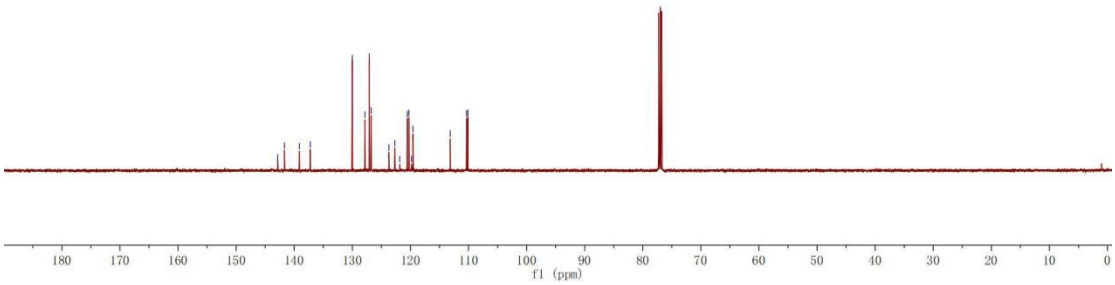


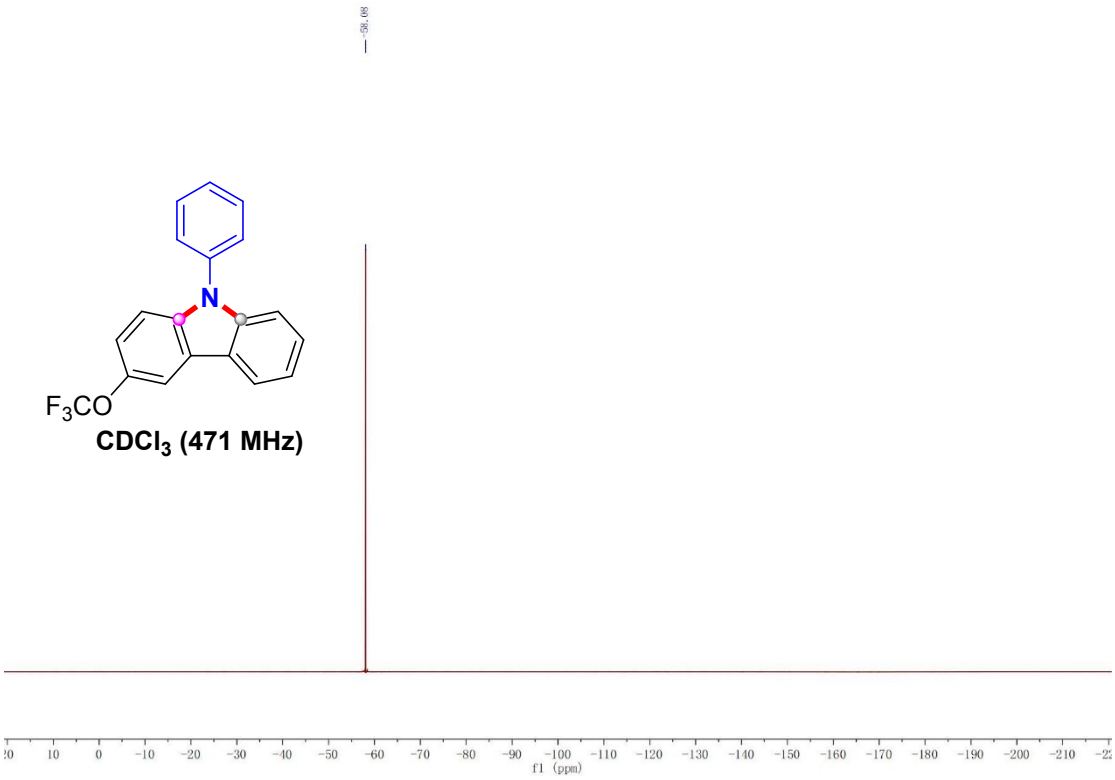
$CDCl_3$ (500 MHz)



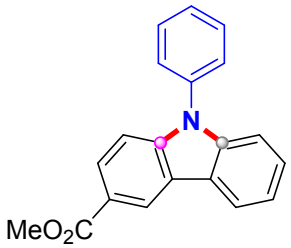


$CDCl_3$ (126 MHz)

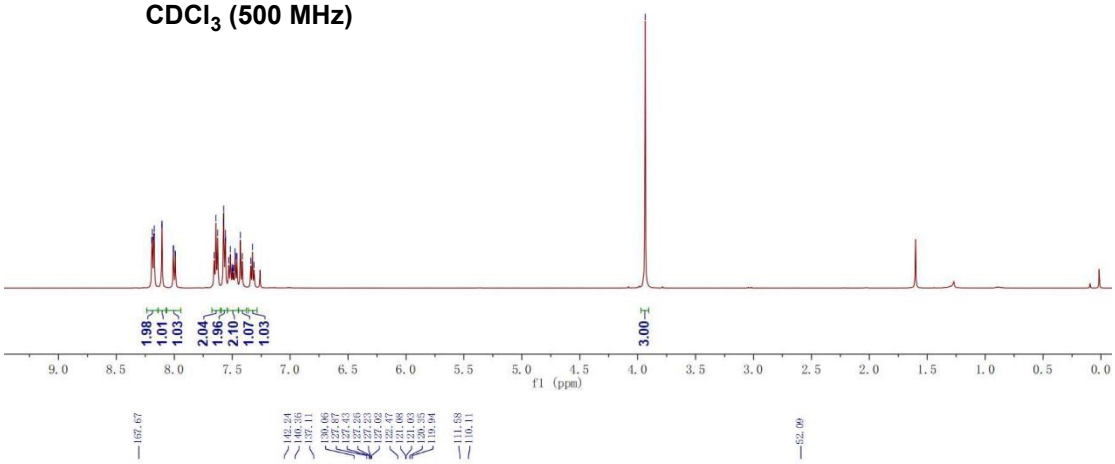


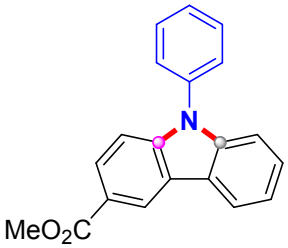

-56.68
N
F3CO
CDCl3 (471 MHz)
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

methyl 9-phenyl-9H-carbazole-3-carboxylate (4l)

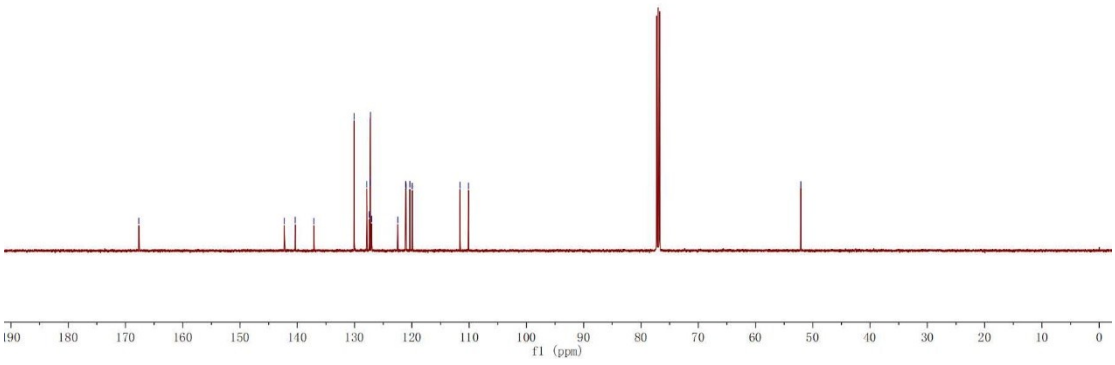


$CDCl_3$ (500 MHz)

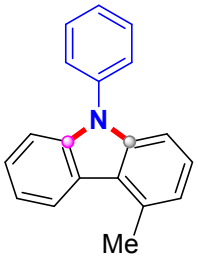




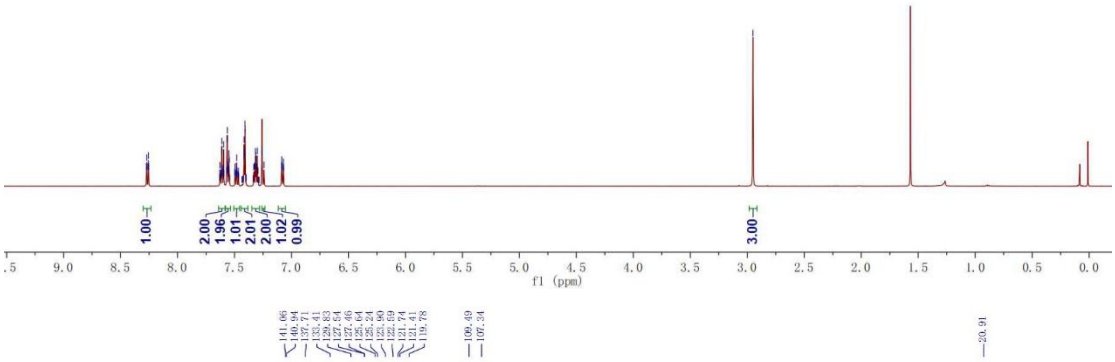
$CDCl_3$ (126 MHz)

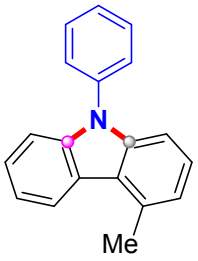


4-methyl-9-phenyl-9H-carbazole (4m)

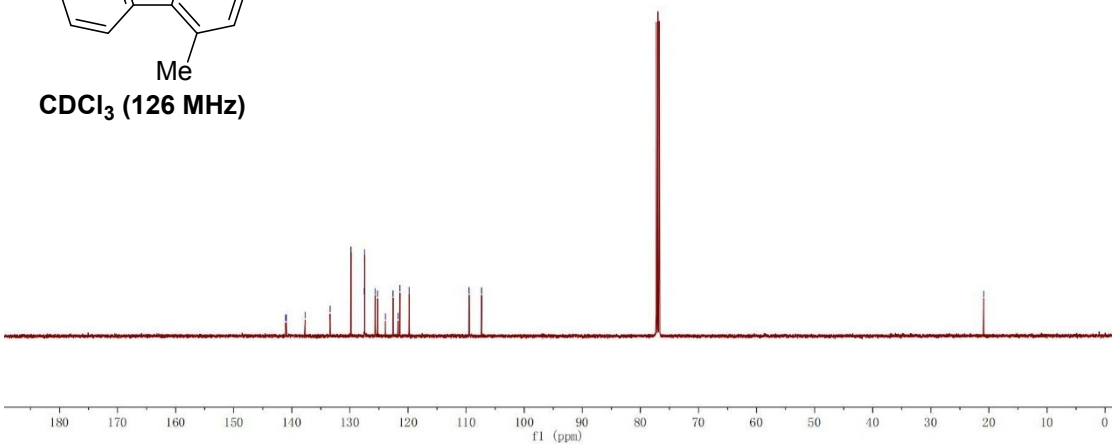


$CDCl_3$ (500 MHz)

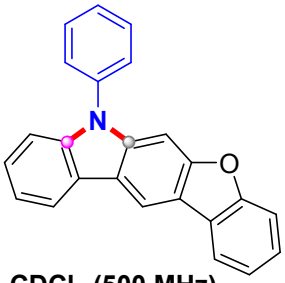




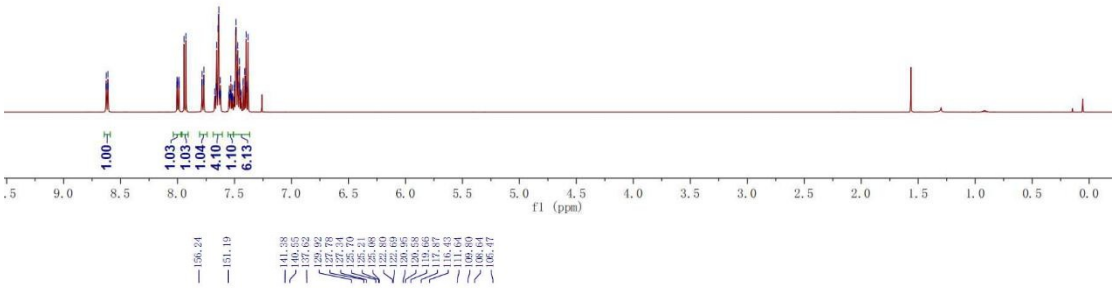
$CDCl_3$ (126 MHz)

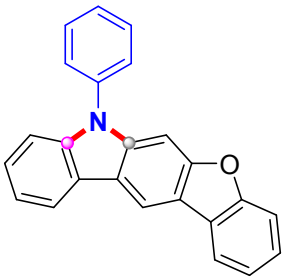


7-phenyl-7H-benzofuro[2,3-b]carbazole (4n)

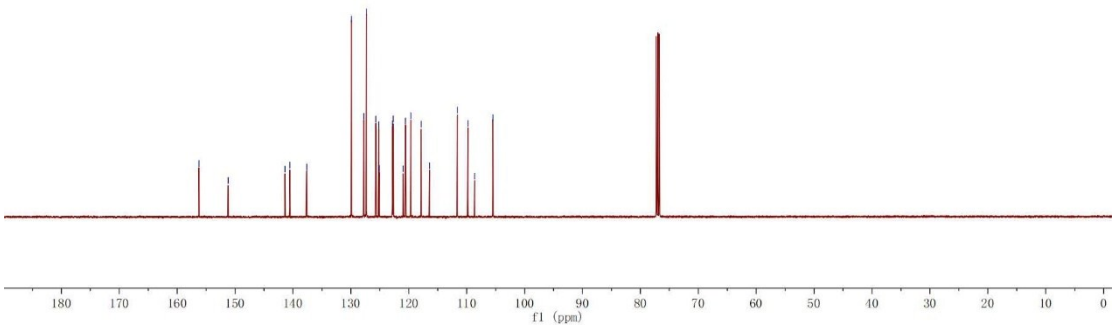


$CDCl_3$ (500 MHz)

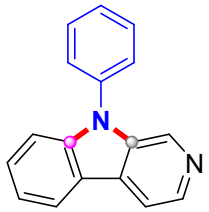




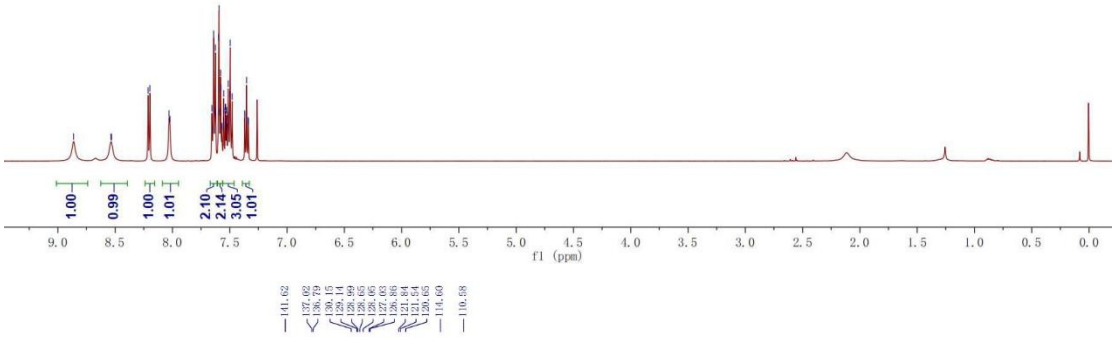
$CDCl_3$ (126 MHz)

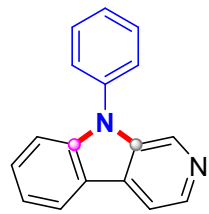


9-phenyl-9H-pyrido[3,4-b]indole (4o)

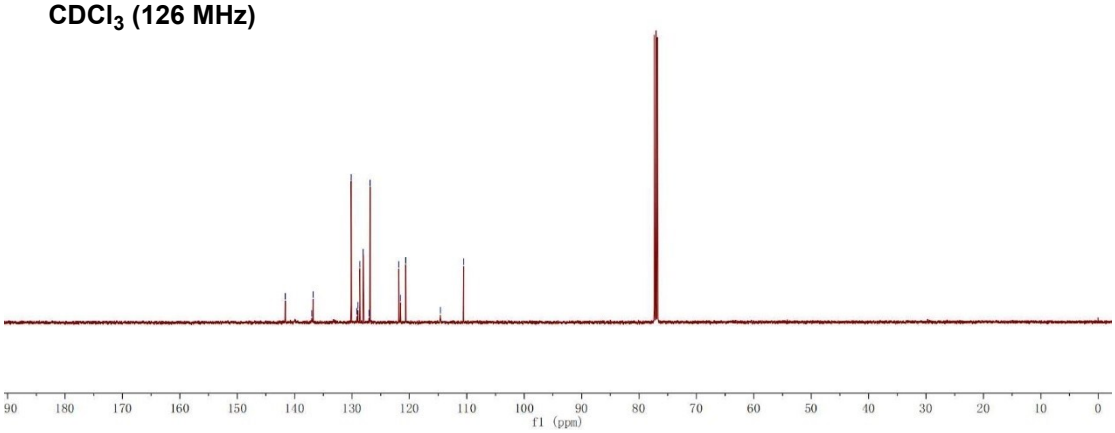


$CDCl_3$ (500 MHz)

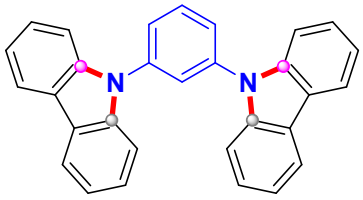




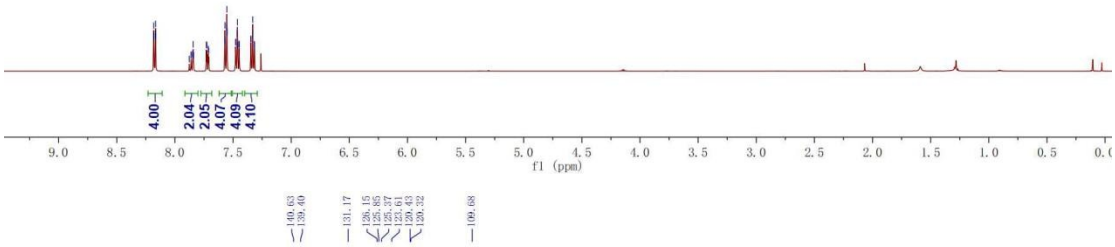
$CDCl_3$ (126 MHz)

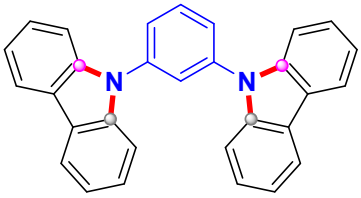


1,3-di(9H-carbazol-9-yl)benzene (5)



$CDCl_3$ (500 MHz)





$CDCl_3$ (126 MHz)