Electronic Supplementary Material (ESI) for Green Chemistry.

Supporting information

Generation of Aryl Radicals from *in situ* Activated Homolytic Scission: Driving Radical Reactions by Ball Milling

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1. General information

Unless otherwise stated, all reagents were purchased from commercial suppliers and used without further purification. All of the ball milling reactions were conducted in a Mixer mill (MM 400 RetschGmbh, Hann, Germany) with 15 mL stainless steel grinding vessels with stainless steel balls, if not mentioned otherwise. Reactions were monitored by Thin Layer Chromatography (TLC) using UV light (254/365 nm) for detection. ^{1}H, ^{13}C and ^{19}F NMR spectra were recorded on Bruker 400, 500 or 600 MHz spectrometer in $CDCl_3$ or d_6-DMSO with tetramethylsilane (TMS) as internal standard. The following abbreviations were used to explain multiplicities: s = singlet, brs = broad singlet, d = doublet, t = triplet, dd = doublet of doublets, m = multiplet and the *J* coupling constants were reported in Hertz unit (Hz). Melting points were measured using an SRS OptiMelt MPA100 apparatus and were uncorrected. High Resolution Mass spectra (HRMS) and LC-MS spectra were recorded on an Agilent 6210 LC/TOFMS. GC-MS experiments in mechanism analysis was performed on an Agilent 6890 GC coupled to Waters GCT Premier TOF MS. X-ray diffraction (XRD) patterns were recorded with a PANalytical X'Pert PRO powder diffractometer using Cu Kα radiation (λ= 0.1541 nm). The working voltage was 40 kV and the working current was 40 mA. The patterns were collected with a 2θ range from 10° to 70°. Crystal measurement was recorded on Bruker D8 Venture.

2. General procedures for the synthesis of substrates

2.1 The synthesis of aryldiazonium tetrafluoroborates

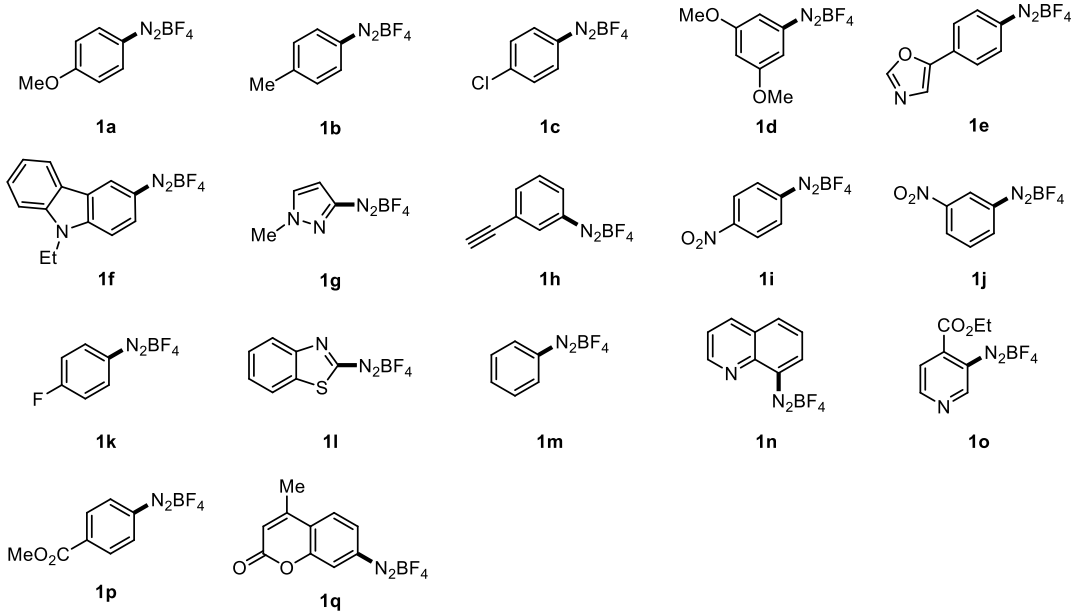


Fig. S1. Aryldiazonium tetrafluoroborates used in this study

All aryldiazonium tetrafluoroborates are known compounds and were synthesized from the corresponding anilines according to the reported procedures (**1a**~**1e**, **1i**~**1k**, **1m** and **1p**~**1q**, method A; **1f**~**1h** and **1n**~**1o**, method B; **1l**, method C).

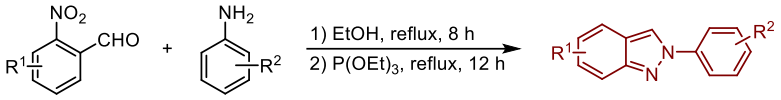
Method A[1]: In a 50 mL round-bottom flask, the aniline (10.0 mmol) was mixed at 0 °C with fluoroboric acid (50 wt.% in H_2O, 3.5 mL) and distilled water (4.0 mL). An aqueous solution of sodium nitrite (700 mg, 10.1 mmol, in 1.5 mL H_2O) was added gradually to the mixture. The mixture was then held at 0 °C for 30 min. The thick precipitate was collected by filtration and redissolved in a minimum amount of acetone. Diethyl ether was added until precipitation of the diazonium tetrafluoroborate, which

was filtered off and washed several times with diethyl ether and dried under vacuum.

Method B[2]: In a 50 mL round-bottom flask, the aniline (10 mmol) was dissolved in a mixture of absolute ethanol (3 mL) and aqueous solution of fluoroboric acid (50 wt.% in H_2O, 2.5 mL). The *tert*-butyl nitrite (2.7 mL) was added dropwise to the solution at 0 °C. The mixture was stirred at room temperature for 1.0 h and diethyl ether (20 mL) was added to precipitate the diazonium tetrafluoroborate. The solid was filtered off and washed with diethyl ether and dried under vacuum.

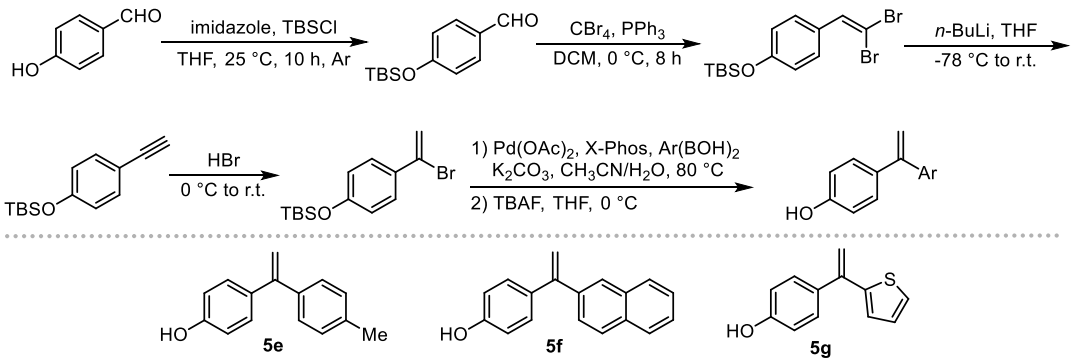
Method C[3]: In a 50 mL round-bottom flask, the benzo[*d*]thiazol-2-amine (6.6 mmol) was mixed at 0 °C with fluoroboric acid (50 wt.% in H_2O, 13 mL). 1.0 mL of concentrated H_2SO_4 and 0.48 g (6.8 mmol) of 30% sodium nitrite solution was added gradually to the mixture. The mixture was then held at 0 °C for 1.5 h. The diazonium salts was removed by filtration, washed successively with a small amount of fluoroboric acid, ice water, alcohol, ether and dried under vacuum.

2.2 The synthesis of substrates 2a~2i



A solution of aniline (6.0 mmol, 1.0 equiv.), and 2-nitrobenzaldehyde (6.0 mmol, 1.0 equiv.) in EtOH (0.5 M) was refluxed for 8 h. The resulting crystalline solid was collected by filtration, and dried under reduced pressure. The collected solid was refluxed for 12 h in triethyl phosphite (60.0 mmol, 10.0 equiv.). The resulting mixture was distilled under reduced pressure to remove triethyl phosphite. Purification by column chromatography with EtOAc/hexane afforded the desired products (65–85%).

2.3 The synthesis of substrates 5e~5g



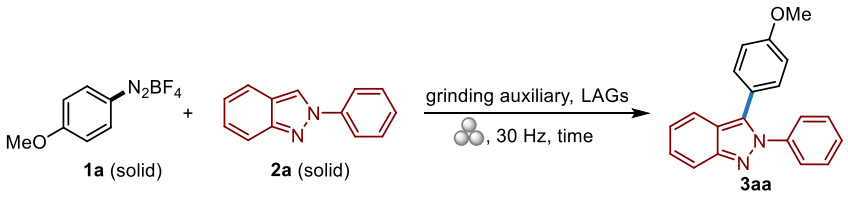
5e~5g were synthesized according to the procedures previously reported.[4]

3. Reaction optimization & typical procedures

3.1 Radical C−H (hetero)arylation reaction of indazoles

To begin the investigation, starting material **1a** and **2a** were milled together under an air atmosphere with NaCl (1.0 g) (Table S1, entry 1). As expected, the desired arylation product **3aa** was obtained in 15% yield. As the small amount of liquid has a strong influence on solid-state reaction outcomes,[5] we envision LAGs could also be used to facilitate this radical C−H (hetero)arylation reaction. Thus, examination using DMSO and DMF as additives (η = 0.051 μL/mg) was performed under the initial conditions (Table S1, entries 2−3). However, the improvement of yields was not significant, a negative effect was considered: rapid decomposition of aryldiazonium salts (after dissolving 20 mg aryldiazonium salt **1a** in 2 mL DMSO or DMF, the solution gradually changed from clear to dark red in 10 minutes). Low-polarity

Table S1. Optimization of the radical C−H arylation reaction of **1a** and **2a**[a]



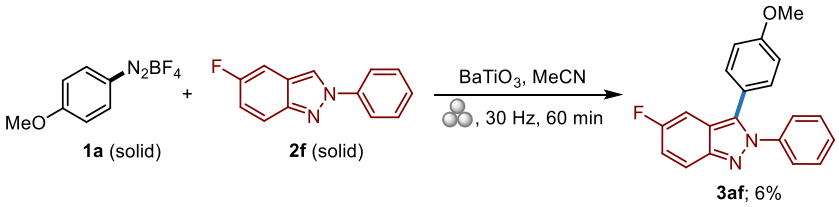
entry	**1a** (equiv.)	grinding auxiliary (g)	LAGs (η = μL/mg)	time (min)	yield (%)[b]
1	2.0	NaCl (1.0)	none	30	15
2	2.0	NaCl (1.0)	DMSO (0.051)	30	20
3	2.0	NaCl (1.0)	DMF (0.051)	30	32
4	2.0	NaCl (1.0)	*n*-hexane (0.051)	30	42
5	2.0	NaCl (1.0)	*n*-heptane (0.051)	30	35
6	2.0	NaCl (1.0)	THF (0.051)	30	59
7	2.0	NaCl (1.0)	dioxane (0.051)	30	51
8	2.0	NaCl (1.0)	MeCN (0.051)	30	55
9	2.0	NaCl (1.0)	CH_2Cl_2 (0.051)	30	55
10	2.0	NaCl (1.0)	Et_2O (0.051)	30	55
11	2.0	NaCl (1.0)	EtOAc (0.051)	30	60
12	2.0	KCl/LiCl (1.0)	EtOAc (0.051)	30	58/23
13	2.0	NaBr/KBr/LiBr (1.0)	EtOAc (0.051)	30	55/35/trace
14	2.0	$NaBF_4$ (1.0)	EtOAc (0.051)	30	n.d.
15	2.0	neutral Al_2O_3 (1.0)	EtOAc (0.051)	30	n.d.
16	2.0	NaCl (0.8)	EtOAc (0.051)	30	58
17	2.0	NaCl (0.6)	EtOAc (0.051)	30	44
18	1.5	NaCl (1.0)	EtOAc (0.051)	30	39
19	1.67	NaCl (1.0)	EtOAc (0.051)	30	55
20	2.25	NaCl (1.0)	EtOAc (0.051)	30	57
21	2.5	NaCl (1.0)	EtOAc (0.051)	30	77/42[c]/62[d]
22	2.75	NaCl (1.0)	EtOAc (0.051)	30	73
23	2.5	NaCl (1.0)	EtOAc (0.017)	30	44
24	2.5	NaCl (1.0)	EtOAc (0.033)	30	57
25	2.5	NaCl (1.0)	EtOAc (0.066)	30	84
26	2.5	NaCl (1.0)	EtOAc (0.083)	30	68
27	2.5	NaCl (1.0)	EtOAc (0.066)	20	82
28	2.5	NaCl (1.0)	EtOAc (0.066)	40	82
29	2.5	NaCl (1.0)	EtOAc (0.066)	30	n.d.[e]

[a] Reaction conditions: **1a**, **2a** (0.3 mmol, 1.0 equiv.), LAGs and grinding auxiliary were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz. [b] Isolated yields. [c] Stainless-steel ball (d_{MB} = 1.2 cm). [d] Stainless-steel ball (d_{MB} = 1.6 cm). [e] Without stainless-steel ball. n.d. = not detected.

alkanes as *n*-hexane and *n*-heptane gave low positive-effect, probably due to low solubility of indazole **2a** in them (Table S1, entries 4−5). Other solvents such as THF, dioxane, MeCN, DCM, Et_2O and EtOAc increased the yields notably. They were beneficial both to the dissolution of indazoles and to the stabilization of aryldiazonium salts (Table S1, entries 6−11). Among them, EtOAc gave the best

performance, therefore, our investigation was continued with EtOAc as the LAG additive (Table S1, entry 11). It is delighted to find that most of the halogen salts improved the reaction efficiency (Table S1, entries 12−13), while non-halogen salts such as $NaBF_4$ and neutral Al_2O_3 gave no target products which is consistent with our hypothesis (Table S1, entries 14−15). The optimal reaction conditions (Table S1, entry 25) were finally obtained after a careful selection of reaction times, milling ball diameters and the amounts of NaCl, **1a** and EtOAc (Table S1, entries 16−28). *Control experiment without stainless-steel ball suggested that the strong mechanical impact provided by ball milling is essential for efficient aryl radicals generation (Table S1, entry 29).*

Condition A: Typical procedure for radical C−H (hetero)arylation reaction of indazoles: A mixture of aryldiazonium tetrafluoroborates **1a**~**1h** (0.75 mmol, 2.5 equiv.), **2a**~**2m** (0.3 mmol, 1.0 equiv.), EtOAc (η = 0.066) and NaCl (1.0 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm). Then, the ball milling vessel was placed in the mixer mill (30 Hz, 30 min). After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane to give desired product **3aa**~**3fa**, **3ab**~**3ah**, **3gg**, **3ha** (20 examples). Because **2i** is poorly soluble in EtOAc, high-polarity CH_2Cl_2 (η = 0.066) was used as LAG additive to get product **3ai**. Reaction time of **3aj**~**3am** and **3aj'** extended to 2 hours.

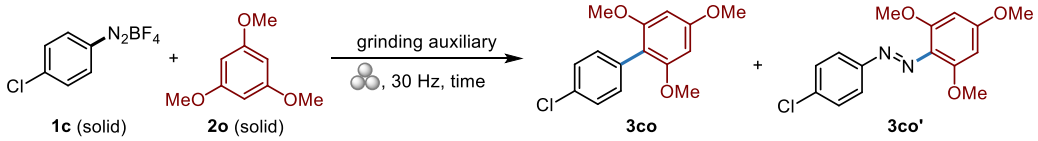


Scheme S1. Reaction conditions: **1a** (0.3 mmol, 1.0 equiv.), **2f** (1.5 mmol, 5.0 equiv.), MeCN (η = 0.12) and $BaTiO_3$ (1.5 mmol, 5.0 equiv.) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz for 60 min. After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane to give **3af**.

3.2 Radical C−H (hetero)arylation reaction of benzenes and other heteroarenes

When we turned to benzenes as radical accepters, an erosion of yield was found in the reaction of 4-chlorophenyldiazonium tetrafluoroborate **1c** and 1,3,5-trimethoxybenzene **2o** (Table S2, entry 1). To the best of our knowledge, a large excess of radical acceptors was always needed,[6] so we increased the amount of benzenes (Table S2, entry 2). Further examination of the grinding auxiliary showed that the type and amount of grinding auxiliary were also crucial for the synthesis of **3co**, exerting a considerable effect on both reaction conversion and chemo-selectivity (Table S2, entries 3−11), where NaCl (1.0 g) gave the best performance. Pleased by this initial result, we sought to further optimize this reaction and immediately found that using 4.0 equiv. of **2o** improved the product yield to 52% with excellent selectivity (Table S2, entry 15). However, the yield could not be further increased by adjusting the reaction time (Table S2, entry 12−13). Several LAG additives were then tried to improve the reaction

Table S2. Optimization of the radical C−H arylation reaction of **1c** and **2o**[a]



entry	**2o** (equiv.)	grinding auxiliary (g)	time (min)	yield (%)[b] (**3co**/**3co'**)
1[c]	0.3 mmol	NaCl (1.0)	30	30/n.d.
2	3.0	NaCl (1.0)	30	38/n.d.
3	3.0	KCl (1.0)	30	31/n.d.
4	3.0	KBr (1.0)	30	22/6
5	3.0	LiBr (1.0)	30	trace/n.d.
6	3.0	$NaBF_4$ (1.0)	30	n.d./4
7	3.0	neutral Al_2O_3 (1.0)	30	6/55
8	3.0	none	30	n.d./n.d.
9	3.0	NaCl (0.8)	30	37/n.d.
10	3.0	NaCl (0.6)	30	28/n.d.
11	3.0	NaCl (0.4)	30	24/n.d.
12	3.0	NaCl (1.0)	20	29/n.d.
13	3.0	NaCl (1.0)	40	39/n.d.
14	2.0	NaCl (1.0)	30	22/n.d.
15	4.0	NaCl (1.0)	30	52/n.d.
16	5.0	NaCl (1.0)	30	32/n.d.
17[d]	4.0	NaCl (1.0)	-	n.d./91
18[e]	4.0	NaCl (1.0)	30	n.d./6

[a] Reaction conditions: **1c** (0.5 mmol, 1.0 equiv.), **2o** and grinding auxiliary were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz. [b] Isolated yields. [c] Using typical procedure for radical C−H (hetero)arylation reaction of indazoles. [d] **1c** (0.5 mmol, 1.0 equiv.), **2o** (3.0 equiv.) and NaCl (1.0 g) were added in MeCN/H_2O (5:1, 2.4 mL) at room temperature in a 5 mL flask, and then the mixture was stirred at 70 °C under air for 10 min. [e] Neat reaction conditions: **1c** (0.5 mmol, 1.0 equiv.), **2o** (4.0 equiv.) and NaCl (1.0 g) were stirred at 70 °C under air for 30 min. n.d. = not detected.

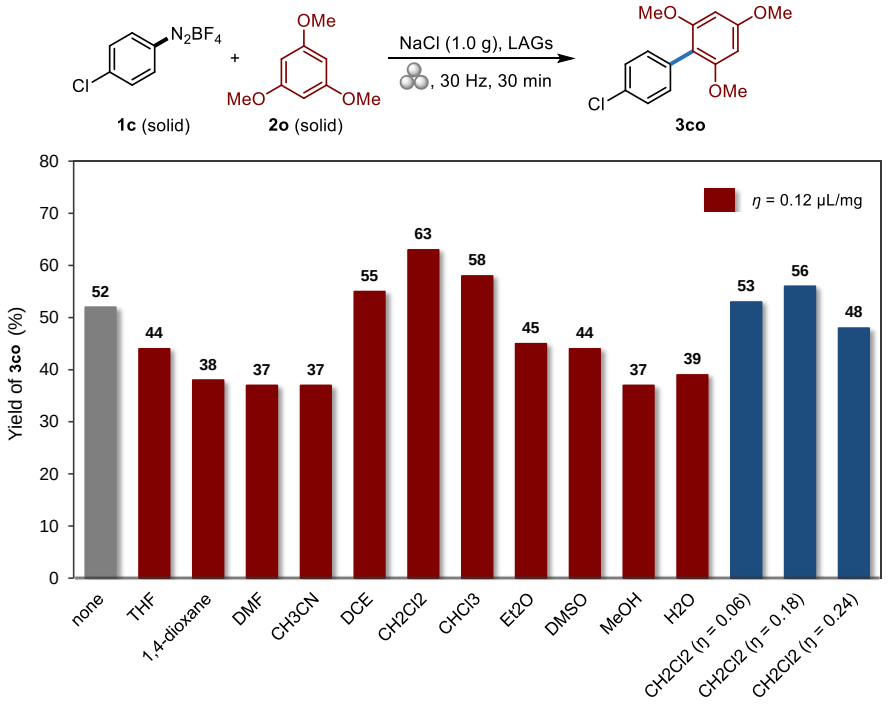
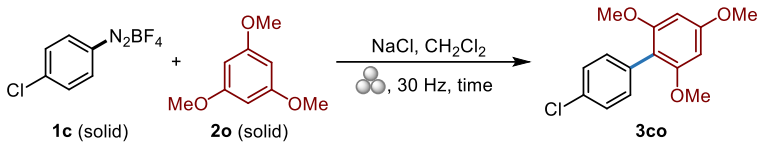


Fig. S2. The influences of the LAGs on the radical C−H arylation reaction of **1c** and **2o**

considering the solid nature of both substrates. Thankfully, a very small amount of CH_2Cl_2 increased the yield of **3co** to the best of 63% (Fig. S2). *Surprisingly, when the reaction was performed in MeCN/H_2O at 70 °C,[7] a large amount of azo by-product **3co'** appeared quickly within 10 min but offered no products (Table S2, entry 17), demonstrating an obvious mechanical force controlled biaryl generation under facile conditions. Neat control experiment resulted in none of **3co**, suggesting that mechanical force was a critical factor (Table S2, entry 18).*

Condition B-1: Typical procedure for radical C−H (hetero)arylation reaction of other heteroarenes: A mixture of aryldiazonium tetrafluoroborates **1a**, **1c**, **1k**~**1l** (0.5 mmol, 1.0 equiv.), **2s**, **2u** (2.0 mmol, 4.0 equiv.) or **2r** (2.5 mmol, 5.0 equiv.) and NaCl (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm). Then, the ball milling vessel was placed in the mixer mill (30 Hz, 30 min). After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane to give the desired products **3ar**, **3cs**, **3ku** and **3lu**.

Table S3. Optimization of feeding method of **1c** and **2o**[a]



1c (solid) **2o** (solid) **3co**

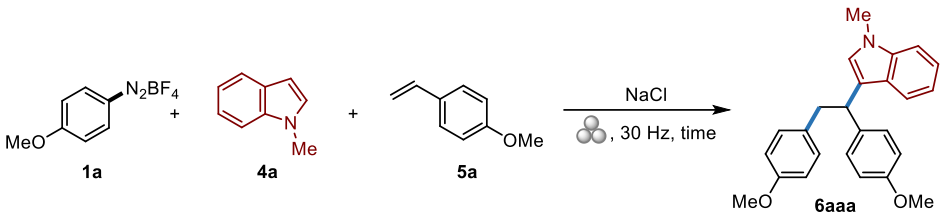
entry	**1c** : **2o** (mmol : mmol)	NaCl (g)	CH_2Cl_2 (μL)	time (min)	yield/%[b]
1	0.5 : 1.0	1.0	154	30	22
2	0.5+0.5 : 1.0	1.0+0.5	154+73	30+30	45
3	0.5+0.5 : 0.5	0.5+0.5	84+73	30+30	70
4	0.5+0.25 : 0.5	1.0+0.5	144+67	30+30	52

[a] Reaction conditions: **1c**, **2o**, CH_2Cl_2 and NaCl were pre-milled at 30 Hz followed by adding another portion of **1c**, CH_2Cl_2 and NaCl and milled for another time. [b] Isolated yields.

Condition B-2: Typical procedure for radical C−H (hetero)arylation reaction of benzenes: A mixture of aryldiazonium tetrafluoroborates **1a**, **1c** or **1i** (0.5 mmol, 1.0 equiv.), **2o**~**2q** (0.5 mmol, 1.0 equiv.), NaCl (0.5 g) and CH_2Cl_2 (η = 0.12) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) and pre-milled at 30 Hz for 30 min, followed by adding another portion of **1a**, **1c** or **1i** (0.5 mmol, 1.0 equiv.), CH_2Cl_2 (η = 0.12) and NaCl (0.5 g) and milled at 30 Hz for another 30 min. After the reaction was finished, TLC monitoring showed benzenes were completely convert to the biaryl products, and the remaining diazonium salts could be removed from the crude products by rinsing with 10 mL of solvent (petroleum ether:ethyl acetate=100:1, *v/v*), and then concentrated under reduced pressure to give desired product **3ao**, **3co**, **3io**, **3cp**~**3cq**.

3.3 Radical cascade addition reaction

Table S4. Optimization of the radical cascade addition reaction of **1a**, **4a** and **5a**[a]



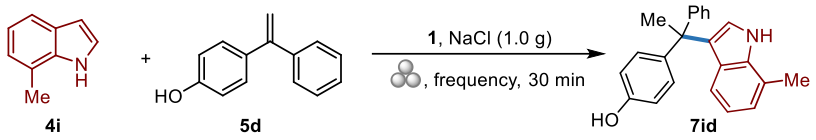
entry	grinding auxiliary (g)	time (min)	yield (%)[b]
1	NaCl (1.0)	20	32
2	NaCl (1.0)	30	60
3	NaCl (1.0)	40	56
4	NaCl (1.0)	60	42
5	NaCl (0.6)	30	48
6	NaCl (0.8)	30	52
7	none	30	n.d.

[a] Reaction conditions: **1a** (0.75 mmol, 1.5 equiv.), **4a** (1.0 mmol, 2.0 equiv.), **5a** (0.5 mmol, 1.0 equiv.) and NaCl were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz. [b] Isolated yields. n.d. = not detected. The substrate ratio was according to the reported value[8] without modification.

Condition C: Typical procedure for radical cascade addition reaction: A mixture of **1** (0.75 mmol, 1.5 equiv.), **4** (1.0 mmol, 2.0 equiv.), **5** (0.5 mmol, 1.0 equiv.) and NaCl (1.0 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm). Then, the ball milling vessel was placed in the mixer mill (30 Hz, 30 min). After the reaction was completed, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane as eluent to give the desired products **6aaa**, **6mba**, **6acb** and **6adc** (4 examples).

3.4 HAT-addition reaction

Table S5. Optimization of HAT-addition reaction of **4i** and **5d**[a]



entry	**1** (mol%)	NaCl (g)	frequency (Hz)	yield (%)[b]
1	**1a** (100)	1.0	20	60
2	**1a** (150)	1.0	20	52
3	**1d** (100)	1.0	20	55
4	**1j** (100)	1.0	20	34
5	**1a** (0)	1.0	20	n.d.
6	**1a** (20)	1.0	20	26
7	**1a** (30)	1.0	20	32
8	**1a** (40)	1.0	20	49
9	**1a** (50)	1.0	20	67
10	**1a** (60)	1.0	20	72
11	**1a** (70)	1.0	20	84

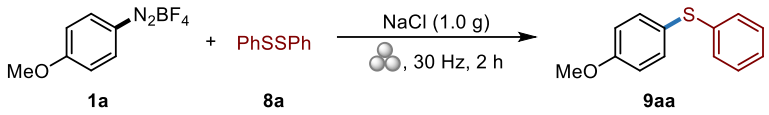
12	**1a** (80)	1.0	20	61
13	**1a** (70)	none	20	0
14	**1a** (70)	1.0	30	56
15	**1a** (70)	1.0	25	61

[a] Reaction conditions: **1**, **4i** (0.3 mmol, 1.0 equiv.), **5d** (0.3 mmol, 1.0 equiv.) and NaCl were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at a specific frequency for 30 min. [b] Isolated yields.

Condition D: Typical procedure for HAT-addition reaction: A mixture of aryldiazonium tetrafluoroborates **1a** (0.21 mmol, 70 mol%), **4a** and **4d**~**4j** (0.3 mmol, 1.0 equiv.), **5d**~**5g** (0.3 mmol, 1.0 equiv.) and NaCl (1.0 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm). Then, the ball milling vessel was placed in the mixer mill (20 Hz, 30 min). After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane to give the desired product **7ad**, **7dd**~**7id** and **7ee**~**7eg** (10 examples).

3.5 Radical cross-coupling reaction

Table S6. Optimization of radical cross-coupling reaction of **1a** and **8a**[a]



1a **8a** **9aa**

entry	**8a** (equiv.)	yield (%)[b]
1	0.50	44
2	0.75	67
3	1.00	68
4	1.25	82
5	1.50	67
6	1.75	72
7	2.00	80

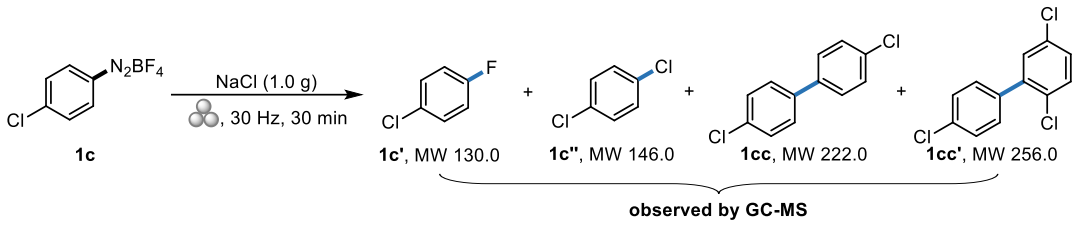
[a] Reaction conditions: **1a** (0.5 mmol, 1.0 equiv.), **8a** and NaCl (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz for 2 h. [b] Isolated yields.

Condition E: Typical procedure for radical cross-coupling reaction: A mixture of aryldiazonium tetrafluoroborates **1a**, **1c**, **1g**, **1n**, **1l** (0.5 mmol, 1.0 equiv.), **1o** and **1p** (1.0 mmol), **8a**~**8e** (0.75 mmol, 1.25 equiv.) and NaCl (1.0 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm). Then, the ball milling vessel was placed in the mixer mill (30 Hz, 2 h). After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane to give the desired products **9aa**~**9ac**, **9cb**, **9na**, **9la**, **9ga**, **9oa**, **9pd**, **9ae** and **9ce** (11 examples). CH_2Cl_2 (η = 0.12) was used as LAG additive for **9na**, **9ga**, **9oa** and **9pd**.

4. Experimental probes on reaction mechanism

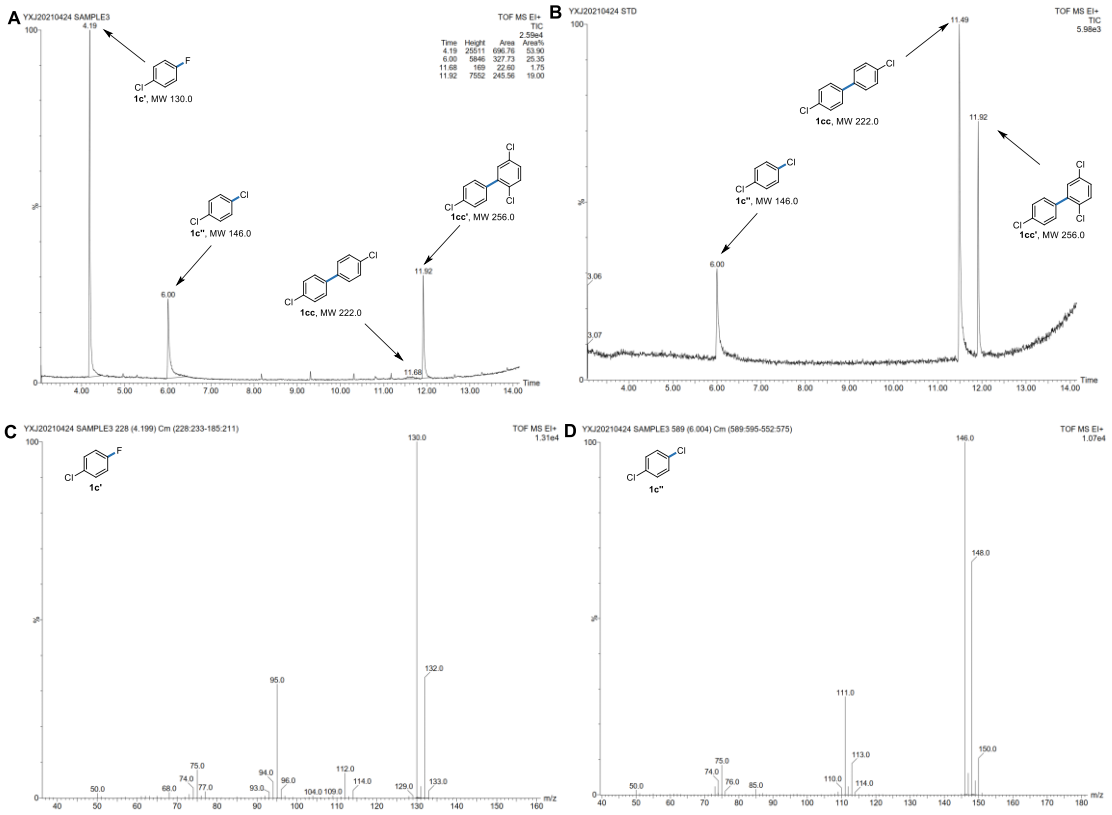
4.1 Exploration of radical initiation mechanism

1) Control experiments



Scheme S2. Reaction of **1c** and NaCl under ball-milling. Reaction conditions: **1c** (0.5 mmol, 1.0 equiv.) and NaCl (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz for 30 min. After the reaction was finished, the reaction mixture was passed through a short silica gel column eluted with ethyl acetate. After concentration, the resulted mixture was analyzed by GC-MS measurement with reference samples, indicating the formation of **1c'** (t_R = 4.19 min), **1c''** (t_R = 6.00 min), **1cc** (t_R = 11.68 min) and **1cc'** (t_R = 11.92 min) (Fig. S3).

GC-MS analysis conditions: Injector temperature, 315 °C; Carrier gas, helium; Column flow, 1 mL/min; Temperature program, 80 °C hold 2 min, then was heated at a rate of 20 °C/min to 310 °C, followed by maintaining at 310 °C for 8 min.



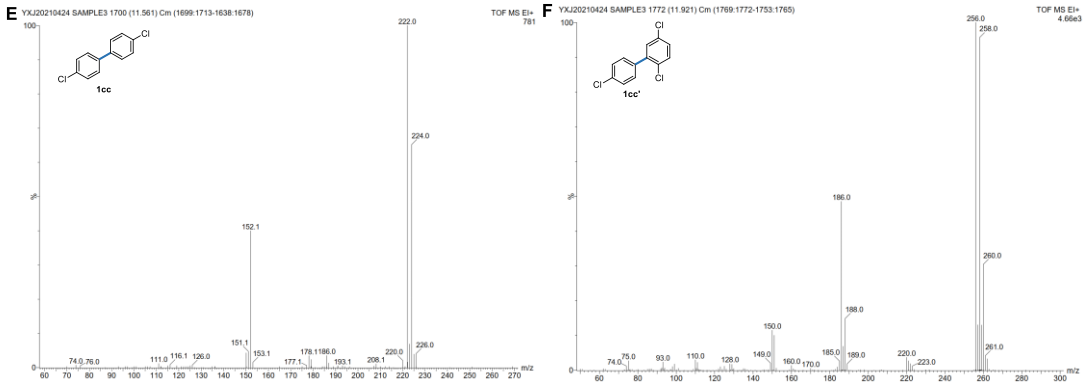
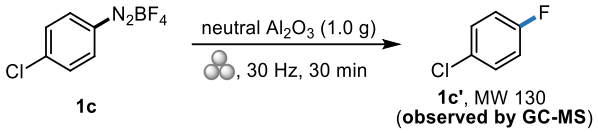


Fig. S3. GC-MS spectra of the mechanochemical reaction of **1c** and NaCl (**A**, **C**~**F**) and the standard samples (**B**)



Scheme S3. Reaction of **1c** and neutral Al_2O_3 under ball-milling. Reaction conditions: **1c** (0.5 mmol, 1.0 equiv.) and neutral Al_2O_3 (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz for 30 min. After the reaction was finished, the reaction mixture was passed through a short silica gel column eluted with ethyl acetate. After concentration, the resulted mixture was analyzed by GC-MS measurement with reference samples, indicating the formation of **1c'** (t_R = 4.26 min) (Fig. S4).

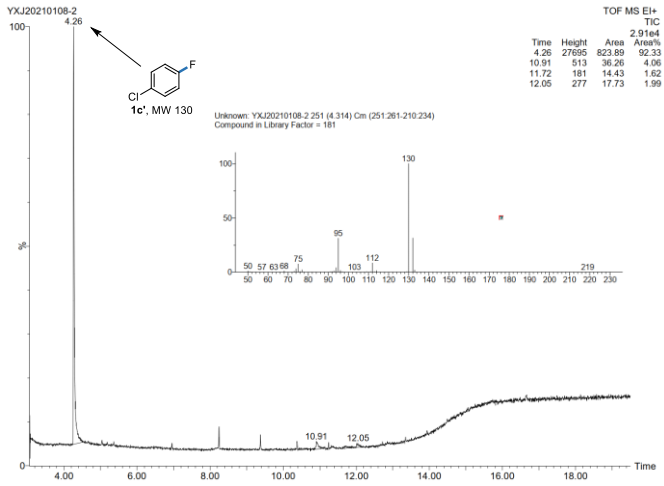
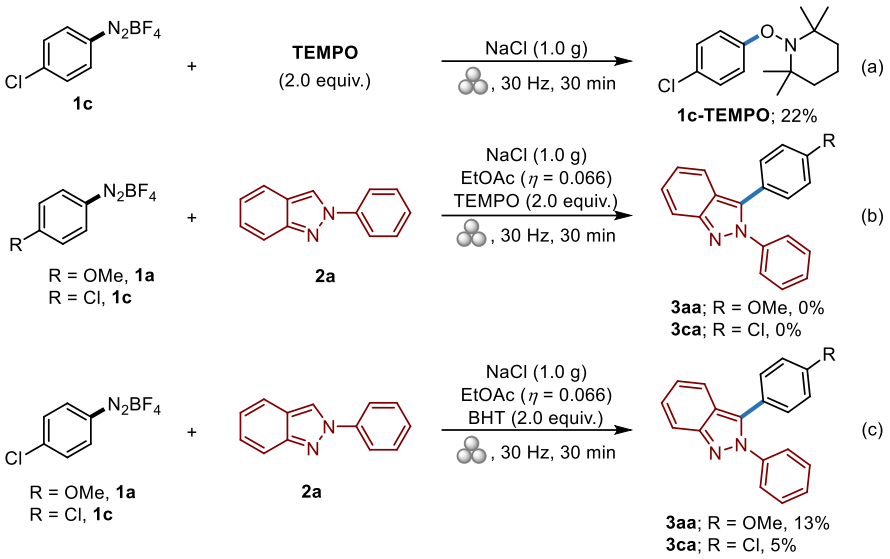


Fig. S4. GC-MS spectra of the mechanochemical reaction of **1c** and neutral Al_2O_3



Scheme S4. Radical trapping experiments. Reaction conditions: (a) **1c** (0.5 mmol, 1.0 equiv.), NaCl (1.0 g) and TEMPO (2.0 equiv.) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz for 30 min. (b) **1a** or **1c** (0.75 mmol, 2.5 equiv.) was milled with **2a** (0.3 mmol, 1.0 equiv.) and NaCl (1.0 g) in the presence of TEMPO (2.0 equiv.). (c) **1a** or **1c** (0.75 mmol, 2.5 equiv.) was milled with **2a** (0.3 mmol, 1.0 equiv.) and NaCl (1.0 g) in the presence of BHT (2.0 equiv.).

2) Powder X-ray diffraction analysis

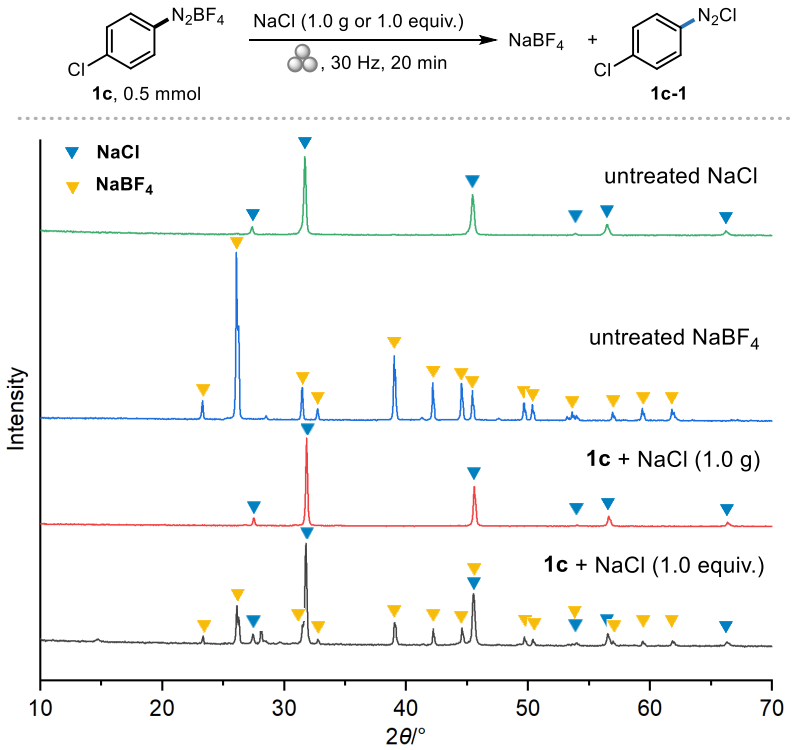


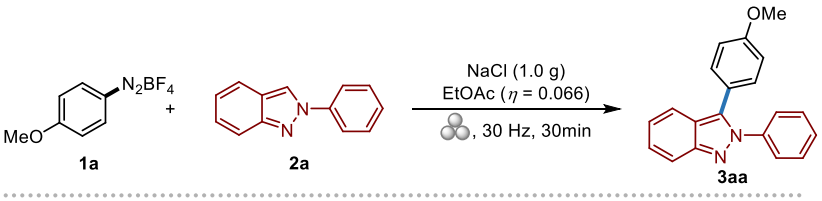
Fig. S5. Powder X-ray diffraction analysis

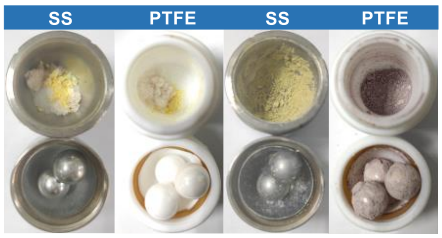
Referred to the untreated NaCl and $NaBF_4$ powder X-Ray spectrum, new $NaBF_4$ peaks were observed after the reaction of **1c** and NaCl (1.0 equiv.), indicating the metathesis reaction of **1c** and NaCl had

occurred to generate $NaBF_4$ and an active intermediate **1c-1**. No peak changes were observed after the reaction of **1c** and NaCl (1.0 g), suggesting only small amount of metathesis reaction product was formed as compared with that of NaCl, which was in favor of reducing the potential reaction risk from active intermediate **1c-1**.

3) The effect of grinding vessel/ball material on reaction yield

In order to eliminate potential catalytic behavior of some leaching metals such as Fe, Co and Ni from grinding vessel/balls,[9] we used stainless steel grinding vessel (25 mL) with stainless steel balls (d_{MB} = 1.4 cm) and teflon (PTFE) grinding vessel (25 mL) with zirconia balls (d_{MB} = 1.4 cm) to carry out the radical C−H arylation reaction of **1a** and **2a**, respectively.





vessel material	SS	PTFE
yield of **3aa** (%)	75	43

Scheme S5. Reaction conditions: **1a** (0.75 mmol, 2.5 equiv.), **2a** (0.3 mmol, 1.0 equiv.), EtOAc (η = 0.066) and NaCl (1.0 g) were placed in a grinding vessel (stainless steel or teflon, 25 mL) with balls (2 × stainless steel ball or 3 × zirconia ball, d_{MB} = 1.4 cm) in a mixer mill, milling at 30 Hz for 30 min. SS = stainless steel, PTFE = poly tetra fluoroethylene.

4) Reaction temperature monitoring and the effect of frequency on reaction yield

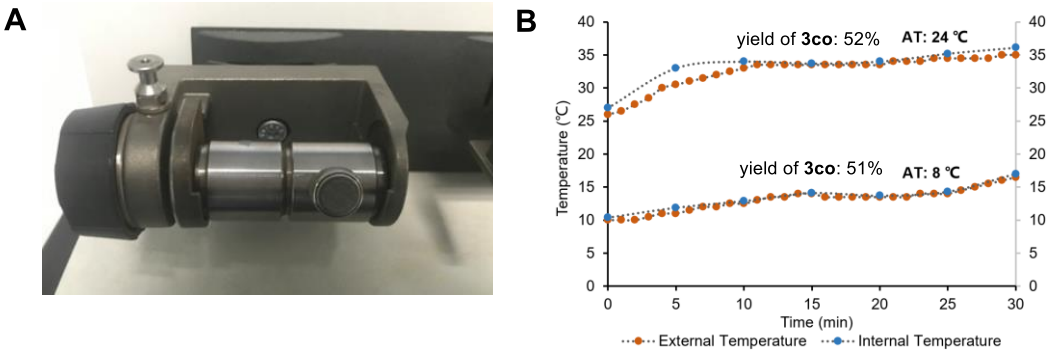


Fig. S6. (**A**) Online temperature monitoring device *via* iButton. (**B**) Change trend of stainless-steel vessel temperature (milling at 30 Hz). The milling device was placed at a separated room with ambient temperature (AT) of 8 °C or 24 °C. Stainless-steel vessel external and internal temperatures were logged during milling using online iButton temperature logger (iButton DS1922T-F5#) and IR thermometer, respectively. [Reaction conditions: **1c** (0.5 mmol, 1.0 equiv.), **2o** (2.0 mmol, 4.0 equiv.) and NaCl (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at a 30 Hz for 30 min.]

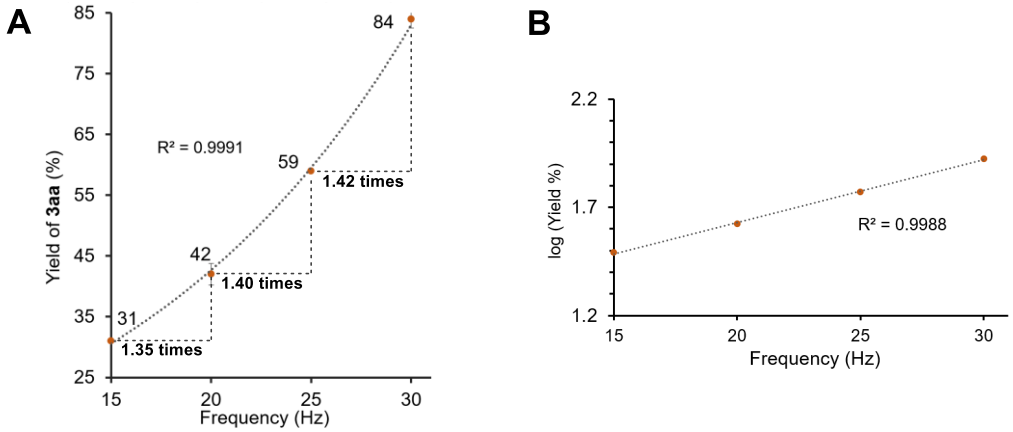


Fig. S7. Evidence for an exponential effect of frequency on reaction yield for the radical C−H arylation reaction of **1a** and **2a**. The milling device was placed at a separated room with ambient temperature (AT) of 8 °C (milling for 30 min). (**A**) Percent yield is plotted versus frequency and fit with an exponential curve. (**B**) The log of the yield is plotted versus frequency. Error bars were calculated from three standard deviations from the mean of each dataset for each frequency point. [Reaction conditions: **1a** (0.75 mmol, 2.5 equiv.), **2a** (0.3 mmol, 1.0 equiv.), EtOAc (η = 0.066) and NaCl (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at a specific frequency for 30 min.]

4.2 Kinetic analysis of radical cross-coupling reaction

Upon the reaction optimization of **1a** and **8a** (see details in Table S6), we performed a kinetic analysis to provide additional information on the mechanochemical transformation rate. The kinetic curve of radical cross-coupling reaction shows sigmoidal, a typical mechanochemical feature influenced by both chemical and mechanical factors (Fig. S8, orange data points). In stark contrast, the kinetics of solution reaction under literature conditions (Scheme S6) were modelled as classical first-order (Fig. S8, blue data points).

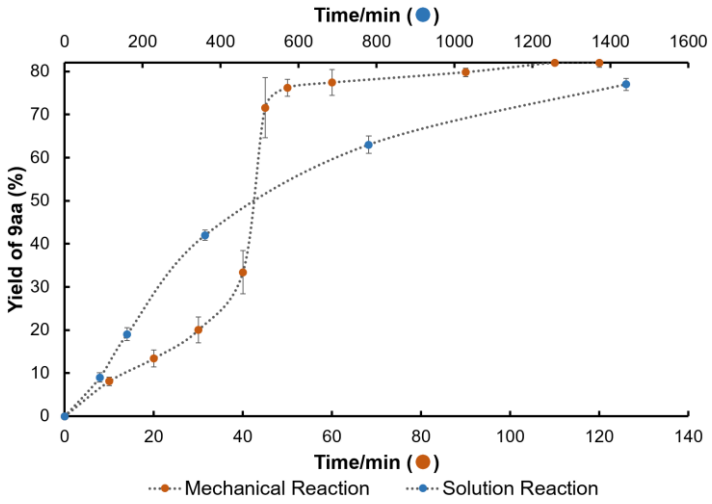
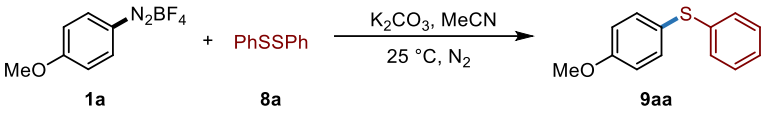


Fig. S8 Kinetic profiles for the synthesis of **9aa** in solution or under mechanical milling conditions. Error bars were calculated from three standard deviations from the mean of each dataset for each time point.

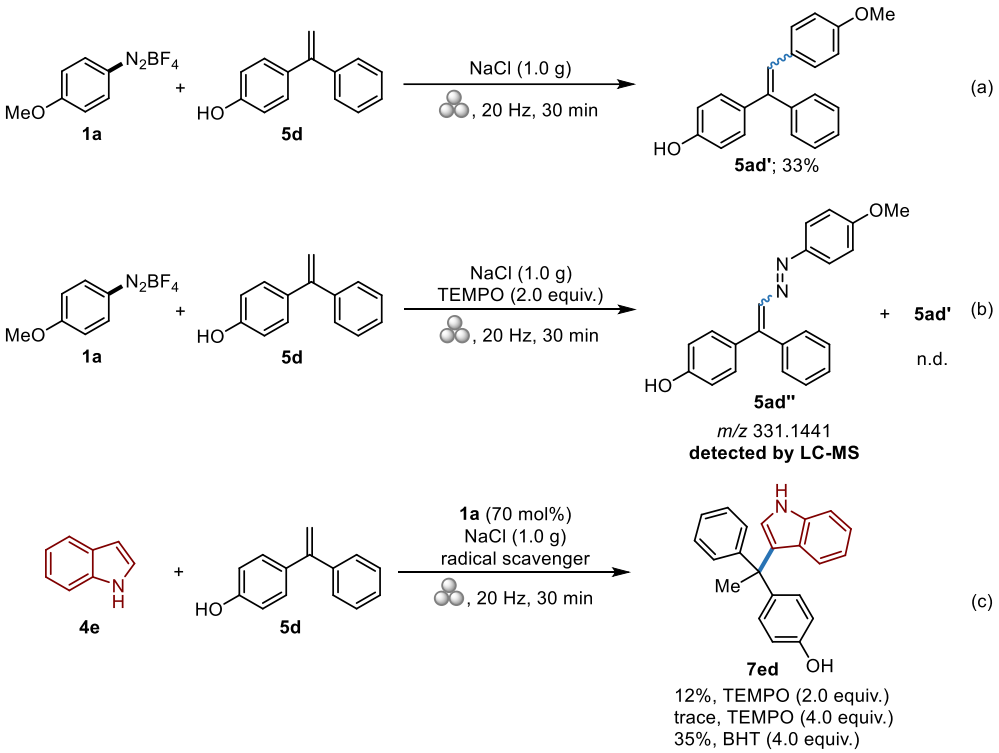


Scheme S6. Reaction conditions: **1a** (0.2 mmol), **8a** (0.18 mmol) and K_2CO_3 (0.2 mmol) in MeCN (1.0 mL) under N_2 atmosphere at 25 °C.

4.3 Exploration of the HAT-addition mechanism

1) Control experiments

We investigated different types and amounts of scavengers to verify the radical process (Scheme S7c). Experimentally, 2,2,6,6-tetramethylpiperidine-1-oxyl (TEMPO, 2.0 and 4.0 equiv.), the typical radical inhibitors, suppressed the reaction and afforded 12% and trace amounts of the product, respectively. Surprisingly, when using the 4.0 equiv. of butylated hydroxytoluene (BHT), the product can also be obtained in 35% yield which implies a possible non-radical reaction pathway.



Scheme S7. Radical trapping experiments. Reaction conditions: (a) **1a** (0.3 mmol, 1.0 equiv.), **5d** (0.3 mmol, 1.0 equiv.) and NaCl (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 20 Hz for 30 min. (b) **1a** (0.3 mmol, 1.0 equiv.), **5d** (0.3 mmol, 1.0 equiv.), NaCl (1.0 g) and TEMPO (2.0 equiv.) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 20 Hz for 30 min. (c) **1a** (0.21 mmol, 70 mol%), **4e** (0.3 mmol, 1.0 equiv.), **5d** (0.3 mmol, 1.0 equiv.), NaCl (1.0 g) and radical scavenger were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 20 Hz for 30 min.

The milling mixture of reaction (Scheme S7b) was analyzed by LC-MS measurement after preliminary isolation (silica gel column chromatography, PE:EtOAc = 3:1), indicating the formation of **5ad"** (t_R = 25.613 min) (Fig. S9).

LC-MS analysis conditions: the analytic column used as Waters Xbridge C18 column (250 mm×4.6 mm, 5 μm). The gradient elution was employed with solution A and solution B as mobile phase components. The solution A was methanol and solution B was water. The rate of mobile phase was set at 1.0 mL/min and the column temperature was maintained at 25 °C. The gradient program was set as follows: time/% solution A: 0/30, 20/80, 30/ 95, 50/95, 50.1/30 60/30. The injection volume was 5 μL.

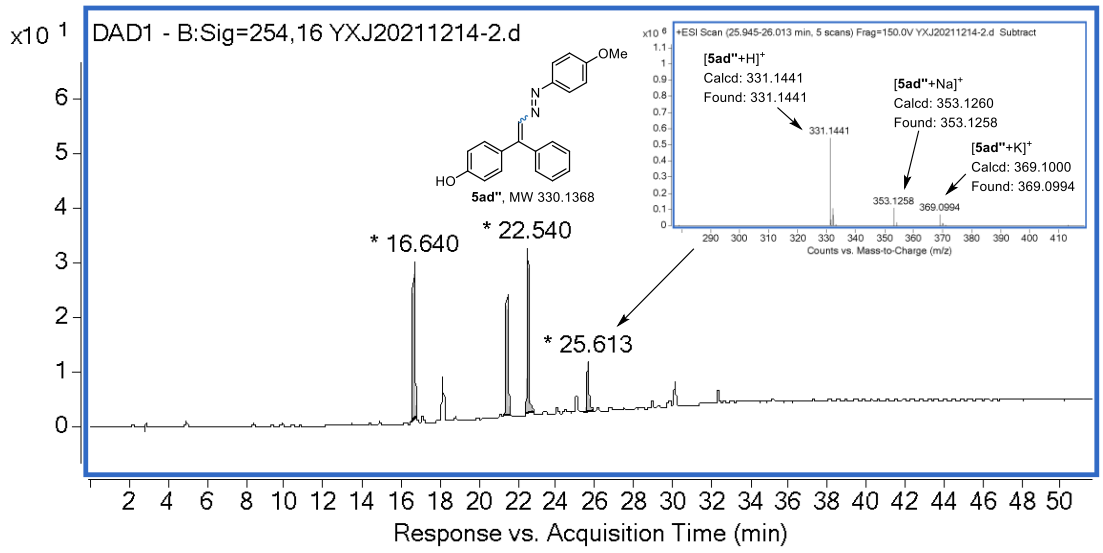
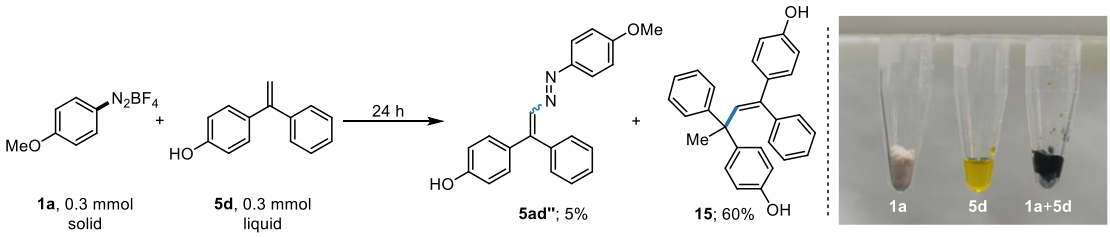


Fig. S9. LC-MS spectra of the reaction products **5ad"**

2) Electrophilic reaction of 1a and 5d

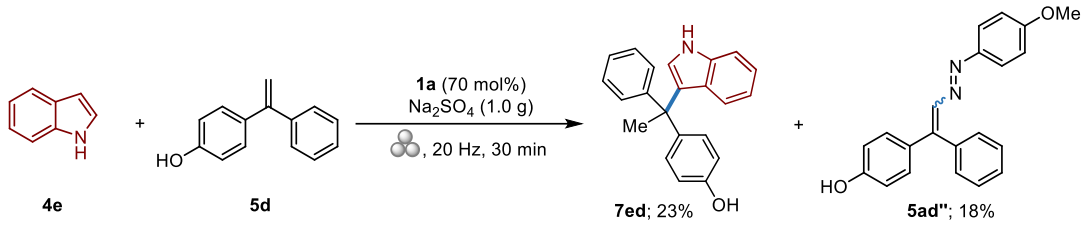
To illustrate the generation of acid of HBF_4 during the HAT-addition reaction, we mixed only **1a** with **5d** and found that the mixture turned to violet black immediately, resulting in 5% azo product **5ad"** and 60% self-coupling product **15** after 24 hours (Scheme S8). This result suggested that the electrophilic reaction to give azo product is a spontaneous process and HBF_4 is subsequently produced. Therefore, the acid-catalyzed reaction pathway cannot be completely precluded.



Scheme S8. Electrophilic reaction of **1a** and **5d**. Reaction conditions: **1a** (0.3 mmol) and **5d** (0.3 mmol) were placed in a centrifugal tube (1.5 mL) standing for 24 hours.

3) Comparative experiment

To demonstrate the hydrogen atom transfer (HAT) is the principal pathway to produce **7ed**, we have carried out the reaction of **4e** with **5d** under the standard conditions using Na_2SO_4 as an alternative grinding auxiliary (Scheme S9), resulting in 23% **7ed** and 18% azo product **5ad"**. Besides, the reaction of **4e** and **5d** proceeded under the standard conditions led to only trace amount of **5ad"** and no self-coupling product **15**. Therefore, we consider that acid catalysis is not a dominant pathway to give **7ed**.



Scheme S9. Comparative experiment. Reaction conditions: **4e** (0.3 mmol, 1.0 equiv.), **5d** (0.3 mmol, 1.0 equiv.), **1a** (0.21 mmol, 70 mol%) and Na_2SO_4 (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) in a mixer mill, milling at 20 Hz for 30 min.

4) Reaction profile of the hydrogen atom transfer (HAT) process

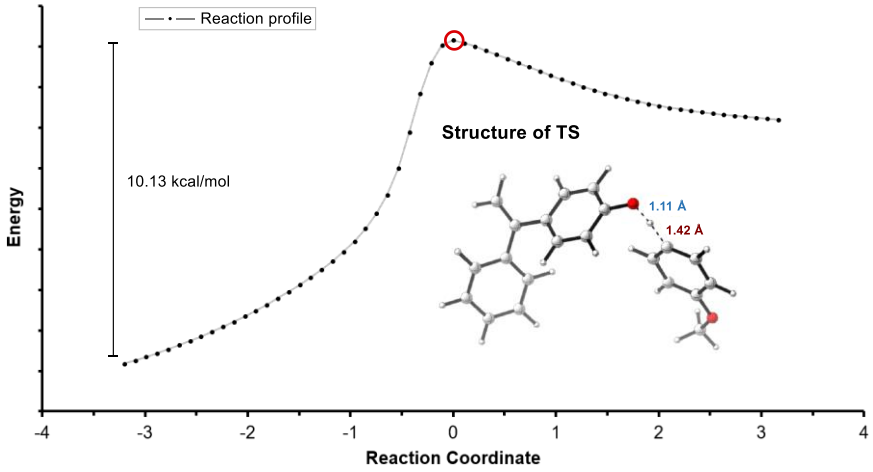
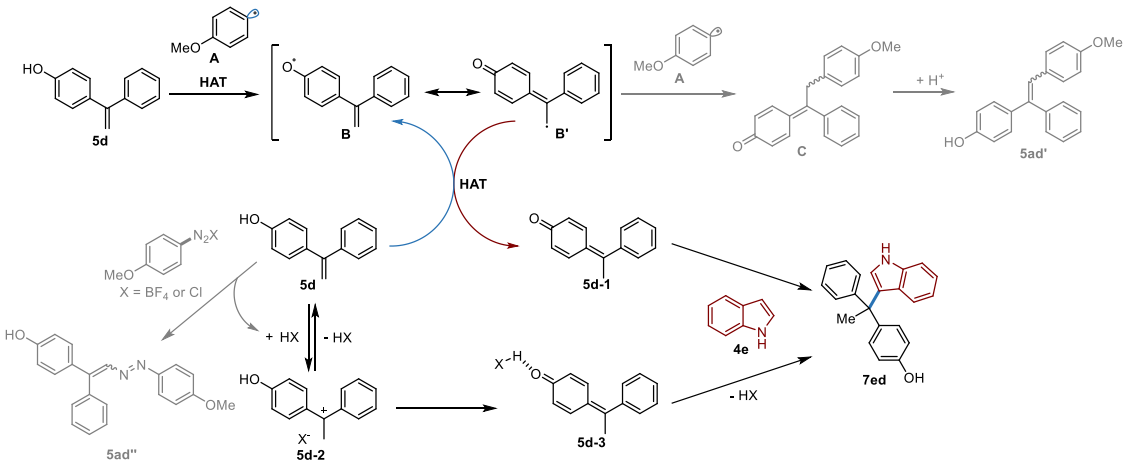


Fig. S10. Reaction profile of the HAT process from **5d** by the 4-methoxyphenyl radical, along with the structure of the transition state (TS, highlighted in the red circle) and a few relevant geometric parameters.

5) Proposed mechanism of HAT-addition reaction



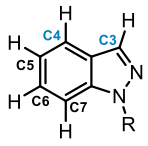
Scheme S10. Proposed mechanism for HAT-addition reaction

5. Natural charge distribution and p_z orbital occupancy of 1*H*-indazole

In order to demonstrate that radical arylation reaction occurs at the C3 and C4 position after *N*-acyl protection of 1*H*-indazole, we calculated the theoretical data of carbon atoms (C3, C4, C5, C6, C7) on the 1*H*-indazole ring with different *N*-acyl groups (Table S7). After acyl substitution, among the five

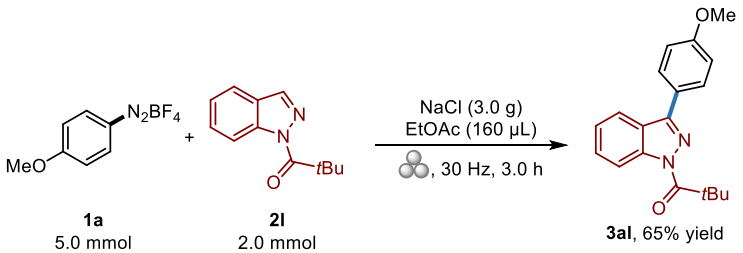
carbon atoms, the smallest p_z orbital occupancy at the C3, C4 carbon atom implicates that C3, C4 may be the most likely nucleophilic reactive site. Thus, the theoretical calculations support the C3, C4 arylation on 1*H*-indazole, while C3 site is more preferred in *t*BuC=O and $ClCH_2C$=O protected 1*H*-indazole because of its larger difference of p_z orbital occupancy at the C3 and C4 carbon atom.

Table S7. Charge distribution and p_z orbital occupancy of the C3, C4, C5, C6 and C7 atoms in 1*H*-indazole

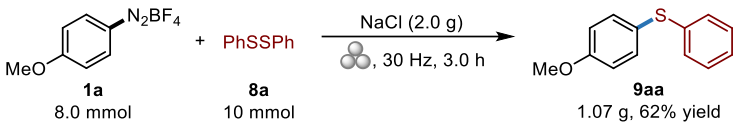


R	Atom	Natural Charge	P_z orbital occupancy
H	C3	-0.00539	1.02509
	C4	-0.19238	0.98220
	C5	-0.25249	1.03587
	C6	-0.21617	0.99841
	C7	-0.25920	1.04506
COMe	C3	0.04171	**0.97614**
	C4	-0.19645	0.98616
	C5	-0.23952	1.01849
	C6	-0.20999	0.98839
	C7	-0.23906	1.00405
CO*t*Bu	C3	0.04646	**0.97326**
	C4	-0.19679	0.98699
	C5	-0.23870	1.01736
	C6	-0.21009	0.98845
	C7	-0.23776	1.00184
$COCH_2Cl$	C3	0.05067	**0.96769**
	C4	-0.19464	0.98756
	C5	-0.23722	1.02254
	C6	-0.20773	0.99374
	C7	-0.23852	1.00667

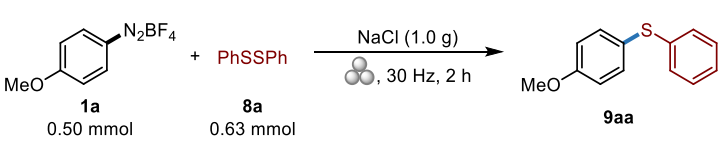
6. Up-scaled reactions and NaCl recycling experiments



Scheme S11. Up-scaled synthesis of **3al**. Reaction conditions: **1a** (5.0 mmol, 2.5 equiv.), **2l** (2.0 mmol, 1.0 equiv.), EtOAc (160 μL) and NaCl (3.0 g) were placed in a stainless-steel vessel (25 mL) with two stainless-steel ball (d_{MB} = 1.4 cm) milling at 30 Hz for 3.0 h. After the reaction was completed, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane as eluent to give **3al** as colorless oil.



Scheme S12. Gram-scale synthesis of **9aa**. Reaction conditions: **1a** (8.0 mmol, 1.0 equiv.), **8a** (10 mmol, 1.25 equiv.) and NaCl (2.0 g) were placed in a stainless-steel vessel (50 mL) with two stainless-steel ball (d_{MB} = 1.4 cm) milling at 30 Hz for 3.0 h. After the reaction was completed, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane (1:100) as eluent to give **9aa** as colorless oil.



entry	Yield/%	recovery rate/%
1st	82	99.5
2nd	78	99.4
3rd	75	99.4
4th	74	99.3
5th	78	99.4

Scheme S13. NaCl recycling experiments. Reaction conditions: **1a** (0.5 mmol, 1.0 equiv.), **8a** (1.25 equiv.) and NaCl (1.0 g) were placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) milling at 30 Hz for 2.0 h. After the reaction was finished, crude reaction mixtures were dissolved in and washed by ethyl acetate, and the residue (NaCl) was collected and dried under reduced pressure for 3.0 h, which can be directly used for the next reaction. The yield of **9aa** and the ratio of NaCl recovery are based on the average of three parallel experiments.

7. Application to the synthesis of pharmaceuticals

7.1 Synthesis of antimicrobial agents 3qa[10]

A mixture of aryldiazonium tetrafluoroborates **1q** (0.75 mmol, 2.5 equiv.), **2a** (0.3 mmol, 1.0 equiv.) and NaCl (1.0 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm). Then, the ball milling vessel was placed in the mixer mill (30 Hz, 30 min). After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane to give desired product **3qa** as yellow solid.

7.2 Synthesis of dantrolene 11[13]

A mixture of **2v** (0.5 mmol, 1.0 equiv.), **10** (0.5 mmol, 1.0 equiv.) and NaCl (1.0 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) and milling at 30 Hz for 30 min. Subsequently, **1i** (0.75 mmol) was added and milling at 30 Hz for 30 min. After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using MeOH/CH_2Cl_2 to give **11** as yellow solid.

7.3 Synthesis of IL-2 cytokine inhibitor 12

Synthesis of 2,5-dimethyl-4'-nitro-1,1'-biphenyl 3iq[12]

A mixture of aryldiazonium tetrafluoroborates **1i** (0.5 mmol, 1.0 equiv.), *p*-xylene **2q** (2.0 mmol, 4.0 equiv.) and NaCl (1.0 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm). Then, the ball milling vessel was placed in the mixer mill (30 Hz, 30 min). After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane to give desired product **3iq** as white solid.

Synthesis of 2',5'-dimethyl-[1,1'-biphenyl]-4-amine 3iq'

3iq (0.3 mmol) and Pd/C (0.01 mmol, 5% Pd, contains 40% H_2O) were added in dry EtOH (4.0 mL),

and then the mixture was stirred at room temperature under H_2 for 30 min. The resulting mixture was filtered, and concentrated under the reduced pressure. Purification by column chromatography with EtOAc/*n*-hexane to give **3iq'** as white oil.

Synthesis of *N*-(2',5'-dimethyl-[1,1'-biphenyl]-4-yl)-2,3-difluorobenzamide 12[12]

A mixture of ethyl 2,3-difluorobenzoate (0.2 mmol, 1.0 equiv.), EDCI (0.2 mmol, 1.0 equiv.), HOBt (0.2 mmol, 1.0 equiv.) and NaCl (0.3 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm) and milling at 25 Hz for 30 min, then **3iq'** (0.2 mmol, 1.0 equiv.) was added and milling at 25 Hz for another 30 min. After the reaction was finished, the contents were scratched off the vessel and purified directly by column chromatography on silica gel using EtOAc/*n*-hexane to give **12** as white solid.

7.4 Synthesis of steroid hormone nuclear receptor 13

A flame dried flask was charged with **7id** (0.3 mmol, 1.0 equiv.) and 60 % NaH (0.72 mmol, 2.4 equiv.) in oil. The flask was then flushed with argon and cooled to 0 °C. Once cool, dimethylformamide (10 mL) was added, and the reaction was allowed to stir until the evolution of hydrogen was completed. Iodomethane (0.66 mmol, 2.2 equiv.) was then added dropwise, and the reaction was allowed to slowly come to room temperature. After the reaction was finished, the solvent was removed and purified by column chromatography on silica gel using EtOAc/*n*-hexane to give 3-(1-(4-methoxyphenyl)-1-phenylethyl)-1,7-dimethyl-1*H*-indole **13** as white solid.

7.5 Synthesis of steroid hormone nuclear receptor 14

Synthesis of *tert*-butyl 3-(1-(4-methoxyphenyl)-1-phenylethyl)-7-methyl-1*H*-indole-1-carboxylate 7fd'

A flame dried flask was charged with **7fd** (0.3 mmol, 1.0 equiv.) and 60 % NaH (0.72 mmol, 2.4 equiv.) in oil. The flask was then flushed with argon and cooled to 0 °C. Once cool, dimethylformamide (10 mL) was added, and the reaction was allowed to stir until the evolution of hydrogen was completed. Iodomethane (0.66 mmol, 2.2 equiv.) was then added dropwise, and the reaction was allowed to slowly come to room temperature. After the reaction was finished, the solvent was removed and purified by column chromatography on silica gel using EtOAc/*n*-hexane to give **7fd'** as colorless oil.

Synthesis of 3-(1-(4-methoxyphenyl)-1-phenylethyl)-7-methyl-1*H*-indole 14[14]

A mixture of **7fd'** (0.3 mmol, 1.0 equiv.), trifluoroacetic acid (0.6 mmol, 2.0 equiv.) and silica gel (0.8 g) was placed in a stainless-steel vessel (15 mL) with a stainless-steel ball (d_{MB} = 1.4 cm). Then, the ball milling vessel was placed in the mixer mill (30 Hz, 60 min). After the reaction was finished, the contents were scratched off the vessel and quenched with saturated $NaHCO_3$ aqueous, then the solvent was removed and purified by column chromatography on silica gel using EtOAc/*n*-hexane to give **14** as colorless oil.

8. Deprotection of 1-(3-(4-methoxyphenyl)-1*H*-indazol-1-yl)-2,2-dimethylpropan-1-one 3al[15]

3al (0.3 mmol, 1.0 equiv.) was dissolved in 8 mL of 0.63 N HCl in isopropanol and the mixture was heated at 80° C for 18 h. After the reaction was finished, the mixture was quenched with saturated $NaHCO_3$ aqueous, then the solvent was removed and purified by column chromatography on silica gel using EtOAc/*n*-hexane to give **3an** as yellow oil.

9. Crystal data for 3aj'

Single crystals of 1-(4-(4-methoxyphenyl)-1*H*-indazol-1-yl)ethan-1-one **3aj'** suitable for X-ray analysis was obtained by slow evaporation of 0.01 M solution in 50:1 mixture of *n*-hexane/CH_2Cl_2 at room 4 °C. A suitable crystal was selected on a Bruker APEX-II CCD diffractometer. The crystal was kept at 170.0 K during data collection. Using Olex2[16], the structure was solved with the ShelXT[17] structure solution program using Intrinsic Phasing and refined with the ShelXL[18] refinement package using Least Squares minimization.

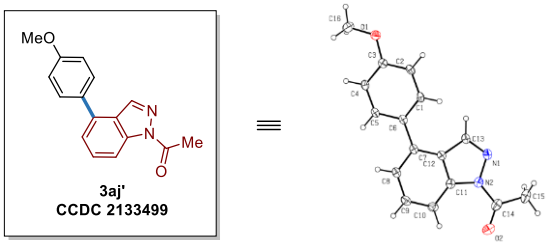


Fig. S11. X-Ray crystal structure of **3aj'**, ellipsoids are drawn at the 30% probability level

Table S8. Crystal data and structure refinement for compound **3aj'**

1-(4-(4-Methoxyphenyl)-1*H*-indazol-1-yl)ethan-1-one 3aj'	
Identification code	220107_yxj001
Empirical formula	$C_{16}H_{14}N_2O_2$
Formula weight	266.29
Temperature/K	170.0
Crystal system	orthorhombic
Space group	Pbca
a/Å	12.4030(5)
b/Å	7.2153(2)
c/Å	29.2429(12)
α/°	90
β/°	90
γ/°	90
Volume/Å^3	2616.99(17)
Z	8
ρ_{calc}g/cm^3	1.352
μ/mm^{-1}	0.091
F(000)	1120.0
Crystal size/mm^3	0.47 × 0.23 × 0.05
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	4.306 to 54.224
Index ranges	-15 ≤ h ≤ 15, -9 ≤ k ≤ 9, -37 ≤ l ≤ 37
Reflections collected	37137
Independent reflections	2890 [R_{int} = 0.0492, R_{sigma} = 0.0251]
Data/restraints/parameters	2890/0/183
Goodness-of-fit on F^2	1.084
Final R indexes [I>=2σ (I)]	R_1 = 0.0415, wR_2 = 0.1042
Final R indexes [all data]	R_1 = 0.0498, wR_2 = 0.1113

Largest diff. peak/hole / e Å^{-3}	0.31/-0.26

Table S9. Fractional atomic coordinates (×10^4) and equivalent isotropic displacement parameters (Å^2×10^3) for **3aj'**. U_{eq} is defined as 1/3 of the trace of the orthogonalised U_{IJ} tensor

Atom	*x*	*y*	*z*	U(eq)
O1	6813.4(8)	2194.6(14)	8563.8(3)	37.1(2)
O2	6783.2(11)	4372.1(19)	4951.8(4)	59.5(4)
N1	8212.7(9)	3570.2(17)	5970.7(4)	36.2(3)
N2	7355.9(10)	3781.4(16)	5671.7(4)	34.7(3)
C1	6912.7(10)	1798.5(17)	7334.2(5)	28.3(3)
C2	7134.9(10)	1584.3(17)	7792.4(5)	30.2(3)
C3	6494.3(10)	2440.7(17)	8122.4(4)	28.8(3)
C4	5608.7(10)	3487.0(17)	7983.7(5)	28.7(3)
C5	5394.1(10)	3692.7(17)	7520.6(5)	28.0(3)
C6	6038.5(10)	2875.8(16)	7185.3(4)	26.3(3)
C7	5803.5(10)	3150.9(16)	6692.9(4)	27.4(3)
C8	4749.0(10)	3294.0(18)	6530.8(5)	32.0(3)
C9	4517.1(11)	3610(2)	6069.2(5)	37.2(3)
C10	5314.2(12)	3801.1(19)	5744.1(5)	36.5(3)
C11	6371.9(11)	3644.2(18)	5901.5(5)	31.0(3)
C12	6626.0(10)	3322.0(16)	6362.0(4)	27.5(3)
C13	7783.3(10)	3303.9(18)	6373.1(5)	31.4(3)
C14	7538.4(14)	4141(2)	5207.8(5)	43.4(4)
C15	8696.6(15)	4221(3)	5067.9(6)	54.1(4)
C16	6233.9(14)	3169(2)	8911.4(5)	46.6(4)

Table S10. Anisotropic displacement parameters (Å^2×10^3) for **3aj'**. The anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+2hka^*b^*U_{12}+\ldots]$

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
O1	37.1(5)	39.0(5)	35.2(5)	2.5(4)	-3.3(4)	1.3(4)
O2	65.5(8)	75.8(9)	37.2(6)	3.2(6)	-1.3(6)	2.0(7)
N1	31.8(6)	36.4(6)	40.2(7)	-1.9(5)	4.4(5)	-1.0(5)
N2	36.2(6)	34.1(6)	33.9(6)	-1.9(5)	4.0(5)	-0.5(5)
C1	23.8(6)	22.3(6)	38.9(7)	-0.4(5)	4.4(5)	1.7(5)
C2	23.8(6)	23.1(6)	43.6(8)	3.6(5)	-1.5(5)	2.4(5)
C3	27.2(6)	23.9(6)	35.2(7)	2.8(5)	-1.6(5)	-5.3(5)
C4	24.0(6)	24.8(6)	37.2(7)	-1.2(5)	4.8(5)	-1.1(5)
C5	21.5(5)	23.1(6)	39.3(7)	0.8(5)	0.6(5)	1.4(5)
C6	22.5(6)	20.2(6)	36.1(7)	0.7(5)	1.3(5)	-2.1(4)
C7	25.8(6)	19.5(5)	36.8(7)	-2.0(5)	1.1(5)	0.0(5)
C8	24.9(6)	30.3(6)	40.9(7)	-1.7(5)	0.3(5)	0.0(5)
C9	29.3(7)	36.9(7)	45.4(8)	-4.0(6)	-7.5(6)	1.5(6)

C10	38.5(7)	35.0(7)	36.2(7)	-3.2(6)	-6.6(6)	0.8(6)
C11	33.8(7)	25.3(6)	33.9(7)	-3.2(5)	1.6(5)	-1.0(5)
C12	27.0(6)	20.9(6)	34.6(7)	-2.9(5)	-0.9(5)	-0.2(5)
C13	26.5(6)	30.9(6)	36.9(7)	-2.2(5)	2.8(5)	-0.6(5)
C14	56.6(9)	36.9(7)	36.7(8)	-2.2(6)	8.8(7)	0.2(7)
C15	60.6(11)	55.3(10)	46.5(9)	0.3(8)	21.9(8)	0.0(8)
C16	58.3(10)	46.7(9)	34.8(8)	0.3(6)	-0.9(7)	4.7(7)

Table S11. Bond lengths for **3aj'**

Atom	Atom	Length/Å	Atom	Atom	Length/Å
O1	C3	1.3618(16)	C4	C5	1.3881(19)
O1	C16	1.4297(18)	C5	C6	1.3956(17)
O2	C14	1.211(2)	C6	C7	1.4823(18)
N1	N2	1.3845(16)	C7	C8	1.3950(18)
N1	C13	1.3058(17)	C7	C12	1.4114(17)
N2	C11	1.3969(17)	C8	C9	1.399(2)
N2	C14	1.3993(19)	C9	C10	1.379(2)
C1	C2	1.3769(19)	C10	C11	1.3948(19)
C1	C6	1.4033(17)	C11	C12	1.4026(18)
C2	C3	1.3943(19)	C12	C13	1.4359(18)
C3	C4	1.3931(18)	C14	C15	1.495(2)

Table S12. Bond angles for **3aj'**

Atom	Atom	Atom	Angle/°	Atom	Atom	Atom	Angle/°
C3	O1	C16	117.62(11)	C8	C7	C12	115.99(12)
C13	N1	N2	105.80(11)	C12	C7	C6	122.38(11)
N1	N2	C11	111.04(11)	C7	C8	C9	122.20(13)
N1	N2	C14	120.56(12)	C10	C9	C8	122.30(13)
C11	N2	C14	128.37(13)	C9	C10	C11	116.02(13)
C2	C1	C6	121.25(12)	N2	C11	C12	106.10(11)
C1	C2	C3	120.64(12)	C10	C11	N2	131.09(13)
O1	C3	C2	115.63(11)	C10	C11	C12	122.80(13)
O1	C3	C4	125.15(12)	C7	C12	C13	134.94(12)
C4	C3	C2	119.21(12)	C11	C12	C7	120.69(12)
C5	C4	C3	119.55(12)	C11	C12	C13	104.34(11)
C4	C5	C6	122.04(12)	N1	C13	C12	112.72(12)
C1	C6	C7	121.83(11)	O2	C14	N2	119.99(15)
C5	C6	C1	117.28(12)	O2	C14	C15	124.67(15)
C5	C6	C7	120.89(11)	N2	C14	C15	115.33(15)
C8	C7	C6	121.62(12)				

Table S13. Torsion angles for **3aj'**

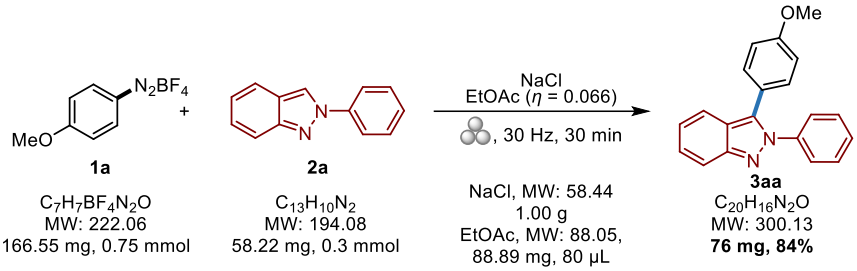
A	B	C	D	Angle/°	A	B	C	D	Angle/°
O1	C3	C4	C5	177.34(11)	C6	C7	C12	C11	-177.81(11)
N1	N2	C11	C10	178.59(14)	C6	C7	C12	C13	-0.2(2)
N1	N2	C11	C12	-0.40(14)	C7	C8	C9	C10	0.0(2)
N1	N2	C14	O2	-178.02(14)	C7	C12	C13	N1	-178.22(13)
N1	N2	C14	C15	1.52(19)	C8	C7	C12	C11	0.92(17)
N2	N1	C13	C12	0.07(15)	C8	C7	C12	C13	178.56(14)
N2	C11	C12	C7	178.69(11)	C8	C9	C10	C11	0.5(2)
N2	C11	C12	C13	0.41(13)	C9	C10	C11	N2	-179.18(13)
C1	C2	C3	O1	-177.48(11)	C9	C10	C11	C12	-0.3(2)
C1	C2	C3	C4	1.41(19)	C10	C11	C12	C7	-0.40(19)
C1	C6	C7	C8	145.23(13)	C10	C11	C12	C13	-178.68(12)
C1	C6	C7	C12	-36.11(18)	C11	N2	C14	O2	-0.2(2)
C2	C1	C6	C5	-1.09(18)	C11	N2	C14	C15	179.31(13)
C2	C1	C6	C7	178.68(11)	C11	C12	C13	N1	-0.32(15)
C2	C3	C4	C5	-1.44(18)	C12	C7	C8	C9	-0.74(18)
C3	C4	C5	C6	0.20(19)	C13	N1	N2	C11	0.21(14)
C4	C5	C6	C1	1.05(18)	C13	N1	N2	C14	178.35(12)
C4	C5	C6	C7	-178.72(11)	C14	N2	C11	C10	0.6(2)
C5	C6	C7	C8	-35.00(17)	C14	N2	C11	C12	-178.36(13)
C5	C6	C7	C12	143.65(12)	C16	O1	C3	C2	175.03(12)
C6	C1	C2	C3	-0.13(19)	C16	O1	C3	C4	-3.79(19)
C6	C7	C8	C9	177.99(12)					

Table S14 Hydrogen atom coordinates (Å×10^4) and isotropic displacement parameters (Å^2×10^3) for **3aj'**

Atom	*x*	*y*	*z*	U(eq)
H1	7359.62	1205.74	7114.58	34
H2	7730.53	845.8	7884.72	36
H4	5154.86	4055.8	8204.56	34
H5	4789.86	4411.79	7429.09	34
H8	4169.1	3172.61	6740.88	38
H9	3784.65	3696.96	5976.61	45
H10	5152.78	4025.92	5431.37	44
H13	8192.47	3118.26	6643.84	38
H15A	9036.18	5316.8	5204.01	81
H15B	8744.63	4297.49	4733.96	81
H15C	9068.37	3102.83	5174.13	81
H16A	6297.78	4506.27	8859.42	70
H16B	6534.53	2858.38	9211.67	70
H16C	5472.22	2810.19	8901.29	70

10. Green chemistry metrics calculations

Different parameters can be used to evaluate the environmental impact of the different synthetic pathways. This part details the calculation of the atom economy (AE), *E*-factor, reaction mass efficiency (RME) and eco-scale score. Calculation based on 5 times recovery of sodium chloride.



Scheme S14. Mechanochemical preparation of 3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole **3aa**

$$\textbf{Atom Economy(AE)} = \frac{\textbf{MW(Product)} \times \textbf{100}}{\textbf{\sum MW(RAW materials)} + \textbf{\sum MW(Reagents)}}$$

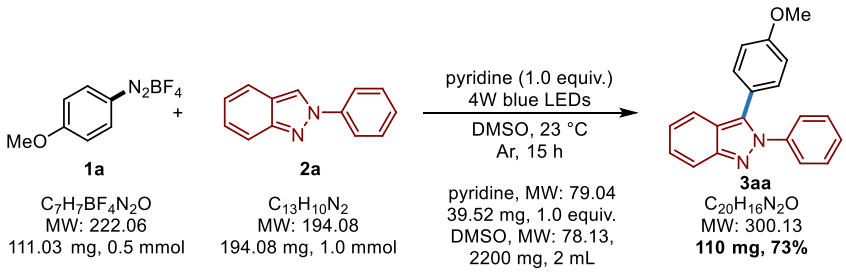
$$= \frac{330.13 \times 100}{222.06 + 194.08 + 58.44 + 88.05} = 58.7\%$$

$$\textbf{Environmental impact factor } (\boldsymbol{E}\textbf{-factor}_1) = \frac{\textbf{\sum } \boldsymbol{m}\textbf{(Input materials)} - \boldsymbol{m}\textbf{(Product)}}{\boldsymbol{m}\textbf{(Product)}}$$

$$= \frac{(166.55 + 58.22 + 1000 \times 0.03 + 88.89) - 76\ \text{mg}}{76\ \text{mg}} = 3.5$$

$$\textbf{Reaction Mass Efficiency (RME)} = \frac{\boldsymbol{m}\textbf{(Product)} \times \textbf{100}}{\textbf{\sum } \boldsymbol{m}\textbf{(Raw materials)}}$$

$$= \frac{76\ \text{mg} \times 100}{(166.55 + 58.22 + 1000 \times 0.03 + 88.89)\ \text{mg}} = 22.1\%$$



Scheme S15. Visible-light-mediated preparation of 3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole **3aa**[19a]

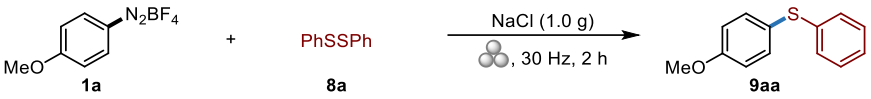
$$\textbf{Atom Economy (AE)} = \frac{330.13 \times 100}{222.06 + 194.08 + 79.04 + 78.13} = 57.6\%$$

$$\textbf{Environmental impact factor } (\boldsymbol{E}\textbf{-factor}_2) = \frac{(111.03 + 194.08 + 39.52 + 2200) - 110\ \text{mg}}{110\ \text{mg}} = 22.1$$

$$\textbf{Reaction Mass Efficiency (RME)} = \frac{110\ \text{mg}}{(111.03 + 194.08 + 39.52 + 2200)\ \text{mg}} \times 100 = 4.3\%$$

Table S15. Calculation of eco-scale score for the preparation of **3aa**

Parameters			Penalty points (Mechanochemical synthesis)	Penalty points (Solution chemistry)
1. Yield (100-X)/2 Mechanochemical synthesis: 84%			**8**	
Solution synthesis: 73%				**14**
2. Price of reaction components (to obtain 10 mmol of end product)				
Reaction components to get 10 mmol of product	**Price/g (Sigma-Aldrich)**	**Price to get 10 mmol of product**		
a. **1a** (6.577 g)	35.97	236.58		
b. **2a** (2.299 g)	Commercially unavailable			
c. NaCl (39.491 g)	0.02	0.79		
d. EtOAc (3.159 mL)	0.06	0.19		
a. **1a** (3.029 g)	35.97	108.95		
b. **2a** (5.295 g)	Commercially unavailable			
c. pyridine (1.079 g)	0.18	0.19		
d. DMSO (60.026 g)	0.13	7.80		
total price (Mechanochemical synthesis) = $237.56; Very expensive (> $50)			**5**	
total price (Solution synthesis) = $116.94; Very expensive (> $50)				**5**
3. Safety Mechanochemical synthesis: none			**0**	
Solution synthesis: a. pyridine (T, toxic) b. DMSO (T, toxic) c. DMSO (F+, extremely flammable)				**5** **5** **10**
4. Technical setup Mechanochemical synthesis: Unconventional activation technique (mechanical activation)			**2**	
Solution synthesis: Unconventional activation technique (photochemical activation) Any additional special glassware (Schlenk tube) (Inert) gas atmosphere				**2** **1** **1**
5. Temperature/Time Mechanochemical synthesis: Room temperature, < 1 h			**0**	
Solution synthesis: Room temperature, < 24 h				**1**
6. Workup and purification Mechanochemical synthesis: Classical chromatography			**10**	
Solution synthesis: Classical chromatography				**10**
Total			**25**	**54**
Eco-scale score			**75**	**46**



$C_7H_7BF_4N_2O$	$C_{12}H_{10}S_2$	NaCl	$C_{13}H_{12}OS$
MW: 221.95	MW: 218.33	MW: 58.44	MW: 216.30
110.98 mg, 0.5 mmol	136.46 mg, 0.625 mmol	1.00 g	**88.68 mg, 82%**

Scheme S16. Mechanochemical preparation of (4-methoxyphenyl)(phenyl)sulfane **9aa**

$$\textbf{Atom Economy}(\textbf{AE}) = \frac{\textbf{MW}(\textbf{Product}) \times \textbf{100}}{\sum\textbf{MW}(\textbf{RAW materials}) + \sum\textbf{MW}(\textbf{Reagents})}$$

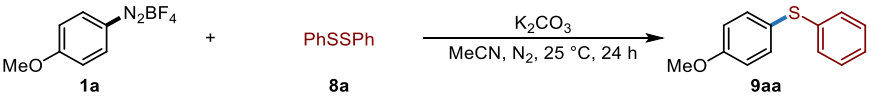
$$= \frac{216.30}{221.95 + 218.33 \times 1.25 + 58.44} \times 100 = 39.1\%$$

$$\textbf{Environmental impact factor } (\boldsymbol{E}\textbf{-factor}_{\mathbf{1}}) = \frac{\sum \boldsymbol{m}(\textbf{Input materials}) - \boldsymbol{m}(\textbf{Product})}{\boldsymbol{m}(\textbf{Product})}$$

$$= \frac{(110.98 + 136.46 + 1000 \times 0.03) - 88.68 \text{ mg}}{88.68 \text{ mg}} = 2.1$$

$$\textbf{Reaction Mass Efficiency } (\textbf{RME}) = \frac{\boldsymbol{m}(\textbf{Product}) \times \textbf{100}}{\sum \boldsymbol{m}(\textbf{Raw materials})}$$

$$= \frac{88.68 \text{ mg}}{(110.98 + 136.46 + 1000 \times 0.03) \text{ mg}} \times 100 = 32.0\%$$



$C_7H_7BF_4N_2O$	$C_{12}H_{10}S_2$	K_2CO_3 MW: 138.20	$C_{13}H_{12}OS$
MW: 221.95	MW: 218.33	27.64 mg, 1.0 equiv.	MW: 216.30
44.39 mg, 0.2 mmol	39.30 mg, 0.18 mmol	MeCN MW: 41.05	**33.31 mg, 77%**
		780.00 mg, 1.0 mL	

Scheme S17. Preparation of (4-methoxyphenyl)(phenyl)sulfane **9aa** based on solution chemistry[21b]

$$\textbf{Atom Economy } (\textbf{AE}) = \frac{216.30}{221.95 + 218.33 \times 0.9 + 138.20 + 41.05 \times 95} \times 100 = 4.9\%$$

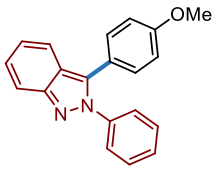
$$\textbf{Environmental impact factor } (\boldsymbol{E}\textbf{-factor}_{\mathbf{4}}) = \frac{(44.39 + 39.30 + 27.64 + 780.00) - 33.31}{33.31} = 25.8$$

$$\textbf{Reaction Mass Efficiency } (\textbf{RME}) = \frac{33.31 \text{ mg}}{(44.39 + 39.3 + 27.64 + 780.00) \text{ mg}} \times 100 = 3.7\%$$

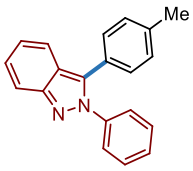
Table S16. Calculation of eco-scale score for the preparation of **9aa**

Parameters			Penalty points (Mechanochemical synthesis)	Penalty points (Solution synthesis)
1. Yield: Mechanochemical synthesis: 88%			**6**	
Solution synthesis: 77%				**12**
2. Price of reaction components (to obtain 10 mmol of end product)				
Reaction components to get 10 mmol of product a. **1a** (2.706 g) b. **8a** (3.328 g) c. NaCl (24.391 g)	**Price/g (Sigma-Aldrich)** 35.97 0.97 0.02	**Price to get 10 mmol of product** 97.3 3.23 0.49		
a. **1a** (2.882 g) b. **8a** (2.551 g) c. K_2CO_3 (1.794 g) d. MeCN (50.649 g)	35.97 0.97 0.20 0.14	103.67 2.47 0.36 7.09		
total price (Mechanochemical synthesis) = \$101.02; Very expensive (> \$50)			**5**	
total price (Solution synthesis) = \$113.59; Very expensive (> \$50)				**5**
3. Safety Mechanochemical synthesis: a. **8a** (N, dangerous for environment)			**5**	
Solution synthesis: a. **8a** (N, dangerous for environment) b. MeCN (T, toxic) c. MeCN (F+, extremely flammable)				**5** **5** **10**
4. Technical setup Mechanochemical synthesis: Unconventional activation technique (mechanoactivation)			**2**	
Solution synthesis: (Inert) gas atmosphere				**1**
5. Temperature/Time Mechanochemical synthesis: Room temperature, < 24 h			**1**	
Solution synthesis: Room temperature, < 24 h				**1**
6. Workup and purification Mechanochemical synthesis: Classical chromatography			**10**	
Solution synthesis: Classical chromatography				**10**
Total			**29**	**49**
Eco-scale score			**71**	**51**

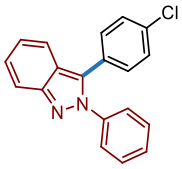
11. Characterization data



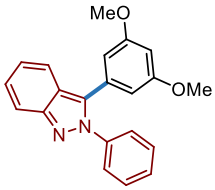
3-(4-Methoxyphenyl)-2-phenyl-2*H*-indazole (3aa).[19a] Yellow oil (76 mg, 84% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.80 (d, *J* = 8.5 Hz, 1H), 7.70 (d, *J* = 8.5 Hz, 1H), 7.48–7.43 (m, 2H), 7.41–7.34 (m, 4H), 7.29 (d, *J* = 9.0 Hz, 2H), 7.15–7.11 (m, 1H), 6.93 (d, *J* = 8.5 Hz, 2H), 3.83 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 159.8, 149.1, 140.5, 135.6, 131.1 (2C), 129.1 (2C), 128.3, 127.1, 126.2 (2C), 122.3 (2C), 121.7, 120.7, 117.8, 114.4 (2C), 55.4.



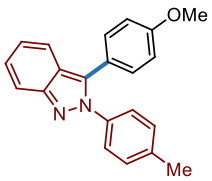
2-Phenyl-3-(*p*-tolyl)-2*H*-indazole (3ba).[19a] Yellow oil (60 mg, 71% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.82 (d, *J* = 9.0 Hz, 1H), 7.72 (d, *J* = 9.0 Hz, 1H), 7.48–7.44 (m, 2H), 7.42–7.36 (m, 4H), 7.28–7.25 (m, 2H, including $CDCl_3$), 7.21 (d, *J* = 8.4 Hz, 2H), 7.14 (ddd, *J* = 8.4, 6.6, 0.6 Hz, 1H), 2.40 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 149.0, 140.4, 138.5, 135.7, 129.7 (2C), 129.6 (2C), 129.1 (2C), 128.3, 127.1, 127.0, 126.2 (2C), 122.5, 121.8, 120.8, 117.8, 21.5.



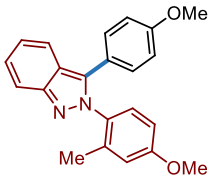
3-(4-Chlorophenyl)-2-phenyl-2*H*-indazole (3ca).[19a] Yellow oil (53 mg, 58% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.82 (d, *J* = 9.0 Hz, 1H), 7.68 (d, *J* = 9.0 Hz, 1H), 7.45–7.36 (m, 8H), 7.31–7.28 (m, 2H), 7.17 (ddd, *J* = 8.4, 6.6, 0.6 Hz, 1H); **^{13}C NMR** (151 MHz, Chloroform-*d*) δ 149.1, 140.1, 134.6, 134.3, 131.0 (2C), 129.3 (2C), 129.3 (2C), 128.7, 128.5, 127.3, 126.2 (2C), 123.0, 121.8, 120.3, 118.0.



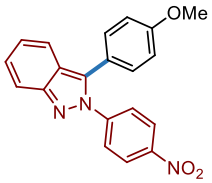
3-(3,5-Dimethoxyphenyl)-2-phenyl-2*H*-indazole (3da).[20] Yellow oil (67 mg, 68% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.81 (d, *J* = 9.0 Hz, 1H), 7.77 (d, *J* = 8.4 Hz, 1H), 7.49–7.46 (m, 2H), 7.44–7.36 (m, 4H), 7.15 (ddd, *J* = 8.4, 6.6, 0.6 Hz, 1H), 6.49 (d, *J* = 2.4 Hz, 2H), 6.47 (t, *J* = 2.4 Hz, 1H), 3.68 (s, 6H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 161.0 (2C), 149.0, 140.3, 135.5, 131.5, 129.1 (2C), 128.5, 127.2, 126.2 (2C), 122.7, 121.7, 120.7, 117.9, 107.9 (2C), 100.9, 55.5 (2C).



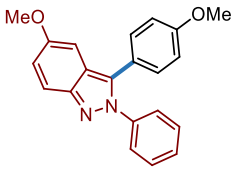
3-(4-Methoxyphenyl)-2-(*p*-tolyl)-2*H*-indazole (3ab).[19a] Yellow oil (71 mg, 75% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.79 (d, *J* = 9.0 Hz, 1H), 7.69 (d, *J* = 9.0 Hz, 1H), 7.37–7.28 (m, 5H), 7.18 (d, *J* = 8.0 Hz, 2H), 7.14–7.09 (m, 1H), 6.93 (d, *J* = 9.0 Hz, 2H), 3.84 (s, 3H), 2.39 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 159.8, 148.9, 138.3, 138.0, 135.5, 131.1 (2C), 129.7 (2C), 127.0, 125.9 (2C), 122.4, 122.3, 121.7, 120.7, 117.8, 114.4 (2C), 55.4, 21.3.



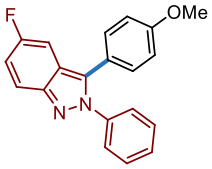
2-(4-Methoxy-2-methylphenyl)-3-(4-methoxyphenyl)-2*H*-indazole (3ac). Yellow oil (85 mg, 82% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.77 (dd, *J* = 12.0, 8.4 Hz, 2H), 7.39–7.35 (m, 1H), 7.29–7.25 (m, 3H), 7.16–7.13 (m, 1H), 6.88 (d, *J* = 8.4 Hz, 2H), 6.79 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.75 (d, *J* = 3.0 Hz, 1H), 3.83 (s, 3H), 3.81 (s, 3H), 1.89 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 160.0, 159.5, 148.7, 136.9, 136.6, 132.7, 130.5 (2C), 129.2, 126.8, 122.2 (2C), 120.8, 120.5, 117.8, 115.9, 114.3 (2C), 111.9, 55.6, 55.4, 18.0; **HRMS (ESI)** *m/z*: calcd for $C_{22}H_{21}N_2O_2$ $[M + H]^+$, 345.1598; found, 345.1607.



3-(4-Methoxyphenyl)-2-(4-nitrophenyl)-2*H*-indazole (3ad).[20a] Yellow oil (64 mg, 62% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.79 (d, *J* = 8.5 Hz, 1H), 7.69–7.64 (m, 3H), 7.60 (d, *J* = 8.5 Hz, 2H), 7.41–7.36 (m, 1H), 7.28 (d, *J* = 8.5 Hz, 2H), 7.15 (dd, *J* = 8.5, 6.0 Hz, 1H), 6.97 (d, *J* = 8.5 Hz, 2H), 3.87 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 160.2, 149.3, 143.1, 136.0, 131.2 (2C), 127.8, 126.4, 126.3, 126.2 (2C), 122.9, 122.1, 121.8, 120.8, 117.8, 114.8 (2C), 55.5.

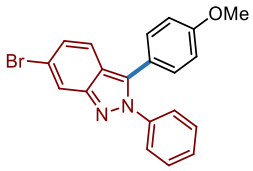


5-Methoxy-3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole (3ae).[21] Yellow oil (69 mg, 70% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.69 (d, *J* = 9.0 Hz, 1H), 7.43–7.33 (m, 5H), 7.29–7.25 (m, 2H, including d, *J* = 8.0 Hz, 2H), 7.07 (dd, *J* = 9.5, 2.5 Hz, 1H), 6.94 (d, *J* = 9.0 Hz, 2H), 6.87 (d, *J* = 2.5 Hz, 1H), 3.84 (s, 3H), 3.83 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 159.6, 155.9, 145.9, 140.5, 134.4, 131.0 (2C), 129.1 (2C), 128.1, 126.0 (2C), 122.7, 122.2, 121.6, 119.3, 114.5 (2C), 96.6, 55.6, 55.4.

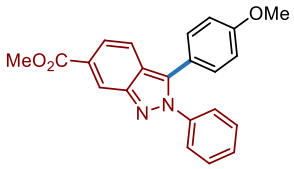


5-Fluoro-3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole (3af).[19a] Yellow oil (67 mg, 71% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.76 (dd, *J* = 9.5, 4.5 Hz, 1H), 7.45–7.37 (m, 5H), 7.29–7.22 (m, 3H), 7.16 (td, *J* = 9.5, 2.5 Hz, 3H), 6.92 (d, *J* = 9.0 Hz, 2H), 3.84 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-

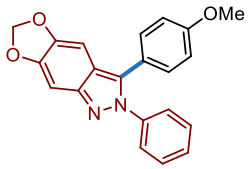
d) δ 159.9, 159.0 (d, J_F = 238.8 Hz), 146.4, 140.3, 135.8 (d, J_F = 8.8 Hz), 130.9 (2C), 129.2 (2C), 128.5, 126.0 (2C), 122.0, 121.0 (d, J_F = 11.3 Hz), 119.9 (d, J_F = 8.8 Hz), 118.7 (d, J_F = 28.8 Hz), 114.6 (2C), 103.1 (d, J_F = 23.8 Hz), 55.4; **^{19}F NMR** (565 MHz, Chloroform-*d*) δ -119.58.



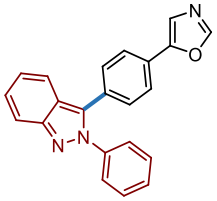
6-Bromo-3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole (3ag). Yellow oil (81 mg, 71% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.96 (s, 1H), 7.55 (d, *J* = 9.0 Hz, 1H), 7.43–7.37 (m, 5H), 7.24 (d, *J* = 9.0 Hz, 2H), 7.19 (dd, *J* = 9.0, 1.5 Hz, 1H), 6.92 (d, *J* = 9.0 Hz, 2H), 3.84 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 160.1, 149.6, 140.1, 136.3, 131.1 (2C), 129.2 (2C), 128.6, 126.1 (2C), 122.3, 121.7, 121.2, 121.1, 120.4, 120.1, 114.6 (2C), 55.5; **HRMS (ESI)** *m/z*: calcd for $C_{20}H_{16}{}^{79}BrN_2O$ $[M + H]^+$, 379.0441; found, 379.0432.



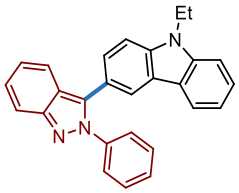
Methyl 3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole-6-carboxylate (3ah). Yellow oil (45 mg, 42% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ [8.58 major, 8.47 minor] (s, 1H), 7.90–7.55 (m, 3H), 7.50–7.27 (m, 6H), [7.02 minor, 6.94 major] (d, *J* = 8.4 Hz, 2H), [3.98 major, 3.88 minor] (s, 3H), [3.85 major, 3.68 minor] (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ [170.2 minor, 167.6 major], [160.0 major, 159.4 minor], [149.1 minor, 148.3 major], [140.5 minor, 140.2 major], [136.0 major, 133.5 minor], [131.12 major, 131.09 minor] (2C), [129.6 minor, 129.3 major], [129.0 major, 128.8 minor], [128.3 major, 128.0 minor], 126.1 (2C), 124.2, [123.6 major, 123.3 minor], [121.9 minor, 121.7 major], [121.3 minor, 120.9 major], [120.8 minor, 119.3 major], [114.6 major, 113.6 minor] (2C), [55.5 major, 55.4 minor], [52.4 major, 52.1 minor]; **HRMS (ESI)** *m/z*: calcd for $C_{22}H_{19}N_2O_3$ $[M + H]^+$, 359.1390; found, 359.1374.



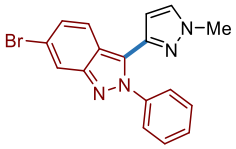
3-(4-Methoxyphenyl)-2-phenyl-2*H*-[1,3]dioxolo[4,5-*f*]indazole (3ai). White solid (43 mg, 42% yield), mp 219−221 °C; **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.40–7.30 (m, 5H), 7.22 (d, *J* = 9.0 Hz, 2H), 7.04 (s, 1H), 6.91 (d, *J* = 8.4 Hz, 2H), 6.88 (s, 1H), 5.97 (s, 2H), 3.83 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 159.7, 150.0, 146.5, 146.3, 140.4, 135.0, 130.9 (2C), 129.0 (2C), 127.8, 125.7 (2C), 122.4, 117.5, 114.4 (2C), 101.2, 95.4, 94.1, 55.4; **HRMS (ESI)** *m/z*: calcd for $C_{21}H_{17}N_2O_3$ $[M + H]^+$, 345.1234; found, 345.1216.



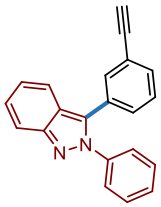
5-(4-(2-Phenyl-2*H*-indazol-3-yl)phenyl)oxazole (3ea). Yellow oil (74 mg, 73% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.95 (s, 1H), 7.83 (d, *J* = 9.0 Hz, 1H), 7.74 (d, *J* = 8.4 Hz, 1H), 7.69 (d, *J* = 7.8 Hz, 2H), 7.48–7.38 (m, 9H), 7.19 (dd, *J* = 8.4, 6.6 Hz, 1H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 151.0, 150.9, 149.0, 140.1, 134.8, 130.3 (2C), 130.1, 129.3 (2C), 128.7, 127.7, 127.4, 126.2 (2C), 124.8 (2C), 123.1, 122.5, 121.9, 120.4, 118.0; **HRMS (ESI)** *m/z*: calcd for $C_{22}H_{16}N_3O$ $[M + H]^+$, 338.1288; found, 338.1282.



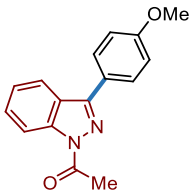
9-Ethyl-3-(2-phenyl-2*H*-indazol-3-yl)-9*H*-carbazole (3fa). Yellow oil (70 mg, 60% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 8.16 (s, 1H), 8.03 (d, *J* = 7.2 Hz, 1H), 7.85 (d, *J* = 8.4 Hz, 1H), 7.81 (d, *J* = 8.4 Hz, 1H), 7.53–7.49 (m, 3H), 7.45 (d, *J* = 7.8 Hz, 1H), 7.43–7.33 (m, 6H), 7.27–7.23 (m, 1H, including $CDCl_3$), 7.17 (dd, *J* = 8.4, 6.6 Hz, 1H), 4.39 (q, *J* = 7.2 Hz, 2H), 1.48 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 148.8, 140.5, 140.4, 139.8, 137.1, 129.1 (2C), 128.3, 127.6, 127.4, 126.4, 126.2 (2C), 123.4, 122.8, 122.4, 121.99, 121.97, 121.1, 120.7, 120.2, 119.5, 117.7, 109.0, 108.9, 37.9, 14.0; **HRMS (ESI)** *m/z*: calcd for $C_{27}H_{22}N_3$ $[M + H]^+$, 388.1808; found, 388.1798.



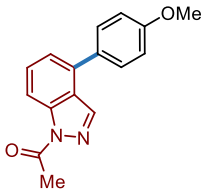
6-Bromo-3-(1-methyl-1*H*-pyrazol-3-yl)-2-phenyl-2*H*-indazole (3gg). Yellow oil (87 mg, 82% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 8.04 (d, *J* = 8.5 Hz, 1H), 7.92 (s, 1H), 7.53–7.50 (m, 2H), 7.49–7.46 (m, 3H), 7.27–7.26 (m, 1H), 7.23 (dd, *J* = 9.0, 1.5 Hz, 1H), 5.71 (d, *J* = 2.5 Hz, 1H), 3.97 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 149.6, 141.8, 140.4, 130.9, 130.6, 129.3, 129.2 (2C), 126.6 (2C), 126.3, 123.9, 121.3, 120.0, 119.8, 106.1, 39.4; **HRMS (ESI)** *m/z*: calcd for $C_{17}H_{14}{}^{79}BrN_4$ $[M + H]^+$, 353.0396; found, 353.0403.



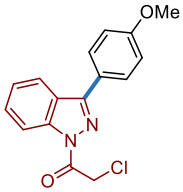
3-(3-Ethynylphenyl)-2-phenyl-2*H*-indazole (3ha). Yellow oil (21 mg, 24% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.82 (d, *J* = 9.0 Hz, 1H), 7.71 (d, *J* = 8.4 Hz, 1H), 7.59 (s, 1H), 7.50 (d, *J* = 7.8 Hz, 1H), 7.46–7.37 (m, 6H), 7.33 (t, *J* = 7.8 Hz, 1H), 7.24 (d, *J* = 7.8 Hz, 1H), 7.20–7.15 (m, 1H), 3.10 (s, 1H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 149.0, 134.0, 134.5, 133.1, 132.1, 130.33, 130.25, 129.3 (2C), 129.0, 128.7, 127.4, 126.1 (2C), 123.1, 121.9, 120.4 (2C), 117.9, 82.9, 78.3; **HRMS (ESI)** *m/z*: calcd for $C_{21}H_{15}N_2$ $[M + H]^+$, 295.1230; found, 295.1215.



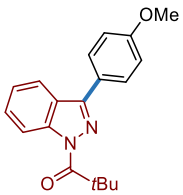
1-(3-(4-Methoxyphenyl)-1*H*-indazol-1-yl)ethan-1-one (3aj). White solid (36 mg, 27% yield), mp 86–88 °C; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.52 (d, *J* = 8.4 Hz, 1H), 7.99–7.92 (m, 3H), 7.58 (ddd, *J* = 8.4, 7.2, 1.2 Hz, 1H), 7.40 (ddd, *J* = 8.4, 7.2, 1.2 Hz, 1H), 7.10–7.05 (m, 2H), 3.90 (s, 3H), 2.84 (s, 3H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 171.4, 160.8, 149.8, 140.6, 129.5 (2C), 129.4, 124.9, 124.8, 124.5, 121.4, 116.1, 114.6 (2C), 55.6, 23.4; **HRMS (ESI)** *m/z*: calcd for $C_{16}H_{15}N_2O_2$ $[M + H]^+$, 267.1128; found, 267.1125.



1-(4-(4-Methoxyphenyl)-1*H*-indazol-1-yl)ethan-1-one (3aj'). White solid (43 mg, 32% yield), mp 130–132 °C; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.42 (d, *J* = 8.0 Hz, 1H), 8.24 (s, 1H), 7.62–7.55 (m, 3H), 7.38 (d, *J* = 7.2 Hz, 1H), 7.07 (d, *J* = 8.8 Hz, 2H), 3.90 (s, 3H), 2.81 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 171.3, 159.9, 139.7, 139.5, 135.6, 131.5, 129.9 (2C), 129.9, 124.9, 123.8, 114.7 (2C), 114.0, 55.6, 23.3; **HRMS (ESI)** *m/z*: calcd for $C_{16}H_{15}N_2O_2$ $[M + H]^+$, 267.1128; found, 267.1122.

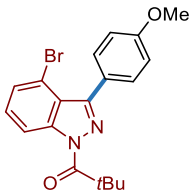


2-Chloro-1-(3-(4-methoxyphenyl)-1*H*-indazol-1-yl)ethan-1-one (3ak). Yellow oil (41 mg, 45% yield); rotamer ratio = 2:1; **^{1}H NMR** (500 MHz, Chloroform-*d*) δ [8.50 major, 8.39 minor] (d, *J* = 8.0 Hz, 1H), 8.00–7.52 (m, 4H, including [7.93 major, 7.55 minor] (d, *J* = 9.0 Hz, 2H)), 7.46–7.40 (m, 1H), 7.09–7.05 (m, 2H), [5.09 major, 5.02 minor] (s, 2H), [3.904 major, 3.895 minor] (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ [166.1 minor, 166.0 major], [161.2 major, 160.0 minor], 151.00, [140.74 minor, 140.72 major], [136.0 minor, 131.09 major], [130.4 minor, 129.9 major], [129.92 minor, 129.64 major] (2C), [125.5 major, 125.0 minor], [124.9 minor, 124.5 major], [123.9 minor, 121.77 major], [115.9 major, 113.7 minor], [114.70 minor, 114.66 major,] (2C), [55.58 major, 55.56 minor], [43.3 major, 43.10 minor]; **HRMS (ESI)** *m/z*: calcd for $C_{16}H_{14}{}^{35}ClN_2O_2$ $[M + H]^+$, 301.0738; found, 301.0743.

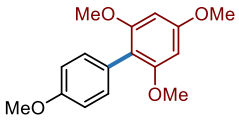


1-(3-(4-Methoxyphenyl)-1*H*-indazol-1-yl)-2,2-dimethylpropan-1-one (3al). Colorless oil (62 mg, 67% yield); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.57 (d, *J* = 8.4 Hz, 1H), 8.01–7.95 (m, 3H), 7.59–7.55 (m, 1H), 7.42–7.38 (m, 1H), 7.09 (d, *J* = 8.8 Hz, 2H), 3.90 (s, 3H), 1.64 (s, 9H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 178.6, 160.7, 148.5, 138.3, 130.7, 129.5 (2C), 129.2, 124.6, 123.6, 121.2, 116.7, 114.5

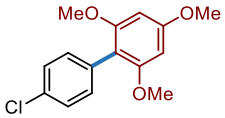
(2C), 55.6, 42.1, 28.1 (3C); **HRMS (ESI)** *m/z*: calcd for $C_{19}H_{21}N_2O_2$ $[M + H]^+$, 309.1598; found, 309.1602.



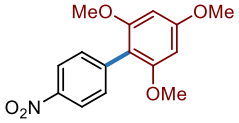
1-(4-Bromo-3-(4-methoxyphenyl)-1*H*-indazol-1-yl)-2,2-dimethylpropan-1-one (3am). Colorless oil (60 mg, 52% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 8.56 (d, *J* = 8.4 Hz, 1H), 7.63 (d, *J* = 8.4 Hz, 2H), 7.52 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.38 (t, *J* = 7.8 Hz, 1H), 7.02 (d, *J* = 8.4 Hz, 2H), 3.90 (s, 3H), 1.58 (s, 9H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 178.6, 160.6, 149.8, 142.8, 132.3 (2C), 130.2, 129.2, 124.2, 123.4, 115.6, 115.0, 113.3 (2C), 55.5, 42.3, 28.0 (3C); **HRMS (ESI)** *m/z*: calcd for $C_{19}H_{20}{}^{79}BrN_2O_2$ $[M + H]^+$, 387.0703; found, 387.0703.



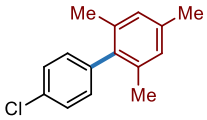
2,4,4',6-Tetramethoxy-1,1'-biphenyl (3ao).[25] White soild (77 mg, 56% yield), mp 101−104 °C (lit.,[22] 103−104 °C); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.29–7.26 (m, 2H, subtracting $CDCl_3$), 6.97–6.93 (m, 2H), 6.24 (s, 2H), 3.87 (s, 3H), 3.84 (s, 3H), 3.74 (s, 6H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 160.4, 158.6 (2C), 158.2, 132.3 (2C), 126.3, 113.3 (2C), 112.2, 91.0 (2C), 56.0 (2C), 55.5, 55.2.



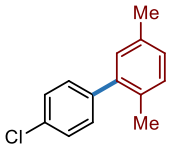
4'-Chloro-2,4,6-trimethoxy-1,1'-biphenyl (3co).[22] Colorless oil (97 mg, 70% yield); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.36–7.33 (m, 2H), 7.29–7.25 (m, 2H, subtracting $CDCl_3$), 6.23 (s, 2H), 3.87 (s, 3H), 3.73 (s, 6H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 160.9, 158.4 (2C), 132.8 (2C), 132.7, 132.4, 128.0 (2C), 111.3, 91.0 (2C), 56.0 (2C), 55.5.



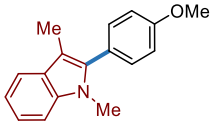
2,4,6-Trimethoxy-4'-nitro-1,1'-biphenyl (3io).[24] Yellow soild (98 mg, 68% yield), mp 167−168 °C (lit.,[24] 167−169 °C); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 8.24–8.20 (m, 2H), 7.53–7.49 (m, 2H), 6.23 (s, 2H), 3.88 (s, 3H), 3.74 (s, 6H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 161.7, 158.3 (2C), 146.4, 141.9, 132.4 (2C), 122.9 (2C), 110.2, 91.0 (2C), 56.0 (2C), 55.6.



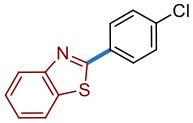
4'-Chloro-2,4,6-trimethyl-1,1'-biphenyl (3cp).[25] White solid (72 mg, 63% yield), mp 64–66 °C (lit.,[25] 64–65 °C); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.41 (d, *J* = 8.2 Hz, 2H), 7.10 (d, *J* = 8.2 Hz, 2H), 6.97 (s, 2H), 2.35 (s, 3H), 2.02 (s, 6H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 139.63, 137.87, 137.06, 136.01 (2C), 132.62, 130.87 (2C), 128.77 (2C), 128.29 (2C), 21.16, 20.84 (2C).



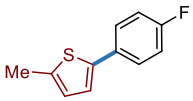
4'-Chloro-2,5-dimethyl-1,1'-biphenyl (3cq).[26] Colorless oil (60 mg, 56% yield); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.40–7.36 (m, 2H), 7.27–7.24 (m, 2H, subtracting $CDCl_3$), 7.18–7.00 (m, 3H), 2.35 (s, 3H), 2.21 (s, 3H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 140.7, 135.5, 132.9, 132.2, 130.7 (2C), 130.5, 128.4, 128.4 (2C), 21.0, 20.0.



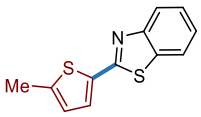
2-(4-Methoxyphenyl)-1,3-dimethyl-1*H*-indole (3ar).[27] Yellow solid (109 mg, 87% yield), mp 126–127 °C (lit.,[27] 126 °C); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.68 (d, *J* = 8.0 Hz, 1H), 7.40 (d, *J* = 7.5 Hz, 3H), 7.33 (t, *J* = 7.5 Hz, 1H), 7.26–7.22 (t, *J* = 7.5 Hz, 1H, subtracting $CDCl_3$), 7.10 (d, *J* = 9.0 Hz, 2H), 3.94 (s, 3H), 3.67 (s, 3H), 2.37 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 159.4, 137.6, 137.2, 132.0 (2C), 128.5, 124.5, 121.6, 119.1, 118.8, 114.0 (2C), 109.3, 108.3, 55.5, 31.0, 9.5.



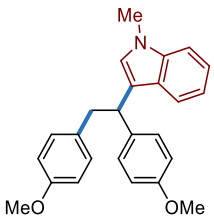
2-(4-Chlorophenyl)benzo[*d*]thiazole (3cs).[28] White solid (70 mg, 57% yield), mp 109–112 °C (lit.,[28] 110–112 °C); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.09–7.99 (m, 3H), 7.89 (d, *J* = 8.0 Hz, 1H), 7.53–7.44 (m, 3H), 7.42–7.36 (m, 1H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 166.7, 154.3, 137.2, 135.2, 132.3, 129.4 (2C), 128.9 (2C), 126.6, 125.5, 123.5, 121.8.



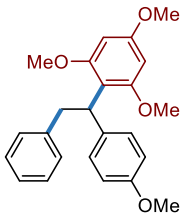
2-(4-Fluorophenyl)-5-methylthiophene (3ku).[30] White solid (62 mg, 64% yield), mp 74–77 °C (lit.,[30] 87–89 °C); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.53–7.48 (m, 2H), 7.08–7.01 (m, 3H), 6.76–6.69 (m, 1H), 2.51 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 162.2 (d, J_F = 245.0 Hz), 141.0, 139.6, 131.1 (d, J_F = 2.5 Hz), 127.3, 127.2, 126.3, 123.0, 115.9, 115.8, 15.6; **^{19}F NMR** (565 MHz, Chloroform-*d*) δ -115.38.



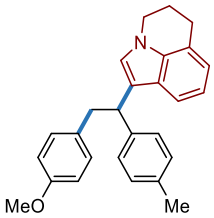
2-(5-Methylthiophen-2-yl)benzo[*d*]thiazole (3lu).[31] Yellow oil (37 mg, 32% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 8.00 (d, *J* = 8.2 Hz, 1H), 7.82 (d, *J* = 8.2 Hz, 1H), 7.49–7.43 (m, 2H), 7.36–7.32 (m, 1H), 6.81–6.78 (m, 1H), 2.56 (s, 3H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 161.8, 153.7, 145.0, 134.9, 134.6, 129.1, 126.6, 126.5, 125.1, 122.9, 121.5, 15.8.



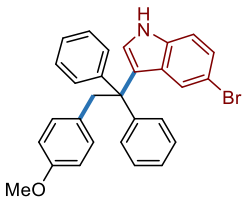
(*R*)-3-(1,2-Bis(4-methoxyphenyl)ethyl)-1-methyl-1*H*-indole (6aaa).[32] Colorless oil (111 mg, 60% yield); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.41 (d, *J* = 8.0 Hz, 1H), 7.28 (d, *J* = 8.0 Hz, subtracting $CDCl_3$), 7.21–7.16 (m, 1H), 7.13–7.09 (m, 2H), 7.03–6.99 (m, 1H), 6.97–6.94 (m, 2H), 6.88 (s, 1H), 6.78–6.71 (m, 4H), 4.39 (dd, *J* = 8.8, 6.0 Hz, 1H), 3.75 (d, *J* = 4.8 Hz, 9H, including s, 6H), 3.46 (dd, *J* = 13.4, 6.0 Hz, 1H), 3.18 (dd, *J* = 13.6, 9.2 Hz, 1H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 157.8, 157.8, 137.3, 136.8, 133.0, 130.1 (2C), 129.2 (2C), 127.4, 126.2, 121.6, 119.8, 118.9, 118.7, 113.6 (2C), 113.5 (2C), 109.2, 55.2 (d, *J* = 1.2 Hz, 2C), 44.4, 42.0, 32.7.



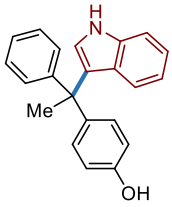
(*R*)-1,3,5-Trimethoxy-2-(1-(4-methoxyphenyl)-2-phenylethyl)benzene (6mba).[32] Yellow oil (102 mg, 54% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.38–7.34 (m, 2H), 7.23–7.19 (m, 2H), 7.17–7.11 (m, 3H), 6.87–6.83 (m, 2H), 6.11 (s, 2H), 4.96 (dd, *J* = 9.5, 7.0 Hz, 1H), 3.80 (d, *J* = 4.6 Hz, 6H, including s, 3H), 3.70 (s, 6H), 3.59–3.50 (m, 2H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 159.5 (2C), 159.2, 157.3, 142.1, 137.5, 129.0 (2C), 129.0 (2C), 127.8 (2C), 125.4, 114.0, 113.1 (2C), 91.5 (2C), 55.8, 55.2, 40.4, 38.6.



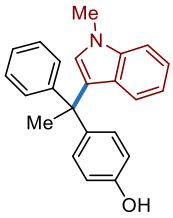
(*R*)-1-(2-(4-Methoxyphenyl)-1-(*p*-tolyl)ethyl)-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinoline (6acb). Colorless oil (59 mg, 31% yield); **^{1}H NMR** (400 MHz, Chloroform-*d*) *δ* 7.30 (d, *J* = 8.0 Hz, 1H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.06 (d, *J* = 8.0 Hz, 2H), 7.02 (d, *J* = 8.8 Hz, 2H), 6.98–6.93 (m, 2H), 6.90 (s, 1H), 6.76 (d, *J* = 8.4 Hz, 2H), 4.44 (dd, *J* = 9.2, 6.4 Hz, 1H), 4.13–4.09 (m, 2H), 3.78 (s, 3H), 3.52 (dd, *J* = 14.0, 6.4 Hz, 1H), 3.26 (dd, *J* = 14.0, 8.8 Hz, 1H), 3.01–2.97 (m, 2H), 2.32 (s, 3H), 2.25–2.22 (m, 2H); **^{13}C NMR** (100 MHz, Chloroform-*d*) *δ* 157.7, 141.9, 135.3, 134.8, 133.2, 130.1 (2C), 128.9 (2C), 128.7, 128.1 (2C), 123.6, 121.7, 119.2, 119.0, 118.5, 117.4, 113.5 (2C), 55.3, 45.2, 44.0, 41.9, 24.8, 23.0, 21.2; **HRMS (ESI)** *m/z*: calcd for $C_{27}H_{28}NO$ $[M + H]^+$, 382.2165; found, 382.2173.



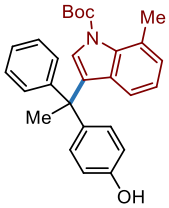
5-Bromo-3-(2-(4-methoxyphenyl)-1,1-diphenylethyl)-1*H*-indole (6adc). Yellow oil (149 mg, 62% yield); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 11.19 (s, 1H), 7.30 (d, *J* = 8.4 Hz, 1H), 7.27–7.20 (m, 8H), 7.19–7.14 (m, 3H), 7.06 (dd, *J* = 8.8, 1.6 Hz, 1H), 6.66 (s, 1H), 6.51 (d, *J* = 8.6 Hz, 2H), 6.43 (d, *J* = 8.6 Hz, 2H), 3.87 (s, 2H), 3.61 (s, 3H); **^{13}C NMR** (100 MHz, DMSO-d_6) δ 157.5, 145.7 (2C), 135.4, 131.6 (2C), 130.3, 129.0 (4C), 128.0, 127.5 (4C), 126.4, 125.9 (2C), 123.2, 123.1, 120.5, 113.6, 112.6 (2C), 110.7, 54.8, 53.5, 45.1; **HRMS (ESI)** *m/z*: calcd for $C_{29}H_{23}NO^{79}Br$ $[M - H]^-$, 480.0957; found, 480.0947.



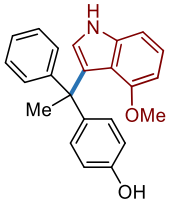
4-(1-(1*H*-Indol-3-yl)-1-phenylethyl)phenol (7ed).[33] Yellow oil (69 mg, 74% yield);**^{1}H NMR** (600 MHz, DMSO-d_6) δ 10.83 (s, 1H), 9.22 (brs, 1H), 7.35 (d, J = 8.4 Hz, 1H), 7.26–7.22 (m, 2H), 7.19–7.15 (m, 3H), 7.01–6.96 (m, 3H, including d, J = 9.0 Hz, 2H), 6.89 (d, J = 8.4 Hz, 1H), 6.77 (t, J = 8.4 Hz, 1H), 6.66 (d, J = 9.0 Hz, 2H), 6.58 (d, J = 2.4 Hz, 1H), 2.12 (s, 3H); **^{13}C NMR** (150 MHz, DMSO-d_6) δ 155.2, 149.0, 138.7, 137.1, 128.9 (2C), 127.9 (2C), 127.7 (2C), 126.0, 125.6, 123.9, 123.8, 121.0, 120.6, 118.1, 114.4 (2C), 111.6, 46.8, 29.7.



4-(1-(1-Methyl-1*H*-indol-3-yl)-1-phenylethyl)phenol (7ad). Yellow oil (55 mg, 56% yield); **^{1}H NMR** (600 MHz, DMSO-d_6) δ 9.23 (s, 1H), 7.36 (d, J = 8.4 Hz, 1H), 7.27–7.22 (m, 2H), 7.19–7.15 (m, 3H), 7.06 (t, J = 7.2 Hz, 1H), 6.95 (d, J = 9.0 Hz, 2H), 6.87 (d, J = 8.4 Hz, 1H), 6.80 (t, J = 7.2 Hz, 1H), 6.64 (d, J = 8.4 Hz, 2H), 6.59 (s, 1H), 3.68 (s, 3H), 2.10 (s, 3H); **^{13}C NMR** (150 MHz, DMSO-d_6) δ 155.2, 148.8, 138.6, 137.4, 128.9 (2C), 128.2, 127.9 (2C), 127.7 (2C), 126.3, 125.7, 123.2, 121.2, 120.7, 118.2, 114.5 (2C), 109.8, 46.8, 32.2, 29.7; **HRMS (ESI)** *m/z*: calcd for $C_{23}H_{21}{}^{35}ClNO$ $[M + Cl]^+$, 362.1317; found, 362.1329.

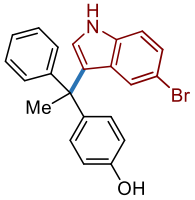


***tert*-Butyl 3-(1-(4-hydroxyphenyl)-1-phenylethyl)-7-methyl-1*H*-indole-1-carboxylate (7fd).** White solid (82 mg, 64% yield), mp 160–163 °C; **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.29–7.19 (m, 5H), 7.12–7.09 (m, 2H), 7.04 (d, J = 7.2 Hz, 1H), 6.94 (t, J = 7.8 Hz, 1H), 6.86–6.83 (m, 2H, including d, J = 7.8 Hz, 1H), 6.75–6.71 (m, 2H), 2.61 (s, 3H), 2.19 (s, 3H), 1.56 (s, 9H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 153.9, 149.8, 147.6, 139.8, 136.0, 130.9, 129.7 (2C), 129.4, 128.4 (2C), 128.1 (2C), 127.4, 127.3, 126.3, 125.4, 122.6, 120.3, 114.8 (2C), 83.4, 47.3, 29.3, 28.2 (3C), 27.1, 22.3; **HRMS (ESI)** *m/z*: calcd for $C_{28}H_{29}NNaO_3$ $[M + Na]^+$, 450.2040; found, 450.2047.

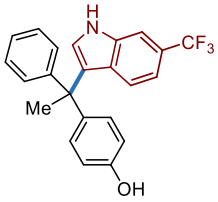


4-(1-(4-Methoxy-1*H*-indol-3-yl)-1-phenylethyl)phenol (7gd). Yellow oil (57 mg, 55% yield); **^{1}H NMR** (600 MHz, DMSO-d_6) δ 10.70 (s, 1H), 9.13 (s, 1H), 7.23–7.19 (m, 2H), 7.15–7.11 (m, 3H), 6.97–6.93 (m, 4H), 6.63 (d, J = 9.0 Hz, 2H), 6.33 (dd, J = 6.6, 2.4 Hz, 1H), 6.02 (s, 1H), 3.21 (s, 3H), 2.17 (s,

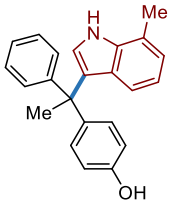
3H); **^{13}C NMR** (150 MHz, DMSO-d_6) δ 154.8, 153.3, 150.3, 140.0, 139.2, 128.8 (2C), 127.7 (2C), 127.2 (2C), 125.0, 125.0, 123.2, 122.0, 116.3, 114.1 (2C), 104.9, 100.2, 54.5, 47.1, 29.3; **HRMS (ESI)** *m/z*: calcd for $C_{23}H_{22}NO_2$ $[M + H]^+$, 344.1645; found, 344.1641.



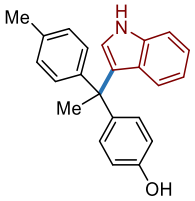
4-(1-(5-Bromo-1*H*-indol-3-yl)-1-phenylethyl)phenol (7dd). Yellow oil (91 mg, 78% yield); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 11.12 (s, 1H), 9.30 (s, 1H), 7.34 (d, J = 8.8 Hz, 1H), 7.29–7.23 (m, 2H), 7.21–7.09 (m, 4H), 6.98–6.90 (m, 3H), 6.74–6.64 (m, 3H), 2.09 (s, 3H); **^{13}C NMR** (100 MHz, DMSO-d_6) δ 155.3, 148.6, 138.3, 135.8, 128.9 (2C), 127.87 (2C), 127.83 (2C), 127.80, 125.8, 125.5, 123.6, 123.2, 122.9, 114.6 (2C), 113.8, 110.8, 46.7, 29.8; **HRMS (ESI)** *m/z*: calcd for $C_{22}H_{18}{}^{79}Br^{35}ClNO$ $[M + Cl]^+$, 426.0266; found, 426.0270.



4-(1-Phenyl-1-(6-(trifluoromethyl)-1*H*-indol-3-yl)ethyl)phenol (7hd). Yellow oil (83 mg, 73% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 8.19 (s, 1H), 7.65 (s, 1H), 7.32–7.17 (m, 8H), 7.11 (d, J = 9.0 Hz, 2H), 6.76 (d, J = 9.0 Hz, 2H), 6.66 (d, J = 2.0 Hz, 1H), 2.25 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 153.8, 148.4, 140.6, 136.1, 129.6 (2C), 128.8, 128.3 (2C), 128.1 (2C), 126.3, 126.24, 126.22, 125.3 (d, J_F = 270 Hz), 123.9 (q, J_F = 32.5 Hz), 122.5, 115.9 (d, J_F = 2.5 Hz), 114.89 (2C), 108.9 (d, J_F = 3.75 Hz), 47.42, 29.71; **^{19}F NMR** (565 MHz, Chloroform-*d*) δ -60.71; **HRMS (ESI)** *m/z*: calcd for $C_{23}H_{17}{}^{19}F_3NO$ $[M - H]^-$, 380.1268; found, 380.1267.

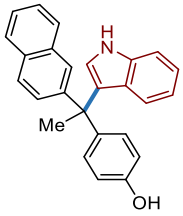


4-(1-(7-Methyl-1*H*-indol-3-yl)-1-phenylethyl)phenol (7id). Yellow oil (82 mg, 84% yield); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 10.76 (d, J = 3.0 Hz, 1H), 9.21 (brs, 1H), 7.26–7.22 (m, 2H), 7.18–7.14 (m, 3H), 6.96 (d, J = 8.5 Hz, 2H), 6.80 (d, J = 7.0 Hz, 1H), 6.72–6.63 (m, 4H), 6.54 (d, J = 2.5 Hz, 1H), 2.43 (s, 3H), 2.11 (s, 3H); **^{13}C NMR** (125 MHz, DMSO-d_6) δ 155.1, 149.0, 138.7, 136.6, 128.9 (2C), 127.9 (2C), 127.6 (2C), 125.6, 125.5, 124.4, 123.4, 121.1, 120.5, 118.7, 118.2, 114.4 (2C), 46.8, 29.6, 16.7; **HRMS (ESI)** *m/z*: calcd for $C_{24}H_{22}NO_3$ $[M + COOH]^+$, 372.1605; found, 372.1620.

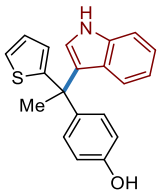


4-(1-(1*H*-Indol-3-yl)-1-(*p*-tolyl)ethyl)phenol (7ee). Yellow oil (81 mg, 83% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.88 (s, 1H), 7.35 (d, J = 7.8 Hz, 1H), 7.17–7.09 (m, 6H), 7.06 (d, J = 7.8 Hz, 2H), 6.94

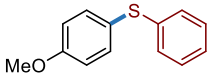
(t, *J* = 7.2 Hz, 1H), 6.72 (d, *J* = 8.4 Hz, 2H), 6.46 (d, *J* = 2.4 Hz, 1H), 2.33 (s, 3H), 2.21 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 153.6, 145.9, 141.3, 137.3, 135.4, 129.7 (2C), 128.7 (2C), 128.3 (2C), 126.5, 126.1, 123.7, 122.3, 121.8, 119.2, 114.7 (2C), 111.3, 47.2, 29.6, 21.1; **HRMS (ESI)** *m/z*: calcd for $C_{23}H_{20}NO$ $[M - H]^-$, 326.1550; found, 326.1561.



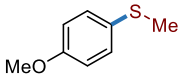
4-(1-(1*H*-Indol-3-yl)-1-(naphthalen-2-yl)ethyl)phenol (7ef). Yellow oil (57 mg, 53% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.91 (s, 1H), 7.81–7.79 (m, 1H), 7.74–7.66 (m, 3H), 7.46–7.40 (m, 3H), 7.37 (d, *J* = 8.4 Hz, 1H), 7.19 (d, *J* = 8.4 Hz, 1H), 7.18–7.13 (m, 3H), 6.93 (t, *J* = 8.4 Hz, 1H), 6.73 (d, *J* = 8.4 Hz, 2H), 6.48 (d, *J* = 2.4 Hz, 1H), 2.33 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 153.7, 146.4, 140.9, 137.3, 133.3, 132.0, 129.8 (2C), 128.4, 127.7, 127.5, 127.4, 126.5, 126.3, 125.9, 125.68, 125.65, 123.9, 122.3, 121.9, 119.3, 114.8 (2C), 111.3, 47.7, 29.6; **HRMS (ESI)** *m/z*: calcd for $C_{26}H_{21}{}^{35}ClNO$ $[M + Cl]^+$, 398.1317; found, 398.1324.



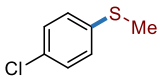
4-(1-(1*H*-Indol-3-yl)-1-(thiophen-2-yl)ethyl)phenol (7eg). Brown oil (46 mg, 48% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.92 (s, 1H), 7.35 (d, *J* = 9.0 Hz, 1H), 7.20–7.12 (m, 5H), 6.96–6.91 (m, 2H), 6.78 (d, *J* = 3.6 Hz, 1H), 6.73 (d, *J* = 8.4 Hz, 2H), 6.66 (d, *J* = 2.4 Hz, 1H), 2.28 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 154.8, 154.0, 140.7, 137.2, 129.1 (2C), 126.3, 126.1, 125.8, 125.4, 123.9, 123.3, 122.0, 121.9, 119.3, 114.8 (2C), 111.3, 45.6, 31.0; **HRMS (ESI)** *m/z*: calcd for $C_{20}H_{16}NOS$ $[M - H]^-$, 318.0958; found, 318.0962.



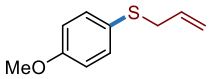
(4-Methoxyphenyl)(phenyl)sulfane (9aa).[34] Colorless oil (89 mg, 82% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.45–7.41 (m, 2H), 7.27–7.22 (m, 2H, subtracting $CDCl_3$), 7.20–7.12 (m, 3H), 6.93–6.89 (m, 2H), 3.83 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 160.0, 138.7, 135.5 (2C), 129.1 (2C), 128.4 (2C), 125.9, 124.5, 115.1 (2C), 55.5.



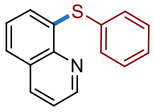
(4-Methoxyphenyl)(methyl)sulfane (9ab).[35] White solid (45 mg, 58% yield), mp 26–29 °C (lit.,[35] 25–26 °C); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.30–7.26 (m, 2H), 6.87–6.84 (m, 2H), 3.79 (s, 3H), 2.45 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 158.3, 130.3 (2C), 128.9, 114.7 (2C), 55.4, 18.2.



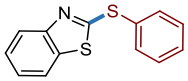
(4-Chlorophenyl)(methyl)sulfane (9cb).[35] Colorless oil (30 mg, 38% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.26–7.23 (m, 2H, subtracting $CDCl_3$), 7.19–7.15 (m, 2H), 2.46 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 137.1, 131.0, 129.0 (2C), 128.1 (2C), 16.2.



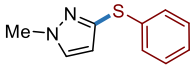
Allyl(4-methoxyphenyl)sulfane (9ac).[36] Colorless oil (58 mg, 64% yield); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.37–7.31 (m, 2H), 6.86–6.81 (m, 2H), 5.90–5.78 (m, 1H), 5.02–4.95 (m, 2H), 3.79 (s, 3H), 3.43 (d, *J* = 6.8 Hz, 2H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 159.2, 134.13, 134.08 (2C), 125.8, 117.4, 114.5 (2C), 55.4, 39.5.



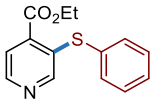
8-(Phenylthio)quinoline (9na).[37] Yellow solid (60 mg, 51% yield), mp 117–119 °C (lit.,[39] 124–125 °C); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 8.99 (dd, *J* = 4.5, 2.0 Hz, 1H), 8.15 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.67–7.64 (m, 2H), 7.56 (dd, *J* = 8.0, 1.0 Hz, 1H), 7.48–7.43 (m, 4H), 7.31 (t, *J* = 7.5 Hz, 1H), 7.02 (dd, *J* = 7.5, 1.5 Hz, 1H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 149.6, 144.8, 140.2, 136.5, 135.8 (2C), 132.0, 129.8 (2C), 129.1, 128.4, 126.8, 125.6, 124.5, 121.9.



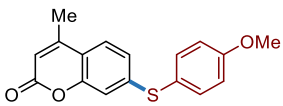
2-(Phenylthio)benzo[*d*]thiazole (9la).[38] Brown oil (64 mg, 53% yield); ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.89 (d, *J* = 5.0 Hz, 1H), 7.78–7.72 (m, 2H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.53–7.46 (m, 3H), 7.41 (ddd, *J* = 8.0, 7.5, 1.5 Hz, 1H), 7.29–7.25 (m, 1H, subtracting $CDCl_3$); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 169.9, 154.0, 135.6, 135.5 (2C), 130.6, 130.1 (2C), 126.3, 124.5, 122.1, 120.9.



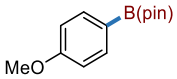
1-Methyl-3-(phenylthio)-1*H*-pyrazole (9ga). Colorless oil (60 mg, 63% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) *δ* 7.37 (d, *J* = 2.0 Hz, 1H), 7.29–7.26 (m, 2H), 7.25–7.21 (m, 2H), 7.16–7.12 (m, 1H), 6.33 (d, *J* = 2.0 Hz, 1H), 3.91 (s, 3H); **^{13}C NMR** (100 MHz, Chloroform-*d*) *δ* 142.7, 136.7, 131.9, 129.0 (2C), 128.6 (2C), 126.2, 111.3, 39.5; **HRMS (ESI)** *m/z*: calcd for $C_{10}H_{11}N_2S$ $[M + H]^+$, 191.0637; found, 191.0645.



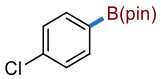
Ethyl 3-(phenylthio)isonicotinate (9oa). Yellow oil (96 mg, 37% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 8.39 (d, *J* = 5.0 Hz, 1H), 8.09 (s, 1H), 7.73 (dd, *J* = 5.0, 0.5 Hz, 1H), 7.58–7.54 (m, 2H), 7.45–7.41 (m, 3H), 4.44 (q, *J* = 7.0 Hz, 2H), 1.42 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) *δ* 165.3, 149.2, 145.6, 137.7, 135.2 (2C), 134.1, 131.0 (2C), 130.1, 129.6, 123.2, 62.1, 14.3; **HRMS (ESI)** *m/z*: calcd for $C_{14}H_{14}NO_2S$ $[M + H]^+$, 260.0740; found, 260.0744.



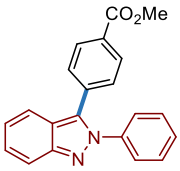
7-((4-Methoxyphenyl)thio)-4-methyl-2*H*-chromen-2-one (9pd). Yellow oil (128 mg, 43% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.48–7.45 (m, 2H), 7.40 (d, *J* = 8.0 Hz, 1H), 7.01 (dd, *J* = 8.5, 2.0 Hz, 1H), 6.98–6.94 (m, 2H), 6.82 (d, *J* = 1.5 Hz, 1H), 6.16 (d, *J* = 1.0 Hz, 1H), 3.86 (s, 3H), 2.36 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 161.0, 160.7, 154.1, 152.3, 146.2, 137.2, 124.7, 122.0, 120.9, 117.1, 115.7, 113.9, 113.7, 55.5, 18.6; **HRMS (ESI)** *m/z*: calcd for $C_{17}H_{14}NaO_3S$ $[M + Na]^+$, 321.0556; found, 321.0552.



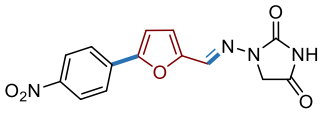
2-(4-Methoxyphenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (9ae).[1] Colorless oil (73 mg, 62% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 7.76 (d, *J* = 8.5 Hz, 2H), 6.90 (d, *J* = 9.0 Hz, 2H), 3.83 (s, 3H), 1.34 (s, 12H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 162.3, 136.7 (2C), 113.5 (2C), 83.7 (2C), 55.2, 25.0 (4C).



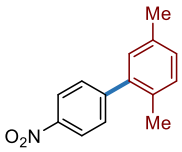
2-(4-Chlorophenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (9ce).[1] Brown oil (62 mg, 52 % yield); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.73 (d, *J* = 8.4 Hz, 2H), 7.34 (d, *J* = 8.4 Hz, 2H), 1.34 (s, 12H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 137.7, 136.2 (2C), 128.1 (2C), 84.1 (2C), 25.0 (4C).



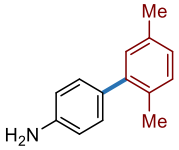
Methyl 4-(2-phenyl-2*H*-indazol-3-yl)benzoate (3qa).[12] Yellow solid (61 mg, 62% yield), mp 158–161 °C (lit.,[12] 164.5–166.3 °C); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 8.06 (d, *J* = 7.8 Hz, 2H), 7.83 (d, *J* = 9.0 Hz, 1H), 7.72 (d, *J* = 8.4 Hz, 1H), 7.46–7.38 (m, 9H), 7.19 (dd, *J* = 8.4, 6.6 Hz, 1H), 3.94 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 166.7, 149.1, 140.1, 134.5, 134.3, 130.1 (2C), 129.8, 129.7 (2C), 129.4 (2C), 128.8, 127.4, 126.2 (2C), 123.4, 122.0, 120.3, 118.1, 52.5.



Dantrolene (11).[15] Yellow solid (52 mg, 33% yield), mp 263–264 °C (lit.,[15] 274 °C); **^{1}H NMR** (500 MHz, DMSO-*d*6) δ 11.34 (s, 1H), 8.31 (d, *J* = 9.0 Hz, 2H), 8.01 (d, *J* = 9.0 Hz, 2H), 7.76 (s, 1H), 7.46 (d, *J* = 3.5 Hz, 1H), 7.04 (d, *J* = 3.5 Hz, 1H), 4.36 (s, 2H); **^{13}C NMR** (100 MHz, DMSO-*d*6) δ 168.9, 153.3, 152.1, 151.1, 146.3, 135.2, 132.6, 124.6 (2C), 124.5 (2C), 115.6, 112.5, 49.0.

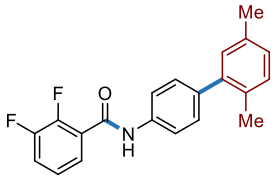


2,5-Dimethyl-4'-nitro-1,1'-biphenyl (3iq).[13] White solid (62 mg, 55% yield), mp 102–104 °C (lit.,[13] 86–87 °C); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 8.28 (d, *J* = 8.5 Hz, 2H), 7.49 (d, *J* = 8.5 Hz, 2H), 7.20 (d, *J* = 7.5 Hz, 1H), 7.17–7.13 (m, 1H), 7.04 (s, 1H), 2.37 (s, 3H), 2.23 (s, 3H); **^{13}C NMR** (125 MHz, Chloroform-*d*) δ 149.1, 146.9, 139.6, 135.8, 132.0, 130.8, 130.2 (2C), 129.3, 123.5 (2C), 21.0, 20.0.

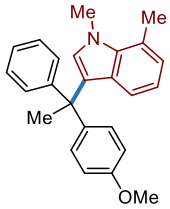


2',5'-Dimethyl-[1,1'-biphenyl]-4-amine (3iq'). White oil (57 mg, 97% yield); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.16–7.11 (m, 3H), 7.04 (d, *J* = 7.2 Hz, 2H), 6.74 (d, *J* = 8.4 Hz, 2H), 3.75 (bs, 1H), 2.34 (s, 3H), 2.25 (s, 3H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 145.1, 135.3, 132.5, 132.4, 130.8, 130.3, 130.2 (2C), 127.5, 114.9 (2C), 21.1, 20.3; **HRMS (ESI)** *m/z*: calcd for $C_{14}H_{16}N$ [M + H]$^+$, 198.1277;

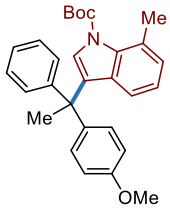
found, 198.1266.



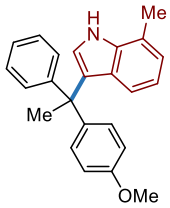
***N*-(2',5'-Dimethyl-[1,1'-biphenyl]-4-yl)-2,3-difluorobenzamide (12).**[12] White solid (55 mg, 82% yield), mp 147–148 °C; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.37 (d, *J* = 13.0 Hz, 1H), 7.96–7.87 (m, 1H), 7.70 (d, *J* = 8.5 Hz, 2H), 7.42–7.32 (m, 3H), 7.30–7.23 (m, 2H), 7.17 (d, *J* = 7.6 Hz, 1H), 7.08 (d, *J* = 9.7 Hz, 2H), 2.36 (s, 3H), 2.26 (s, 3H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 160.46, 150.6 (dd, J_F = 249.0, 15.0 Hz), 148.9 (dd, J_F = 247.0, 14.0 Hz), 141.1, 139.1, 136.2, 135.4, 132.3, 130.6, 130.5, 130.0 (2C), 128.2, 126.7 (d, J_F = 4.0 Hz), 125.0 (dd, J_F = 7.0, 4.0 Hz), 123.8 (d, J_F = 9.0 Hz), 120.8 (d, J_F = 17 Hz), 120.4 (2C).



3-(1-(4-Methoxyphenyl)-1-phenylethyl)-1,7-dimethyl-1*H*-indole (13). White solid (88 mg, 83% yield), mp 142–144 °C; **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.33 (d, *J* = 4.2 Hz, 4H), 7.29–7.25 (m, 1H), 7.25–7.22 (m, 2H), 7.04 (d, *J* = 7.8 Hz, 1H), 6.93 (d, *J* = 7.2 Hz, 1H), 6.89–6.83 (m, 3H), 6.23 (s, 1H), 3.99 (s, 3H), 3.86 (s, 3H), 2.82 (s, 3H), 2.30 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 157.7, 148.9, 141.0, 136.7, 130.4, 129.5 (2C), 128.4 (2C), 127.90 (2C), 127.89, 125.9, 124.1, 123.9, 121.2, 120.6, 118.9, 113.2 (2C), 55.3, 47.3, 36.8, 29.5, 20.0; **HRMS (ESI)** *m/z*: calcd for $C_{25}H_{25}KNO$ $[M + K]^+$, 394.1568; found, 394.1563.

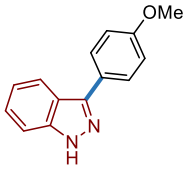


***tert*-Butyl 3-(1-(4-methoxyphenyl)-1-phenylethyl)-7-methyl-1*H*-indole-1-carboxylate (7jd').** Colorless oil (128 mg, 96% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.30–7.21 (m, 5H), 7.19–7.16 (m, 2H), 7.05 (d, *J* = 7.2 Hz, 1H), 6.95 (t, *J* = 7.8 Hz, 1H), 6.89–6.84 (m, 2H, including, d, *J* = 7.8 Hz, 1H), 6.84–6.81 (m, 2H), 3.80 (s, 3H), 2.62 (s, 3H), 2.21 (s, 3H), 1.58 (s, 9H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 158.0, 149.8, 147.6, 139.5, 136.0, 131.0, 129.5 (2C), 129.4, 128.4 (2C), 128.0 (2C), 127.3, 127.2, 126.2, 125.3, 122.6, 120.3, 113.4 (2C), 83.3, 55.3, 47.3, 29.3, 28.2 (3C), 22.3; **HRMS (ESI)** *m/z*: calcd for $C_{29}H_{32}NO_3$ $[M + H]^+$, 442.2377; found, 442.2365.

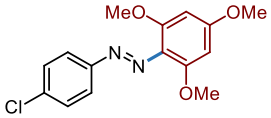


3-(1-(4-Methoxyphenyl)-1-phenylethyl)-7-methyl-1*H*-indole (14).[16] Colorless oil (85 mg, 83% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.81 (brs, 1H), 7.27–7.25 (m, 3H, including $CDCl_3$), 7.23–7.19

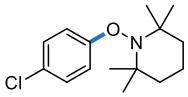
(m, 1H), 7.19–7.15 (m, 2H), 7.01 (d, *J* = 8.4 Hz, 1H), 6.97 (d, *J* = 7.2 Hz, 1H), 6.88 (t, *J* = 7.2 Hz, 1H), 6.83–6.78 (m, 2H), 6.46 (d, *J* = 2.4 Hz, 1H), 3.80 (s, 3H), 2.49 (s, 3H), 2.25 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 157.7, 148.9, 140.9, 136.8, 129.5 (2C), 128.4 (2C), 127.9 (2C), 126.5, 126.1, 125.9, 123.4, 122.4, 120.3, 120.1, 119.4, 113.2 (2C), 55.3, 47.5, 29.6, 16.7.



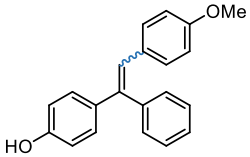
3-(4-Methoxyphenyl)-1*H*-indazole (3an).[17] Yellow oil (58 mg, 87% yield); **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 8.04–7.95 (m, 3H, including d, *J* = 7.8 Hz, 1H), 7.35 (t, *J* = 7.2 Hz, 1H), 7.27–7.24 (m, 1H, including $CDCl_3$), 7.21 (t, *J* = 7.5 Hz, 1H), 7.09 (d, *J* = 8.4 Hz, 2H), 3.90 (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ 159.8, 145.5, 141.8, 129.1 (2C), 126.8, 126.3, 121.22, 121.20, 121.0, 114.6 (2C), 110.4, 55.5.



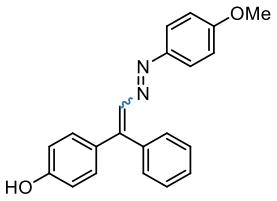
(*E*)-1-(4-Chlorophenyl)-2-(2,4,6-trimethoxyphenyl)diazene (3co').[23] Brown solid, mp 108−110 °C (lit.,[23] 111 °C); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.77 (d, *J* = 8.8 Hz, 2H), 7.42 (d, *J* = 8.8 Hz, 2H), 6.20 (s, 2H), 3.84 (d, *J* = 4.6 Hz, 9H, including s, 6H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 162.5, 155.2 (2C), 152.5, 135.5, 129.0 (2C), 127.3, 123.5 (2C), 91.4 (2C), 56.4 (2C), 55.5.



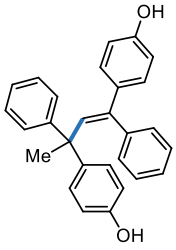
1-(4-Chlorophenoxy)-2,2,6,6-tetramethylpiperidine (1c-TEMPO).[39] White solid (29 mg, 22% yield), mp 89–91 °C (lit.,[39] 89.5–90.5 °C); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.18–7.09 (m, 4H), 1.63–1.54 (m, 5H), 1.44–1.38 (m, 1H), 1.22 (s, 6H), 0.99 (s, 6H); **^{13}C NMR** (100 MHz, Chloroform-*d*) δ 162.3, 128.7 (2C), 124.5, 115.3 (2C), 60.6 (2C), 39.9 (2C), 32.6 (2C), 20.6 (2C), 17.1.



4-(2-(4-Methoxyphenyl)-1-phenylvinyl)phenol (5ad').[40] Yellow oil (30 mg, 33% yield); stereomer ratio = 2.57:1, **^{1}H NMR** (600 MHz, Chloroform-*d*) δ 7.36–7.21 (m, 5H, including $CDCl_3$), 7.21–6.92 (m, 4H, including [7.20 major, 7.01 minor] (d, *J* = 9.0 Hz, 2H), [7.09 minor, 6.94 major] (d, *J* = 8.4 Hz, 2H)], [6.87 minor, 6.84 major] (s, 1H), [6.81 minor, 6.77 major] (d, *J* = 9.0 Hz, 2H), [6.71 minor, 6.67 major] (d, *J* = 9.0 Hz, 2H), 5.10 (brs, 1H), [3.77 minor, 3.75 major] (s, 3H); **^{13}C NMR** (150 MHz, Chloroform-*d*) δ [158.35 minor, 158.23 major], [155.17 major, 155.00 minor], [144.01 minor, 140.91 major], [140.37 minor, 140.27 major], [136.53 major, 133.08 minor], [131.95 major, 130.48 minor], [130.89 minor, 130.78 major] (2C), [130.53 major, 130.44 minor] (2C), [128.90 major, 128.27 minor] (2C), [128.81 major, 127.61 minor] (2C), [127.51 minor, 127.36 major], [127.33 minor, 126.15 major], [115.76 minor, 115.17 major] (2C), [113.57 minor, 113.54 major] (2C), [60.80 minor, 55.30 major].



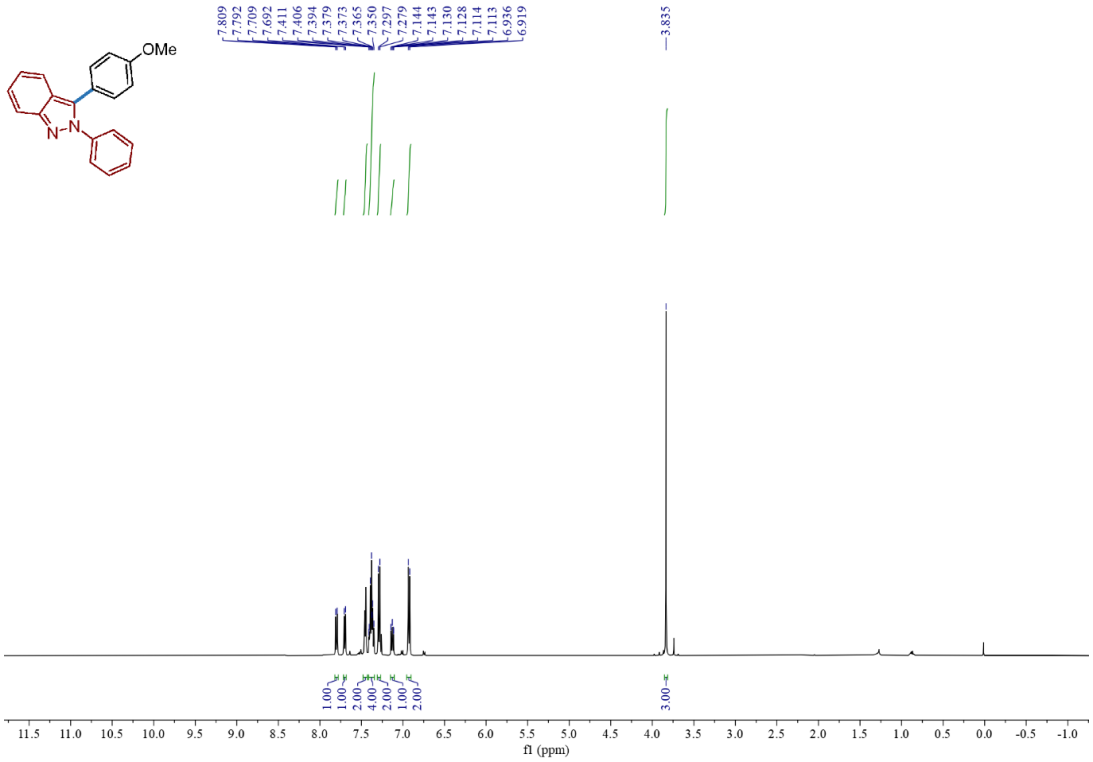
4-(2-((4-Methoxyphenyl)diazenyl)-1-phenylvinyl)phenol (5ad"). Brown oil (5 mg, 5% yield); stereomer ratio = 1.35:1, **^{1}H NMR** (500 MHz, Chloroform-*d*) δ [9.94 major, 9.82 minor] (s, 1H), [7.81 major, 7.68 minor] (s, 1H), [7.62 minor, 7.52 major] (d, *J* = 9.0 Hz, 2H), 7.47–7.34 (m, 5H), [7.31 major, 7.23 minor] (d, *J* = 9.0 Hz, 2H), [7.07 minor, 7.03 major] (d, *J* = 9.0 Hz, 2H), [6.84 minor, 6.83 major] (d, *J* = 9.0 Hz, 2H), [3.83 minor, 3.81 major] (s, 1H); **^{13}C NMR** (150 MHz, DMSO-d_6) δ [161.4 minor, 161.2 major], [158.91 major, 158.17 minor], [149.3 major, 148.9 minor], [147.20 minor, 147.17 major], [142.8 minor, 141.9 major], [140.3 minor, 138.03 major], [133.26 minor, 131.28 major] (2C), [130.0 major, 128.8 minor] (2C), [129.6 minor, 129.2 major], [128.6 minor, 127.6 major] (2C), [128.3 major, 128.2 minor], [115.6 minor, 114.6 major] (2C), [114.63 minor, 114.61 major] (2C), [55.56 minor, 55.53 major]; **HRMS (ESI)** *m/z*: calcd for $C_{21}H_{18}{}^{35}ClN_2O_2$ $[M + Cl]^+$, 365.1062; found, 365.1076.

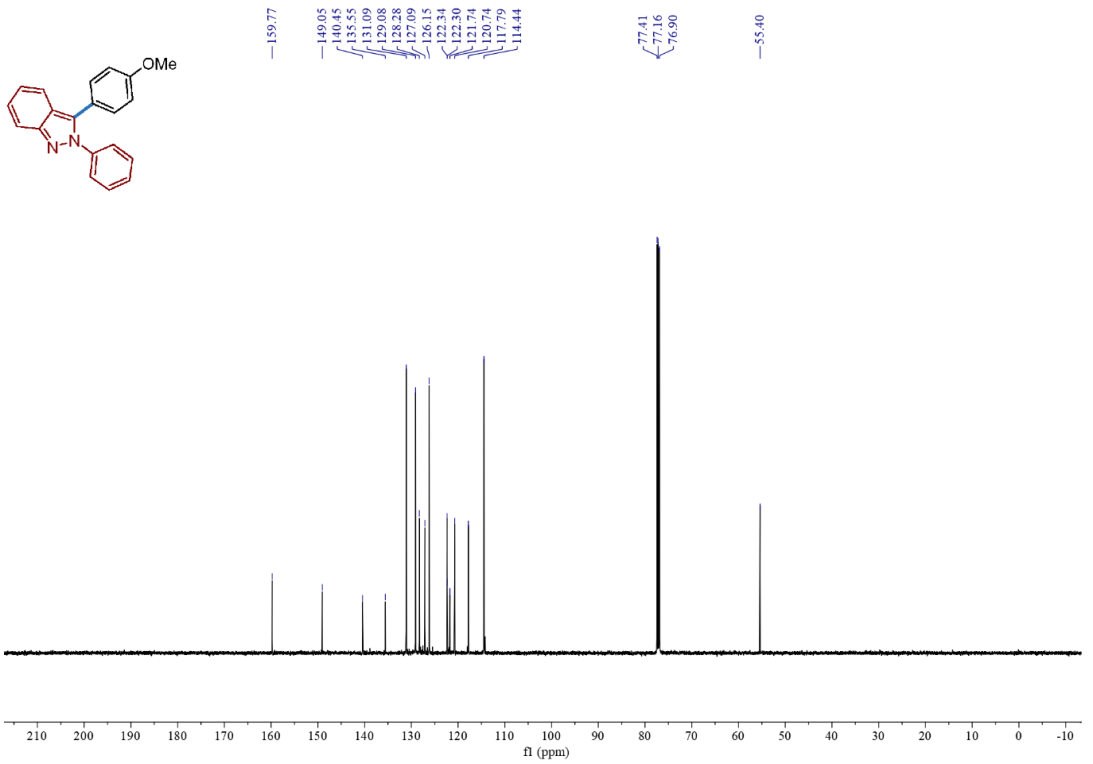


(*E*)-4,4'-(1,3-Diphenylbut-1-ene-1,3-diyl)diphenol (15). Colorless oil (35 mg, 60% yield); **^{1}H NMR** (500 MHz, Chloroform-*d*) δ 9.41 (s, 1H), 9.24 (s, 1H), 7.27–7.23 (m, 2H), 7.21–7.18 (m, 3H), 7.16–7.12 (m, 3H), 6.94 (d, *J* = 8.5 Hz, 4H), 6.86–6.81 (m, 2H), 6.66 (dd, *J* = 9.0, 3.0 Hz, 4H), 6.54 (s, 1H), 1.27 (s, 3H); **^{13}C NMR** (150 MHz, DMSO-d_6) δ 156.6, 155.1, 150.8, 140.4, 140.2, 139.4, 135.8, 134.6, 129.4 (2C), 128.2 (2C), 127.9 (2C), 127.9 (2C), 127.6 (2C), 127.2 (2C), 126.6, 125.5, 114.9 (2C), 114.7 (2C), 48.5, 28.9; **HRMS (ESI)** *m/z*: calcd for $C_{28}H_{24}{}^{35}ClO_2$ $[M + Cl]^+$, 427.1470; found, 427.1484.

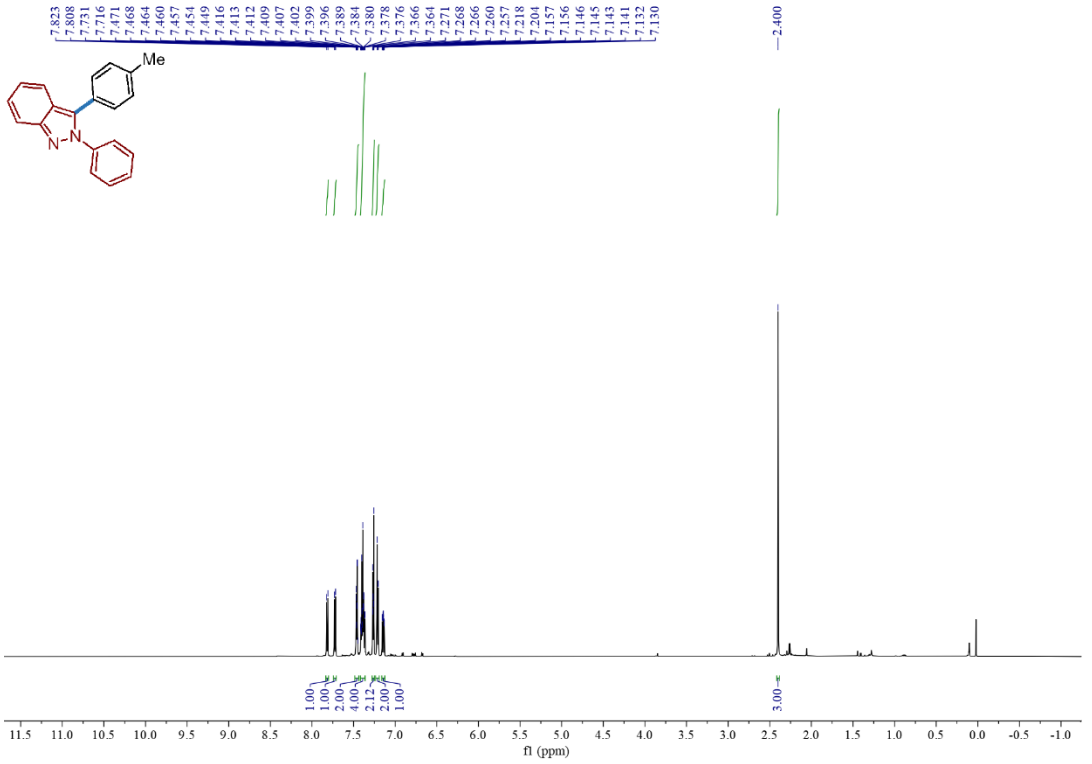
12. NMR spectra

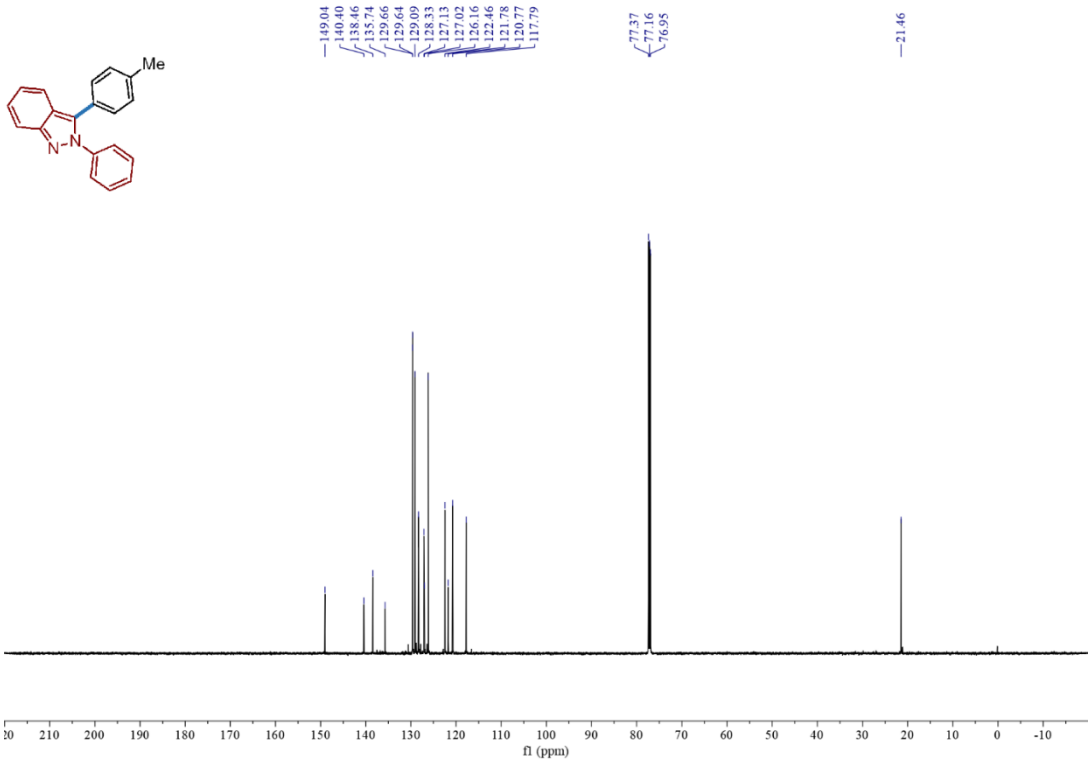
3-(4-Methoxyphenyl)-2-phenyl-2*H*-indazole (3aa)



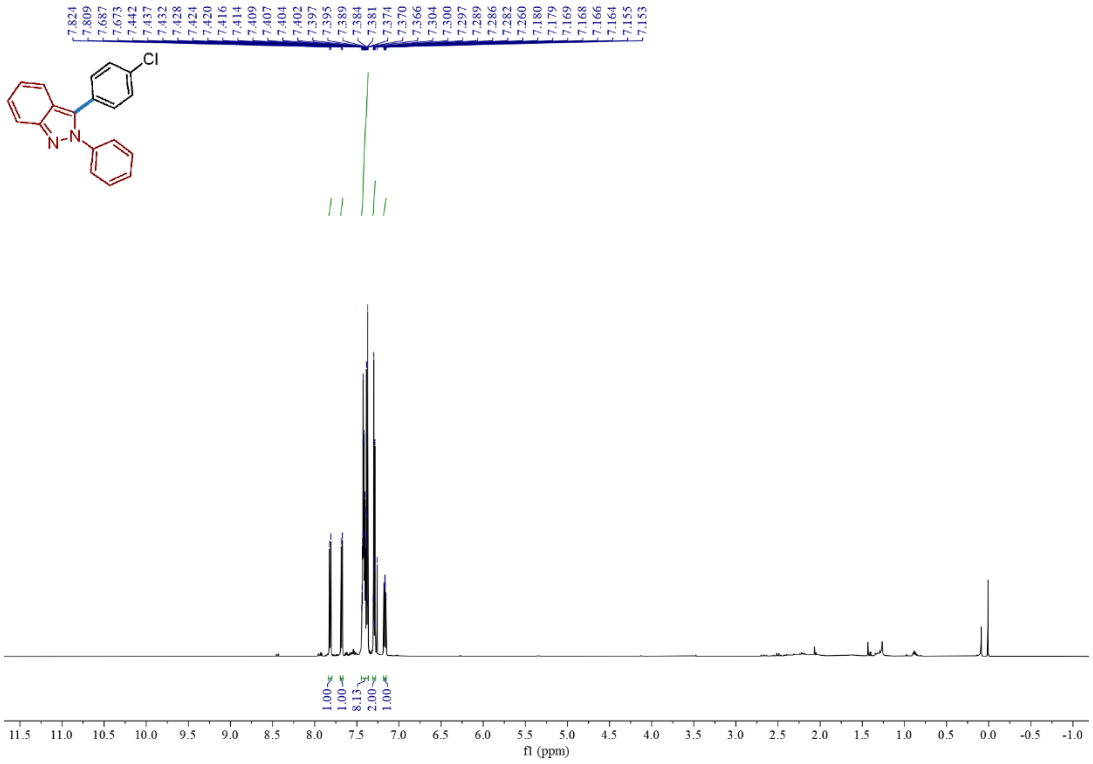


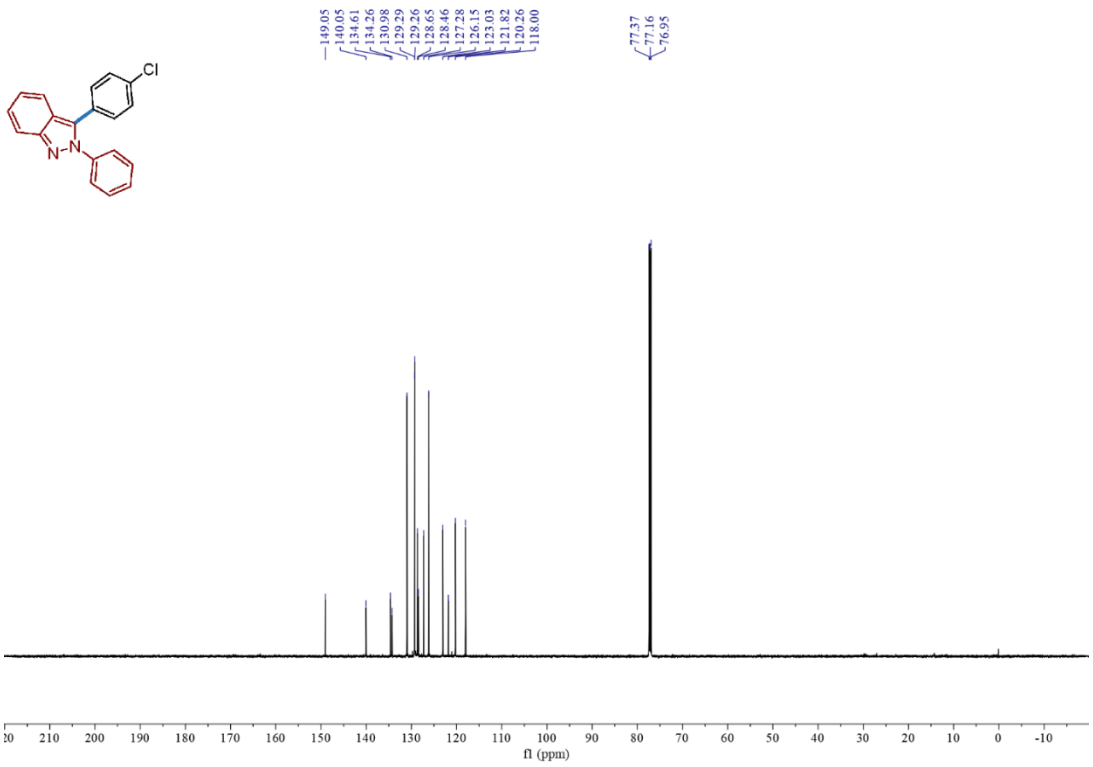
2-Phenyl-3-(*p*-tolyl)-2*H*-indazole (3ba)



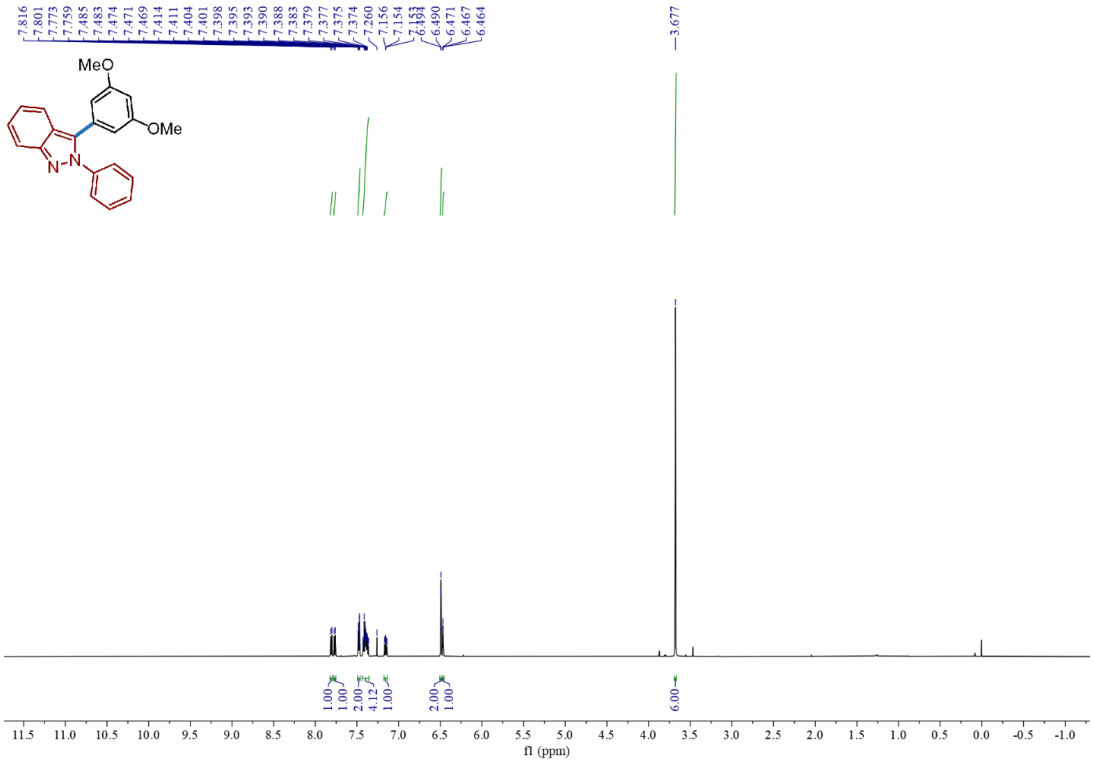


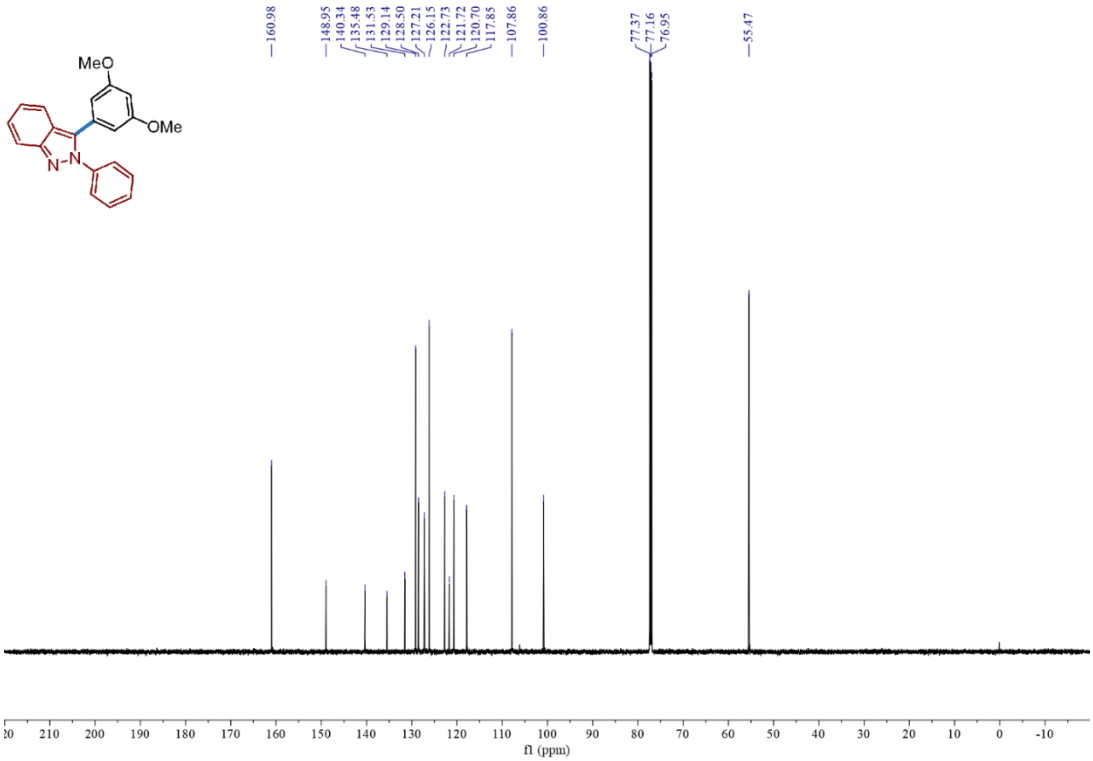
3-(4-Chlorophenyl)-2-phenyl-2*H*-indazole (3ca)



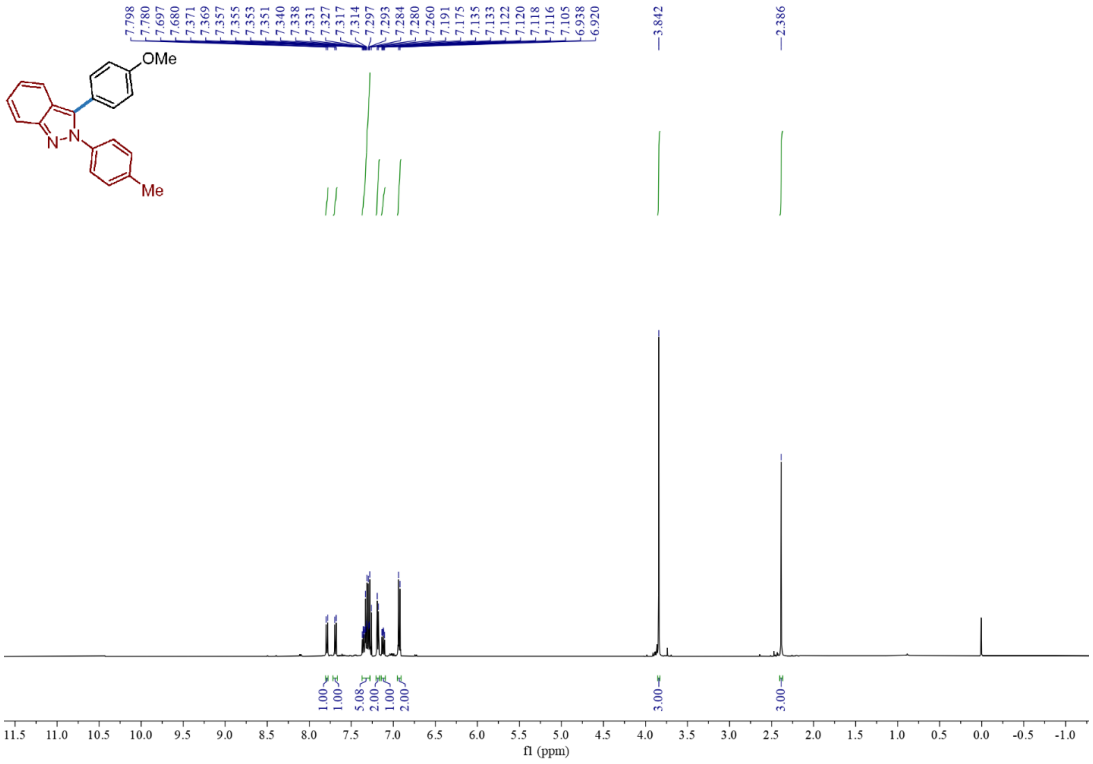


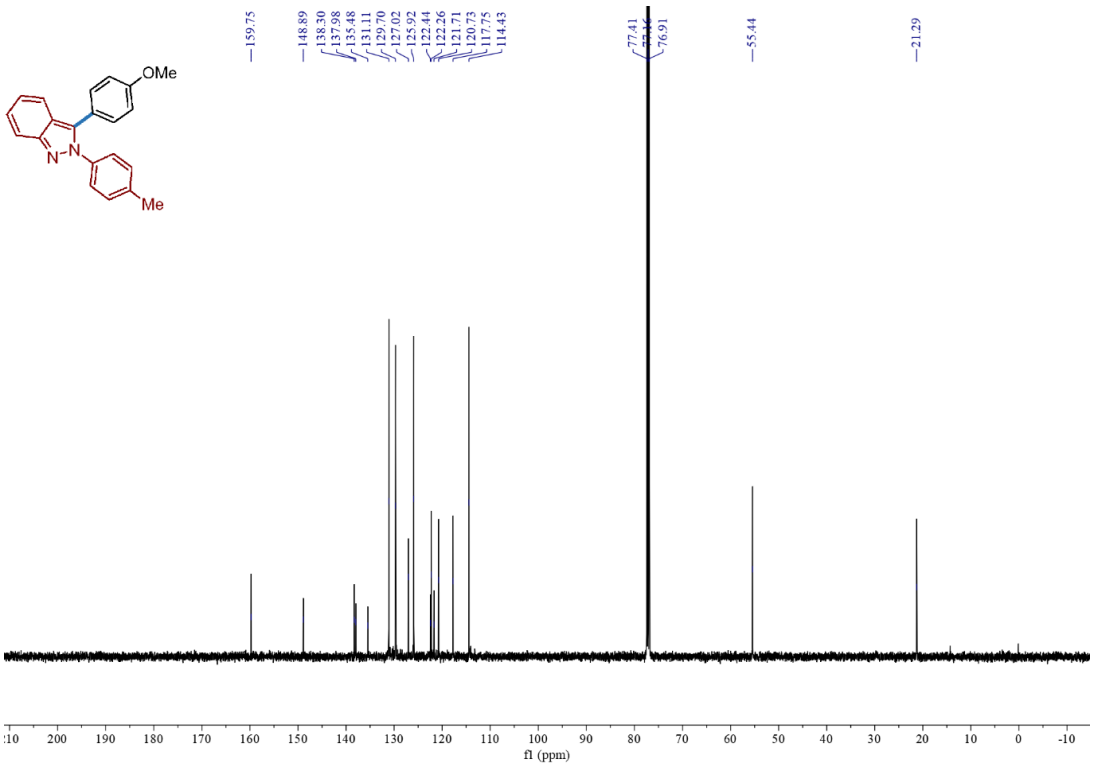
3-(3,5-Dimethoxyphenyl)-2-phenyl-2*H*-indazole (3da)



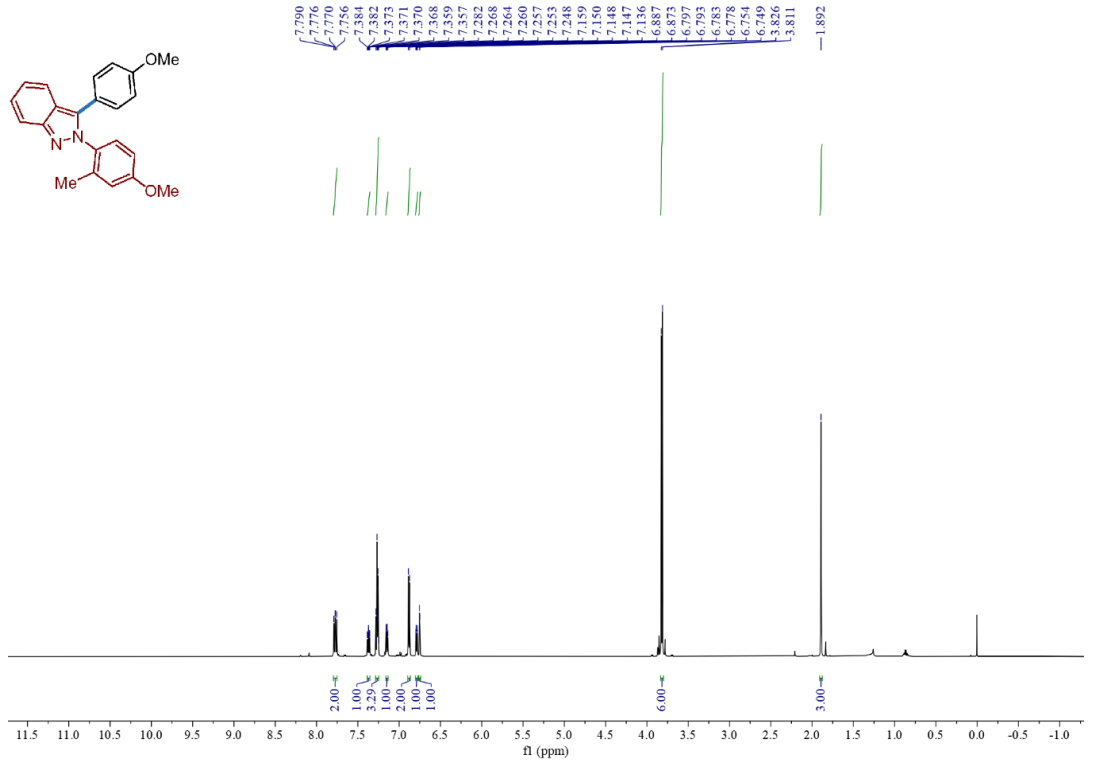


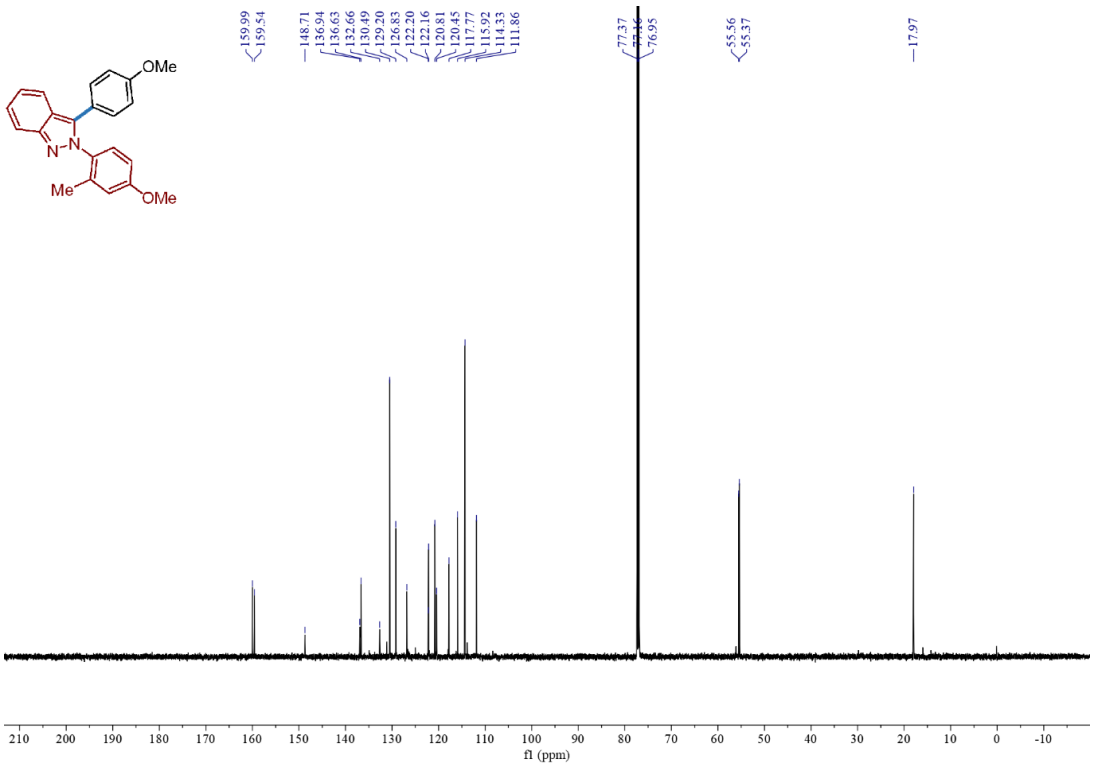
3-(4-Methoxyphenyl)-2-(*p*-tolyl)-2*H*-indazole (3ab)



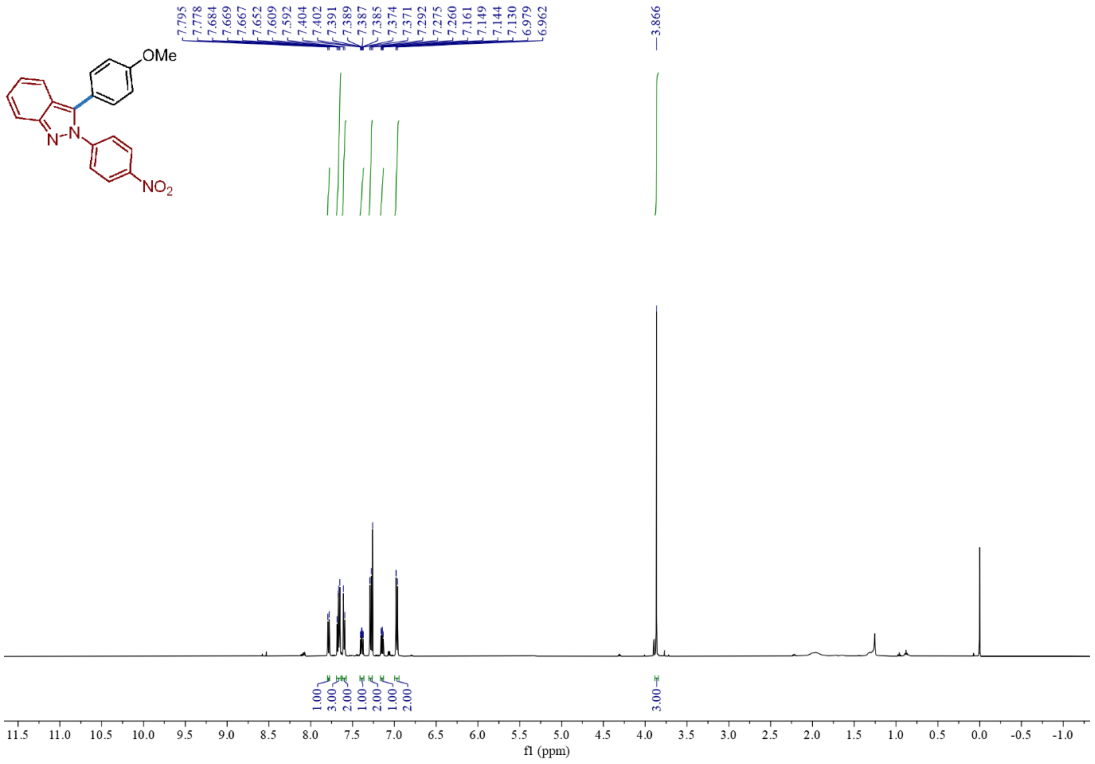


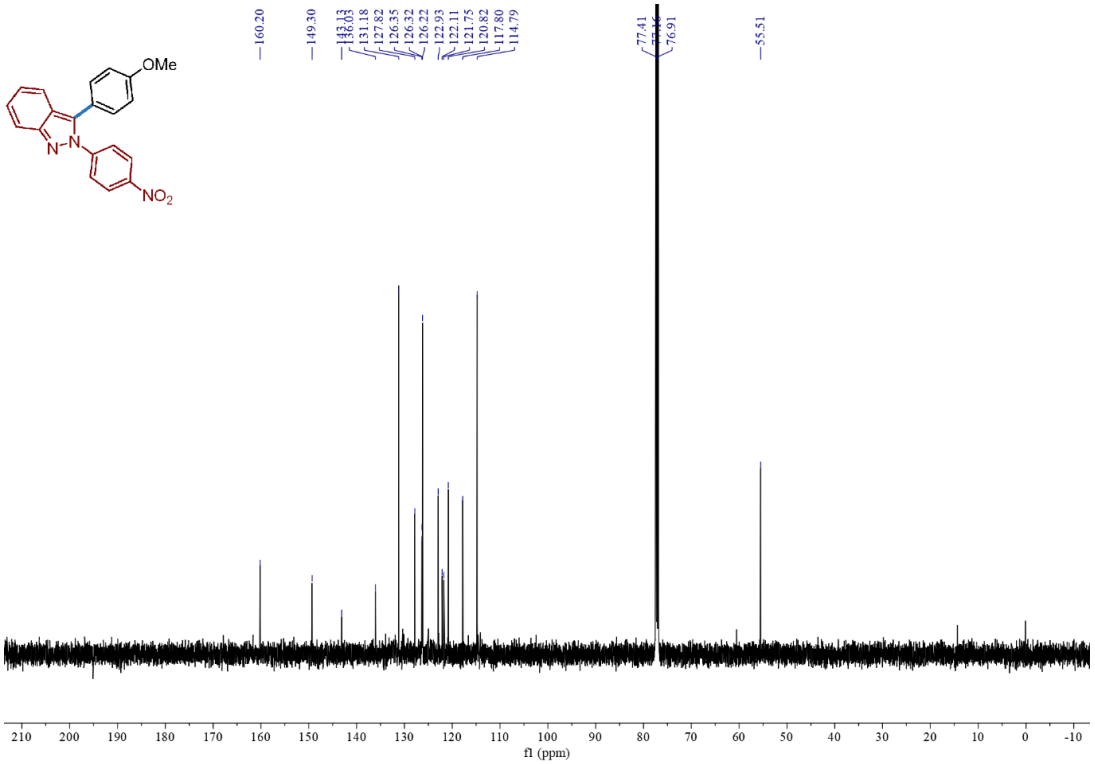
2-(4-Methoxy-2-methylphenyl)-3-(4-methoxyphenyl)-2*H*-indazole (3ac)



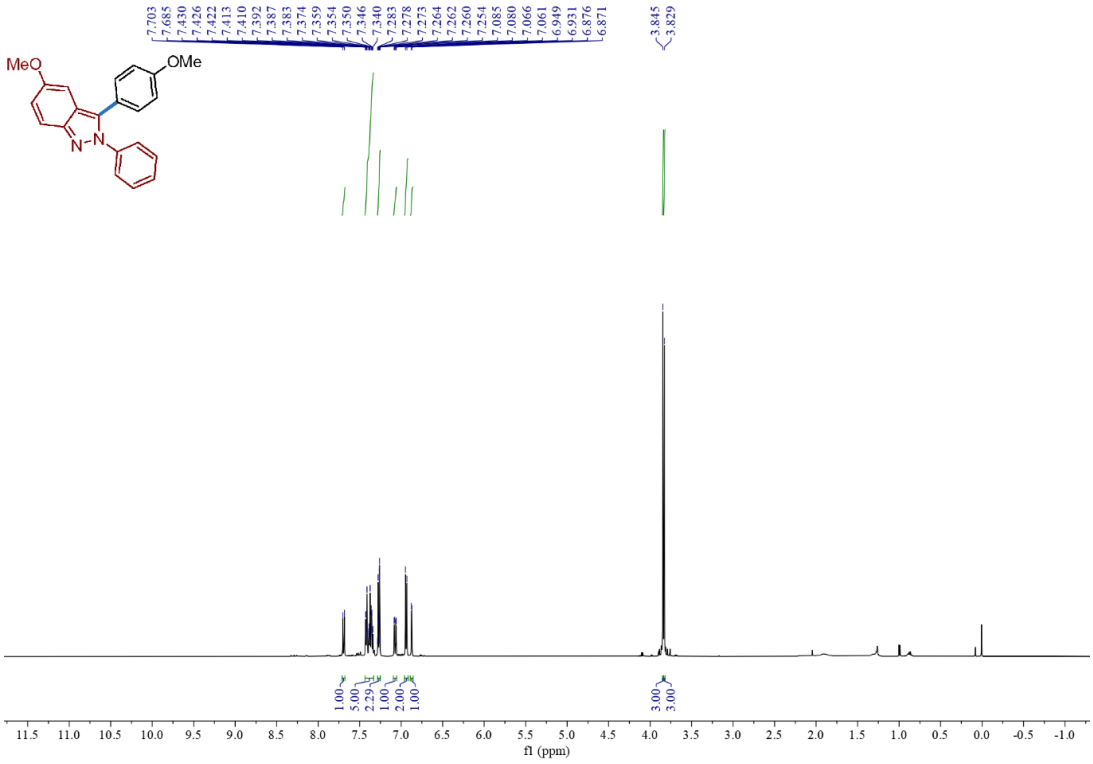


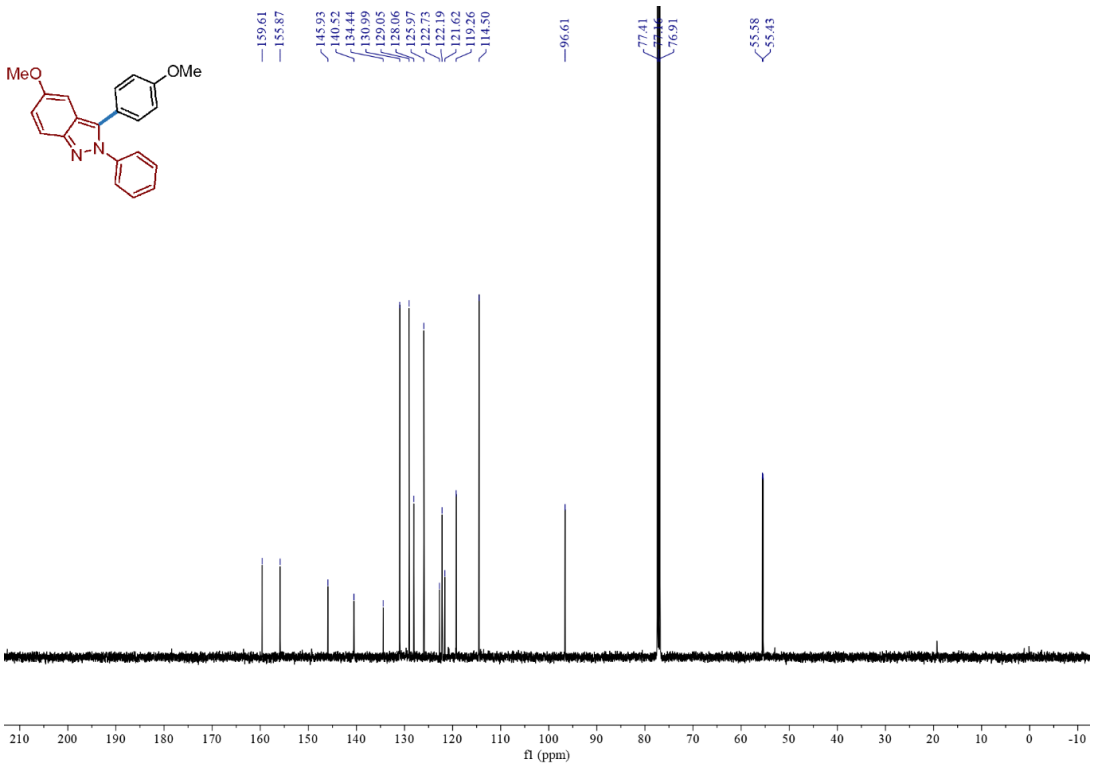
3-(4-Methoxyphenyl)-2-(4-nitrophenyl)-2*H*-indazole (3ad)



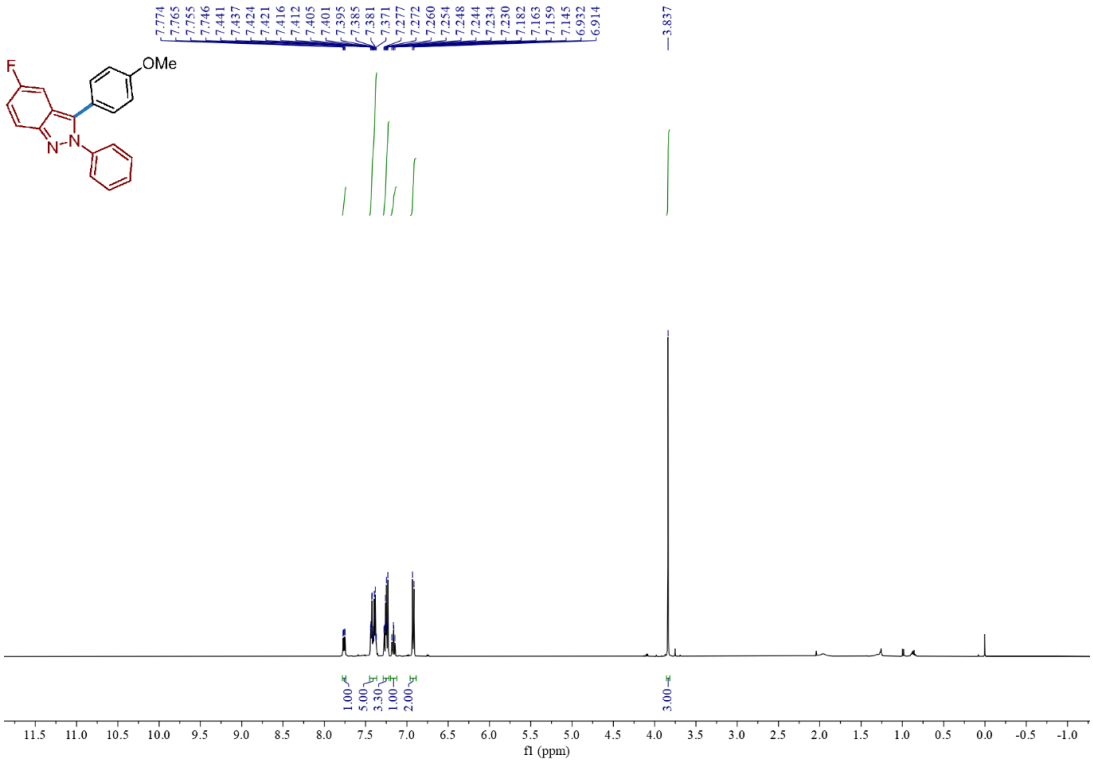


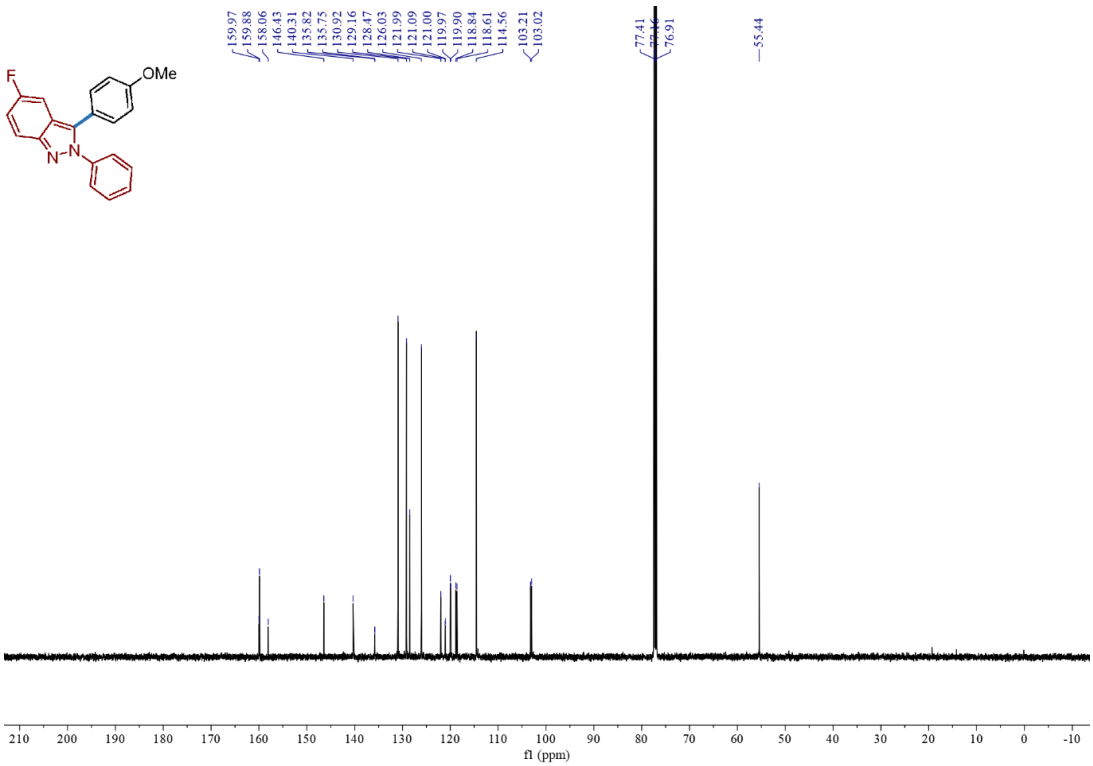
5-Methoxy-3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole (3ae)

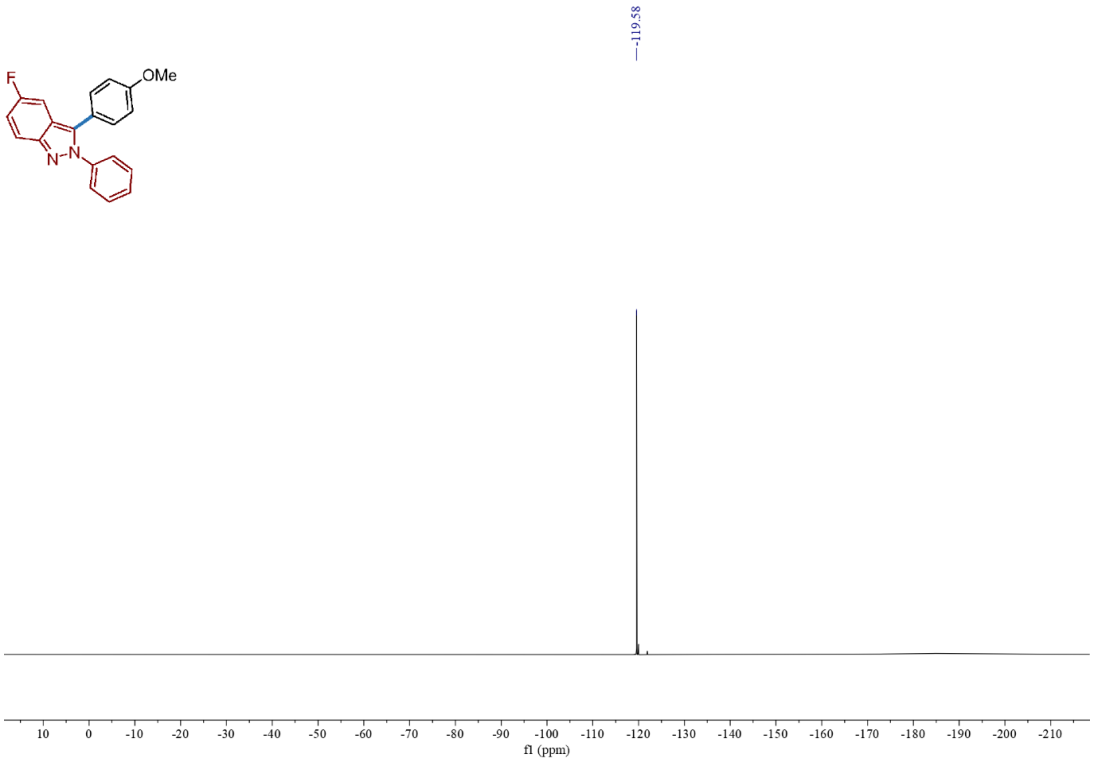




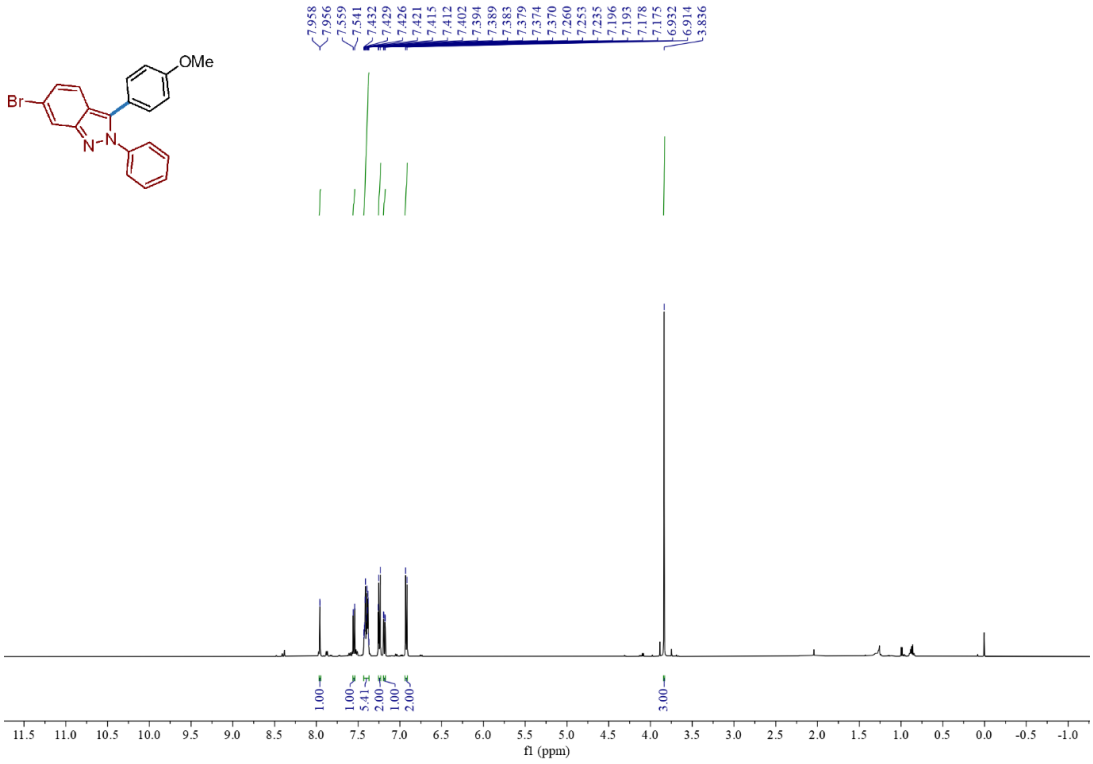
5-Fluoro-3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole (3af)

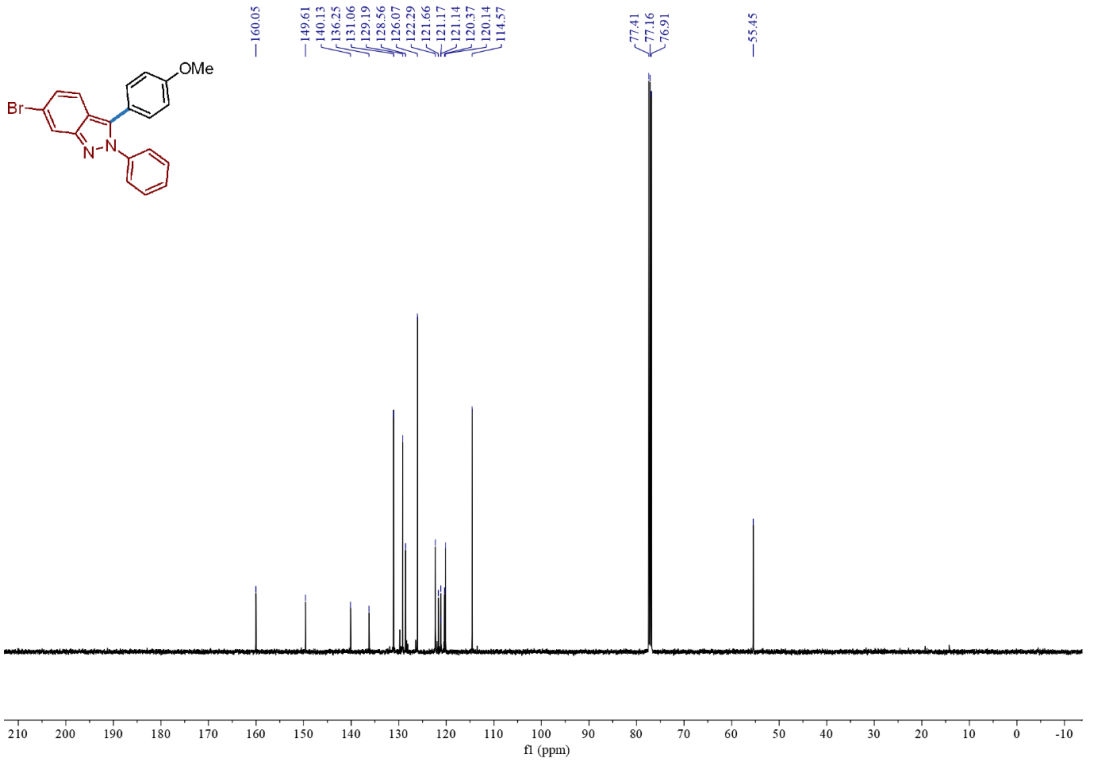




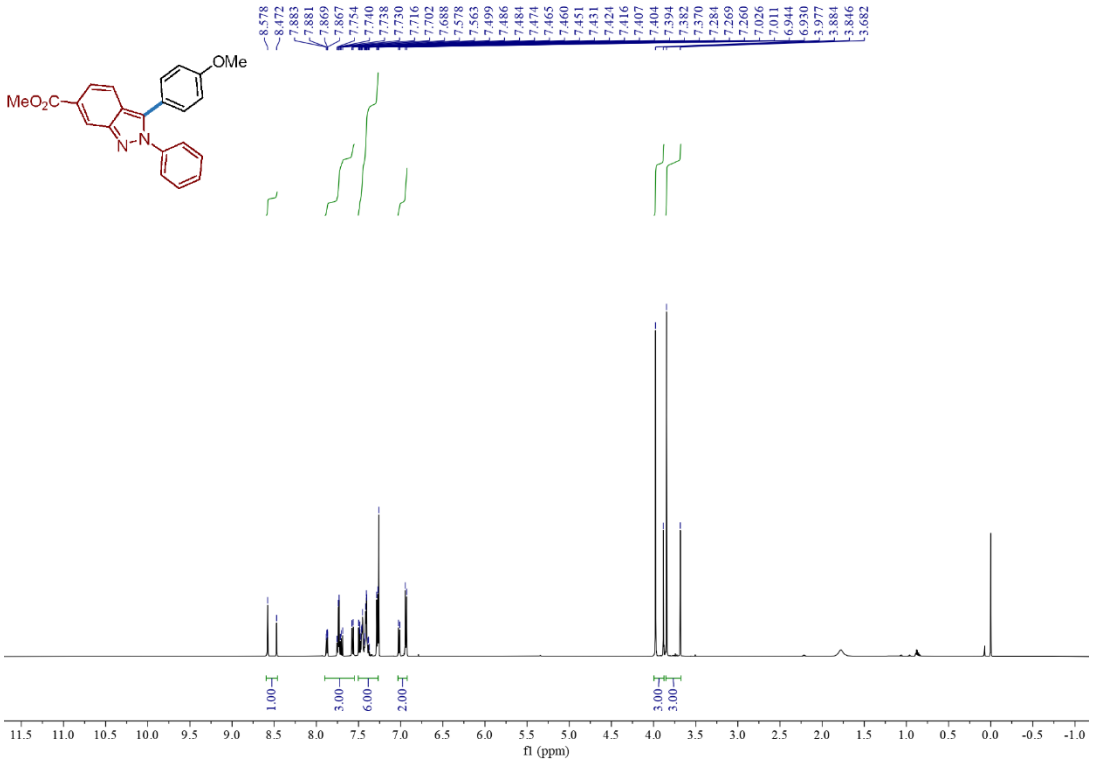

F
OMe
N
N
-119.58
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

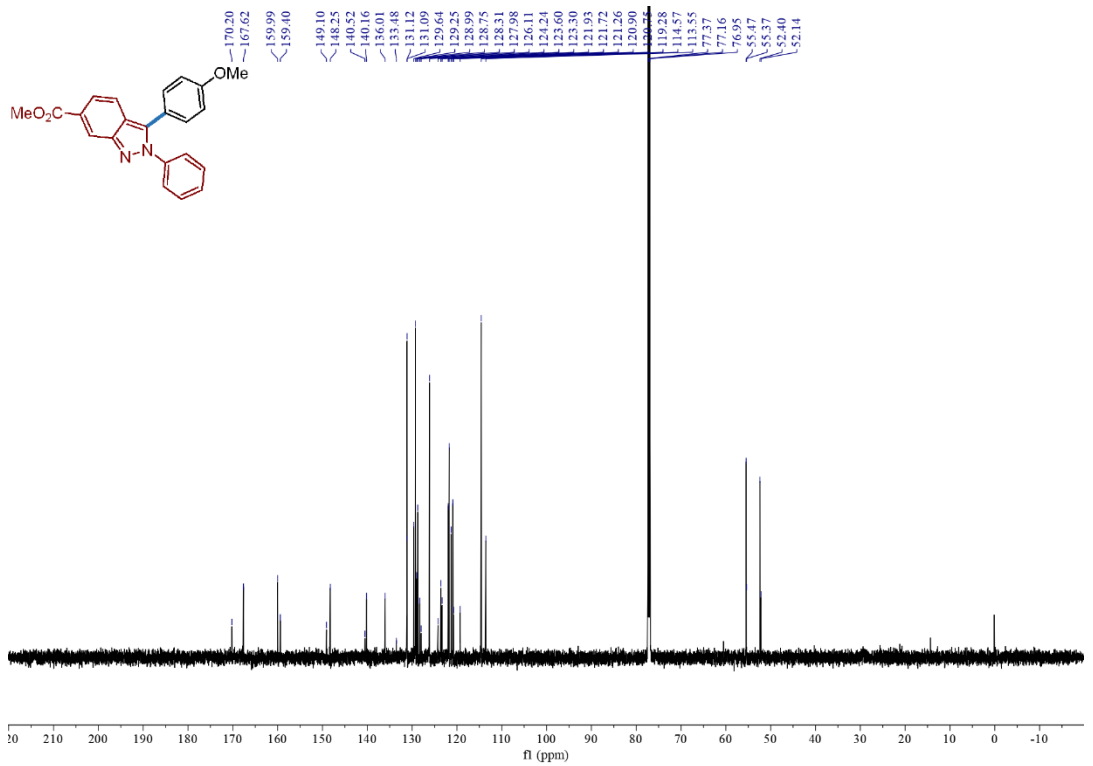
6-Bromo-3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole (3ag)



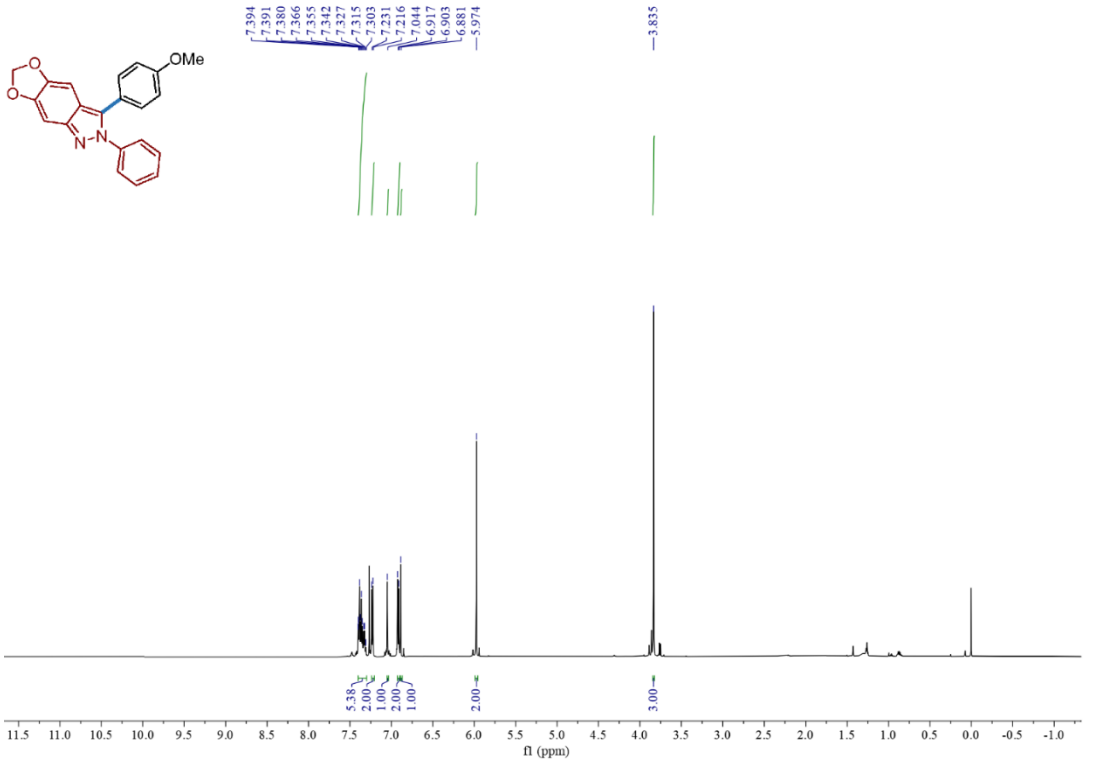


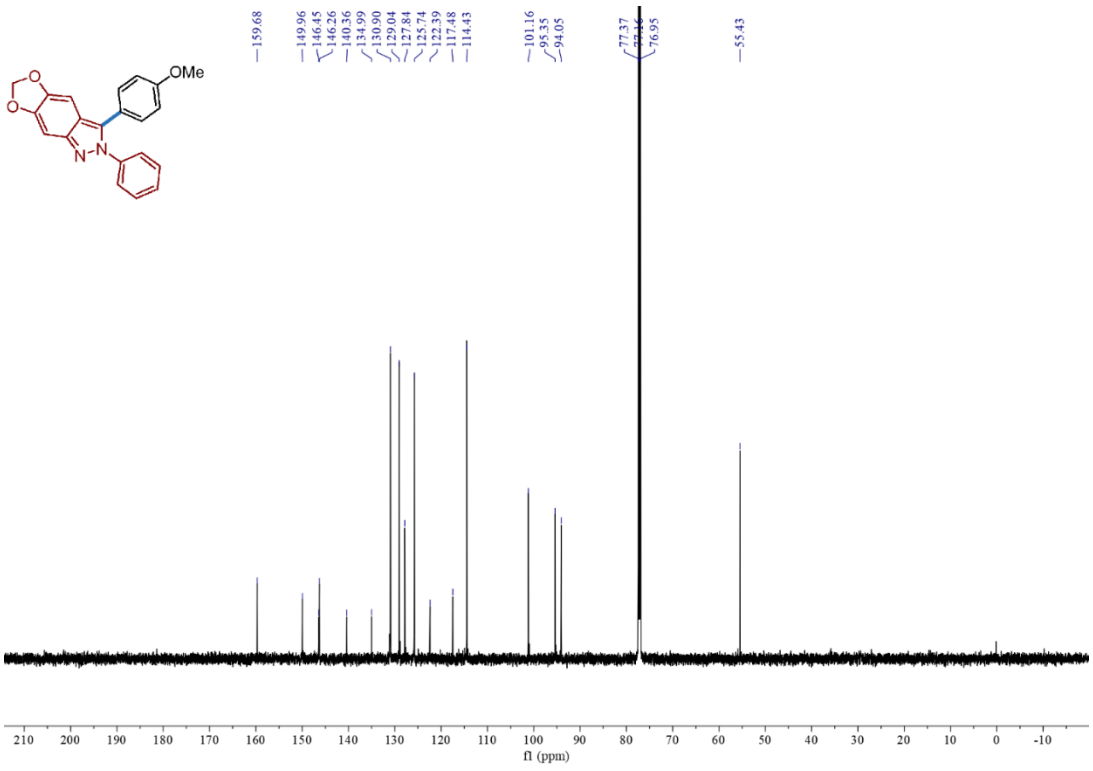
Methyl 3-(4-methoxyphenyl)-2-phenyl-2*H*-indazole-6-carboxylate (3ah)



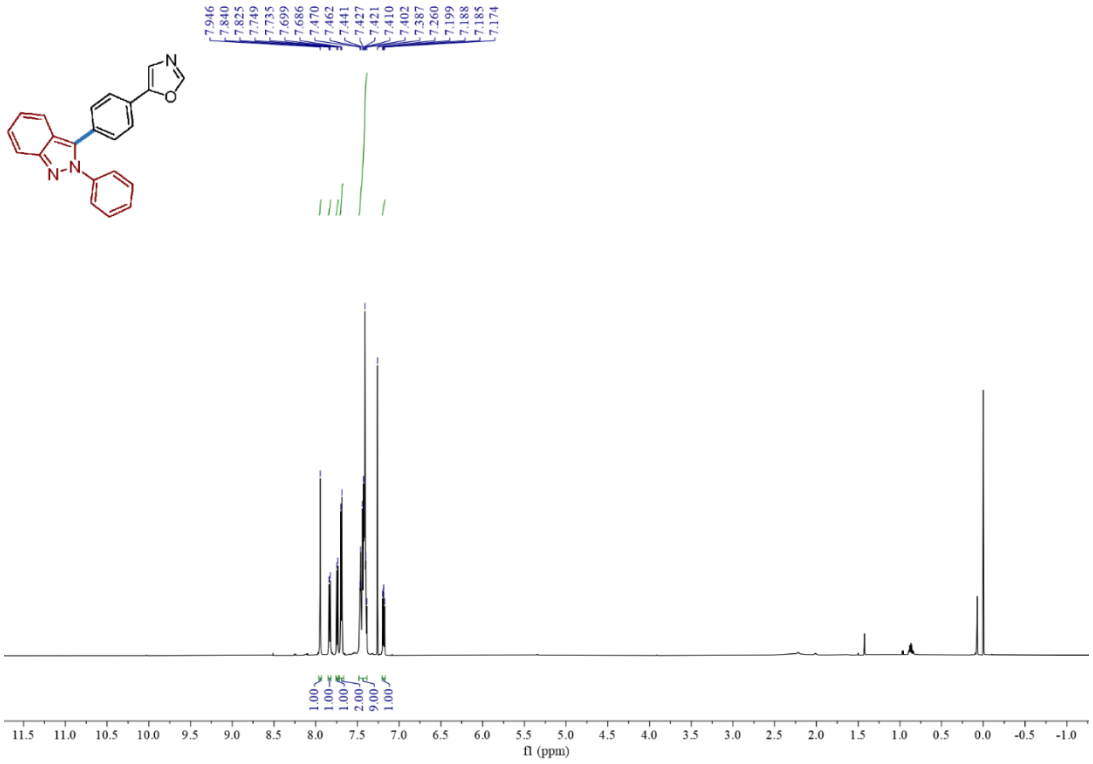


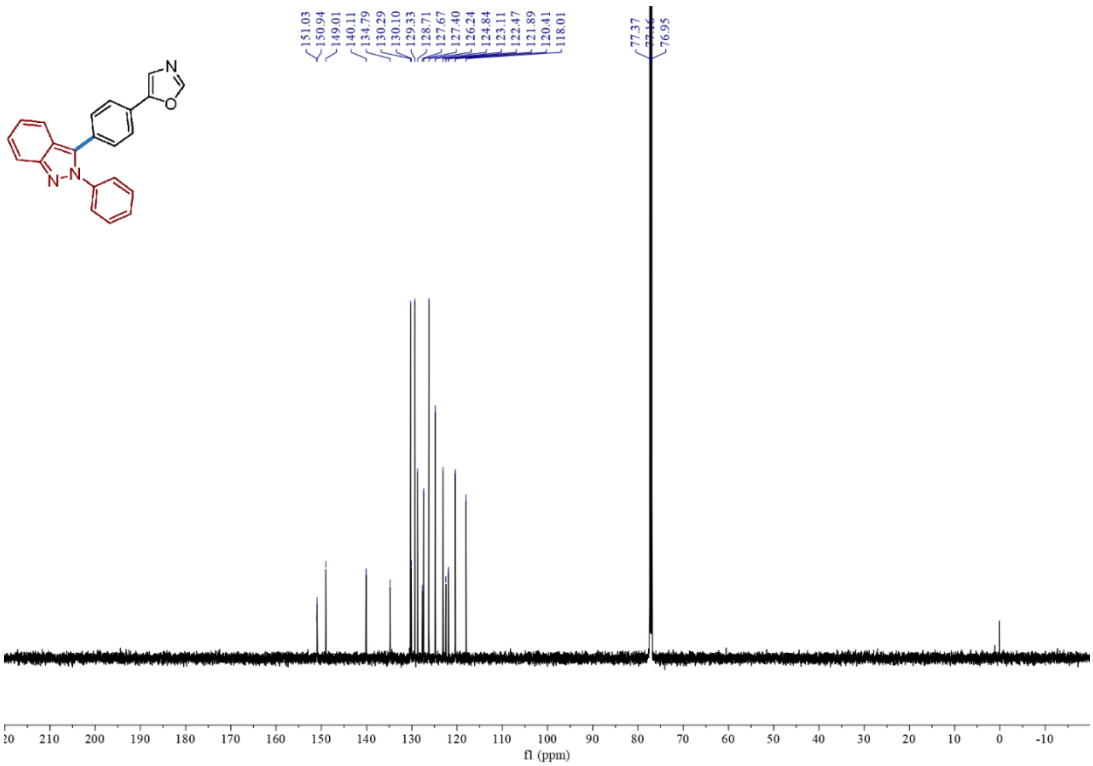
3-(4-Methoxyphenyl)-2-phenyl-2*H*-[1,3]dioxolo[4,5-*f*]indazole (3ai)



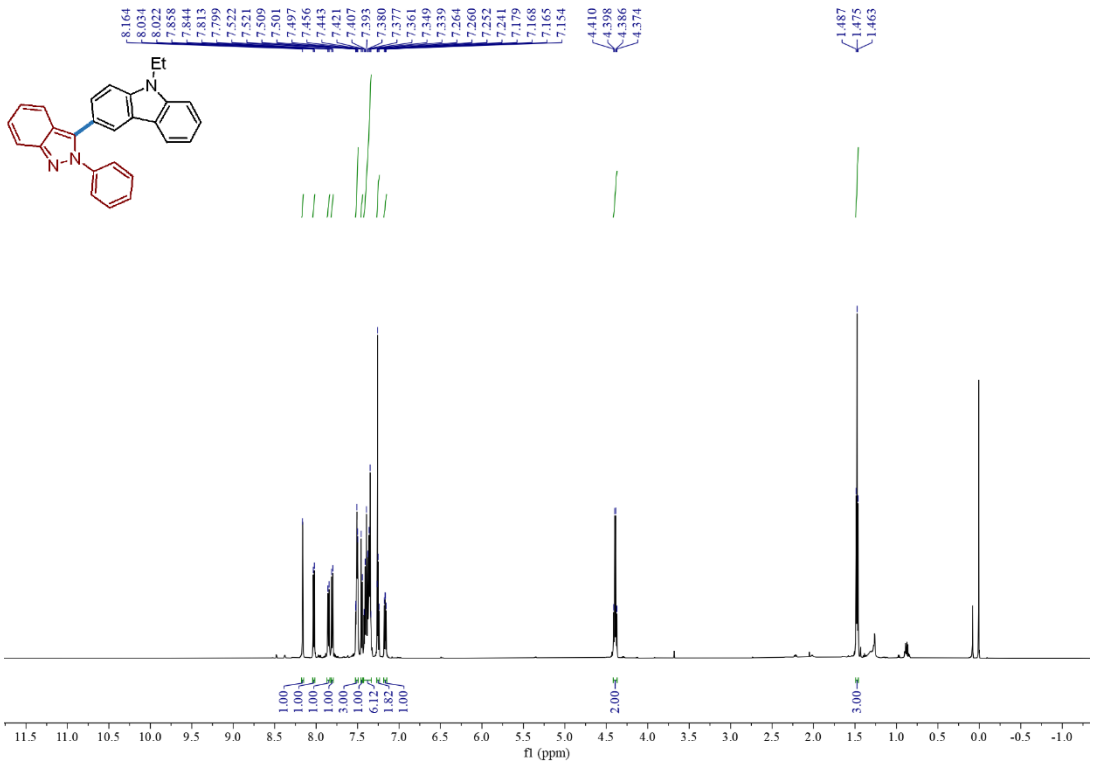


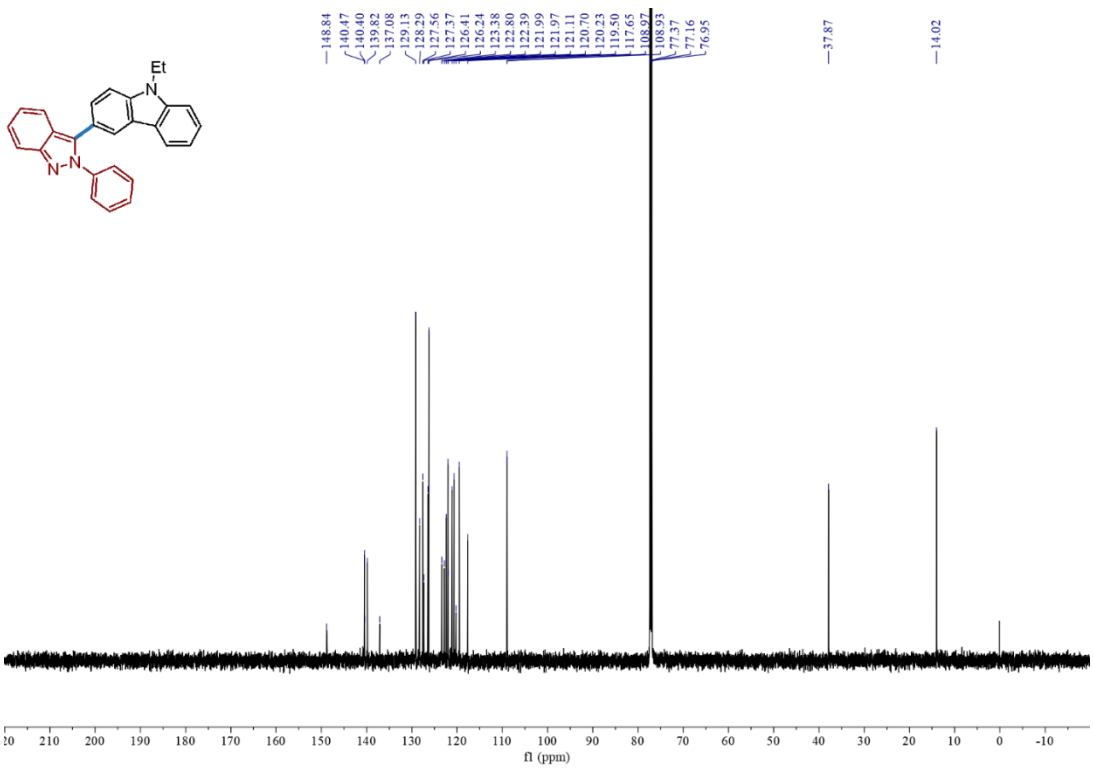
5-(4-(2-Phenyl-2*H*-indazol-3-yl)phenyl)oxazole (3ea)



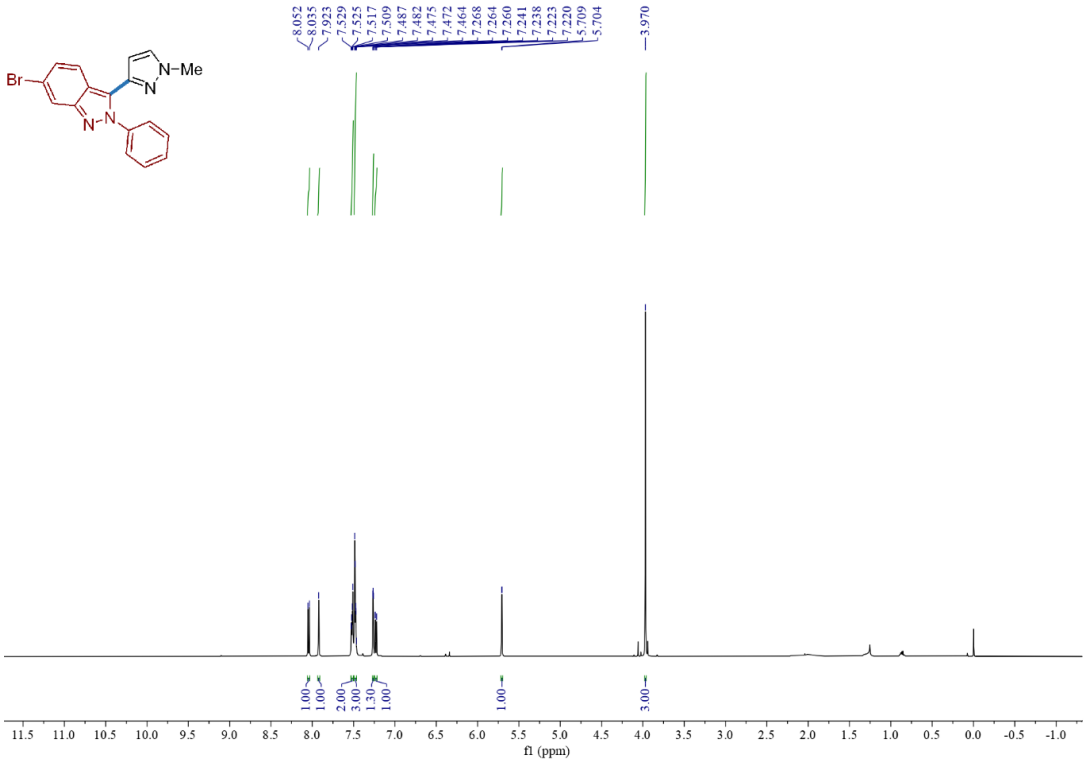


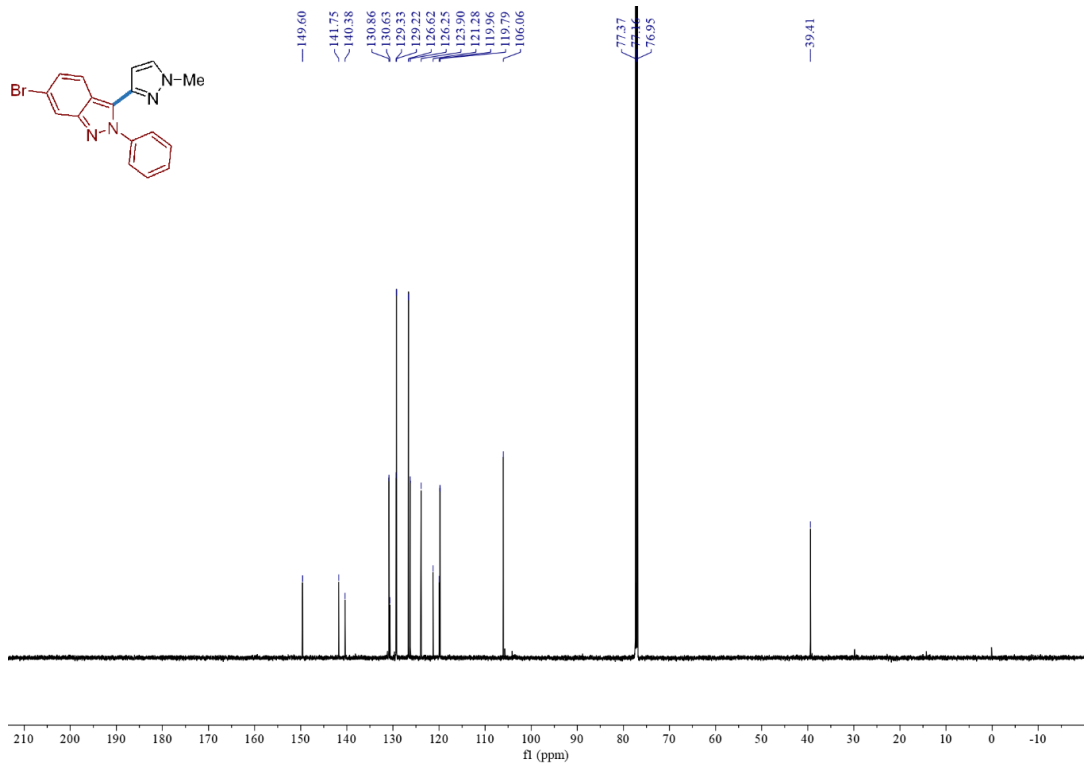
9-Ethyl-3-(2-phenyl-2*H*-indazol-3-yl)-9*H*-carbazole (3fa)



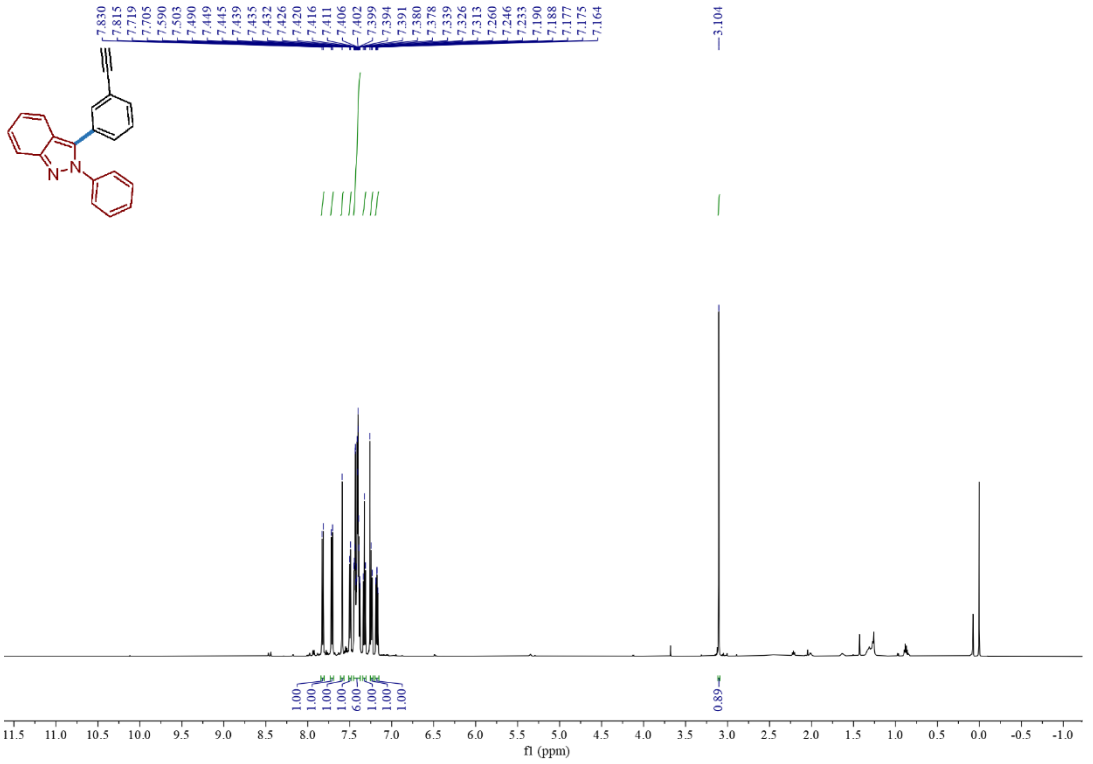


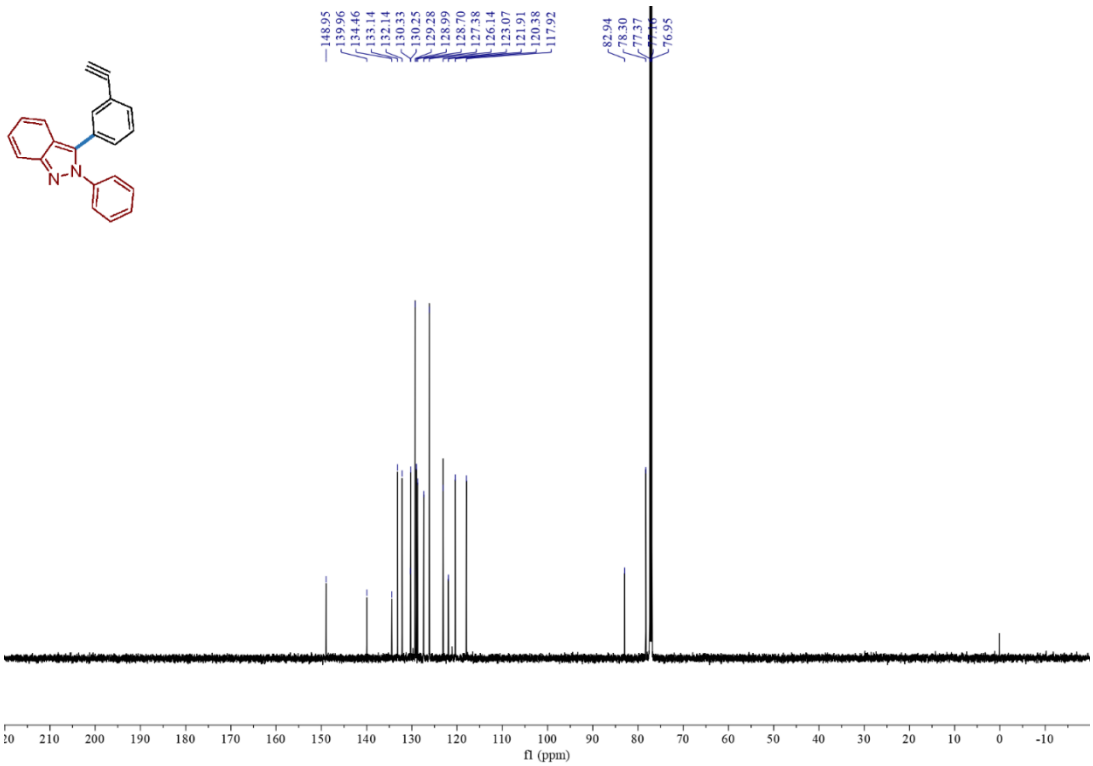
6-Bromo-3-(1-methyl-1*H*-pyrazol-3-yl)-2-phenyl-2*H*-indazole (3gg)



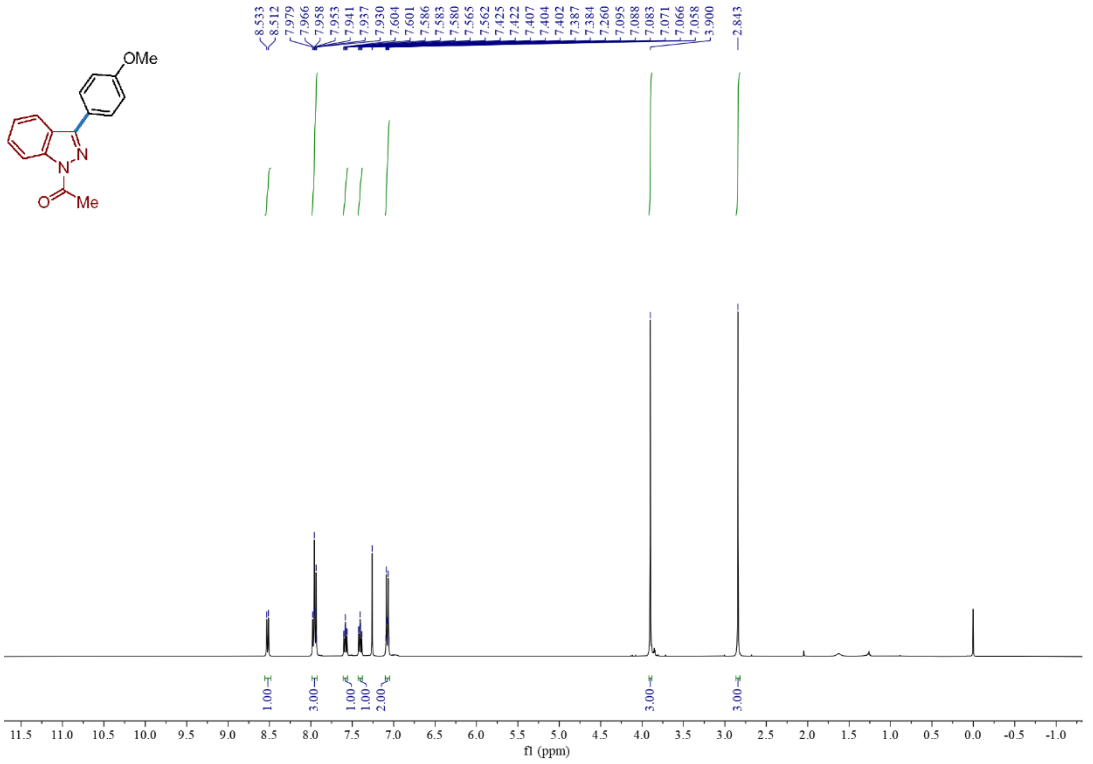


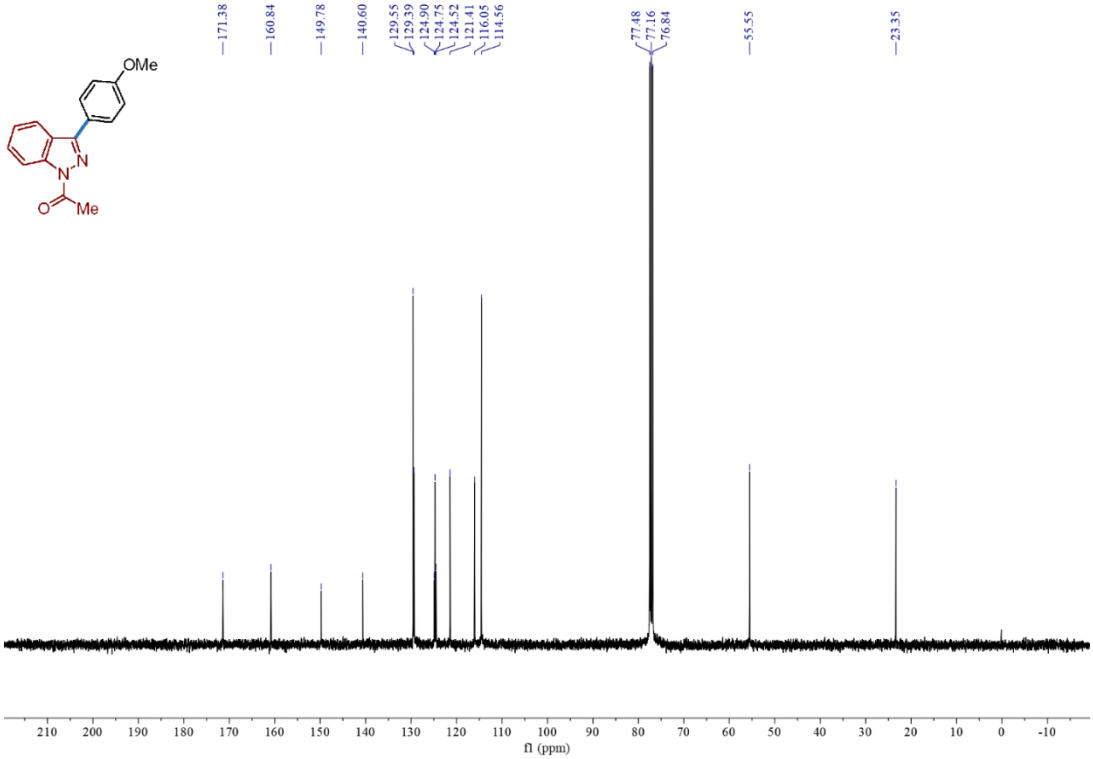
3-(3-Ethynylphenyl)-2-phenyl-2*H*-indazole (3ha)



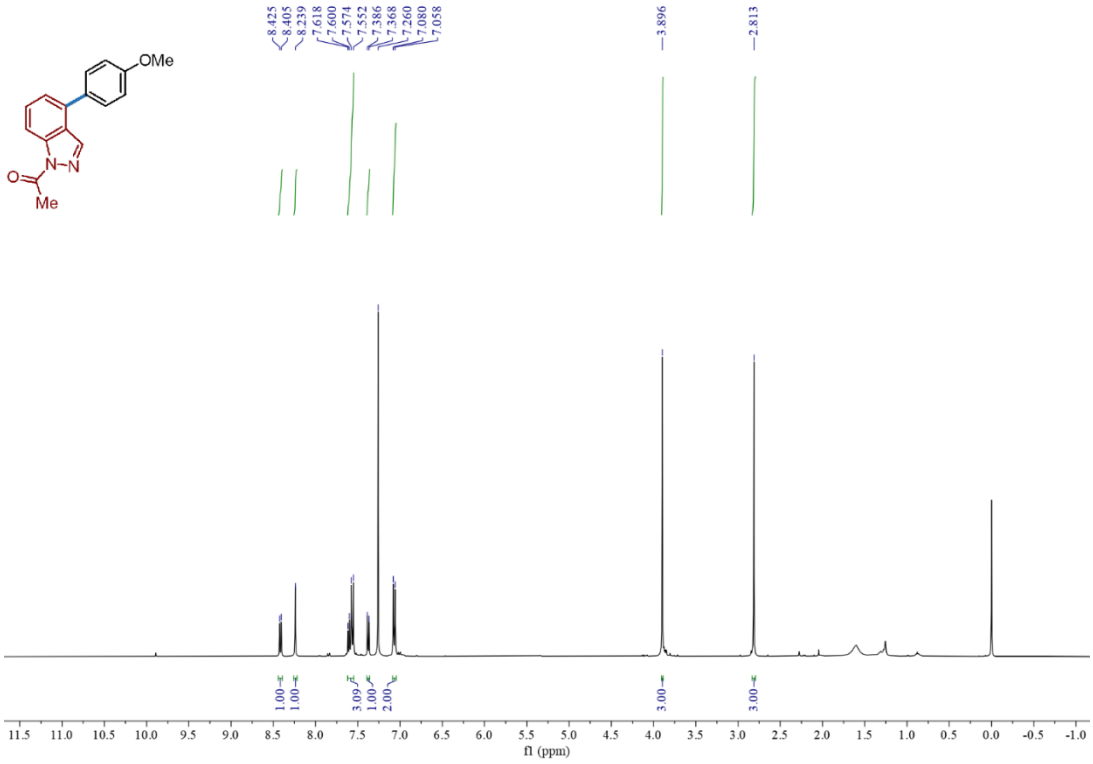


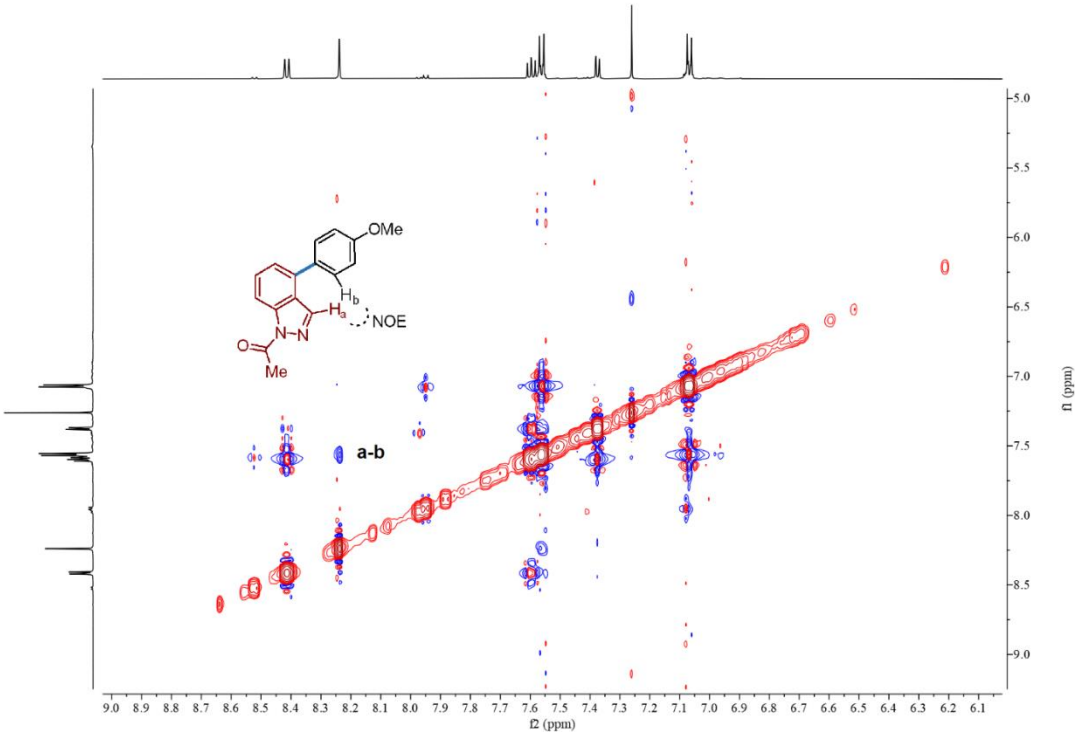
1-(3-(4-Methoxyphenyl)-1*H*-indazol-1-yl)ethan-1-one (3aj)

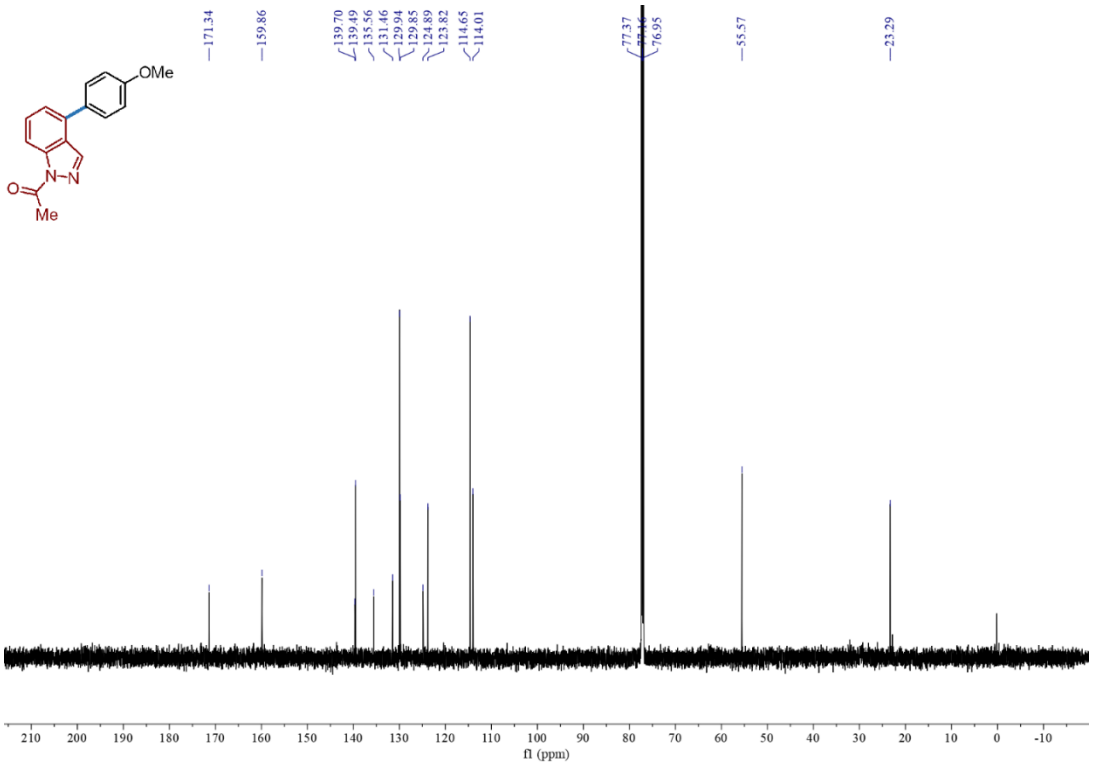




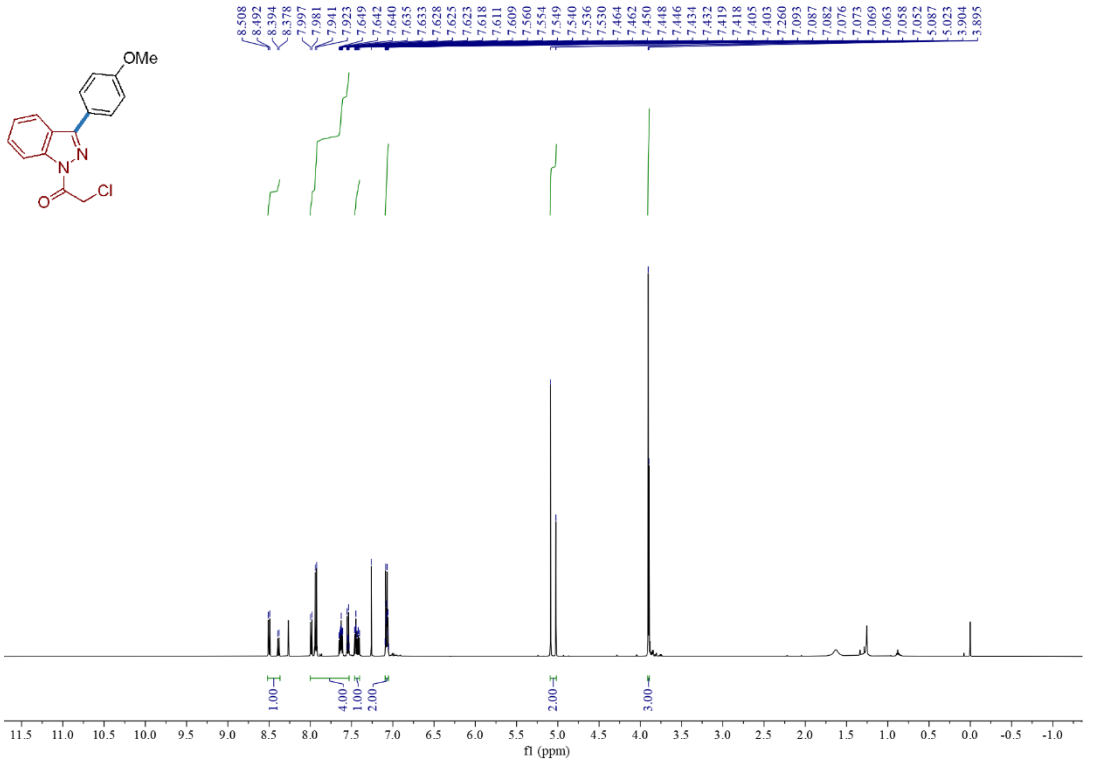
1-(4-(4-Methoxyphenyl)-1*H*-indazol-1-yl)ethan-1-one (3aj')

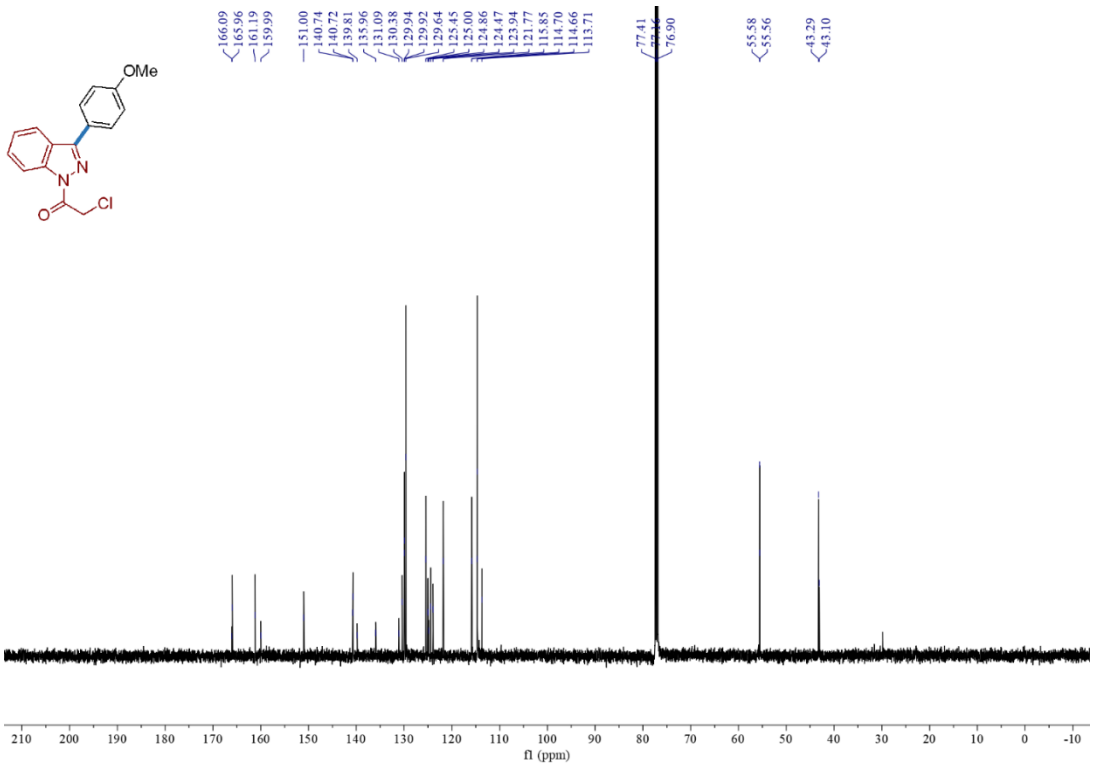




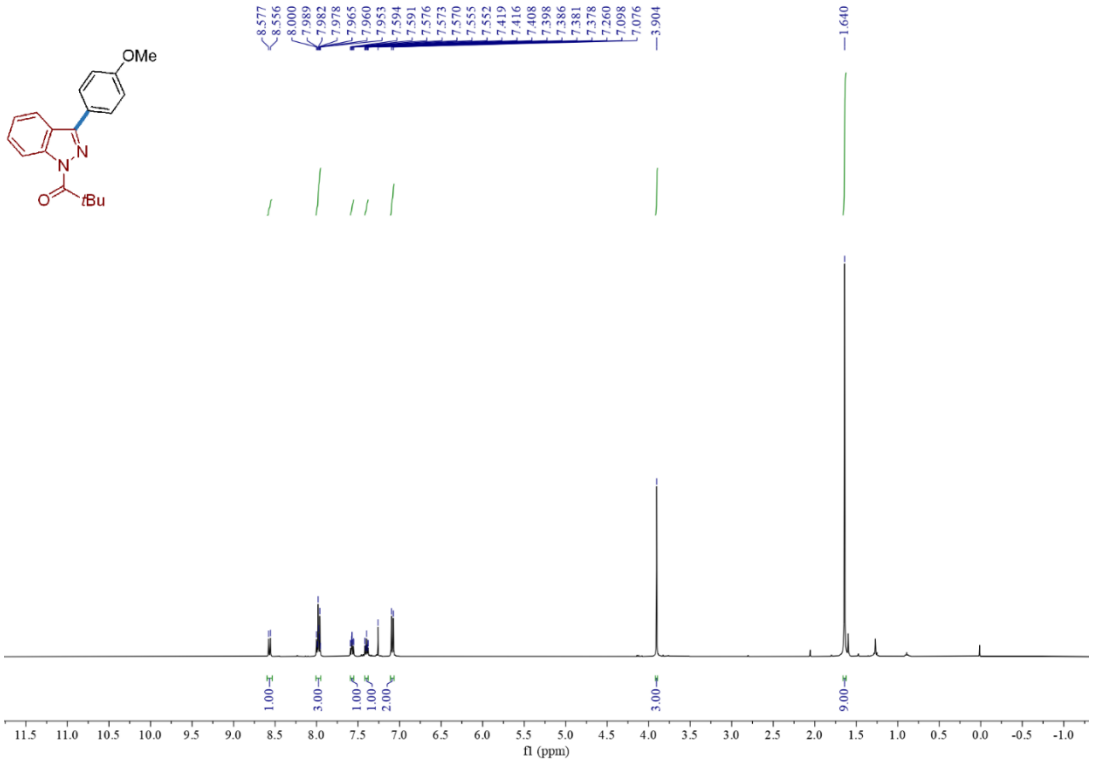

171.34
159.86
139.70
139.49
135.56
131.46
129.94
129.85
124.89
123.82
114.65
114.01
77.37
77.16
76.95
55.57
23.29
OMe
N
N
O
Me
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

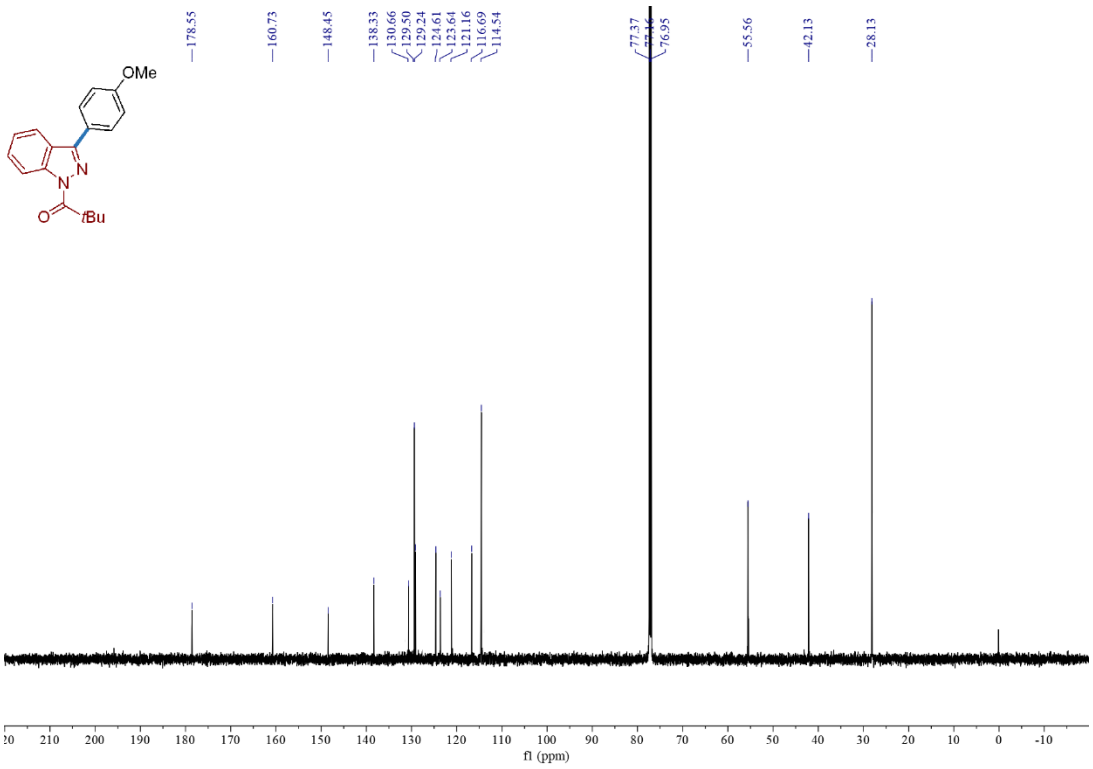
2-Chloro-1-(3-(4-methoxyphenyl)-1*H*-indazol-1-yl)ethan-1-one (3ak)



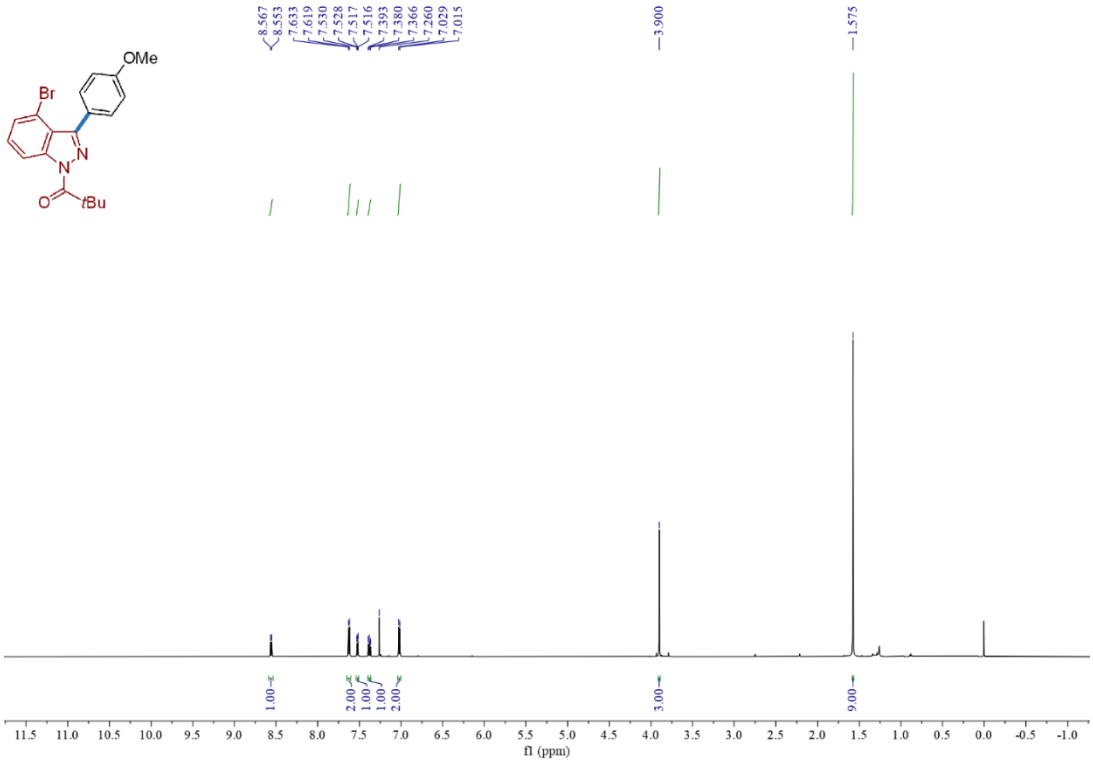


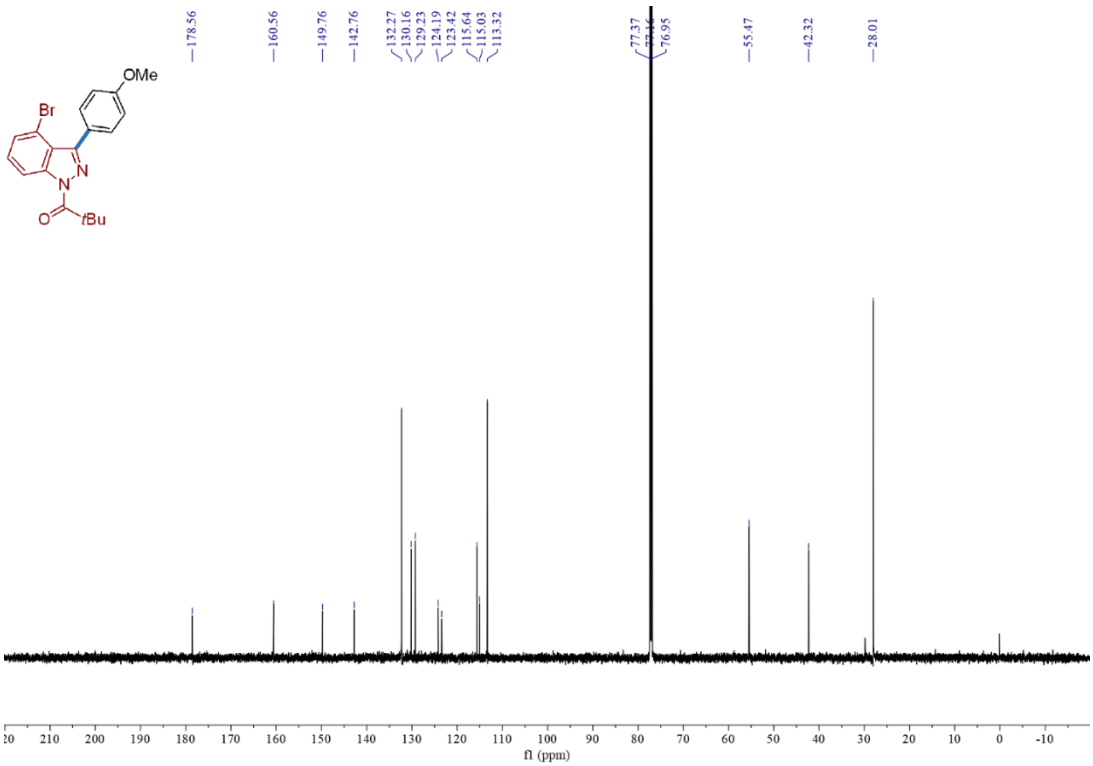
1-(3-(4-Methoxyphenyl)-1*H*-indazol-1-yl)-2,2-dimethylpropan-1-one (3al)



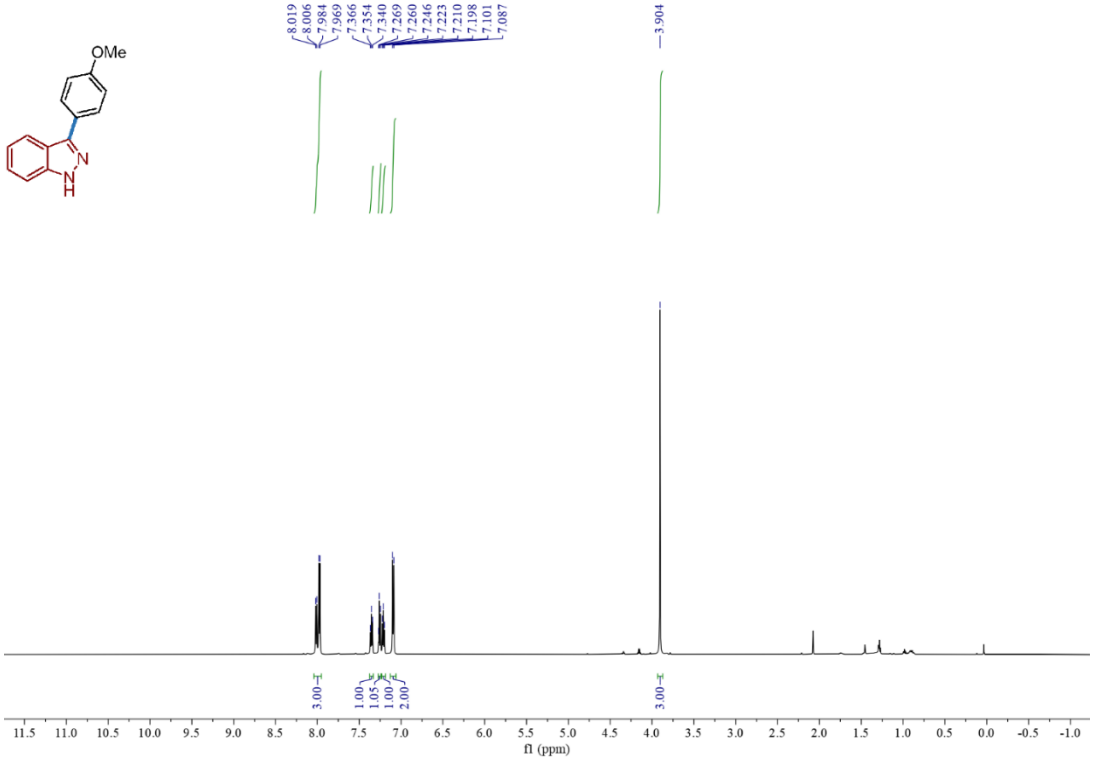


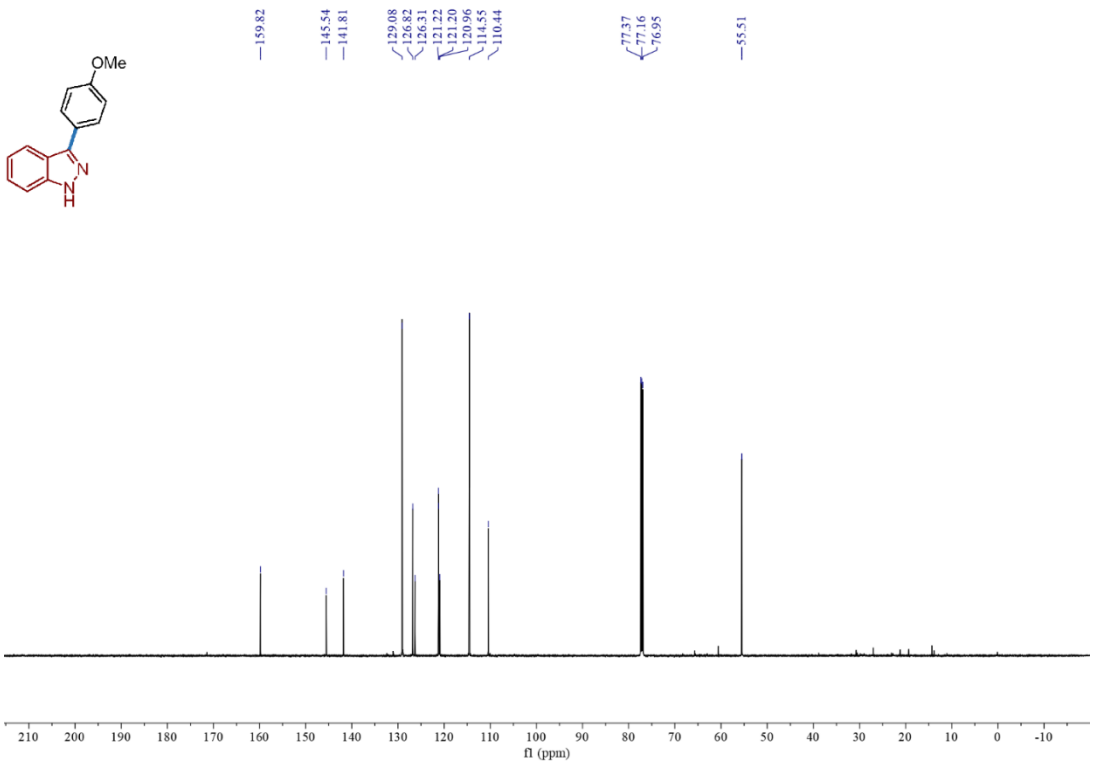
1-(4-Bromo-3-(4-methoxyphenyl)-1*H*-indazol-1-yl)-2,2-dimethylpropan-1-one (3am)



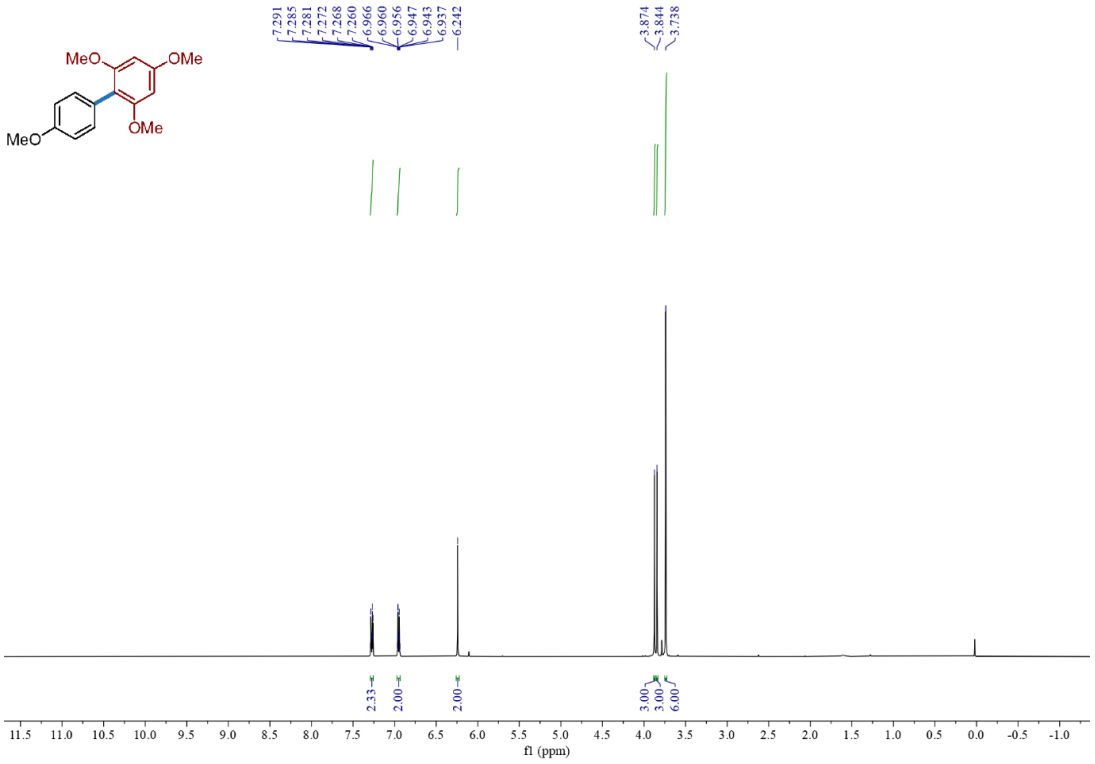


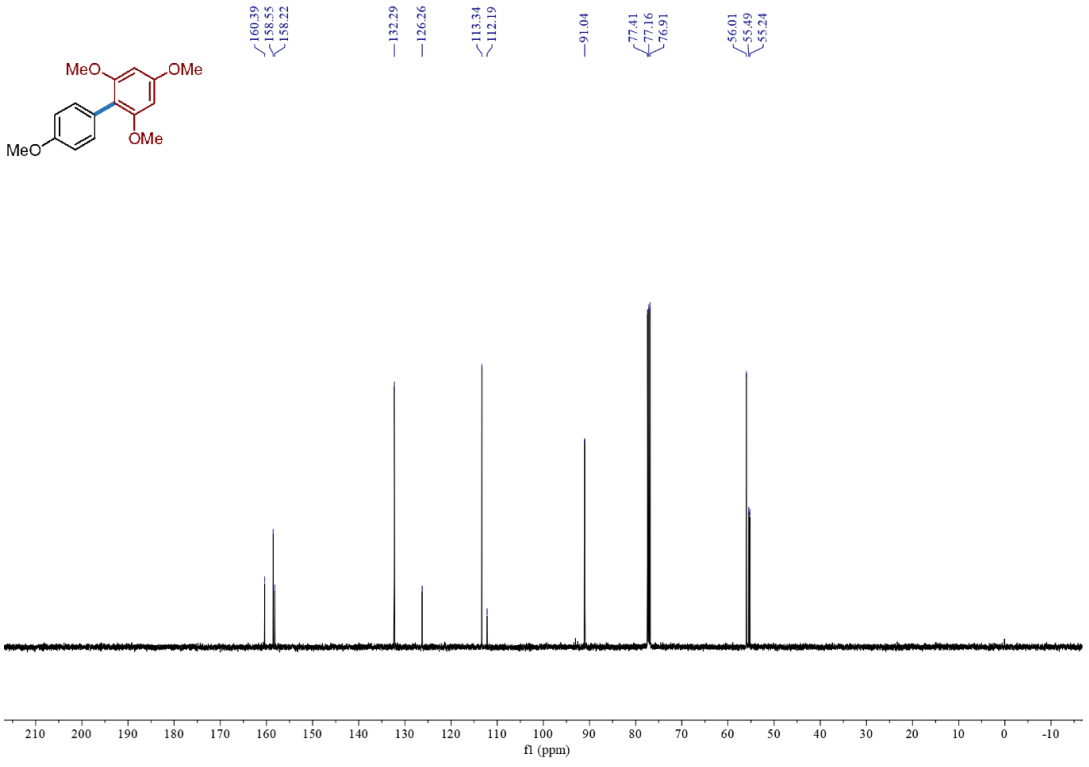
3-(4-Methoxyphenyl)-1*H*-indazole (3am)



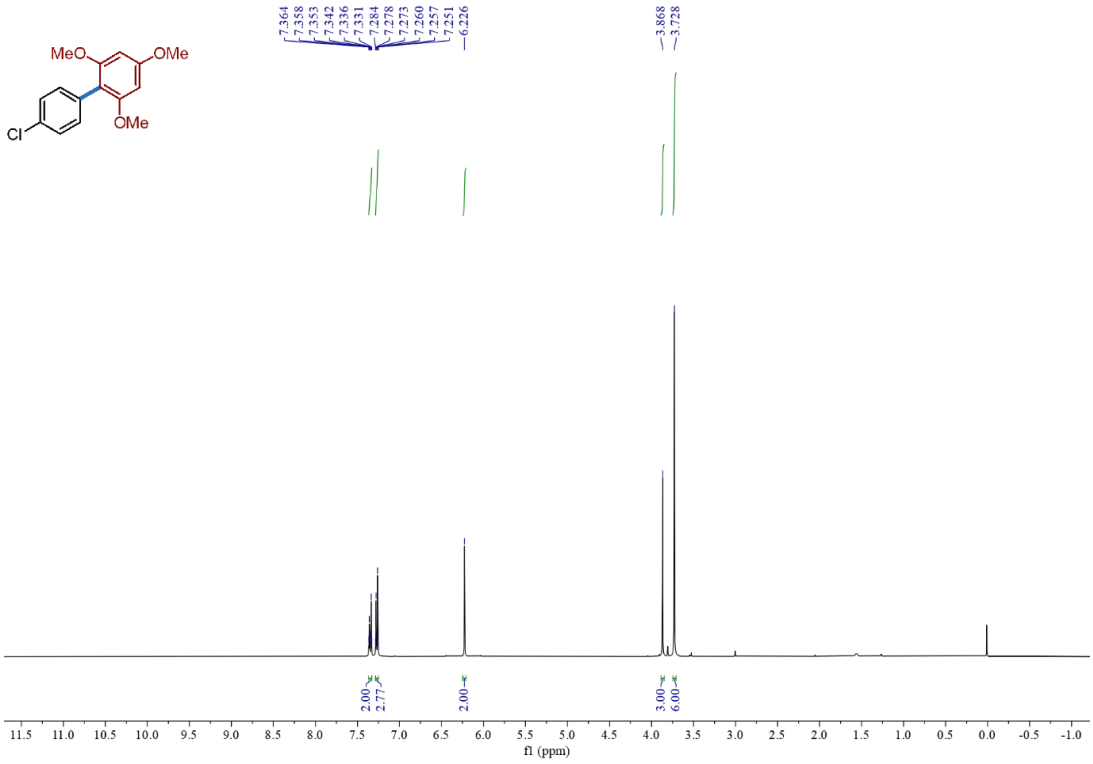


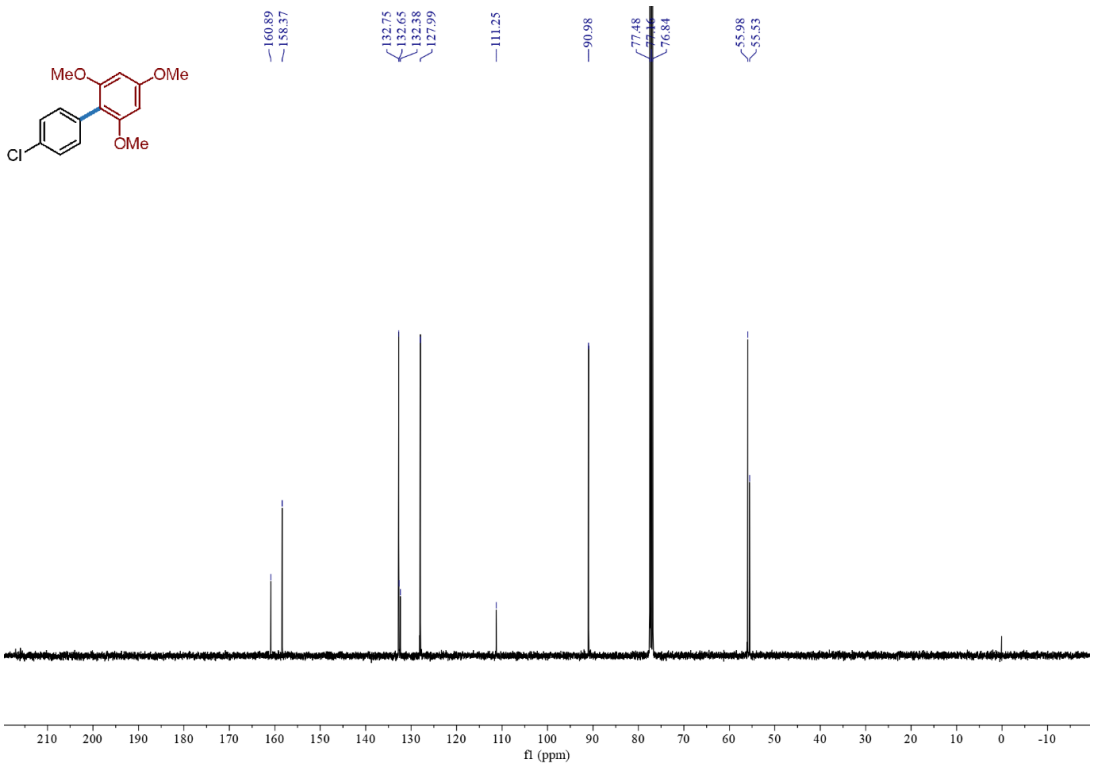
2,4,4',6-Tetramethoxy-1,1'-biphenyl (3ao)



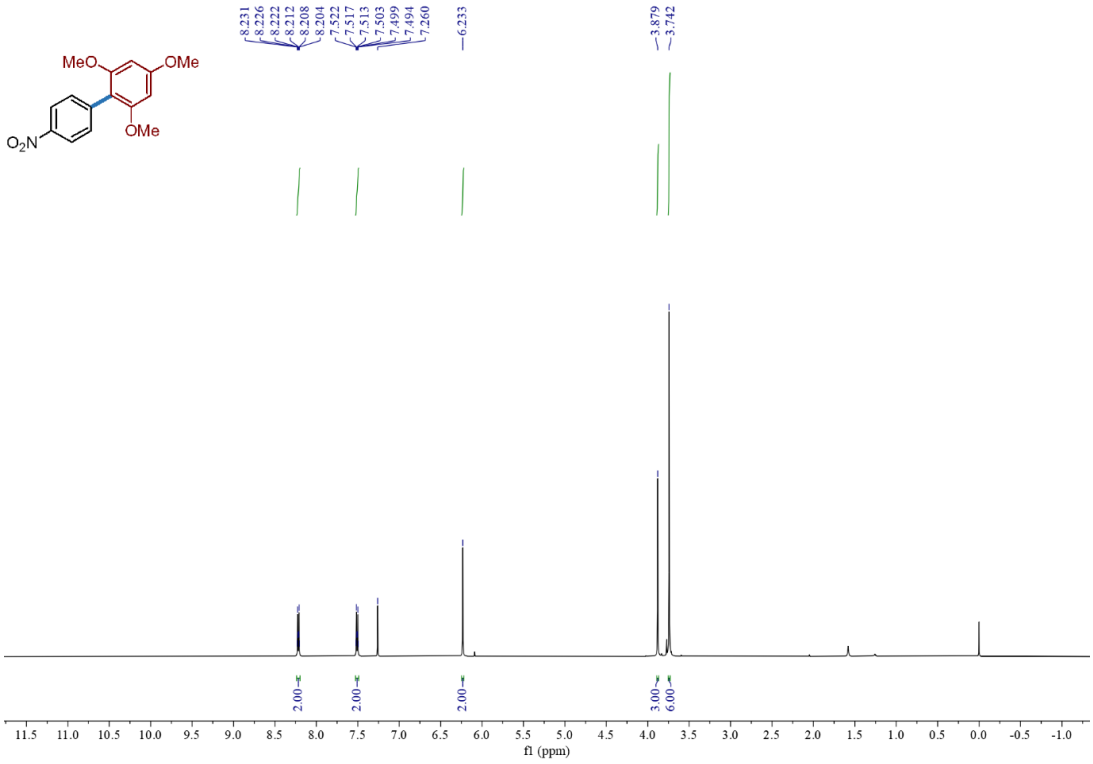


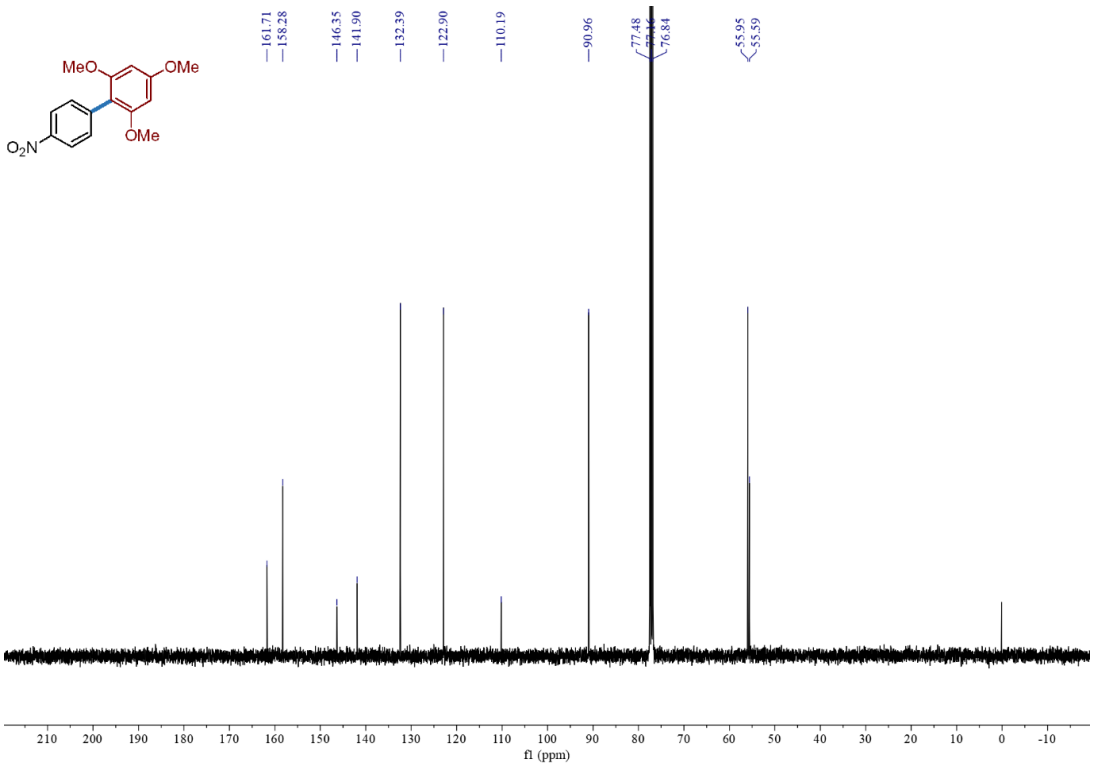
4'-Chloro-2,4,6-trimethoxy-1,1'-biphenyl (3co)



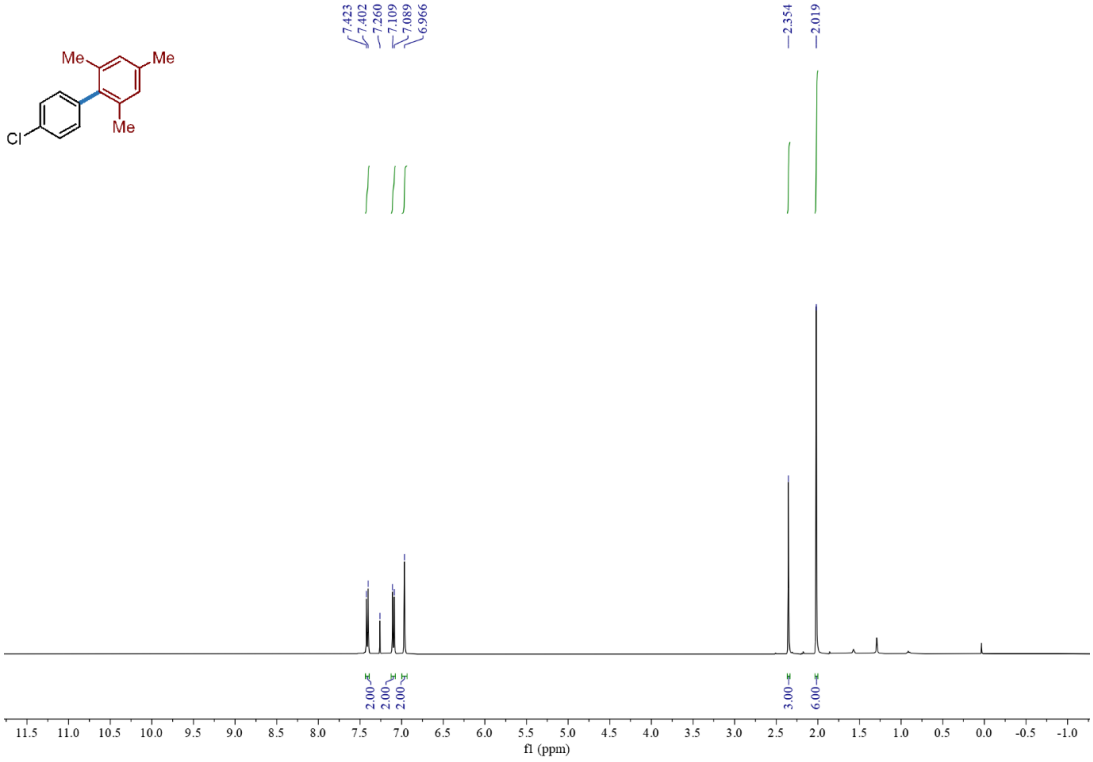


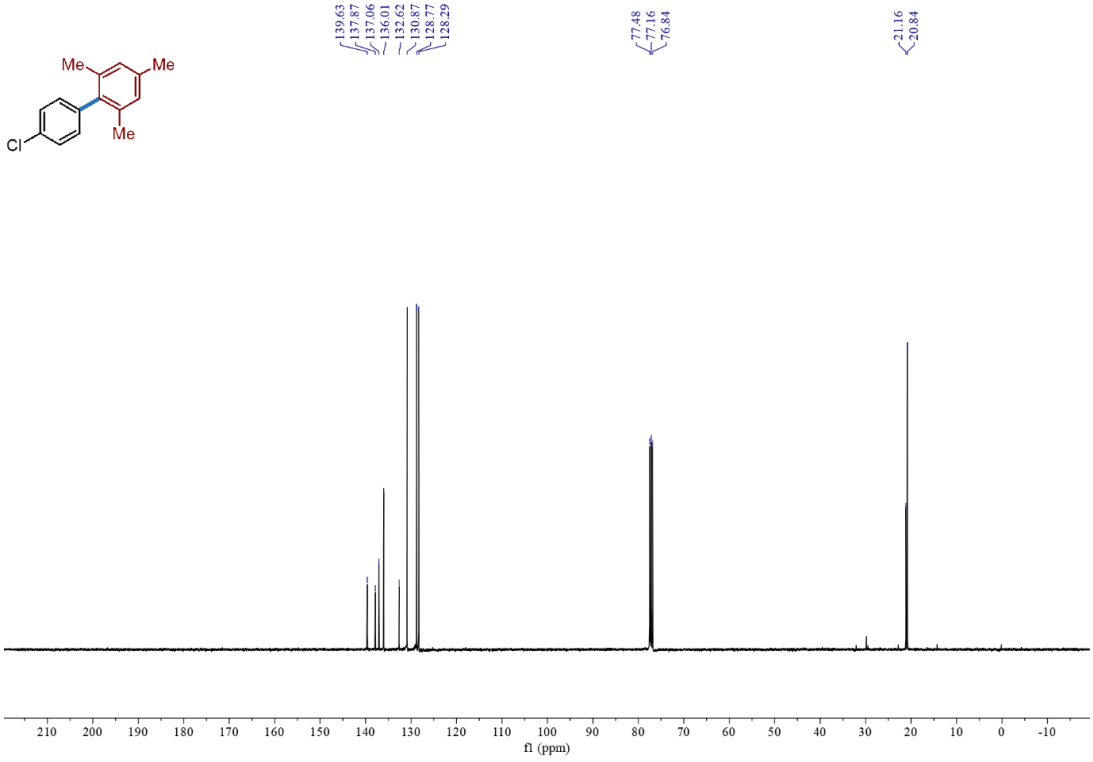
2,4,6-Trimethoxy-4'-nitro-1,1'-biphenyl (3io)



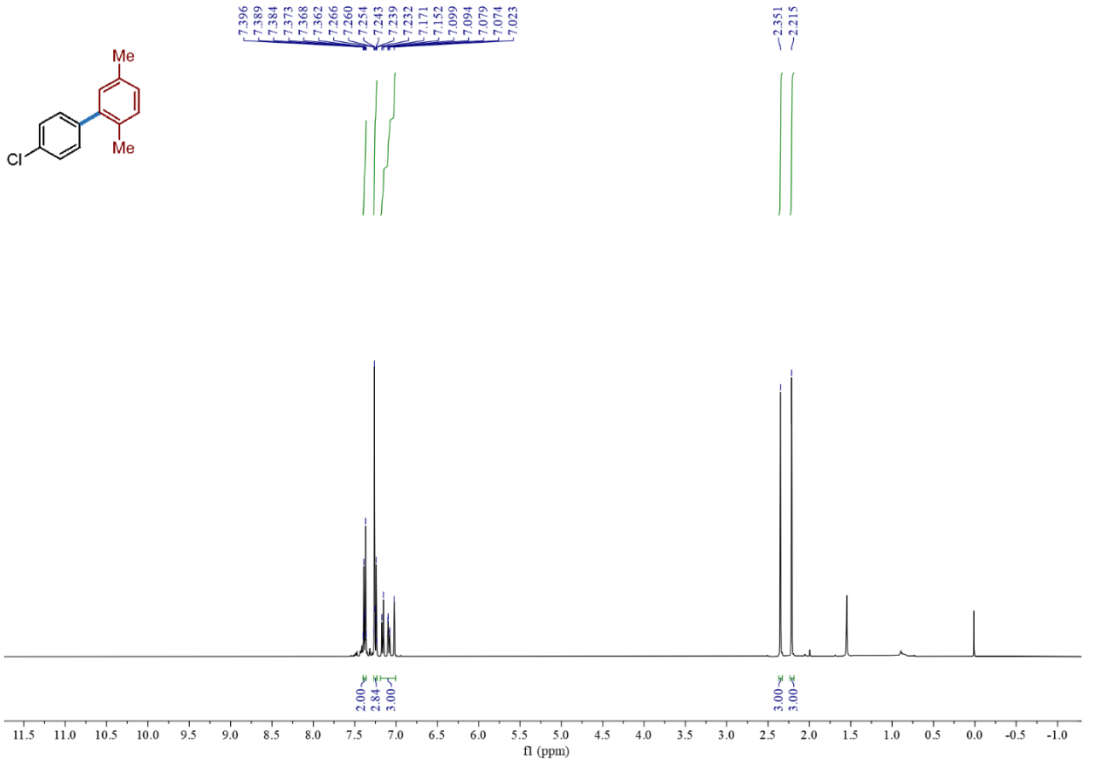


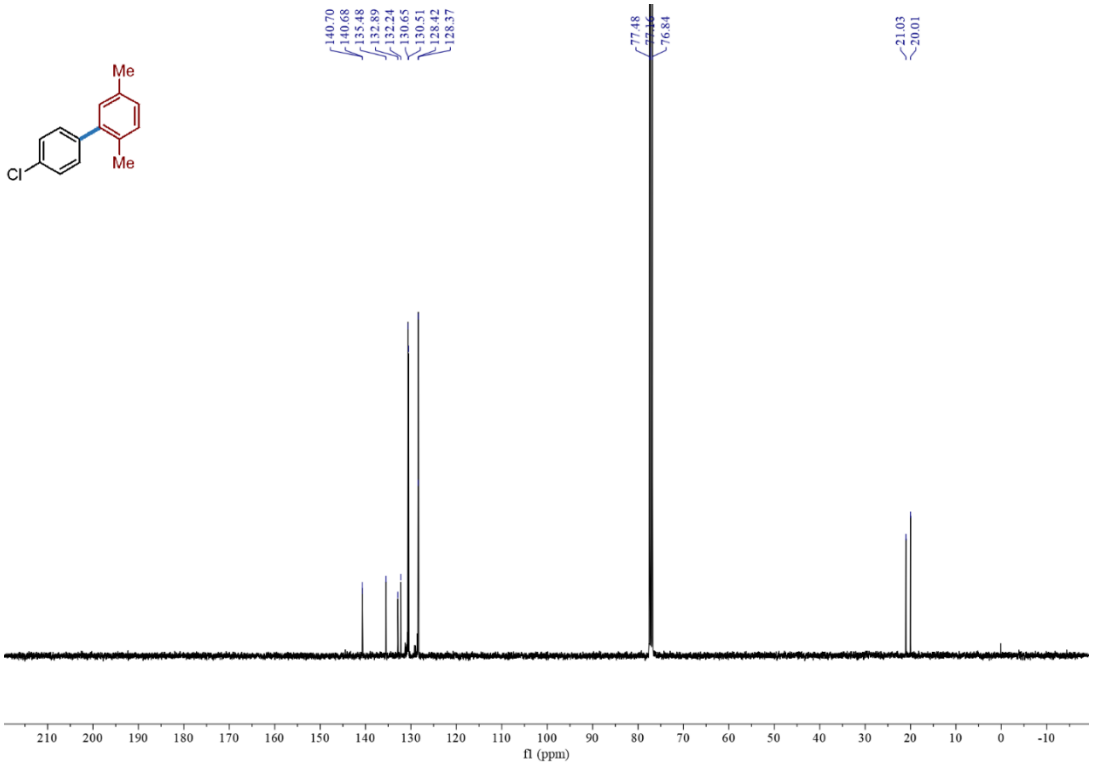
4'-Chloro-2,4,6-trimethyl-1,1'-biphenyl (3cp)



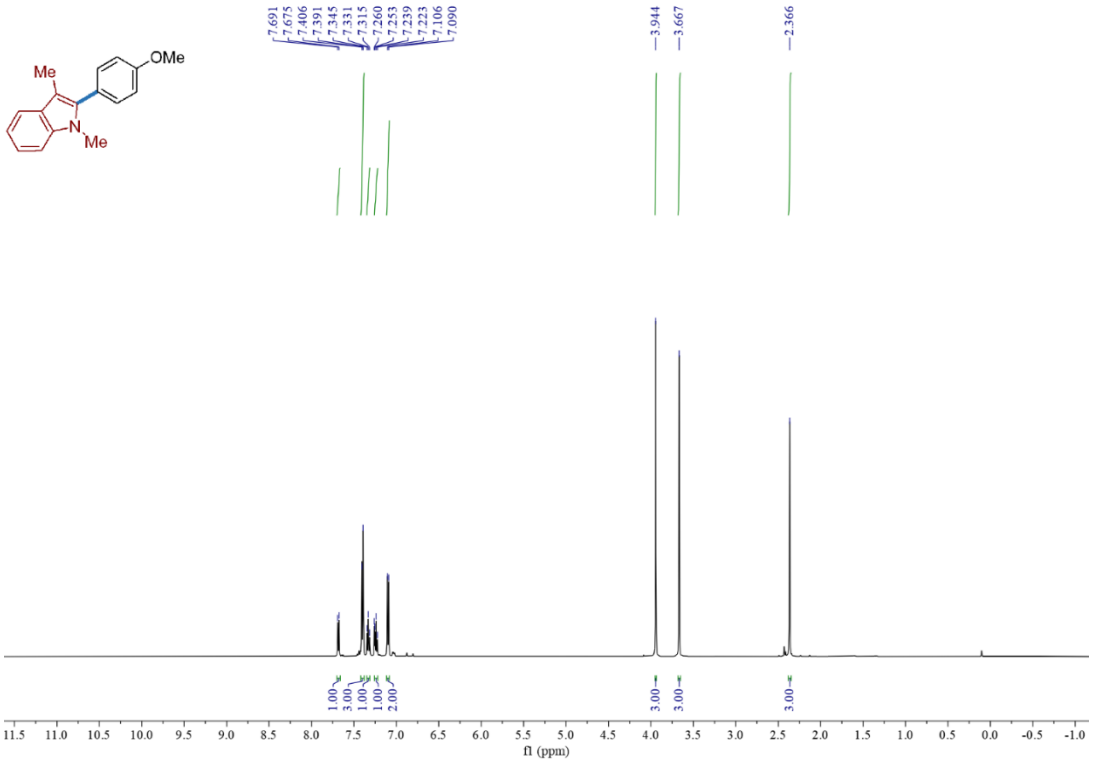


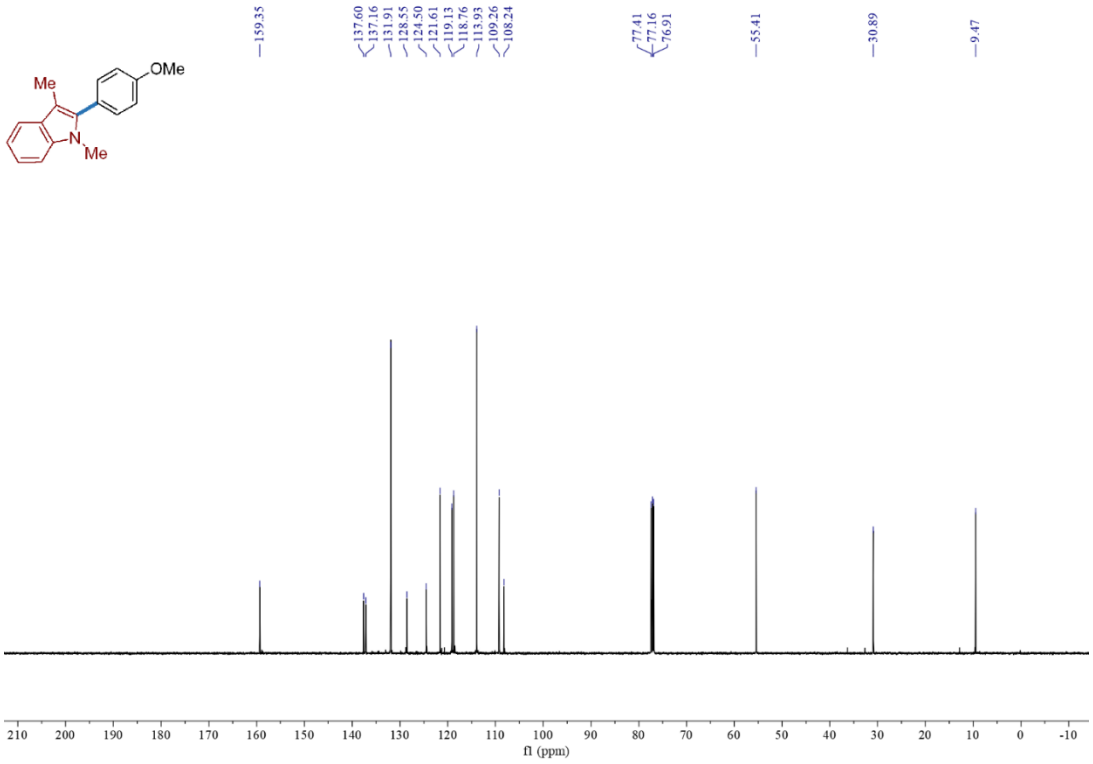
4'-Chloro-2,5-dimethyl-1,1'-biphenyl (3cq)



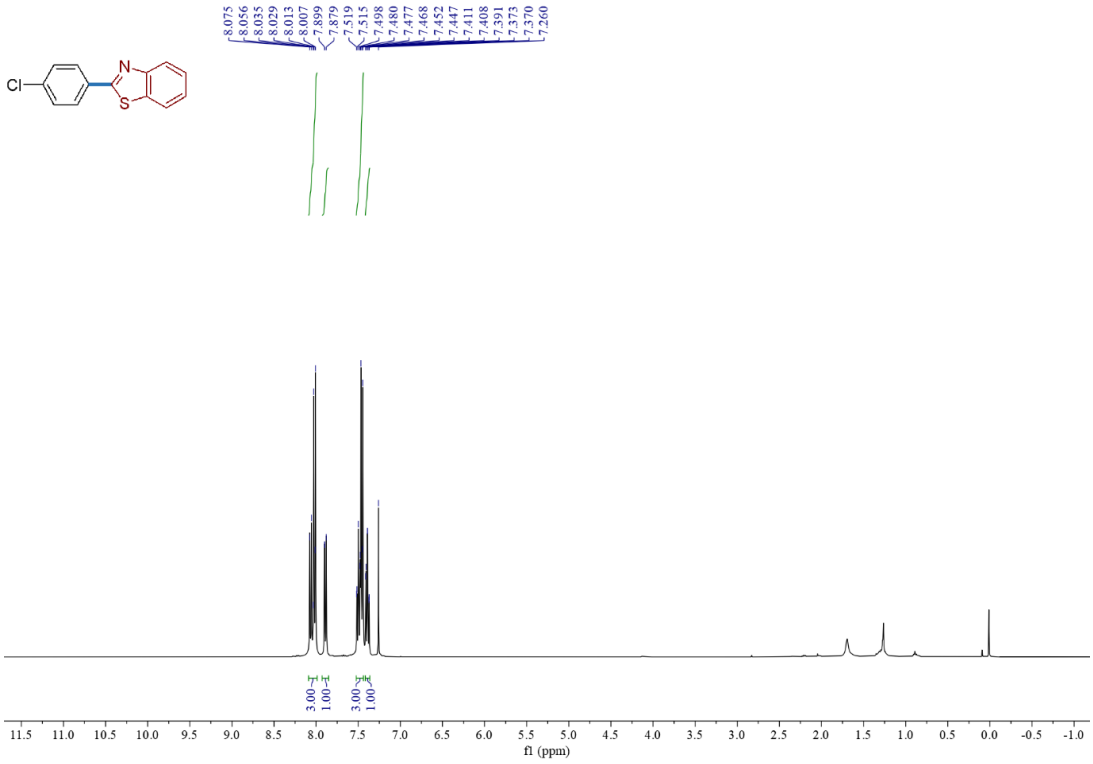


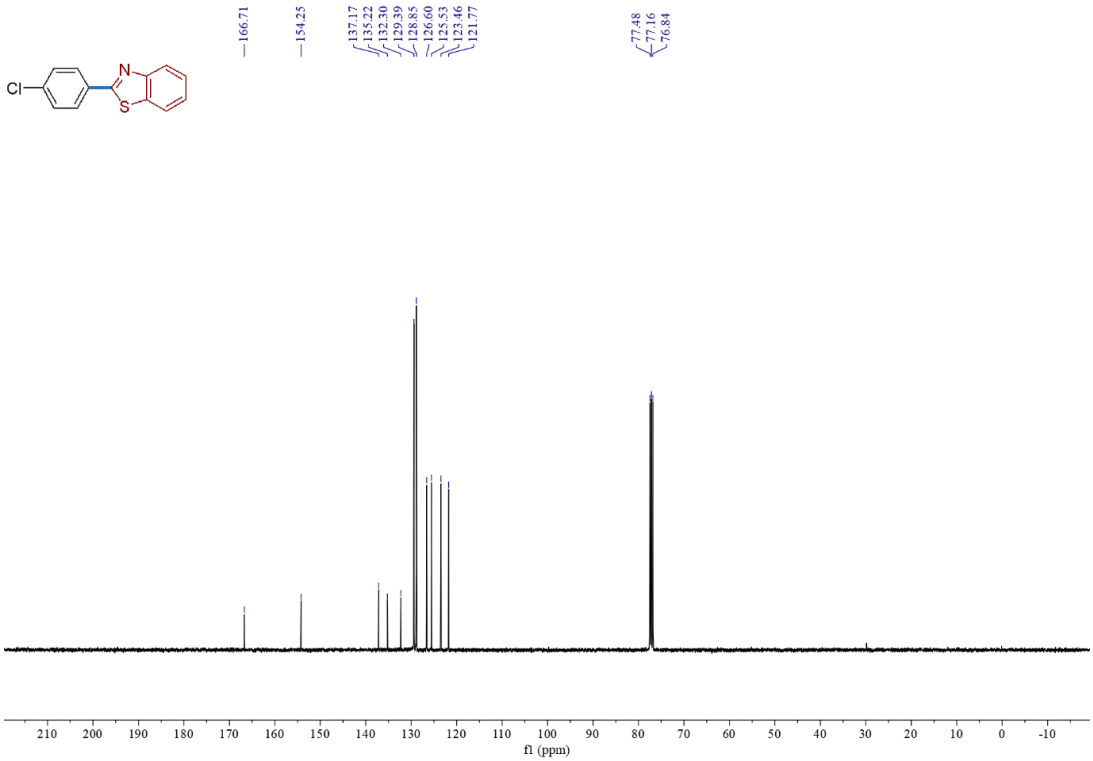
2-(4-Methoxyphenyl)-1,3-dimethyl-1*H*-indole (3ar)



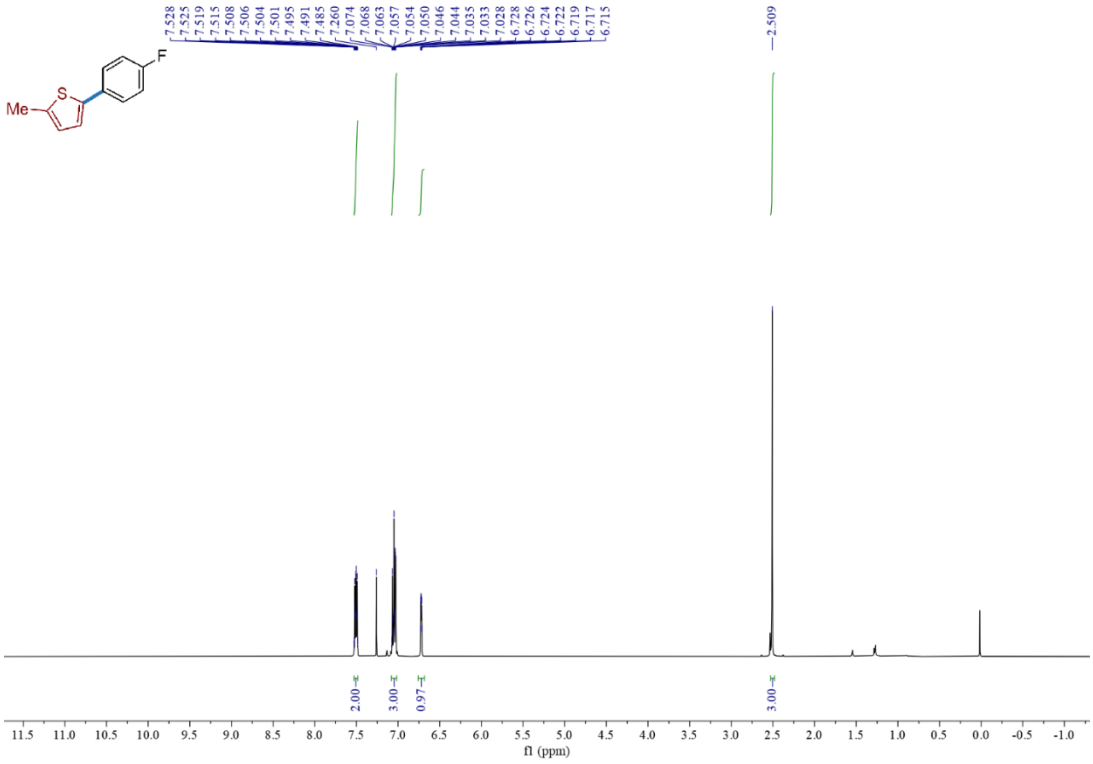


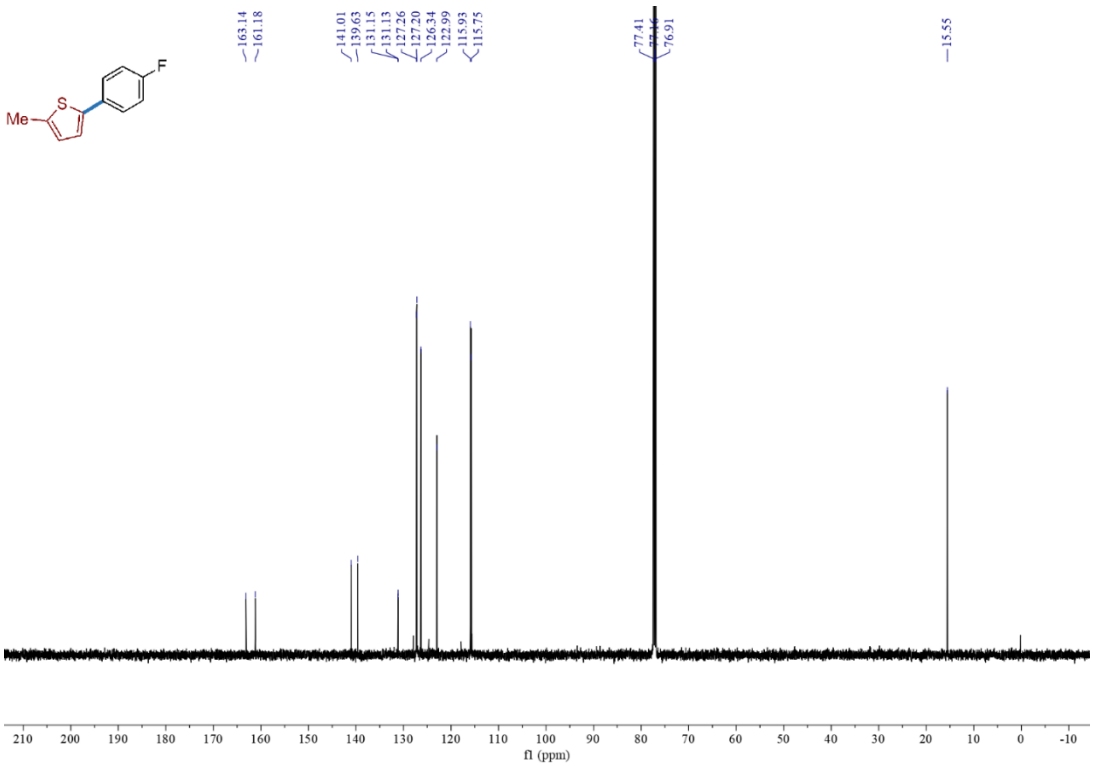
2-(4-Chlorophenyl)benzo[*d*]thiazole (3cs)

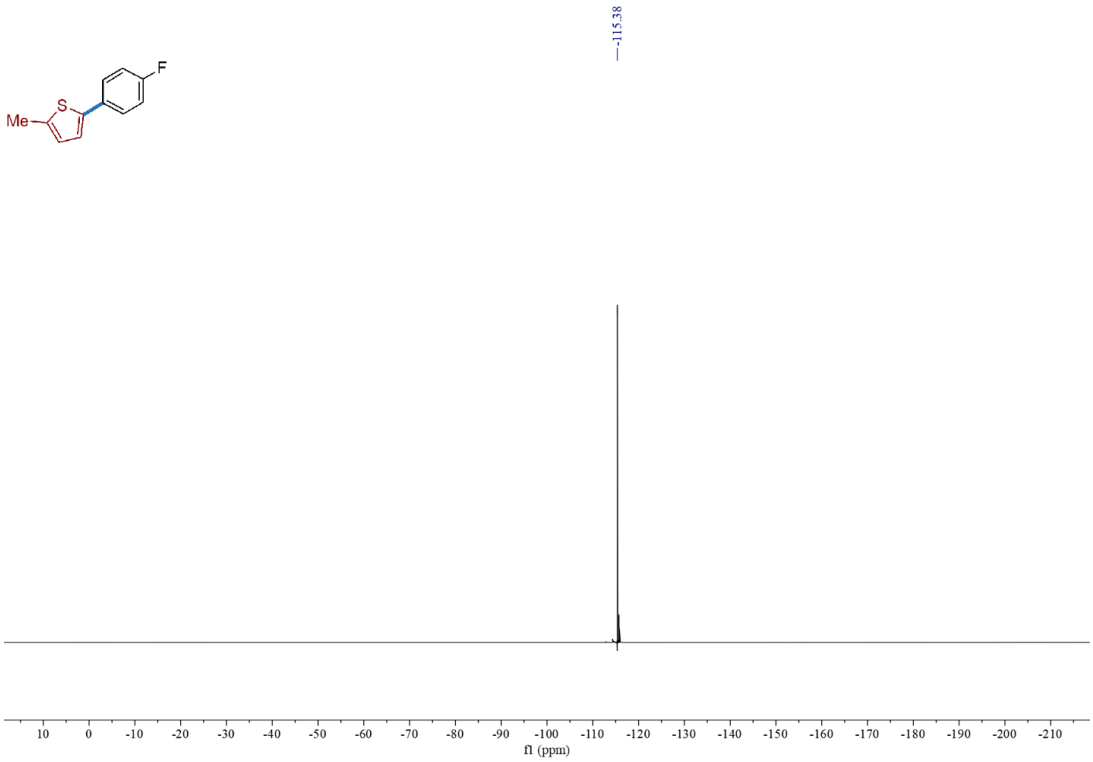




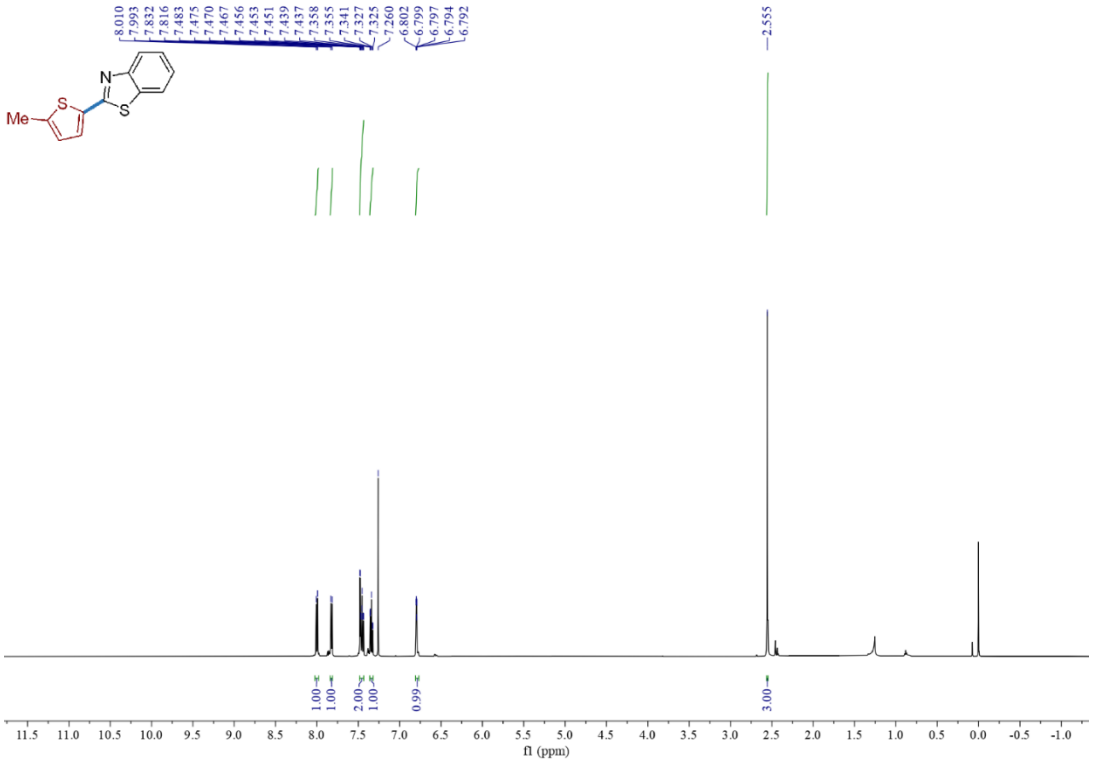
2-(4-Fluorophenyl)-5-methylthiophene (3ku)

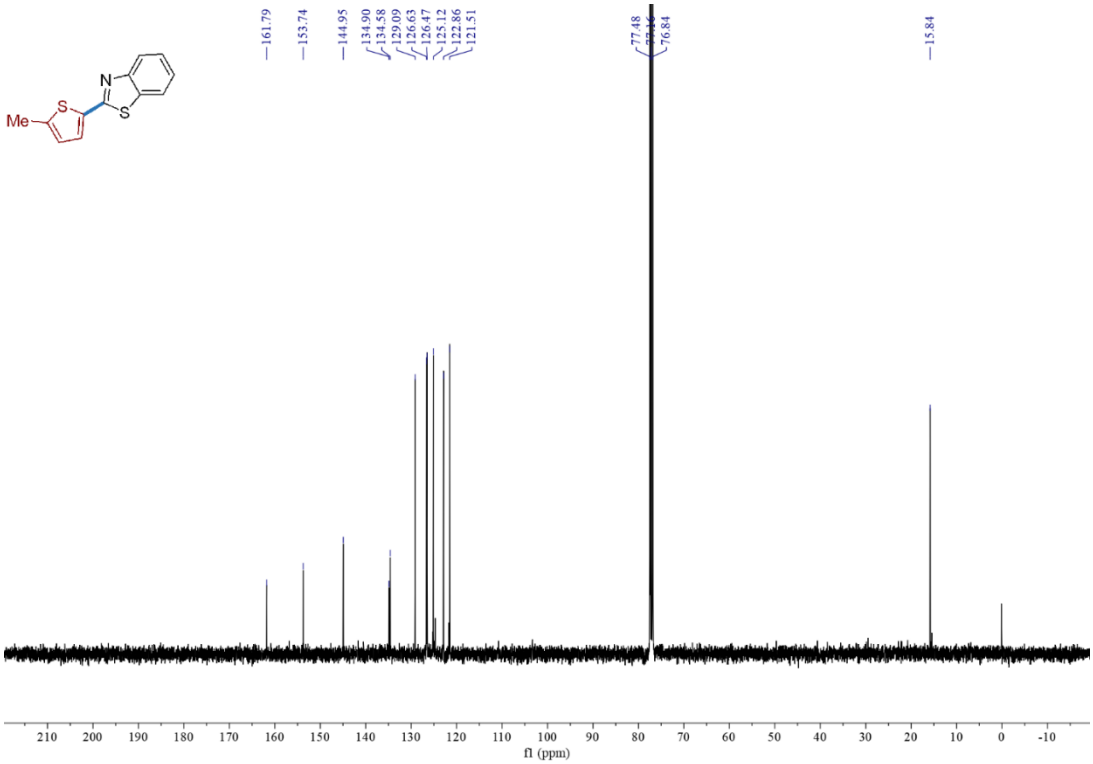




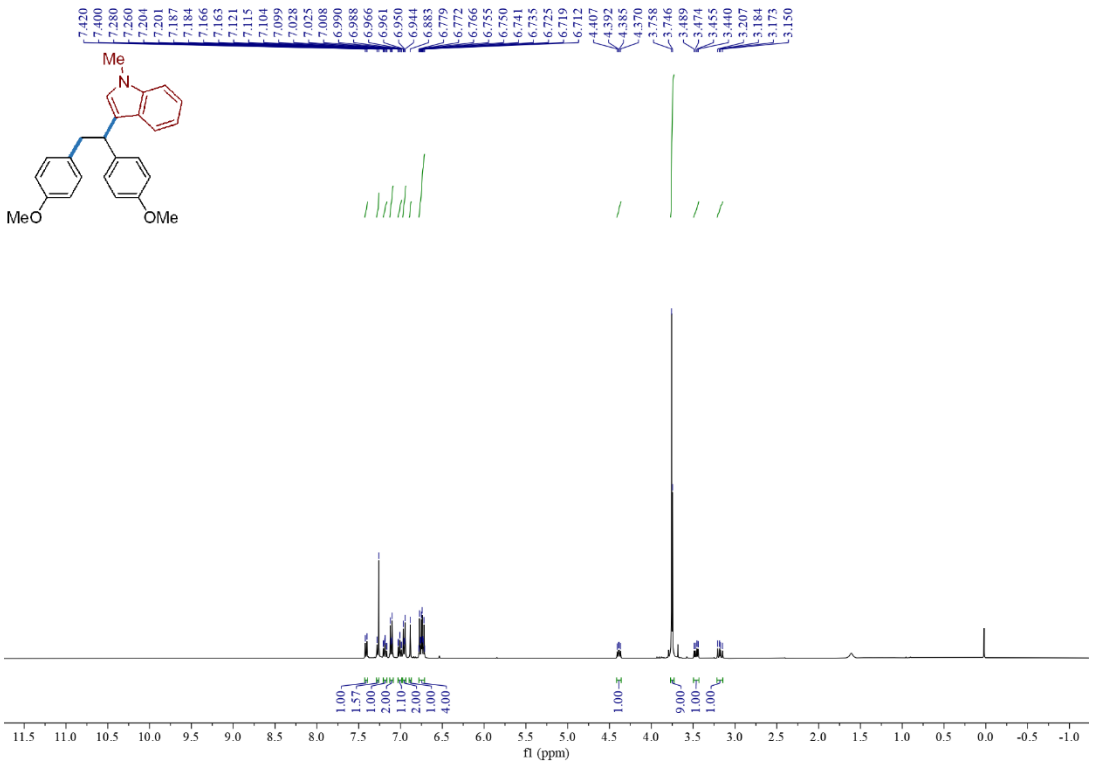

-115.38
F
S
Me
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

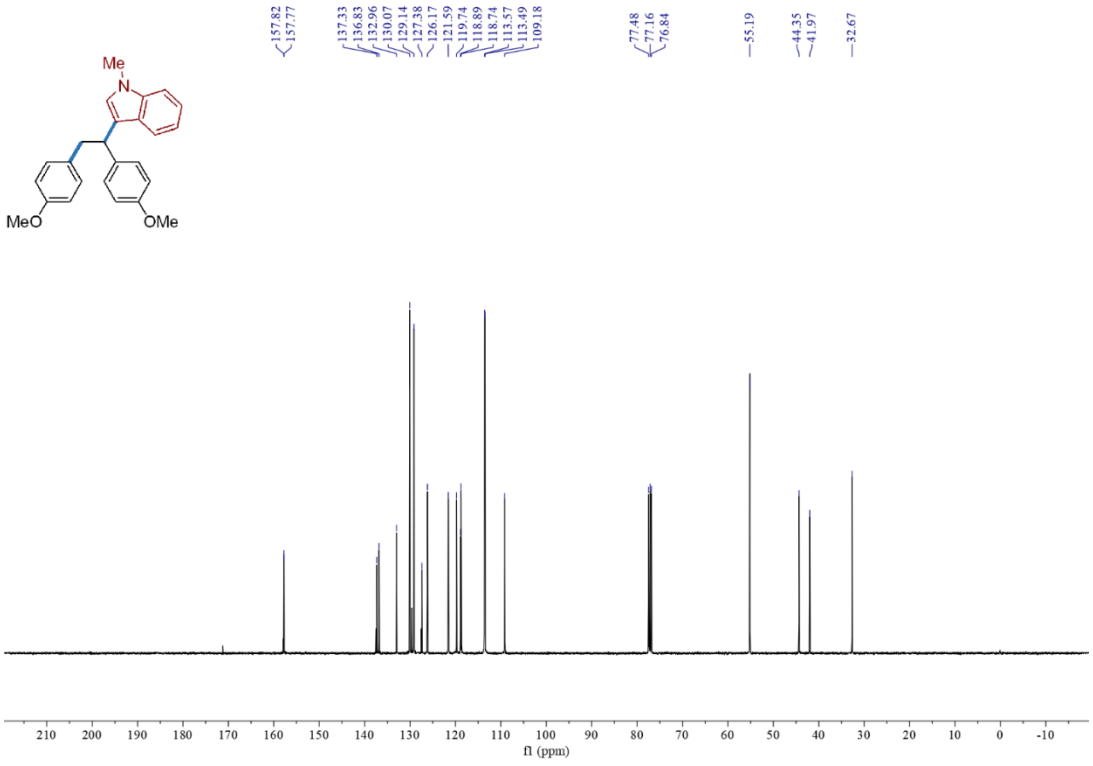
2-(5-Methylthiophen-2-yl)benzo[*d*]thiazole (3lu)



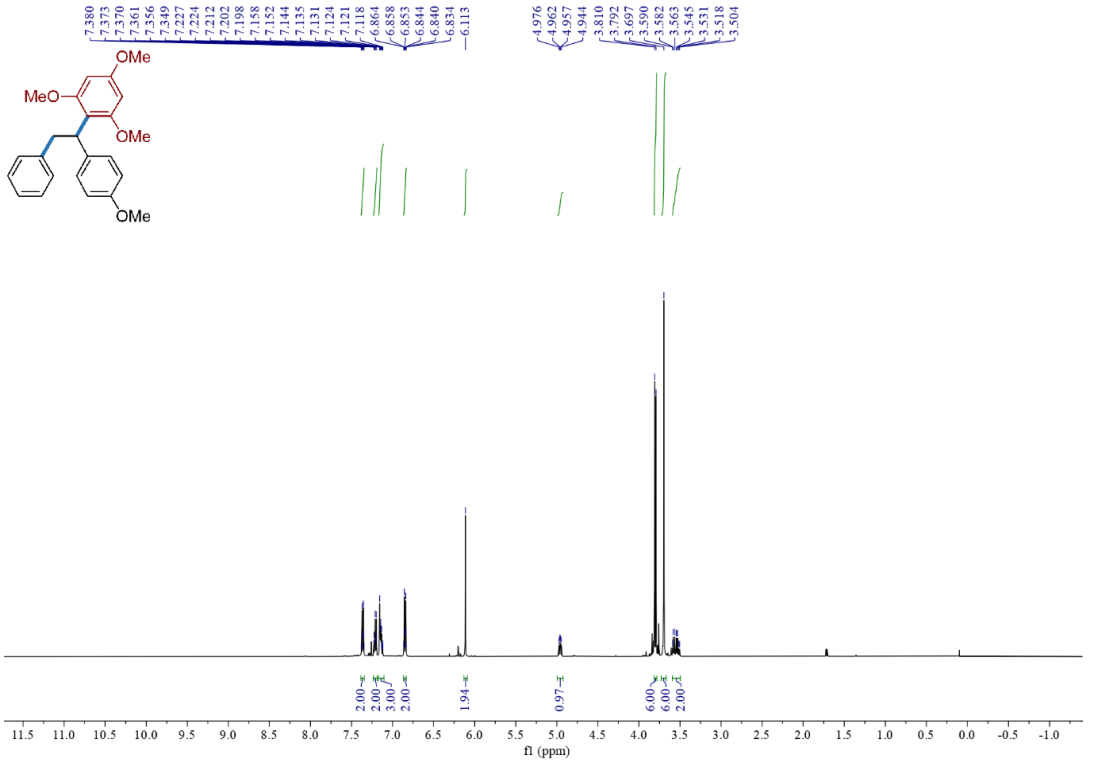


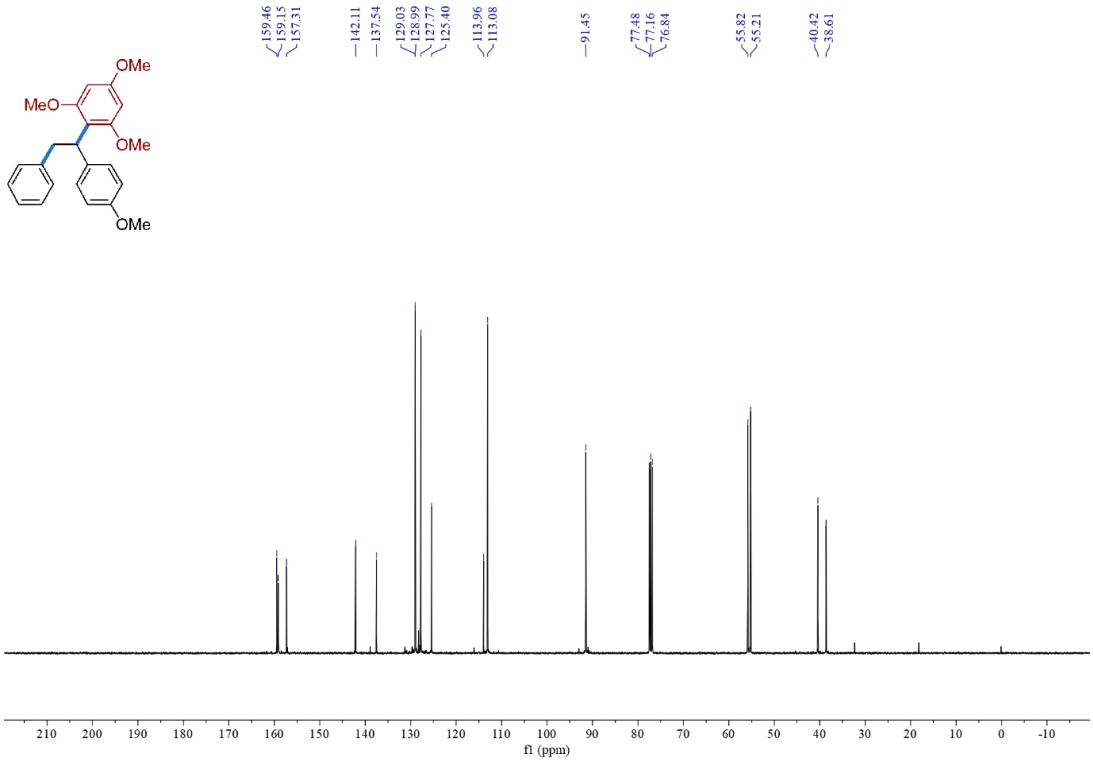
(*R*)-3-(1,2-Bis(4-methoxyphenyl)ethyl)-1-methyl-1*H*-indole (6aaa)



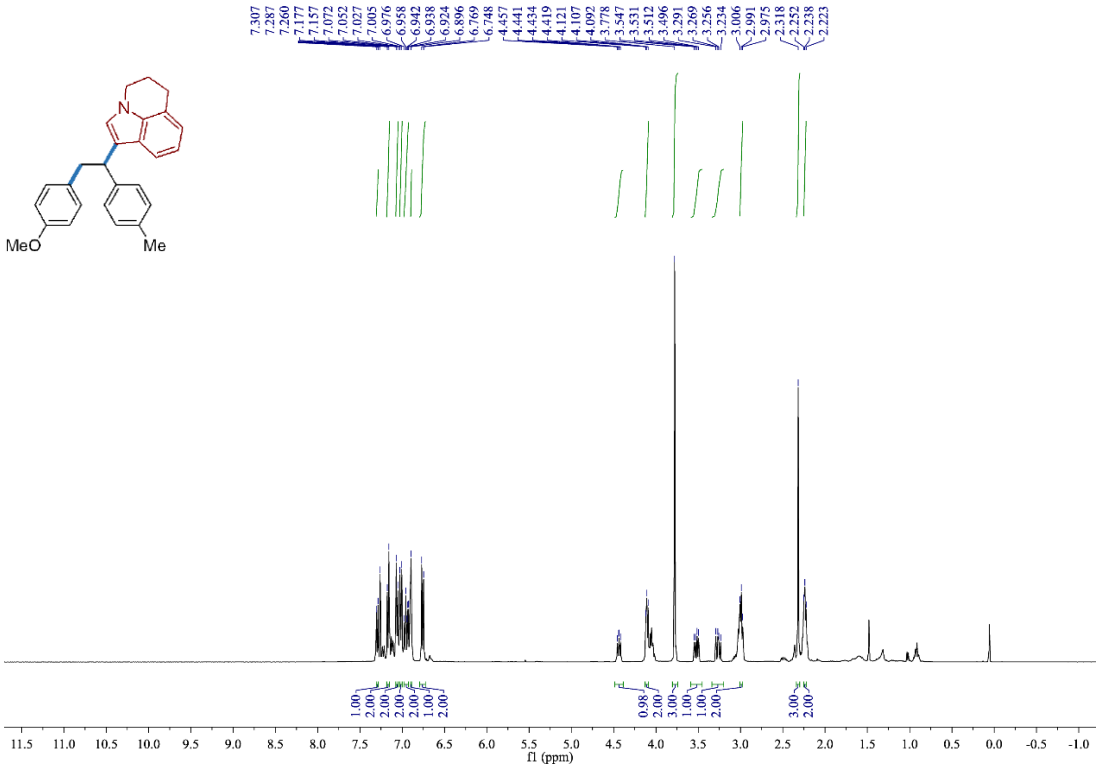


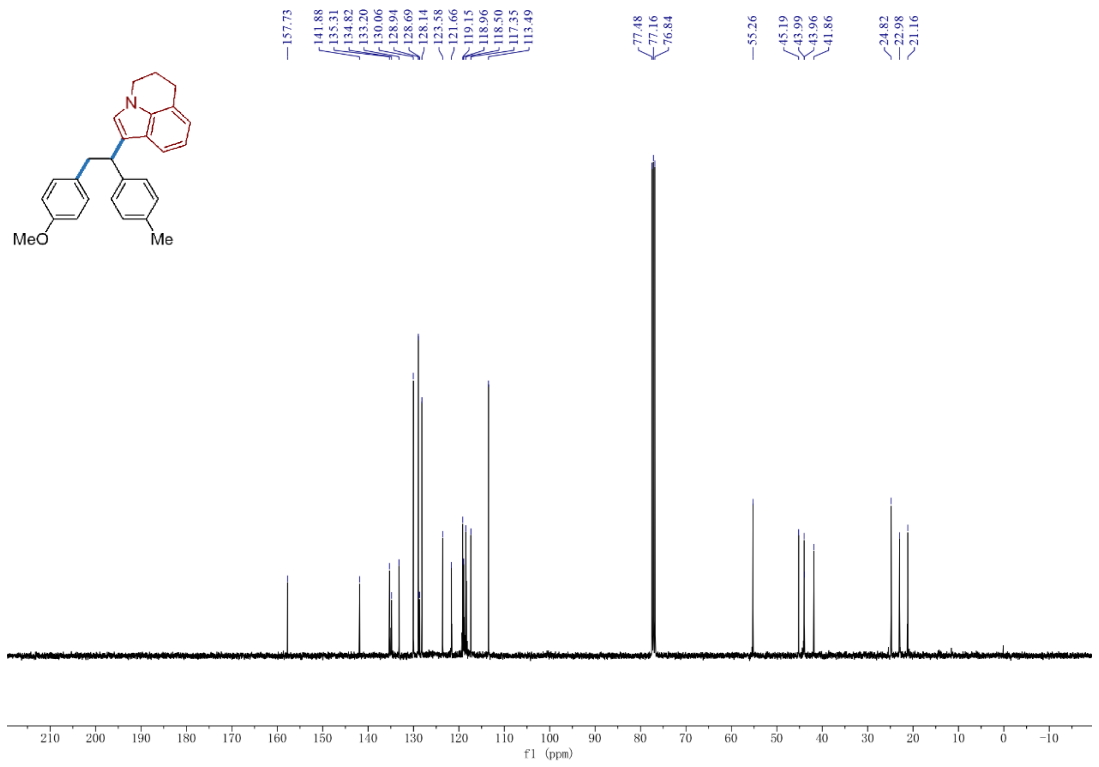
(*R*)-1,3,5-Trimethoxy-2-(1-(4-methoxyphenyl)-2-phenylethyl)benzene (6mba)



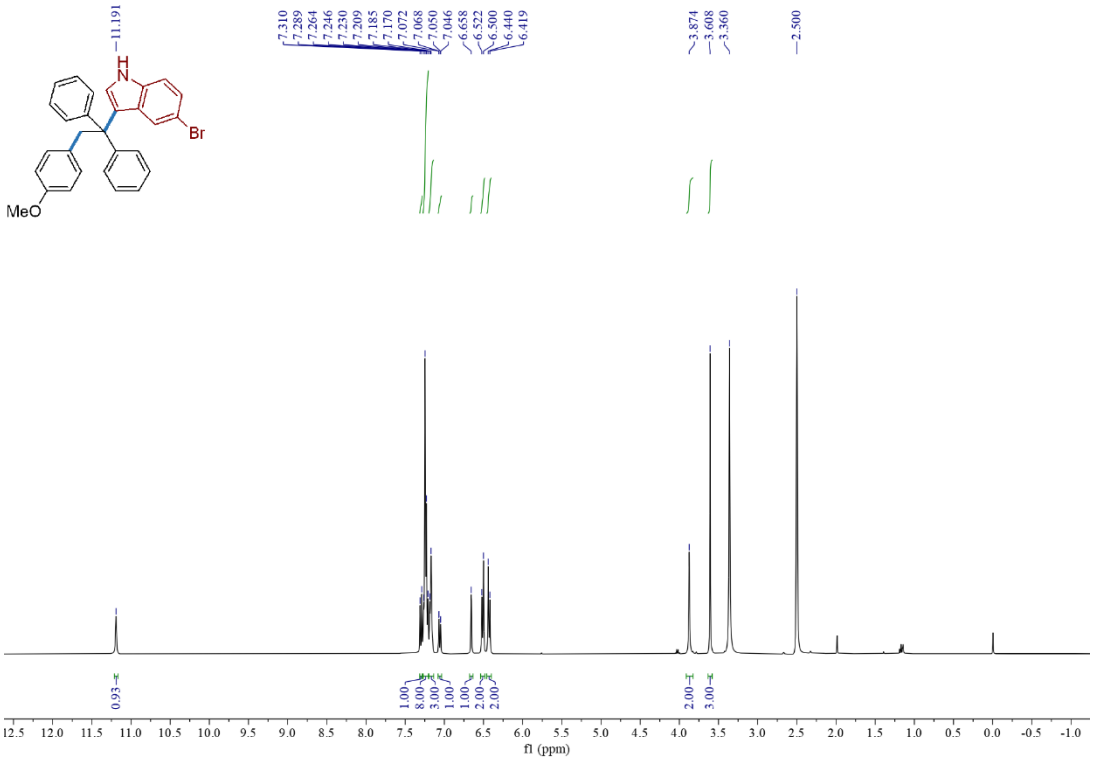


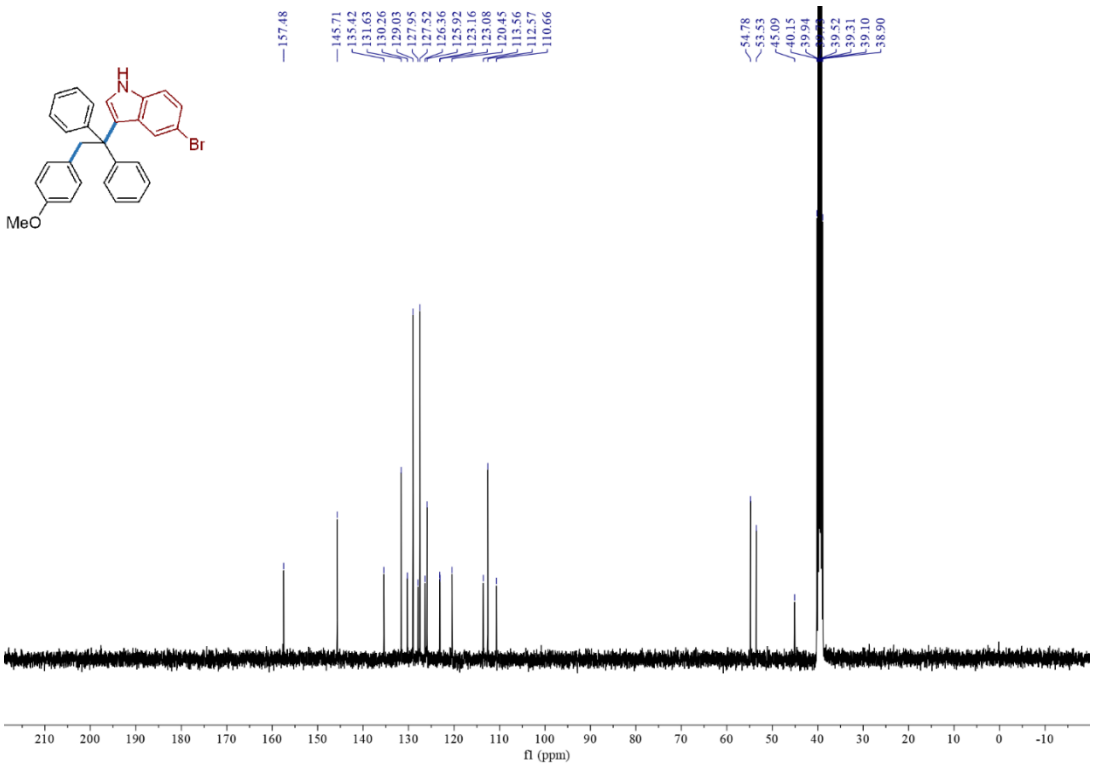
(*R*)-1-(2-(4-Methoxyphenyl)-1-(*p*-tolyl)ethyl)-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinoline (6acb)



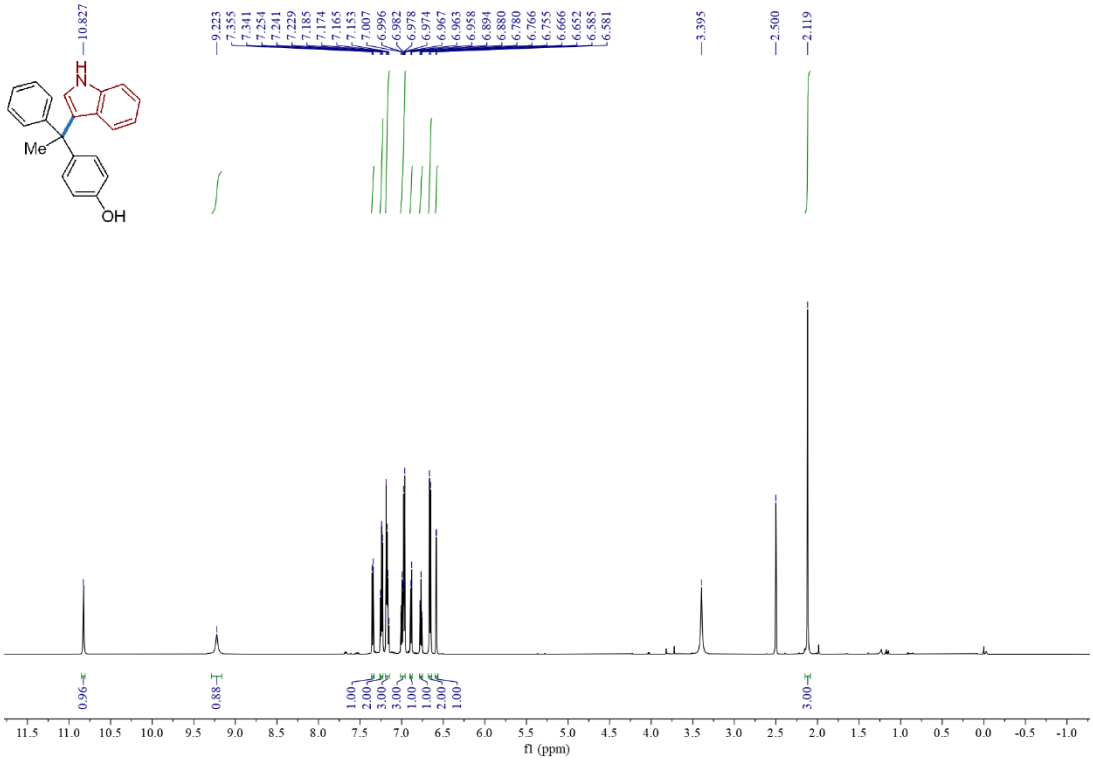


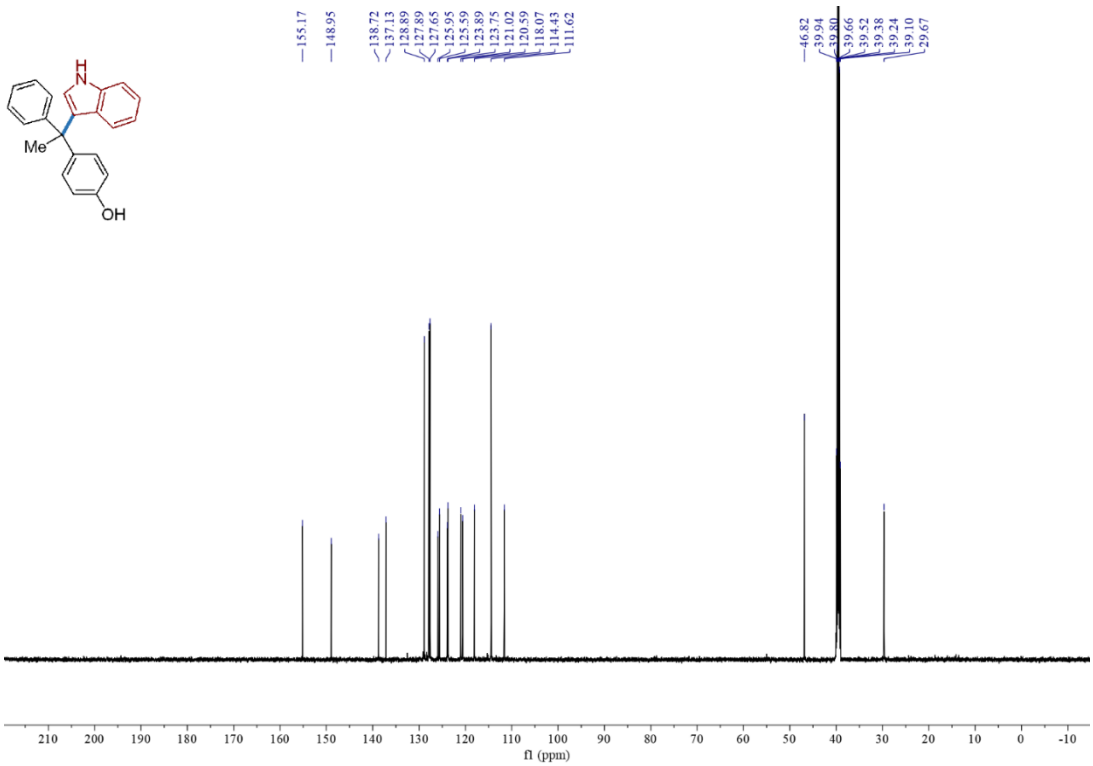
5-Bromo-3-(2-(4-methoxyphenyl)-1,1-diphenylethyl)-1*H*-indole (6adc)



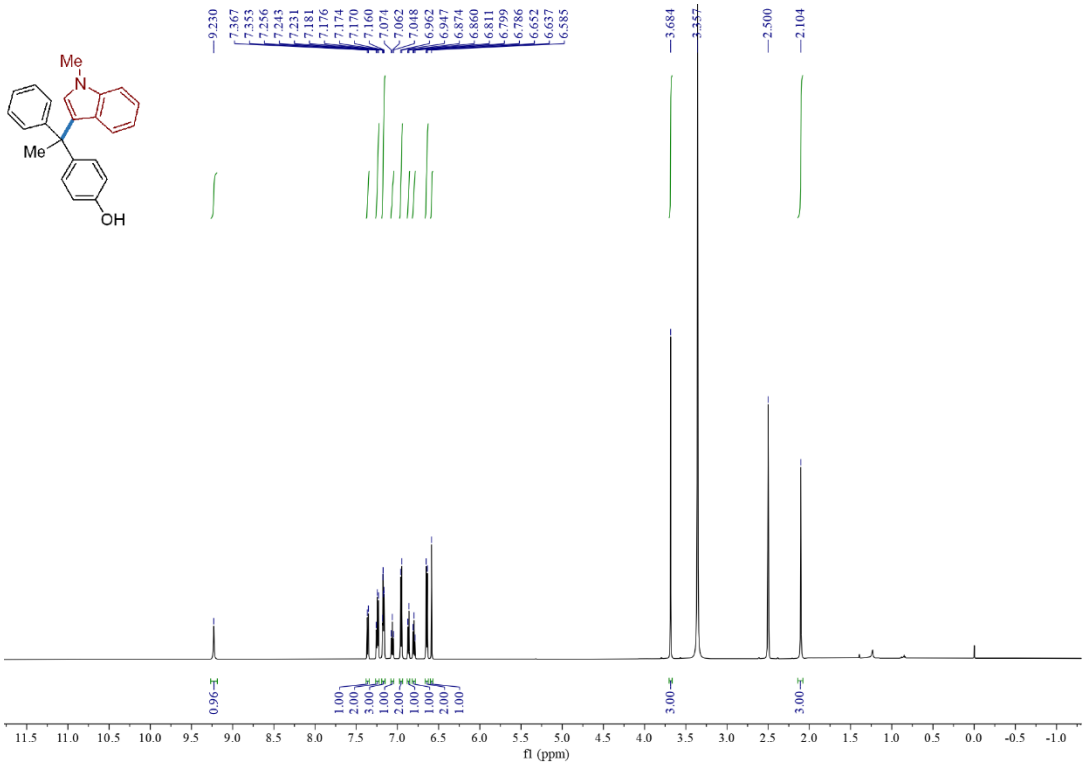


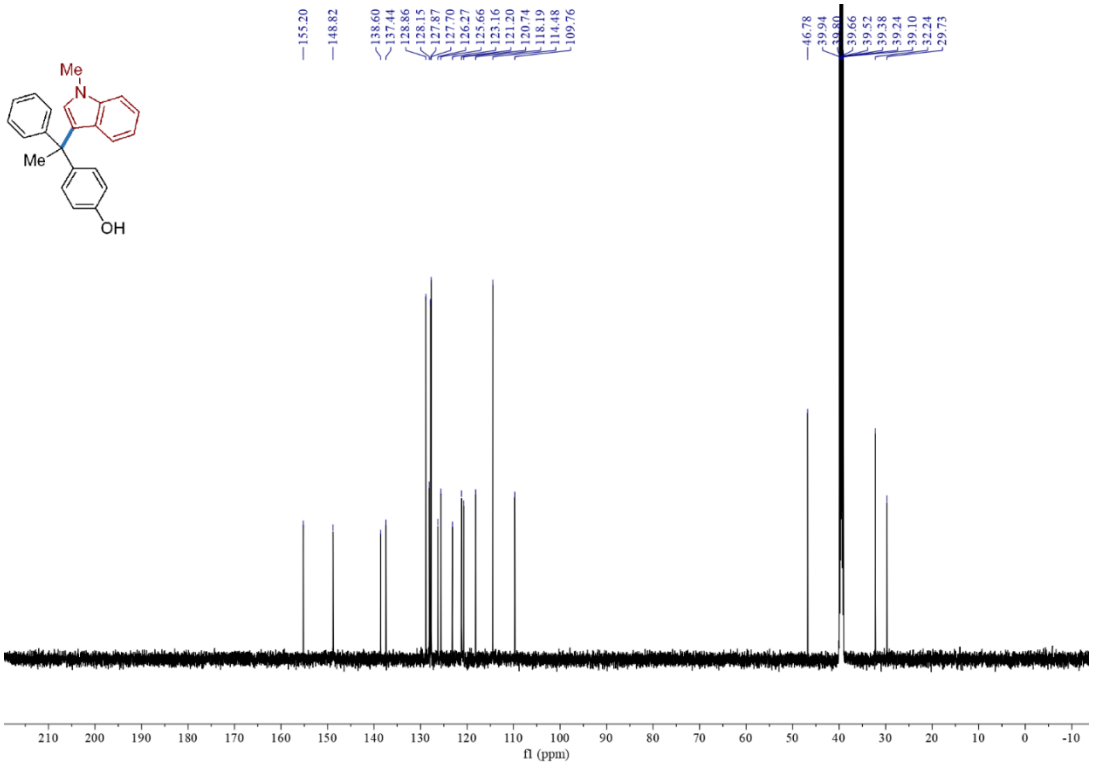
4-(1-(1*H*-Indol-3-yl)-1-phenylethyl)phenol (7ed)



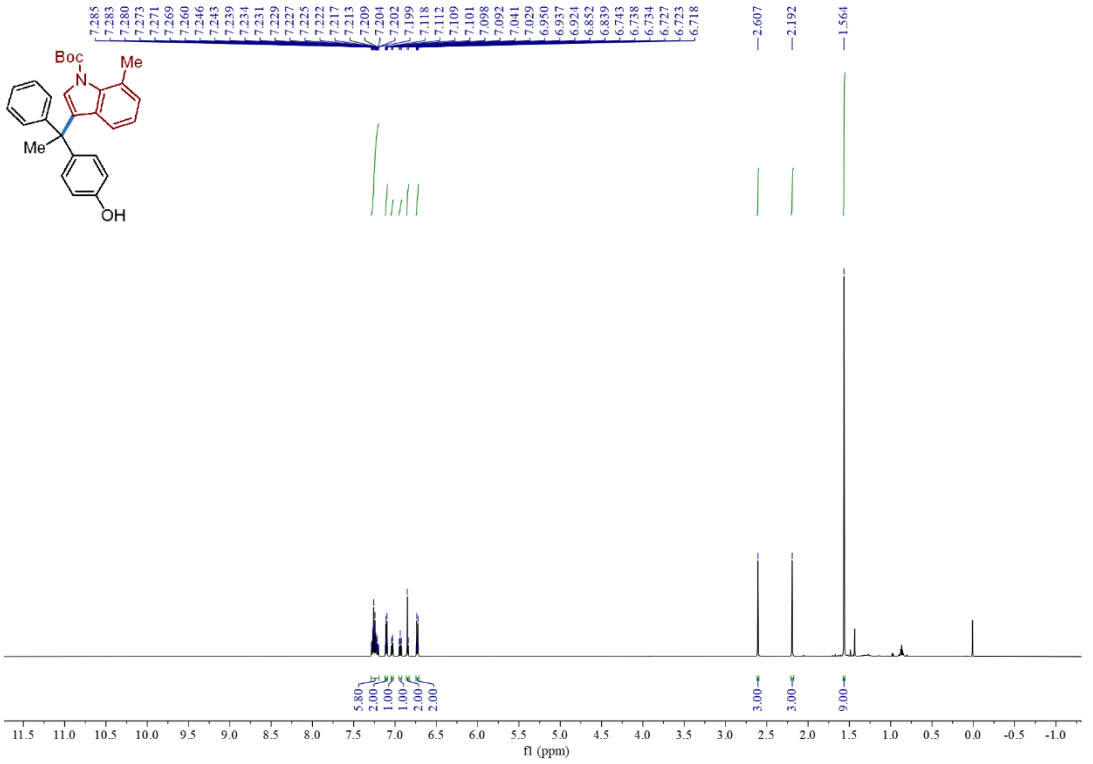


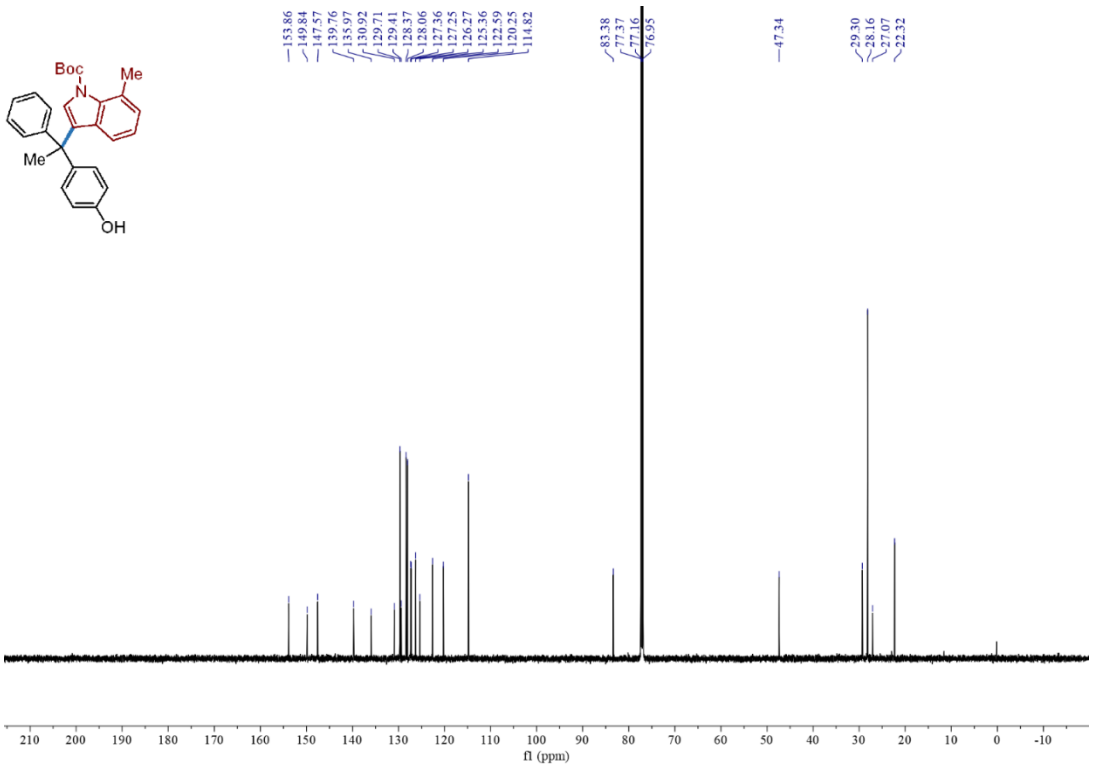
4-(1-(1-Methyl-1*H*-indol-3-yl)-1-phenylethyl)phenol (7ad)



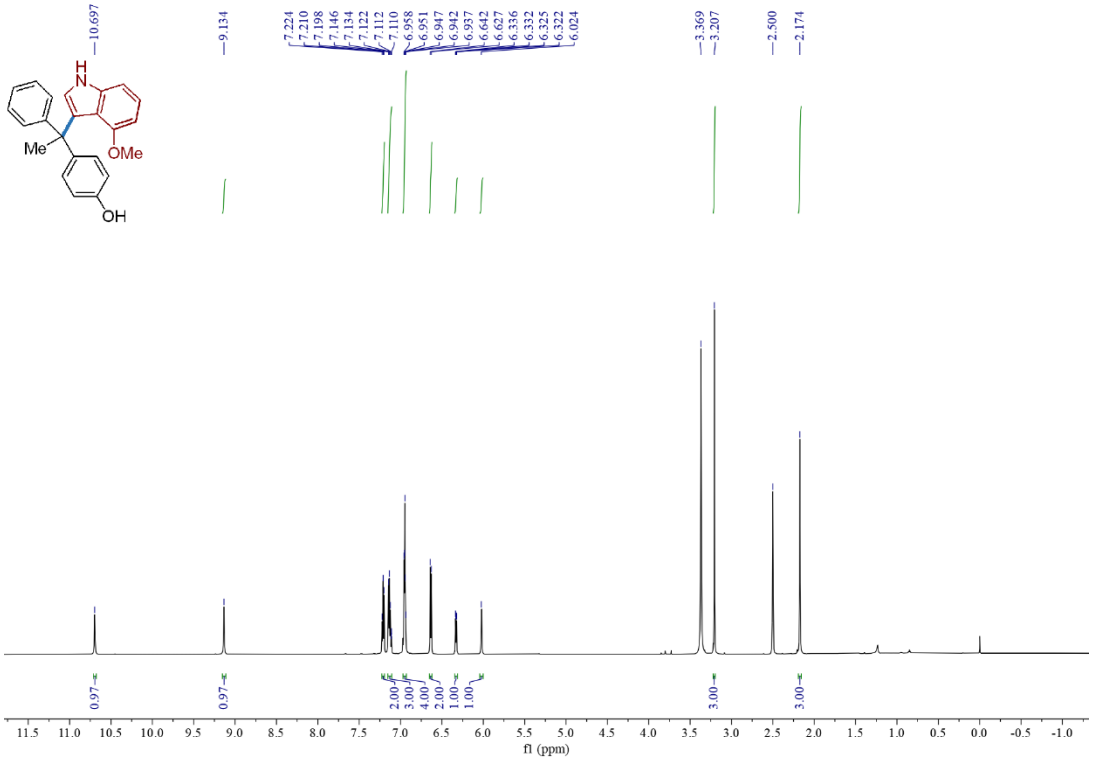


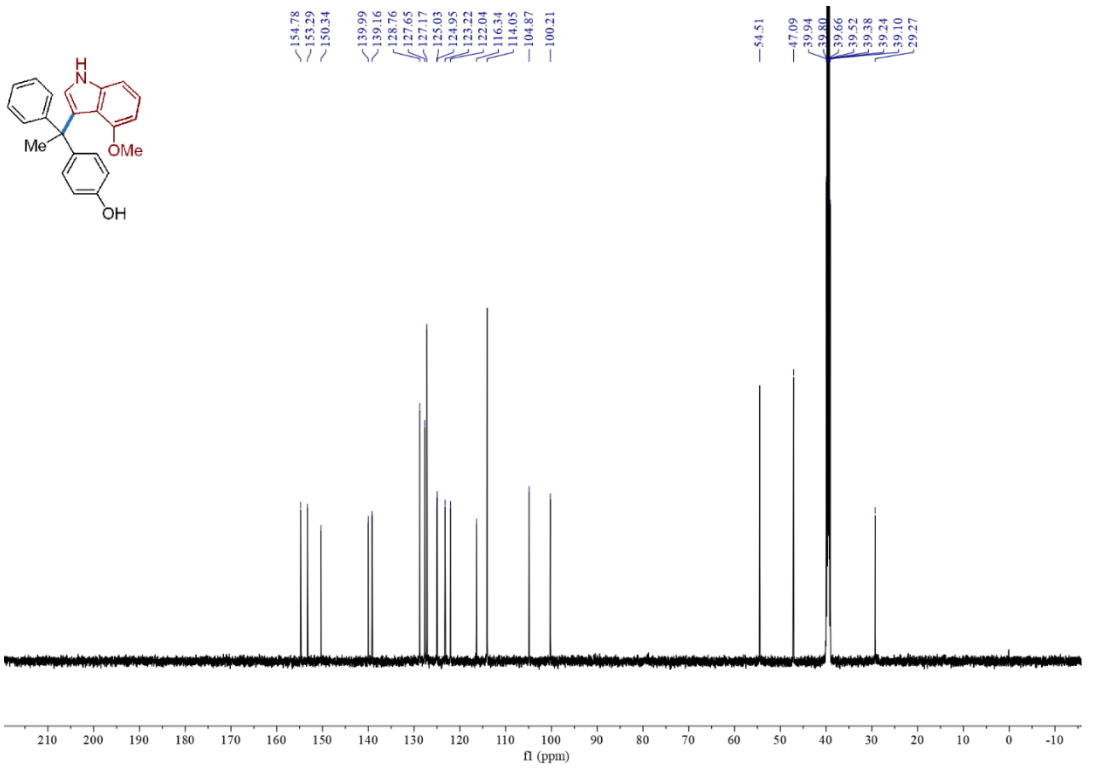
***tert*-Butyl 3-(1-(4-hydroxyphenyl)-1-phenylethyl)-7-methyl-1*H*-indole-1-carboxylate (7fd)**



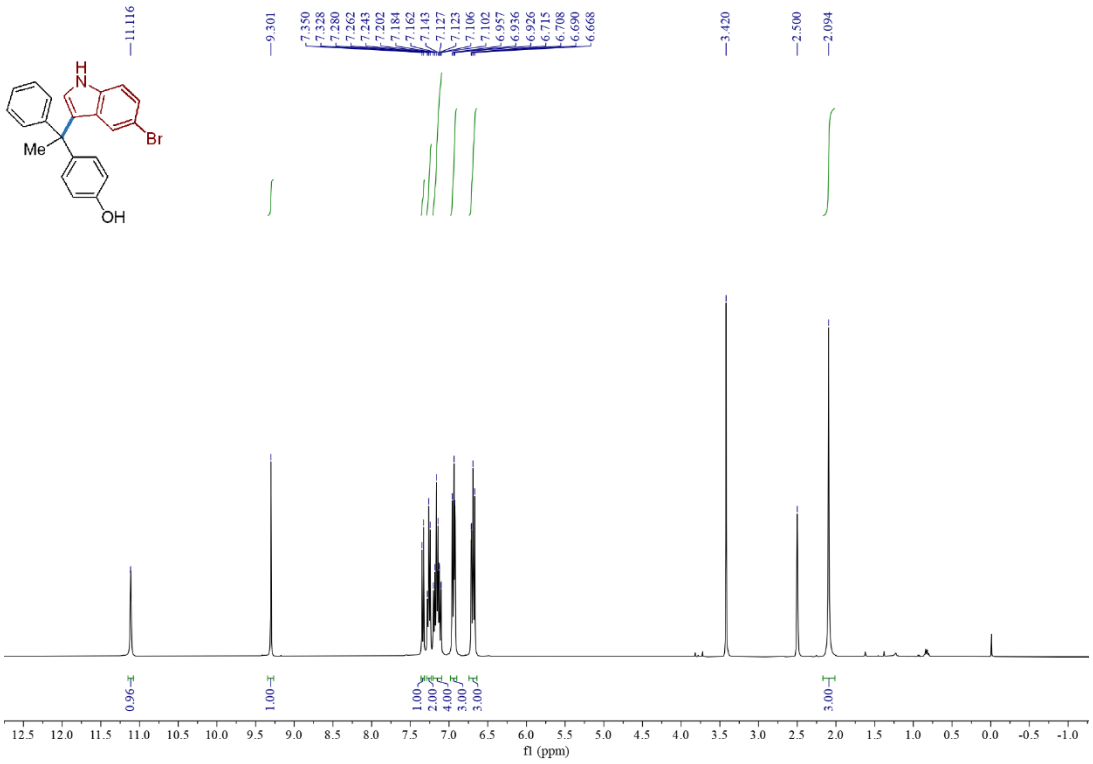


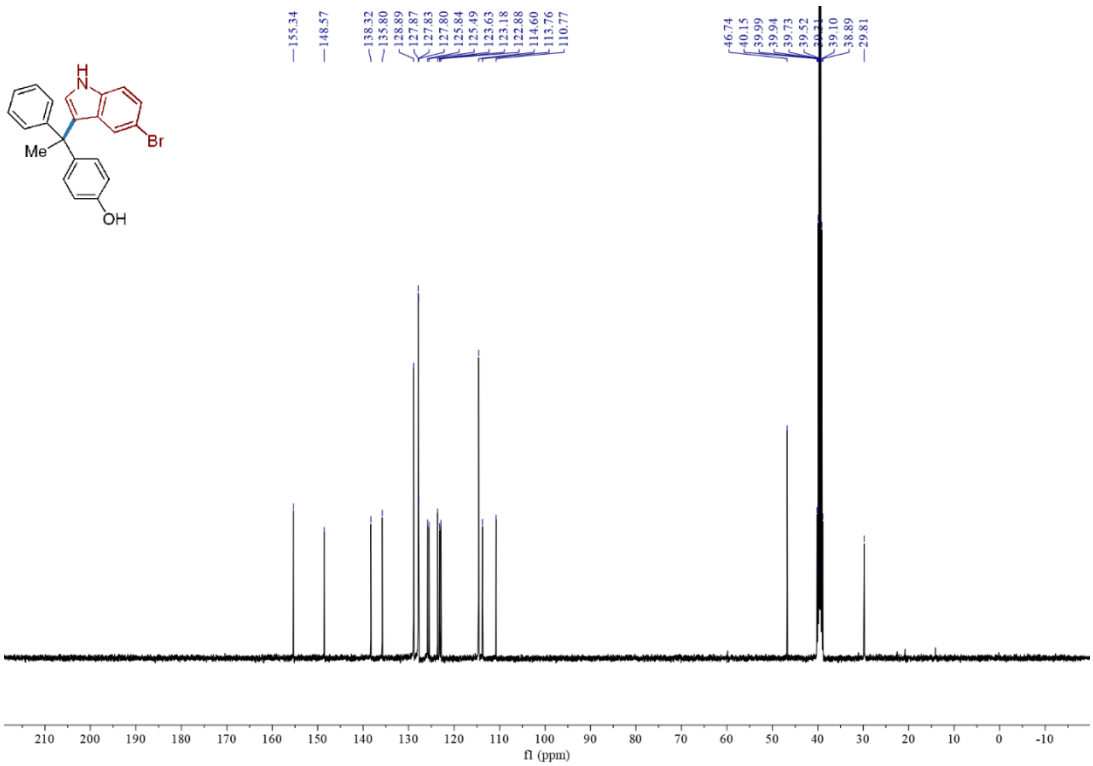
4-(1-(4-Methoxy-1*H*-indol-3-yl)-1-phenylethyl)phenol (7gd)



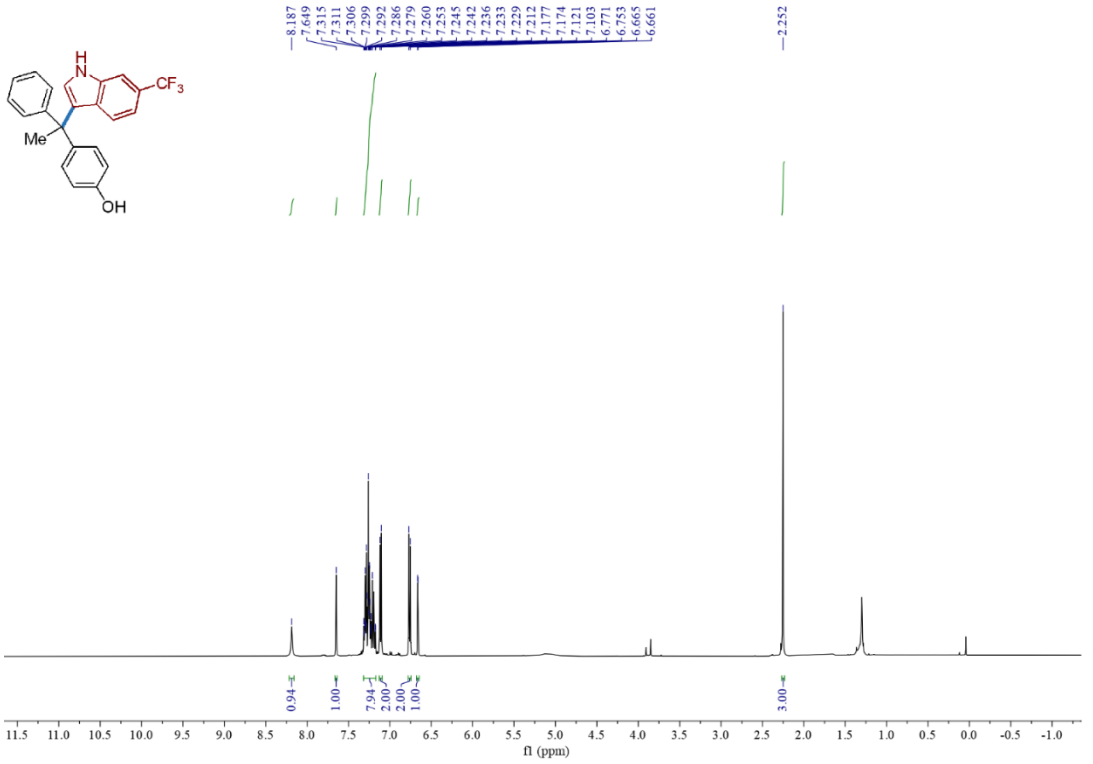


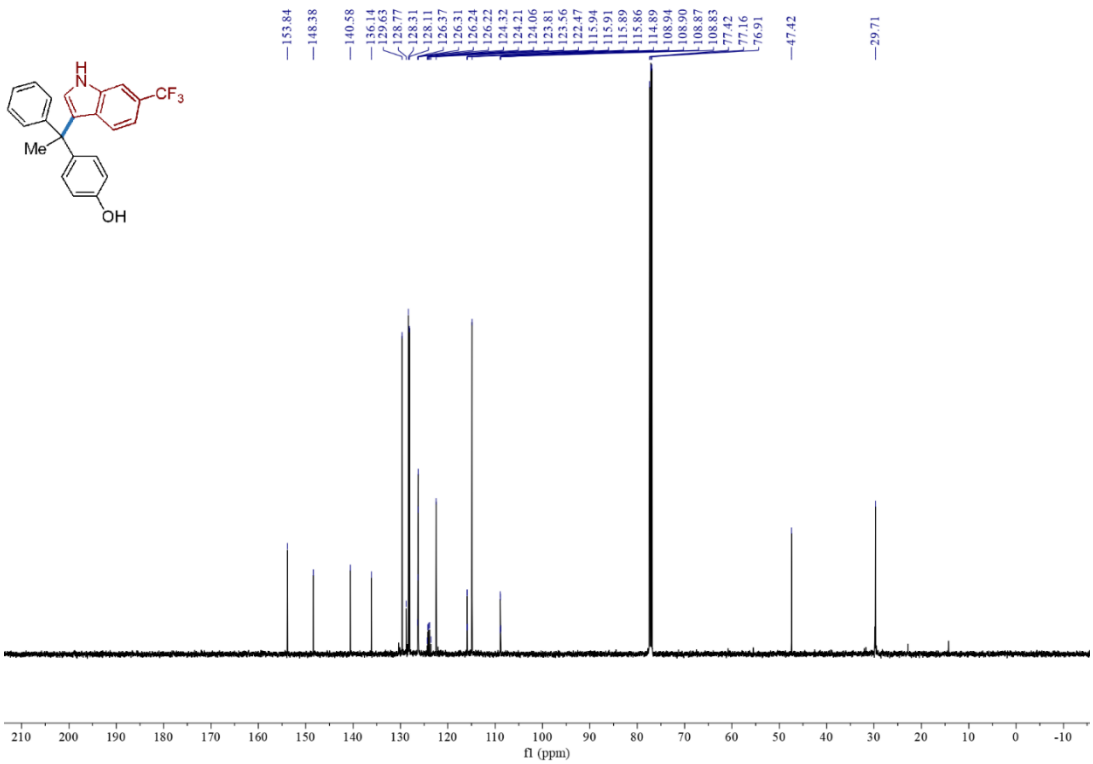
4-(1-(5-Bromo-1*H*-indol-3-yl)-1-phenylethyl)phenol (7dd)

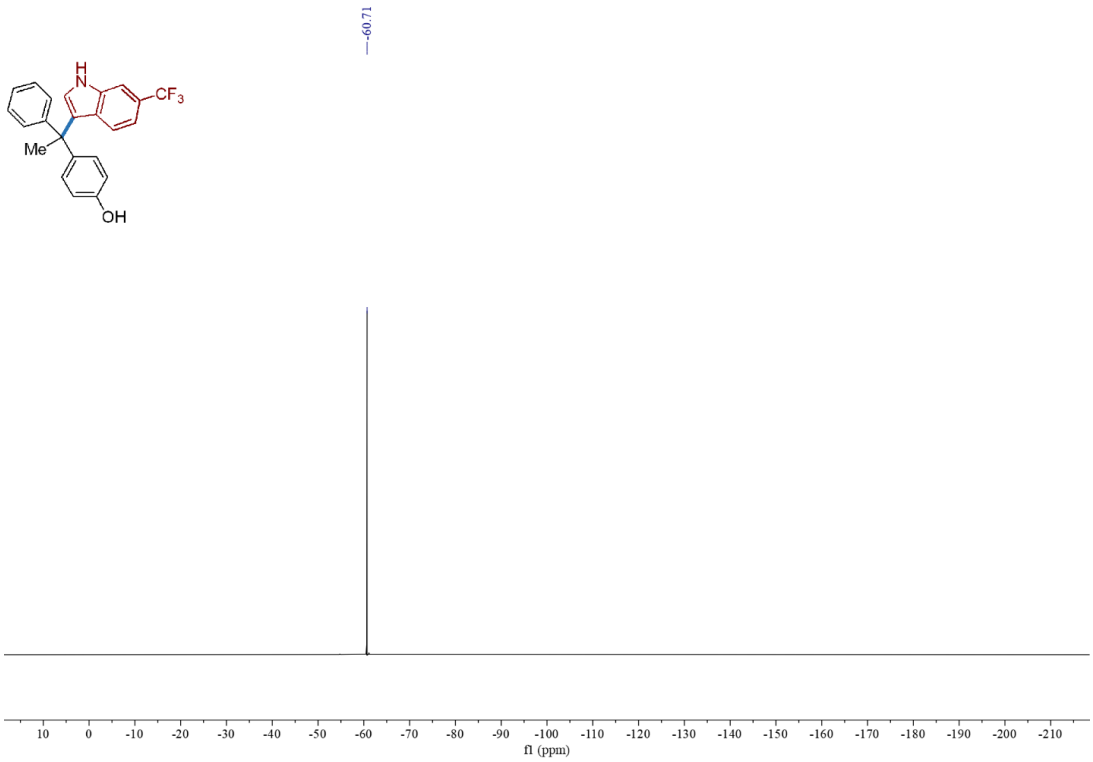




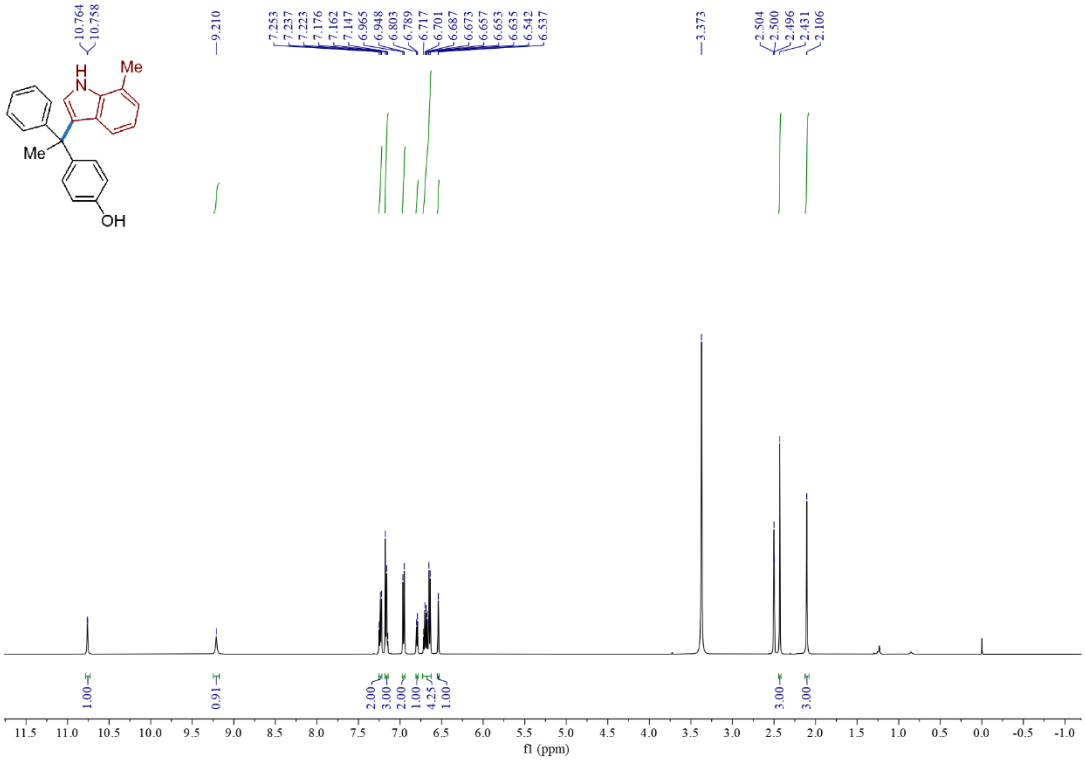
4-(1-Phenyl-1-(6-(trifluoromethyl)-1*H*-indol-3-yl)ethyl)phenol (7hd)

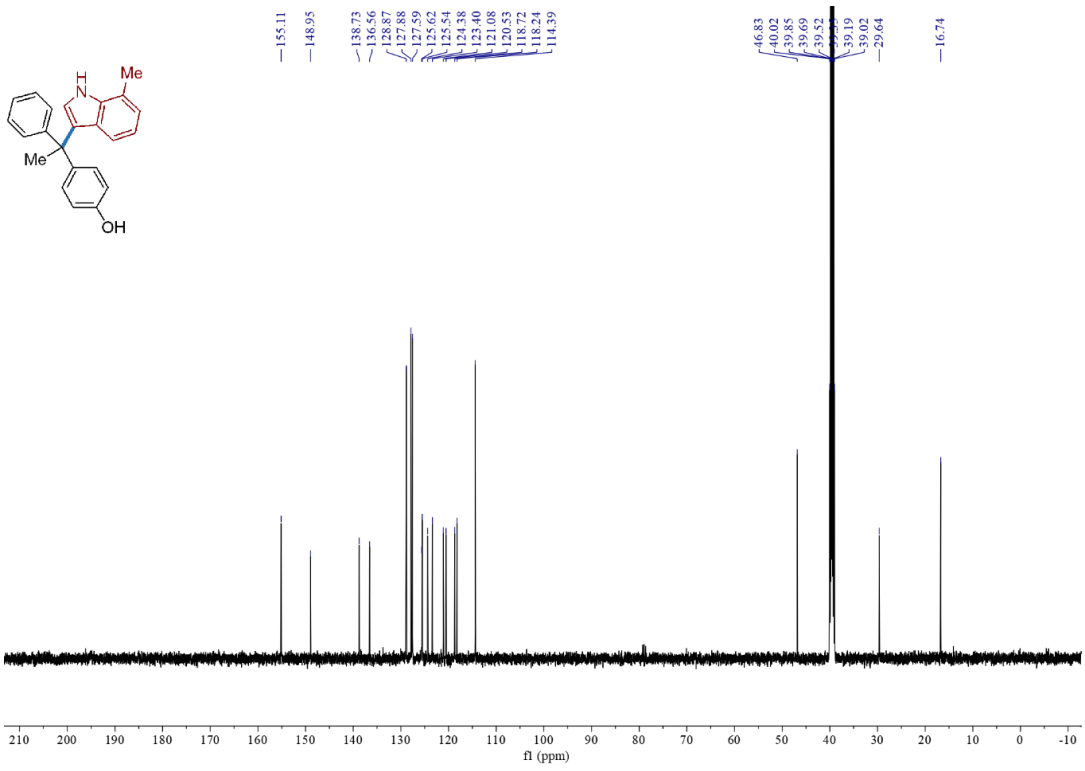




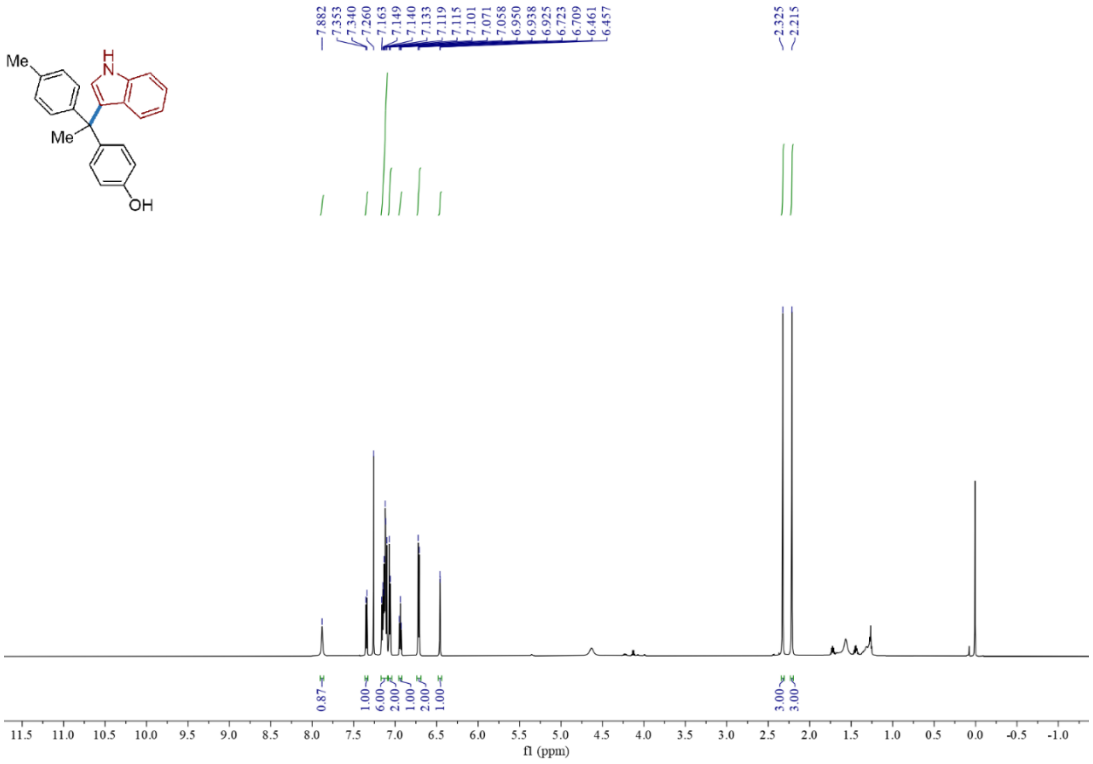

-60.71
H
N
CF3
Me
OH
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

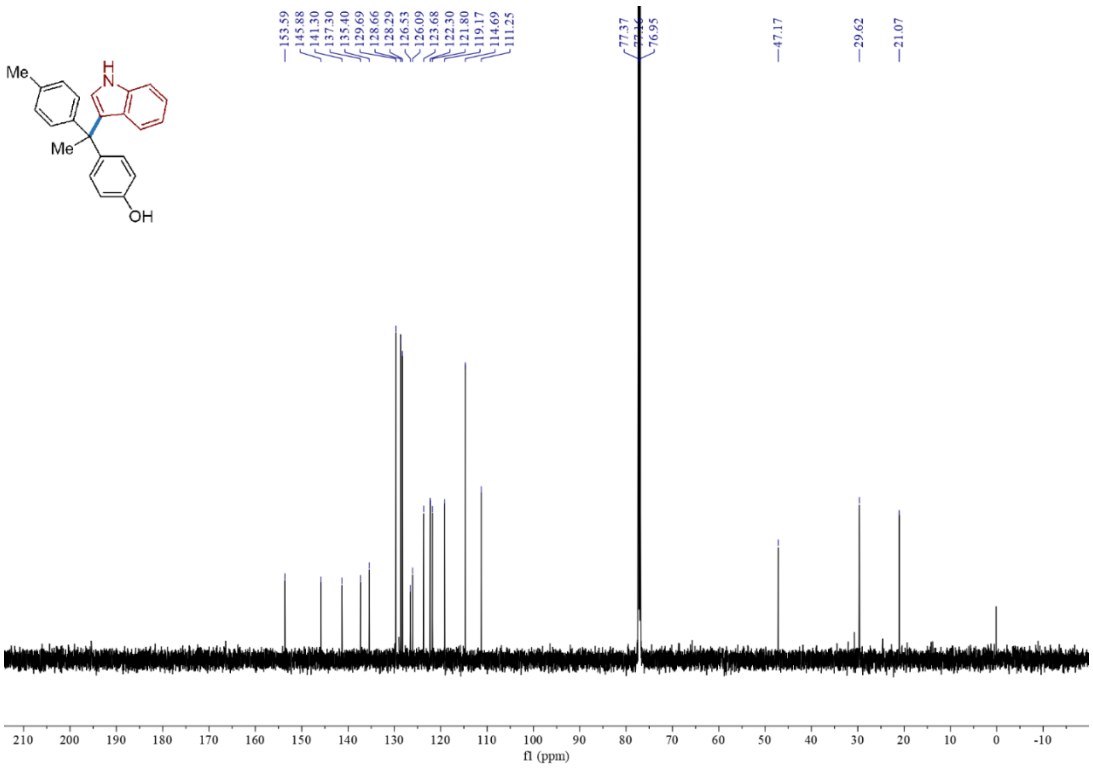
4-(1-(7-Methyl-1*H*-indol-3-yl)-1-phenylethyl)phenol (7id)



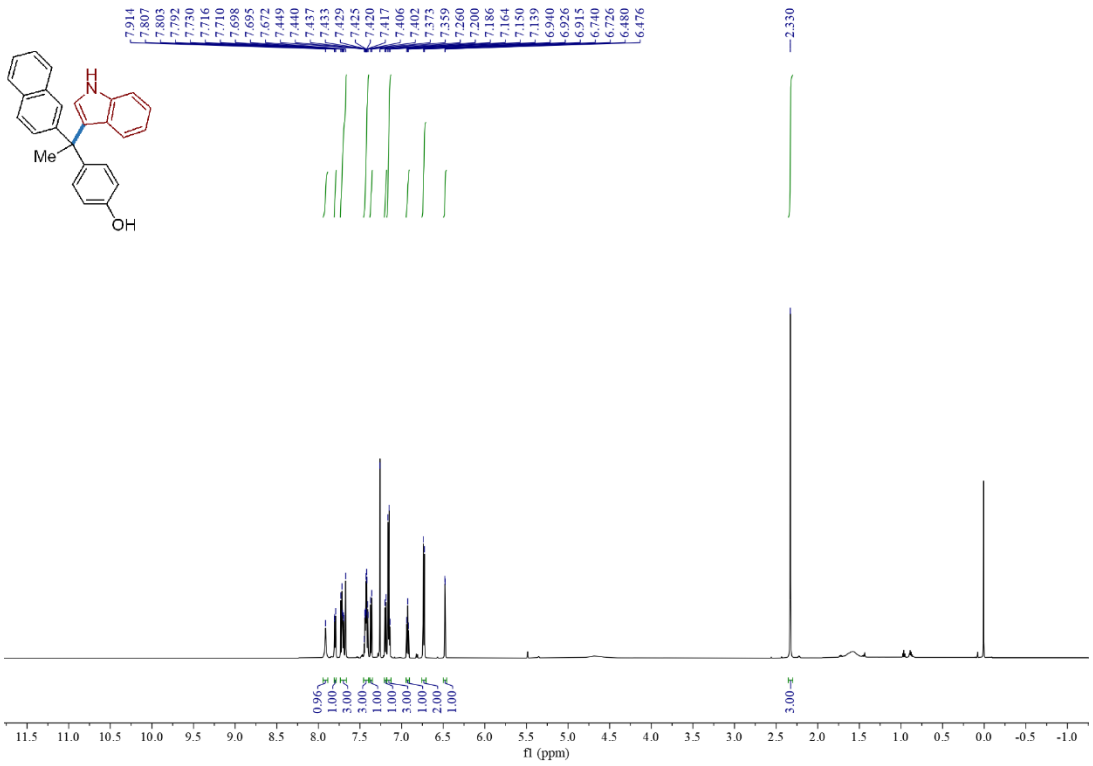


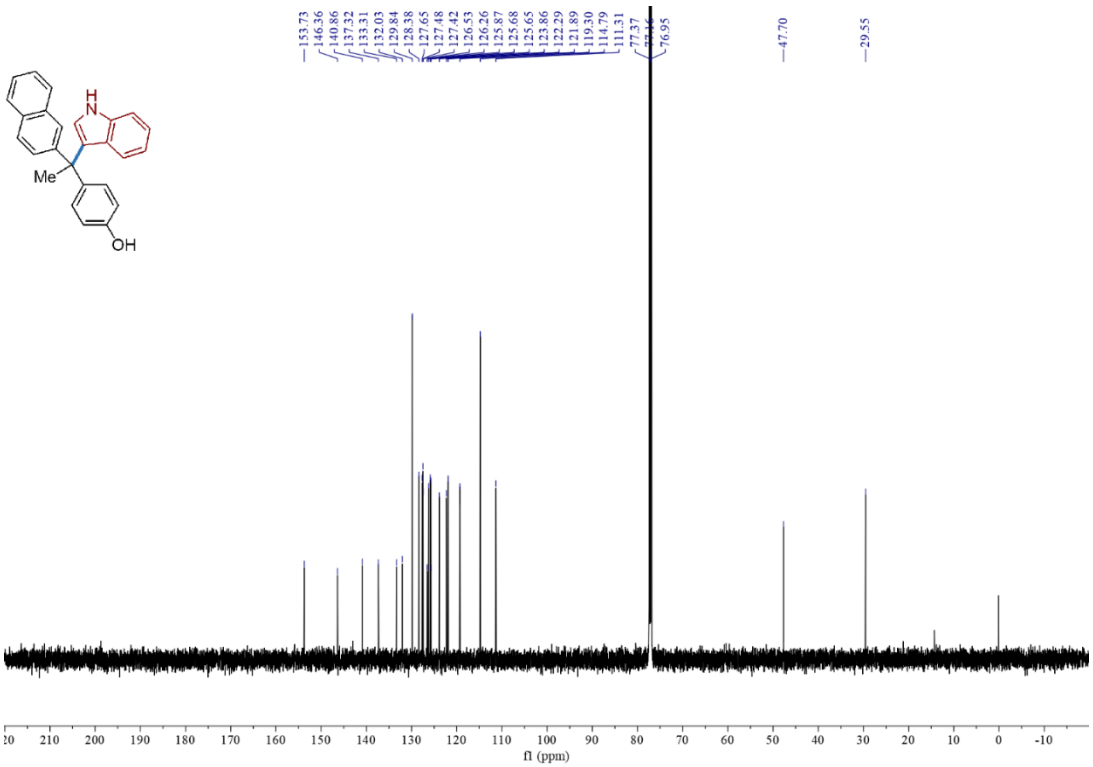
4-(1-(1*H*-Indol-3-yl)-1-(*p*-tolyl)ethyl)phenol (7ee)



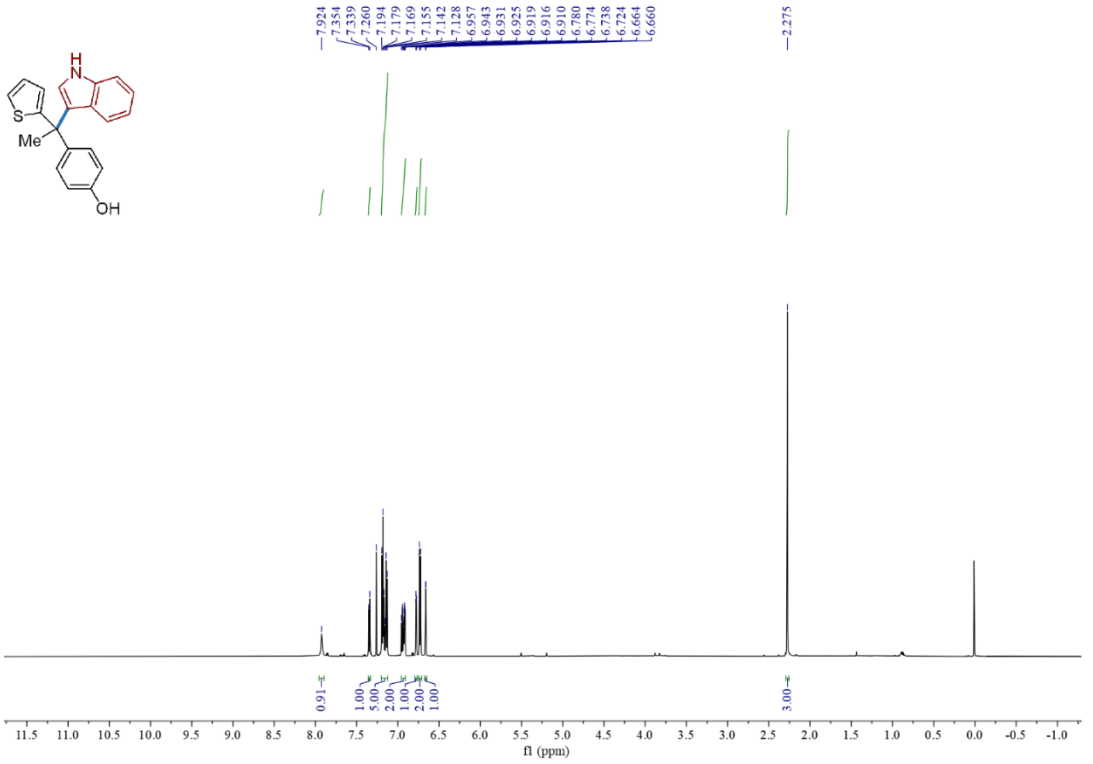


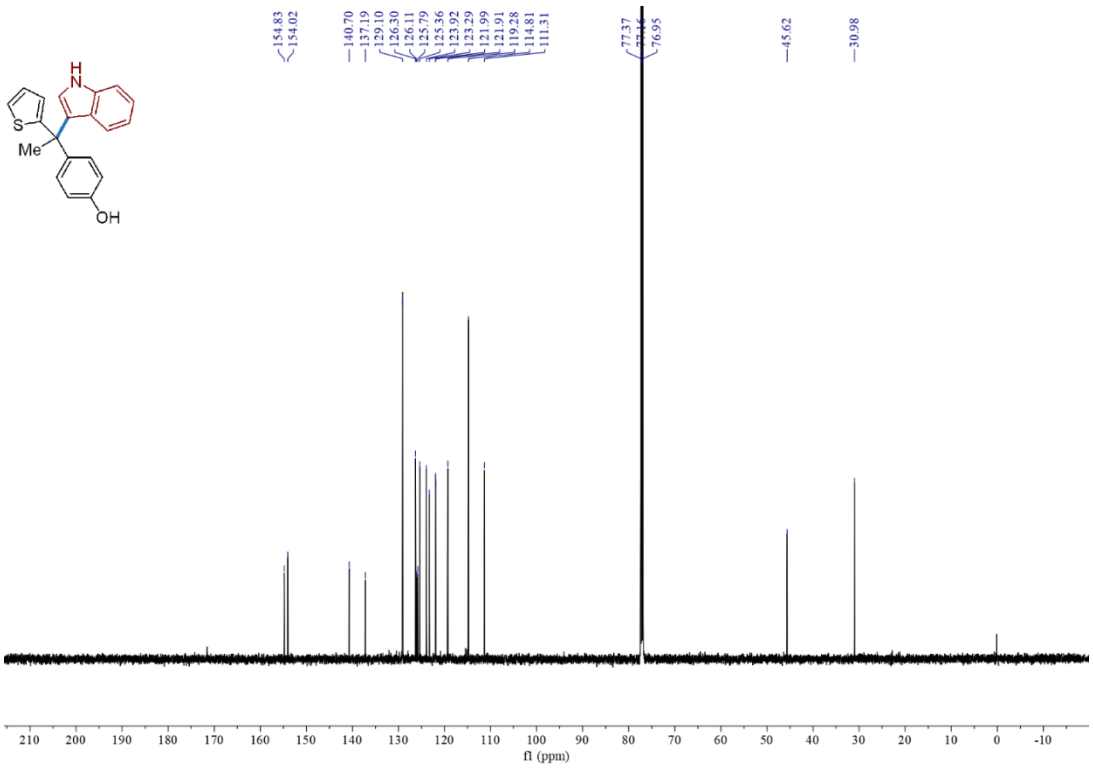
4-(1-(1*H*-Indol-3-yl)-1-(naphthalen-2-yl)ethyl)phenol (7ef)



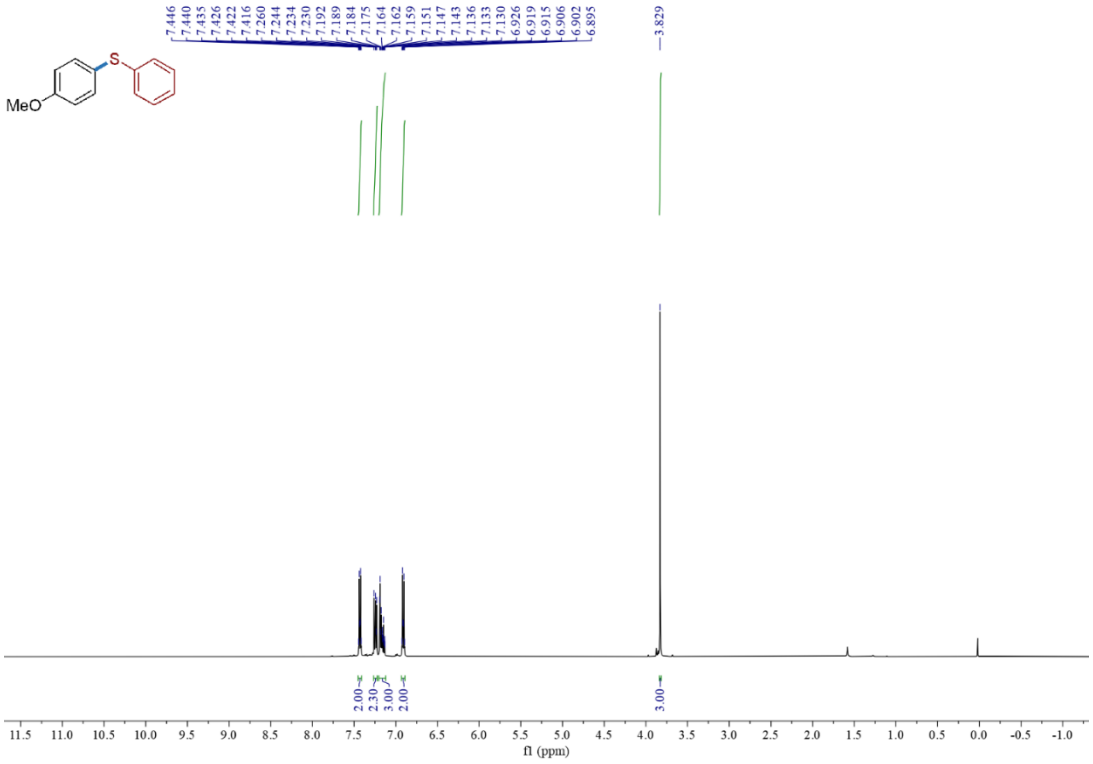


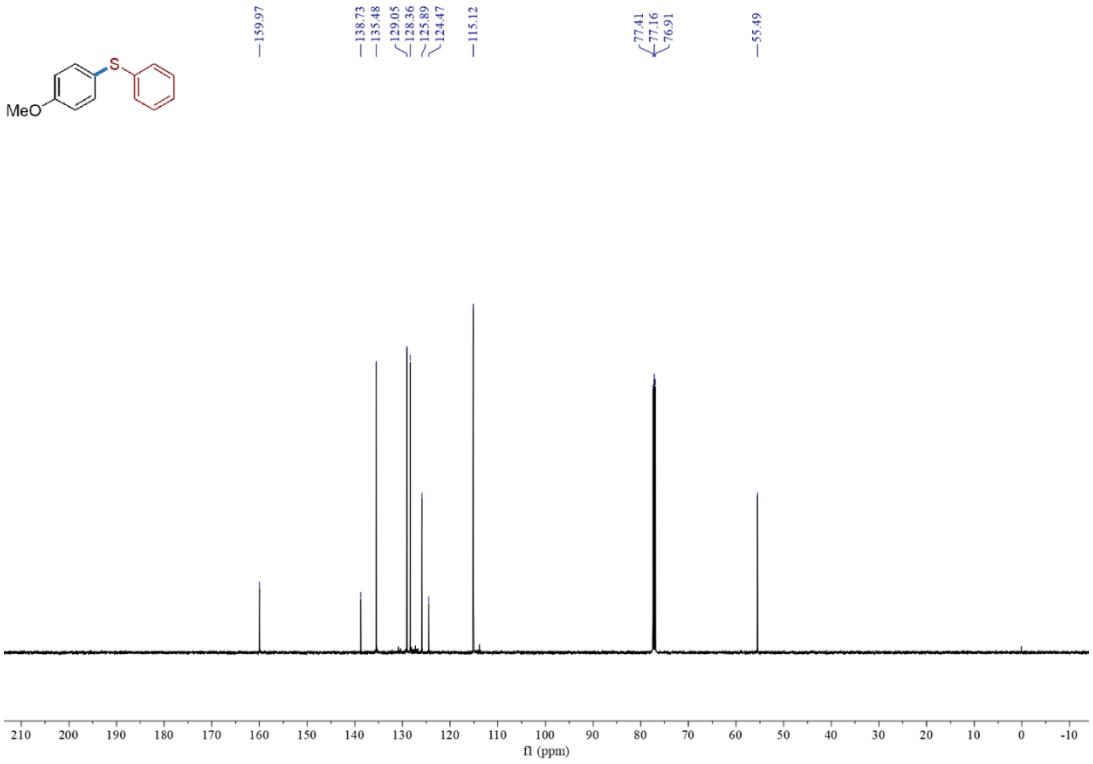
4-(1-(1*H*-Indol-3-yl)-1-(thiophen-2-yl)ethyl)phenol (7eg)



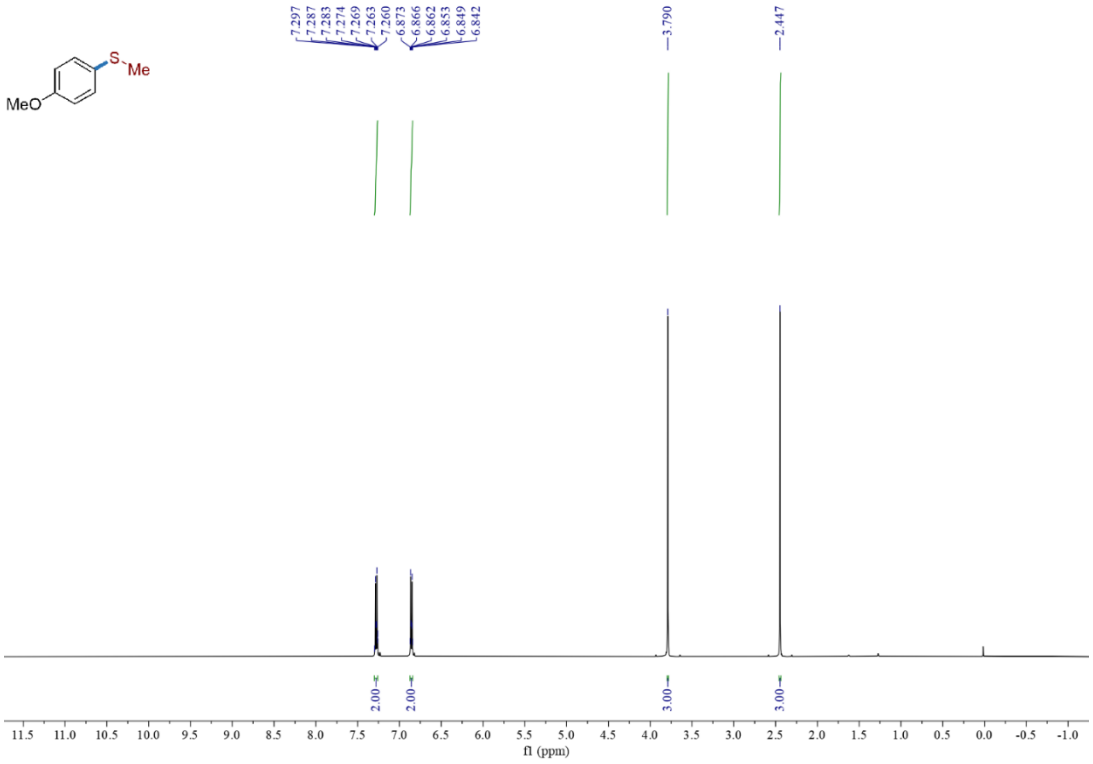


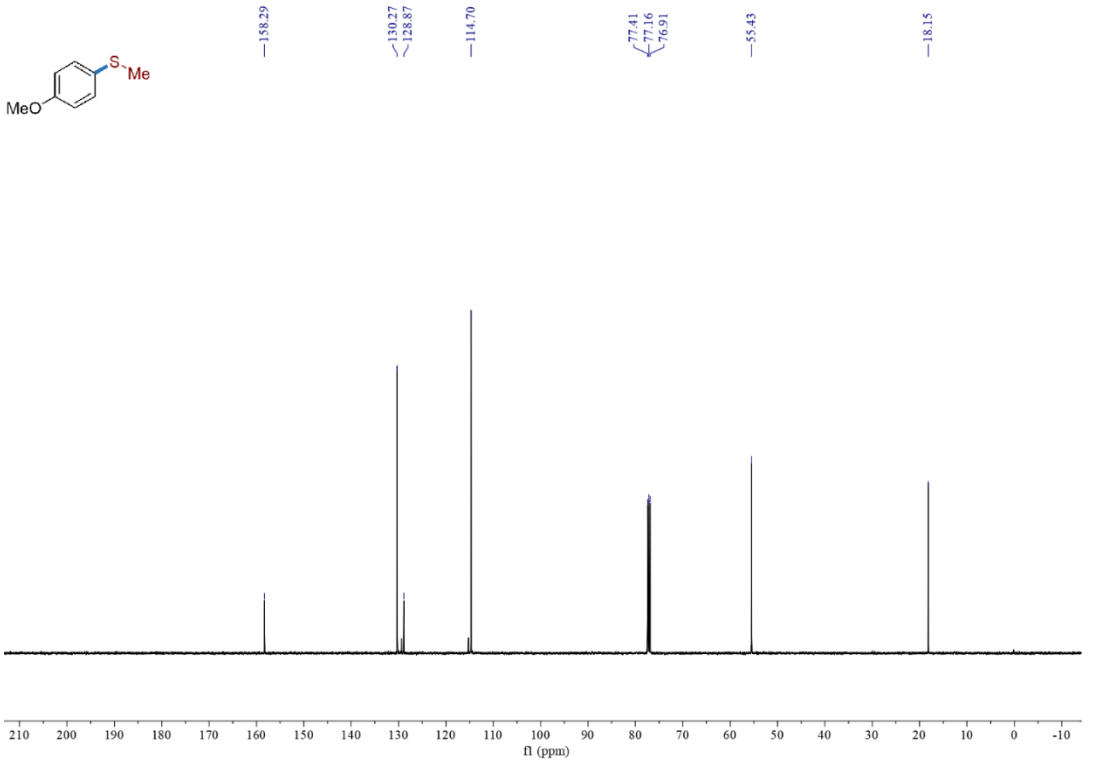
(4-Methoxyphenyl)(phenyl)sulfane (9aa)



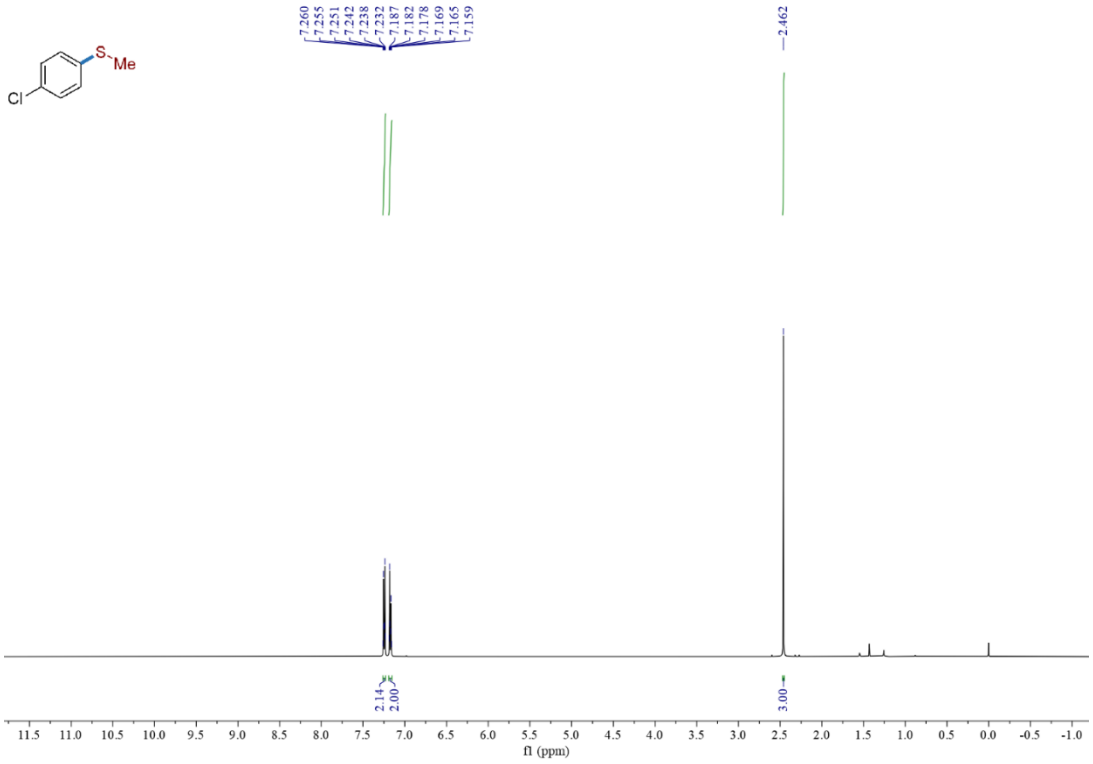


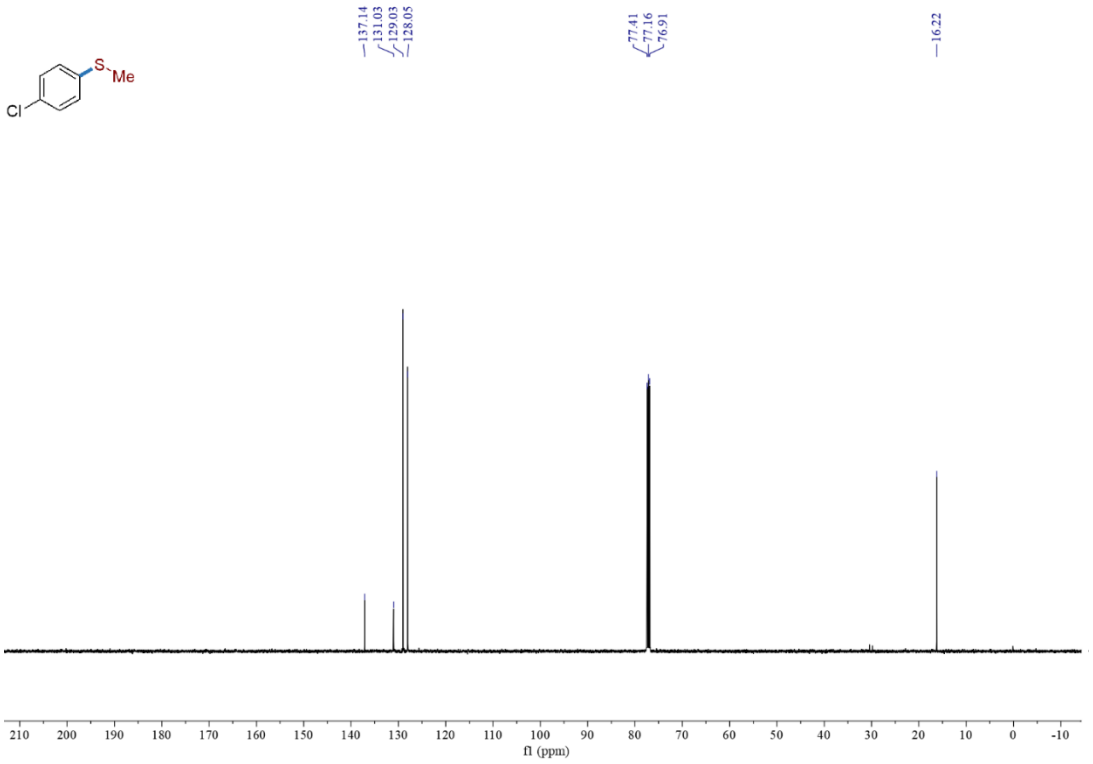
(4-Methoxyphenyl)(methyl)sulfane (9ab)



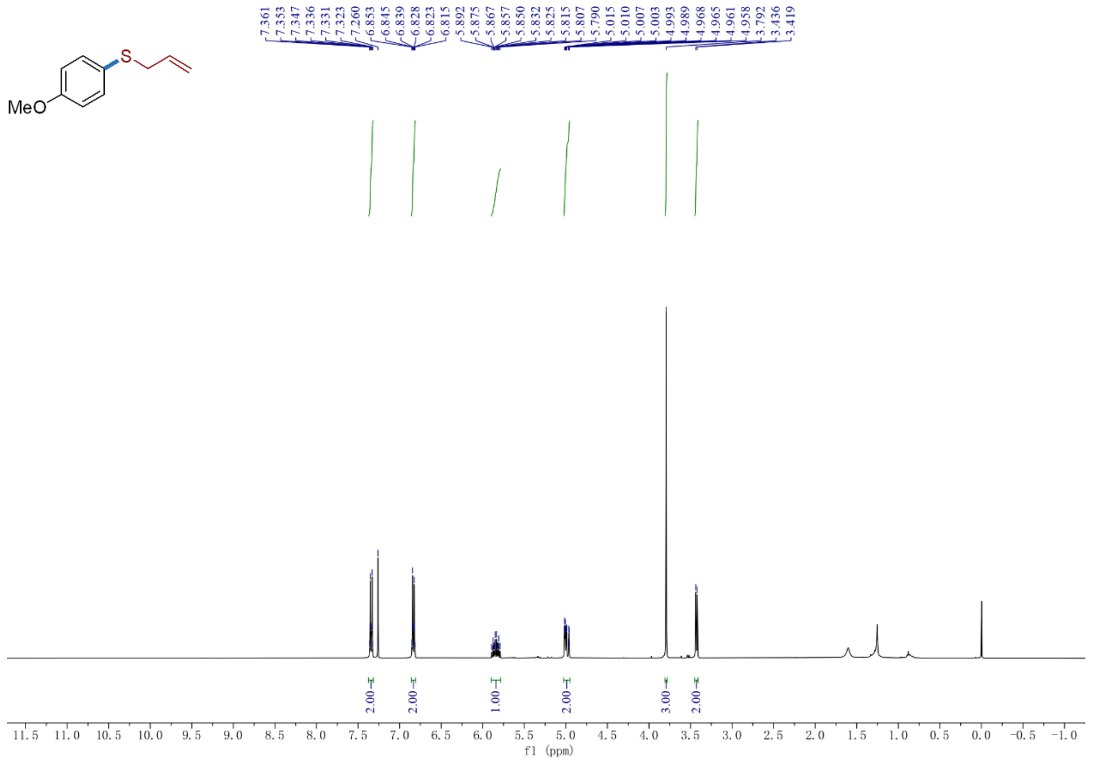


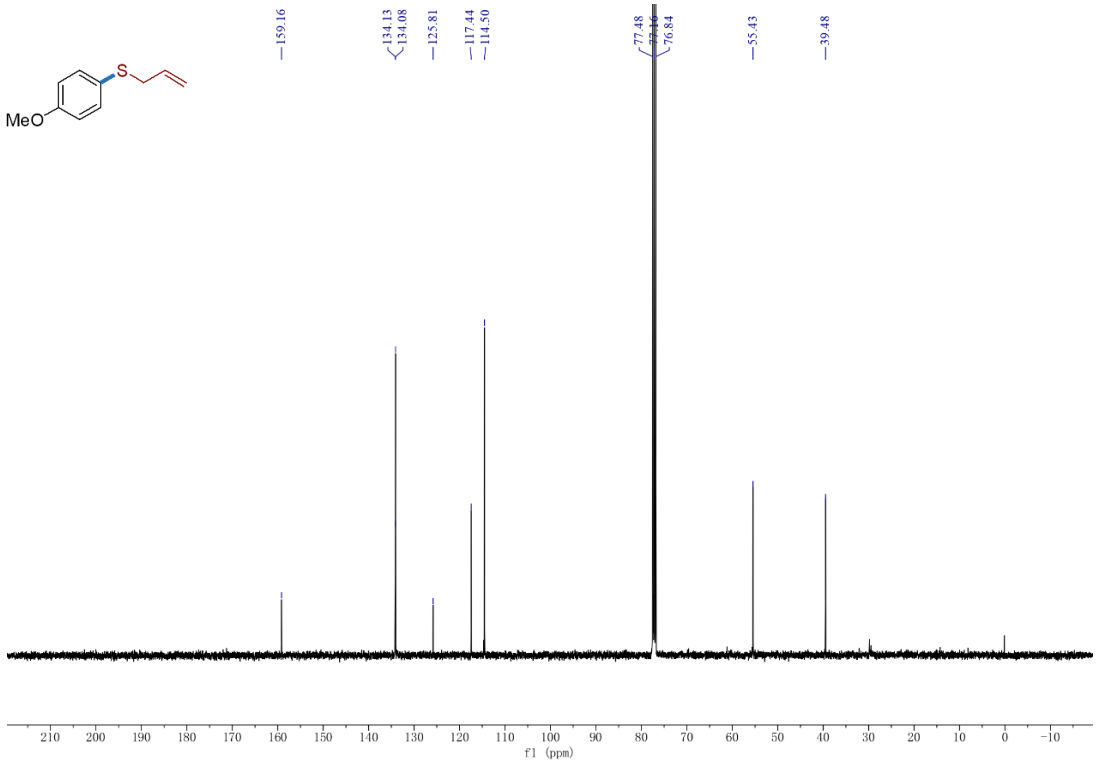
(4-Chlorophenyl)(methyl)sulfane (9cb)



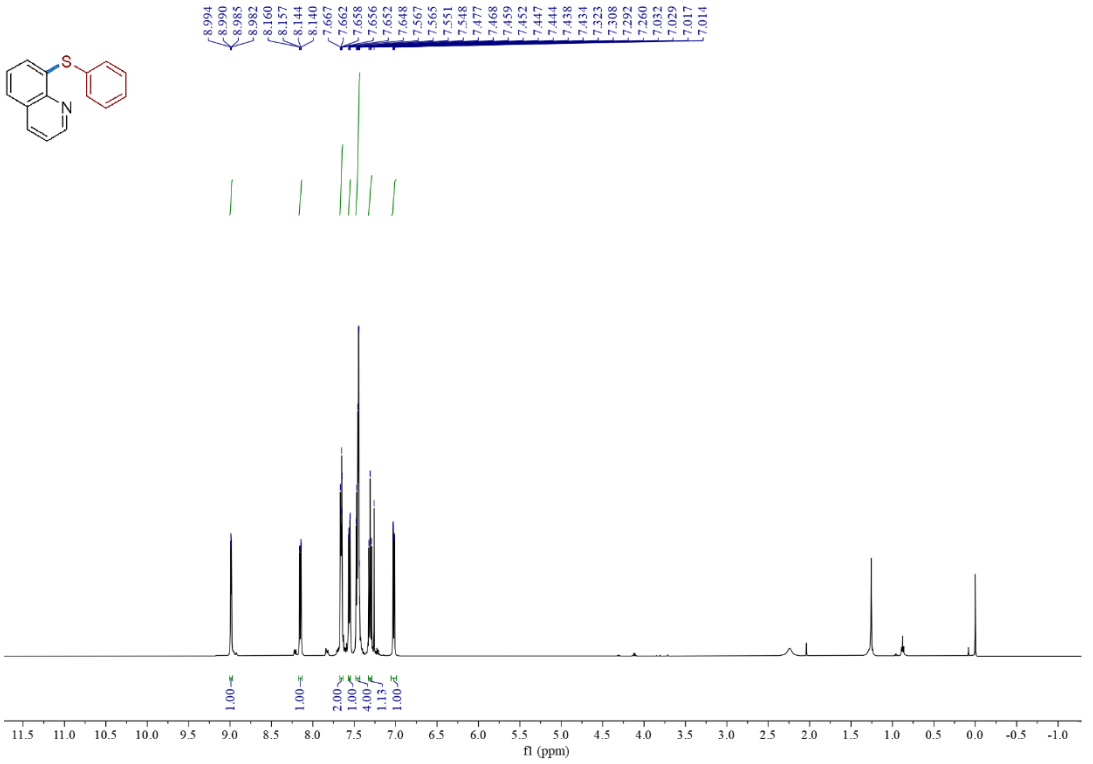


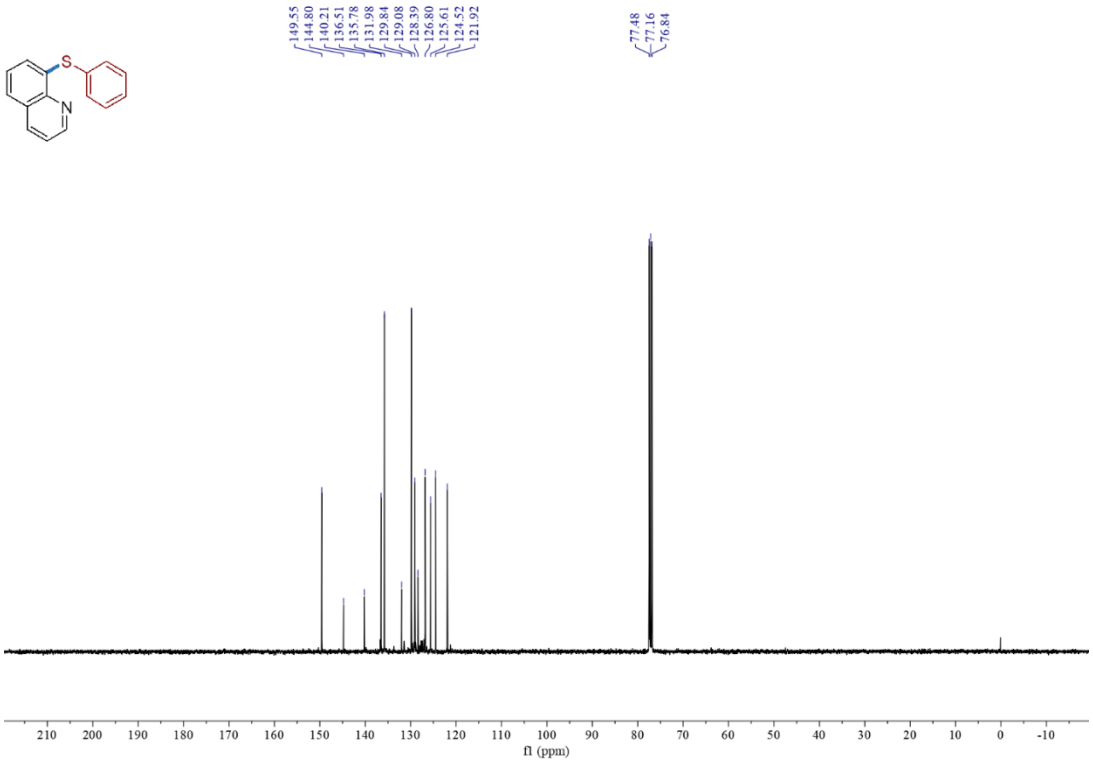
Allyl(4-methoxyphenyl)sulfane (9ac)



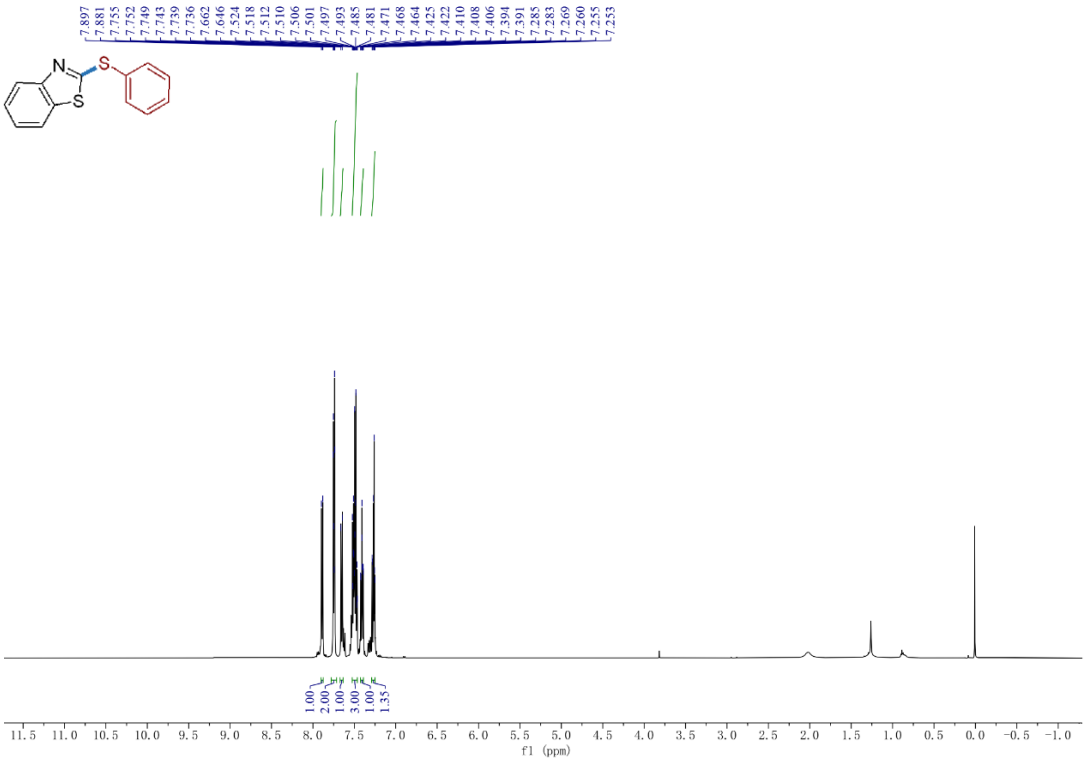


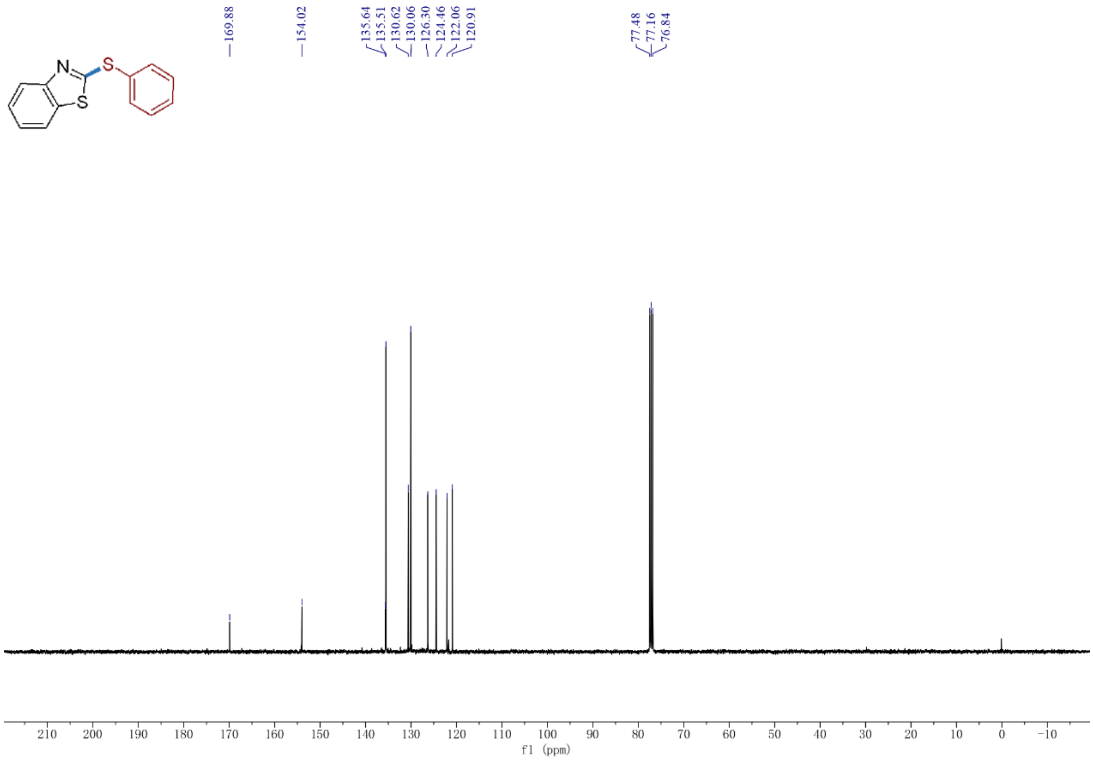
8-(Phenylthio)quinoline (9na)



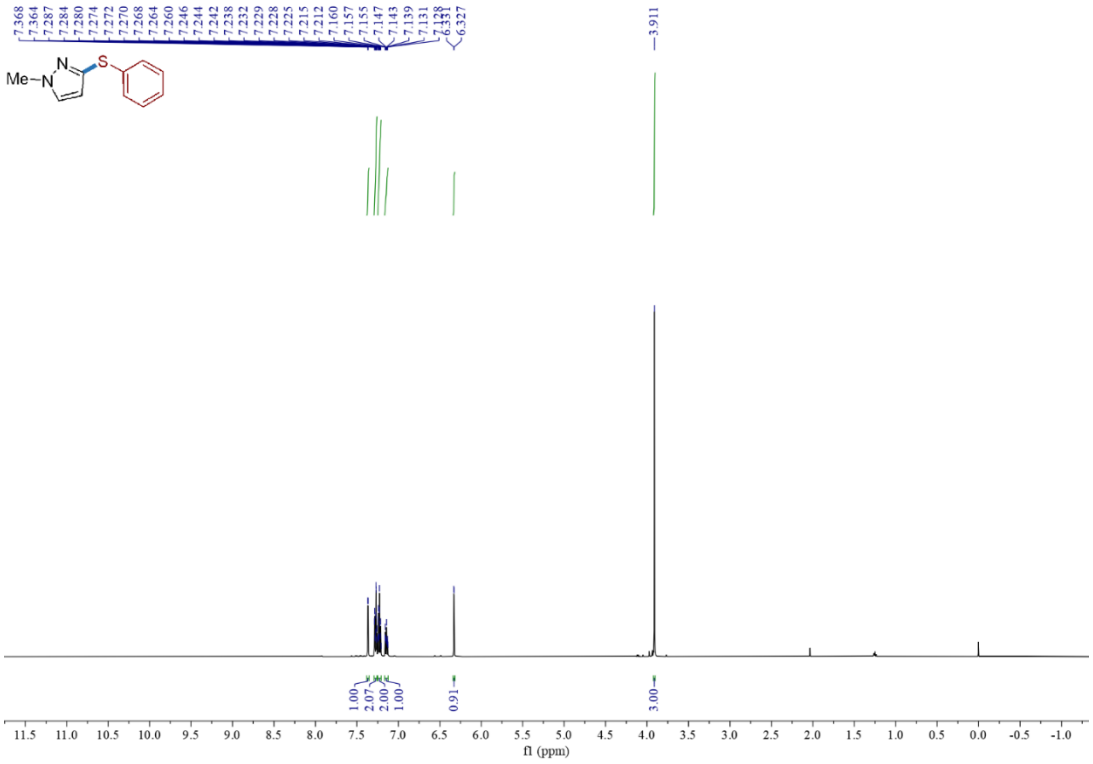


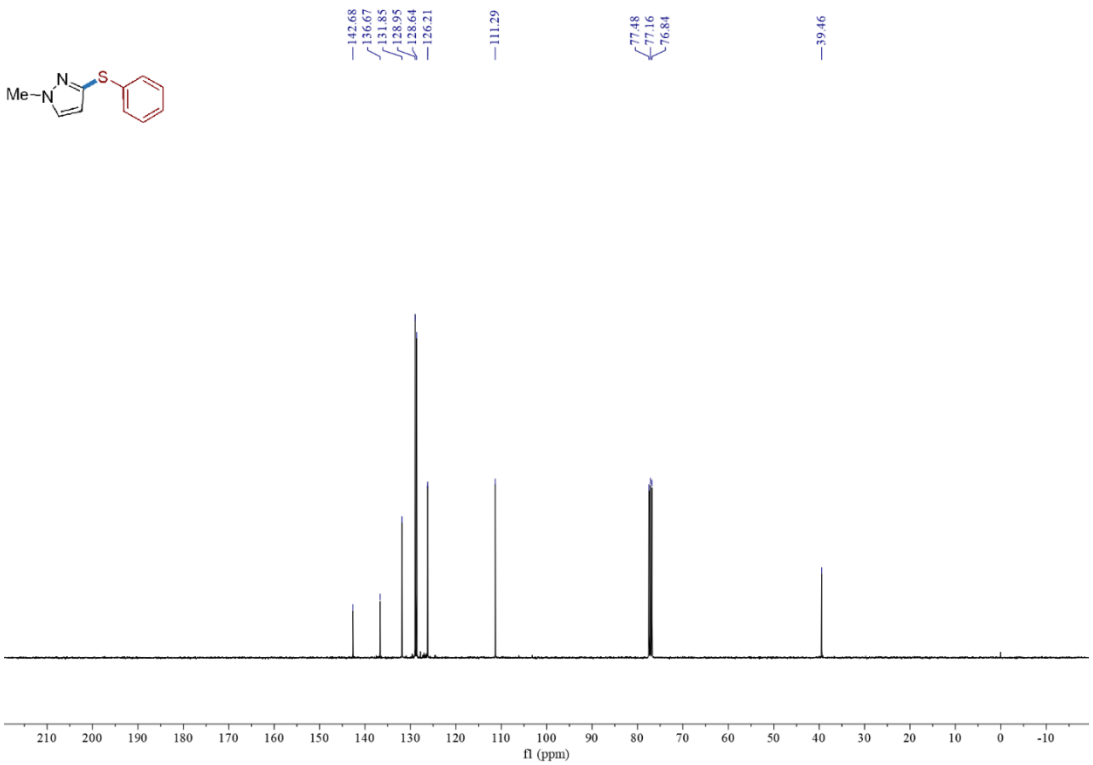
2-(Phenylthio)benzo[*d*]thiazole (9la)



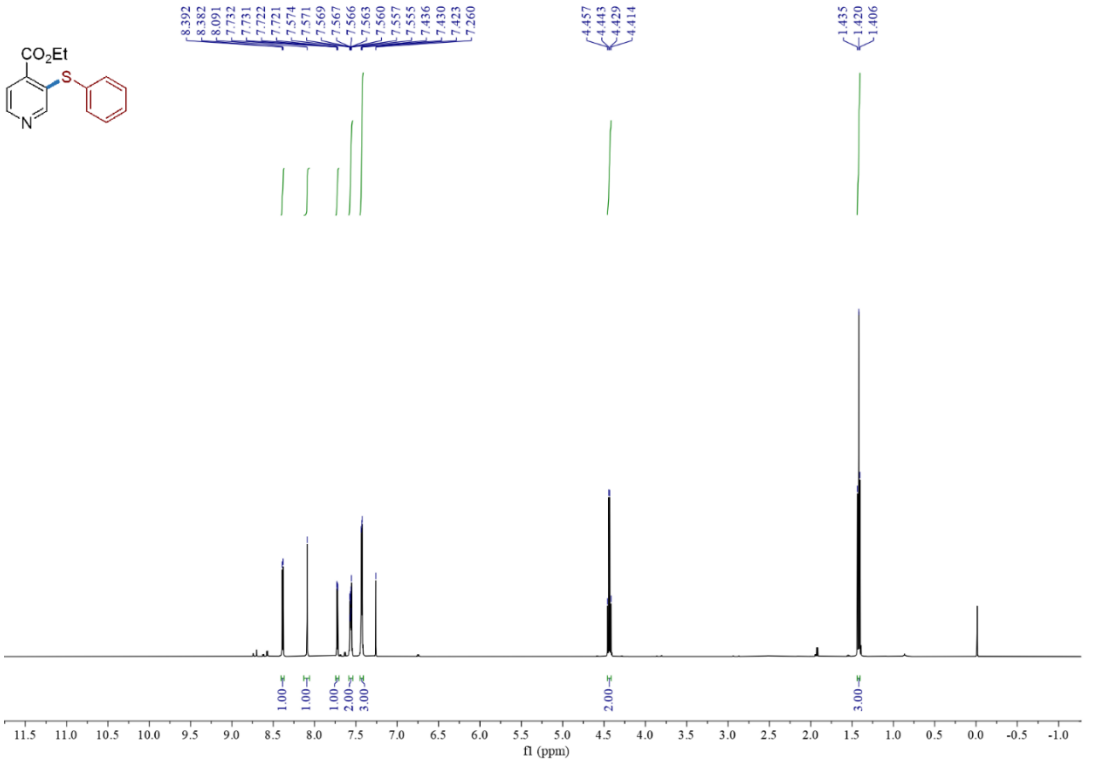


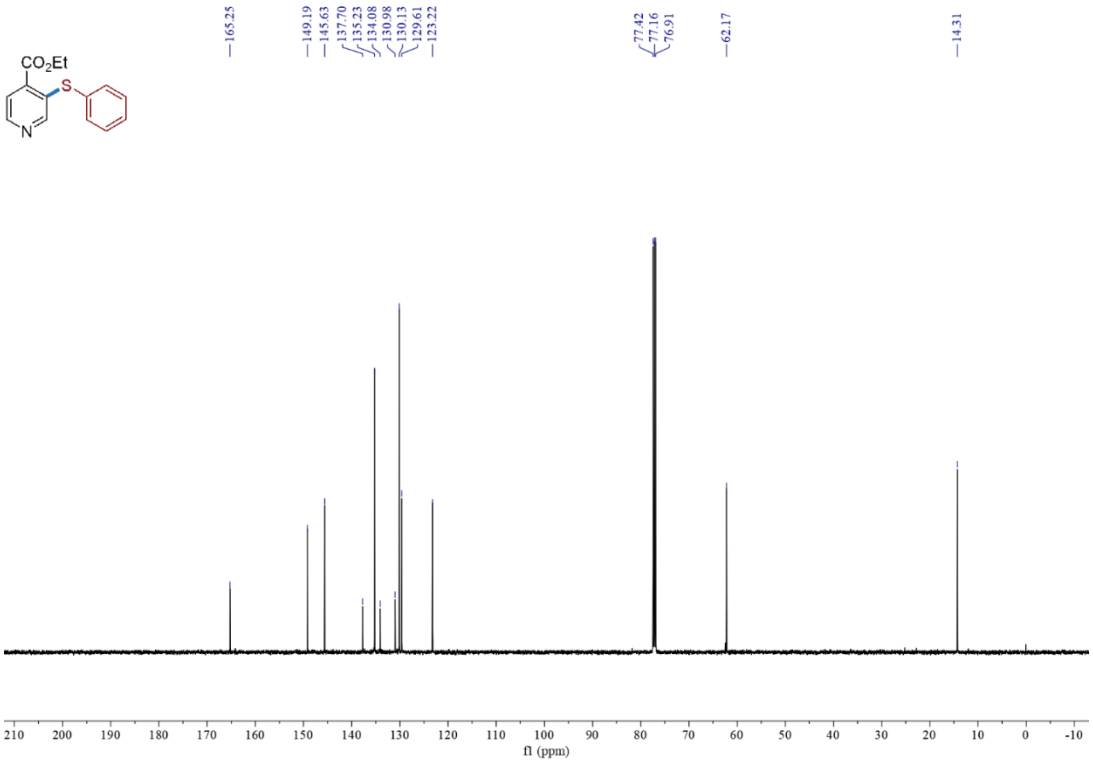
1-Methyl-3-(phenylthio)-1*H*-pyrazole (9ga)



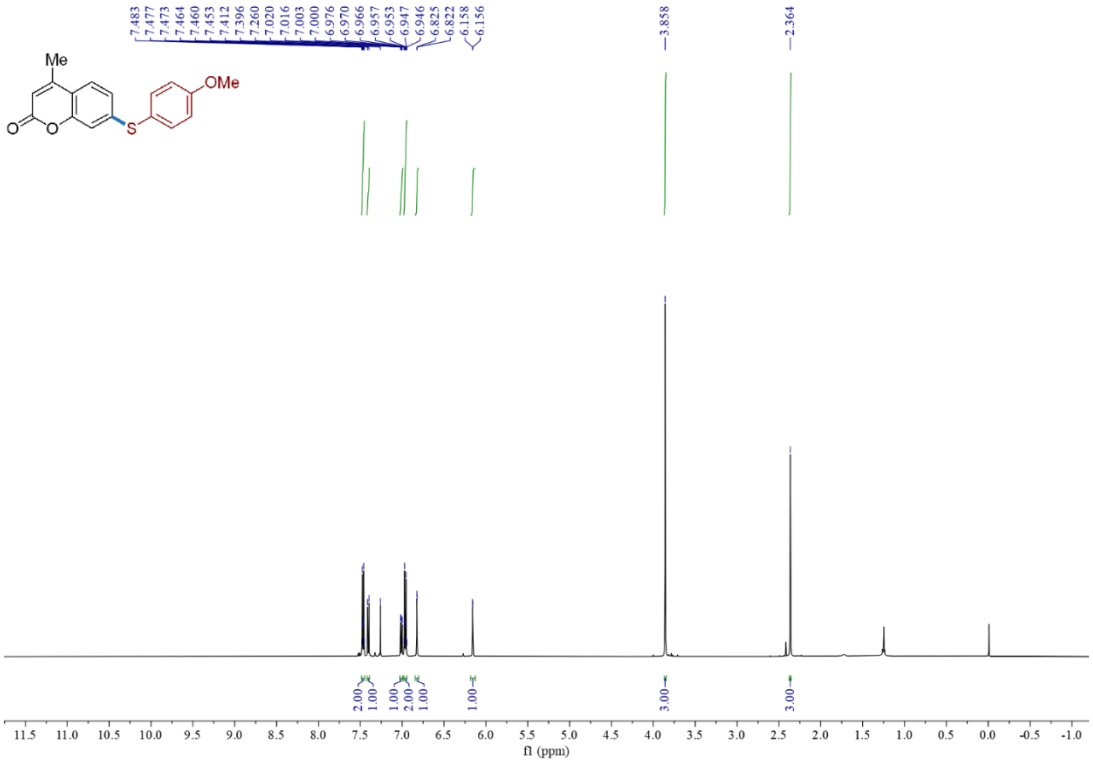


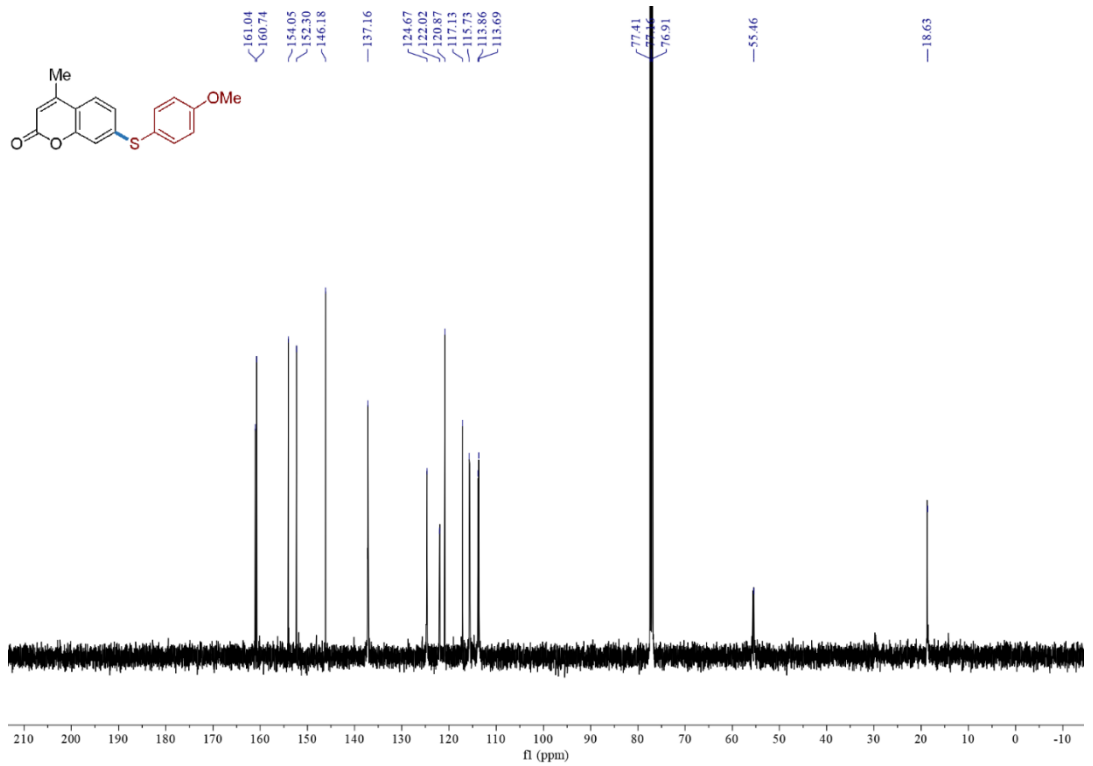
Ethyl 3-(phenylthio)isonicotinate (9oa)



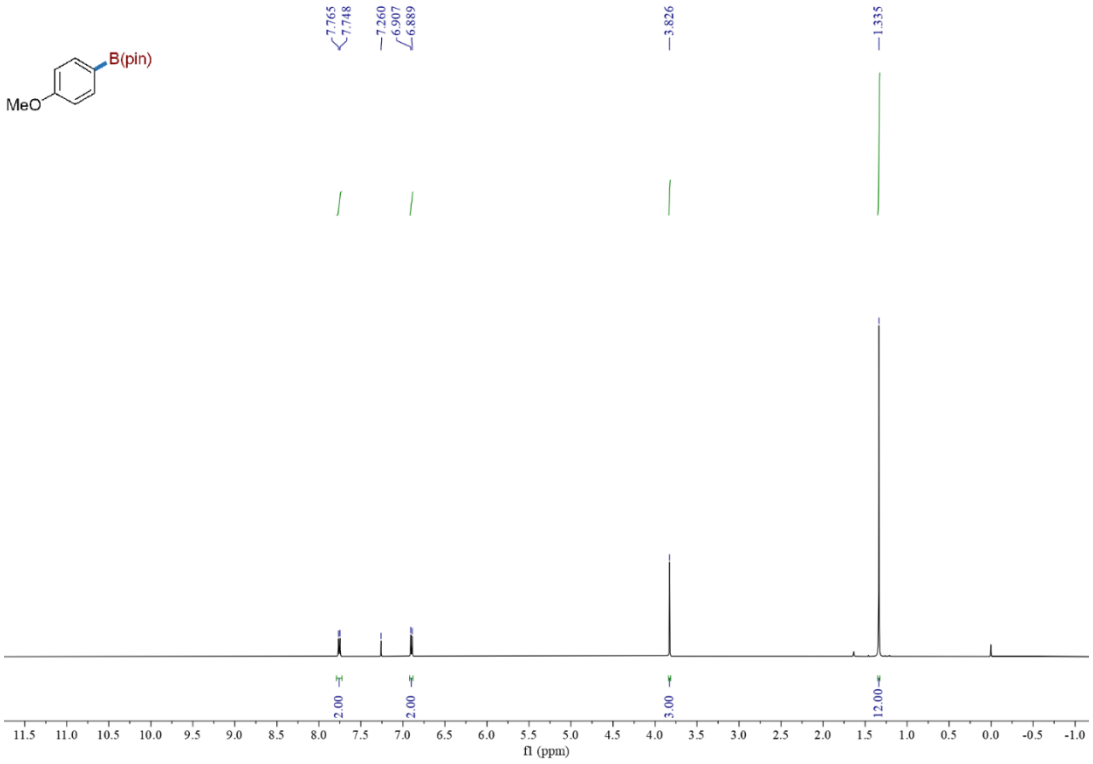


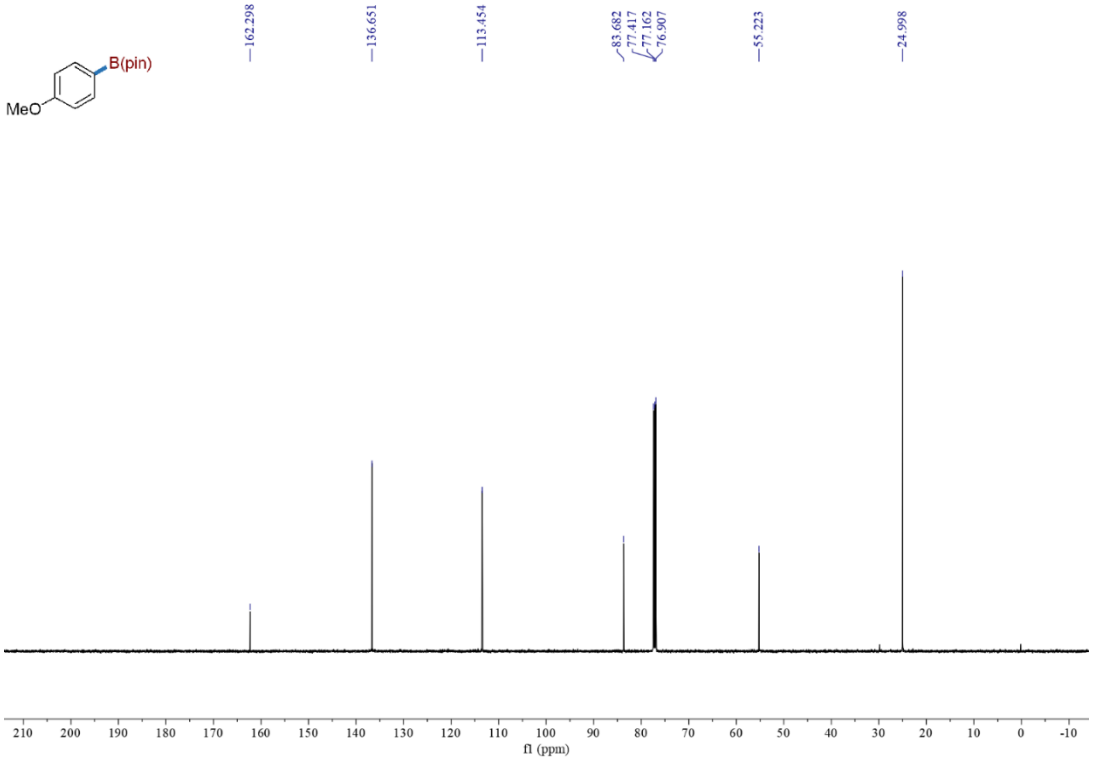
7-((4-Methoxyphenyl)thio)-4-methyl-2*H*-chromen-2-one (9pd)



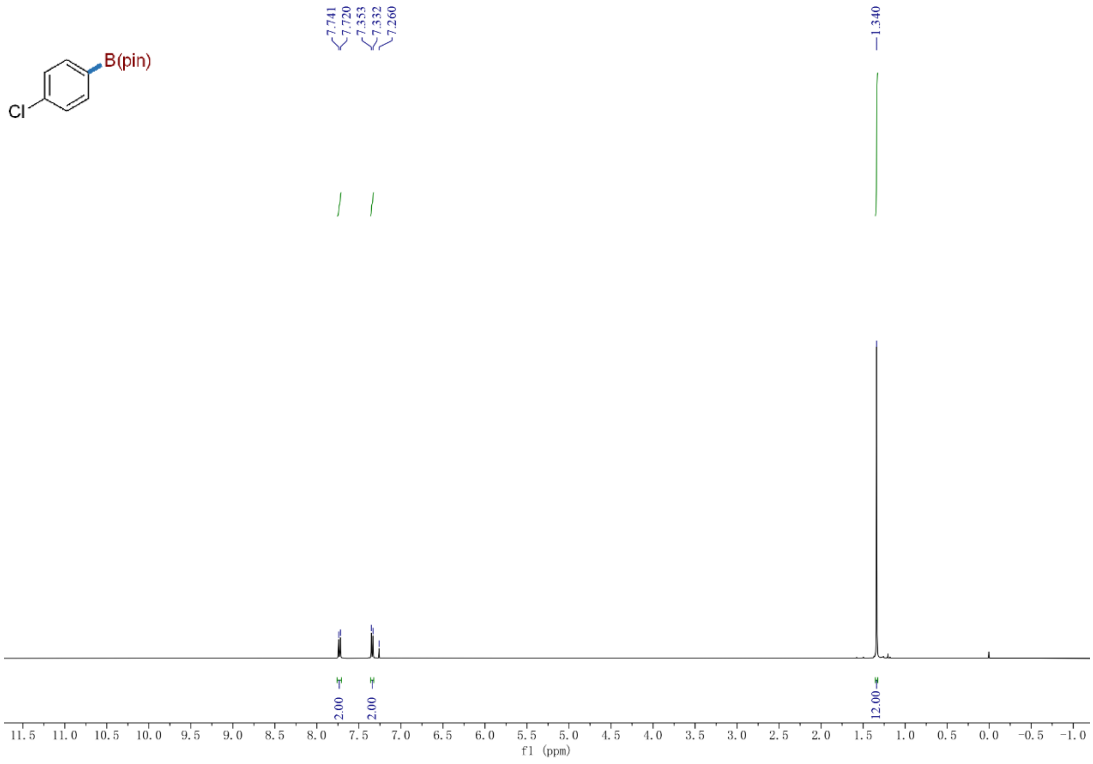


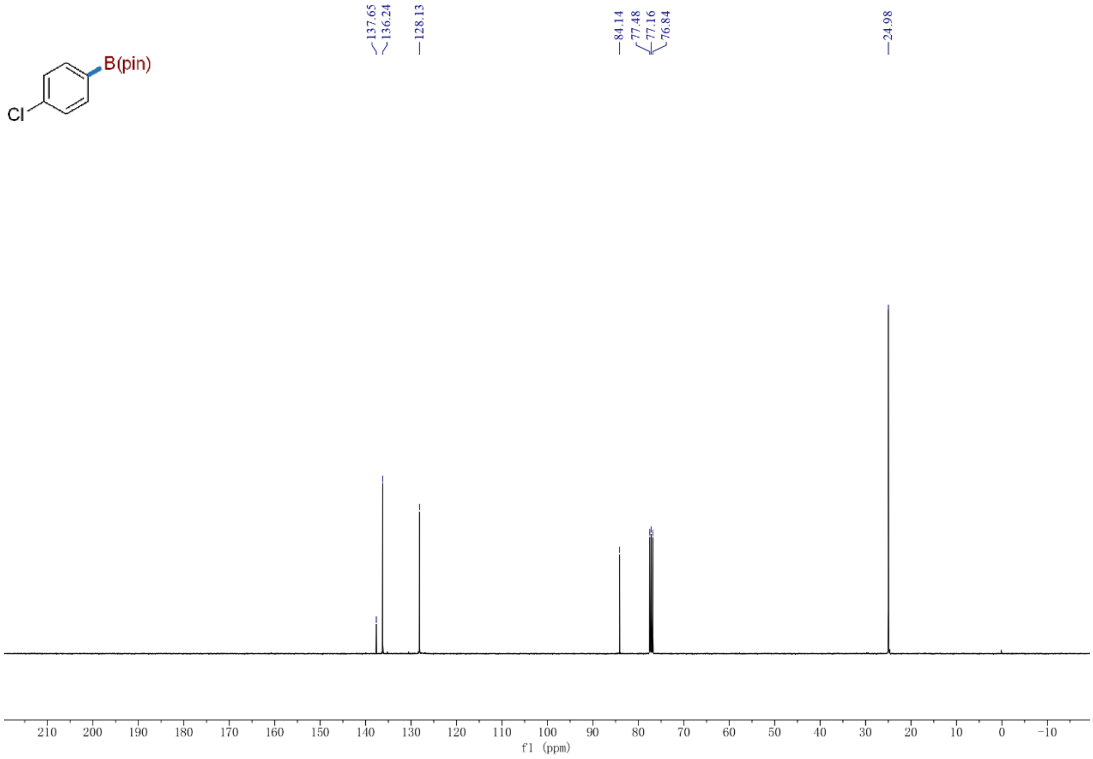
2-(4-Methoxyphenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (9ae)



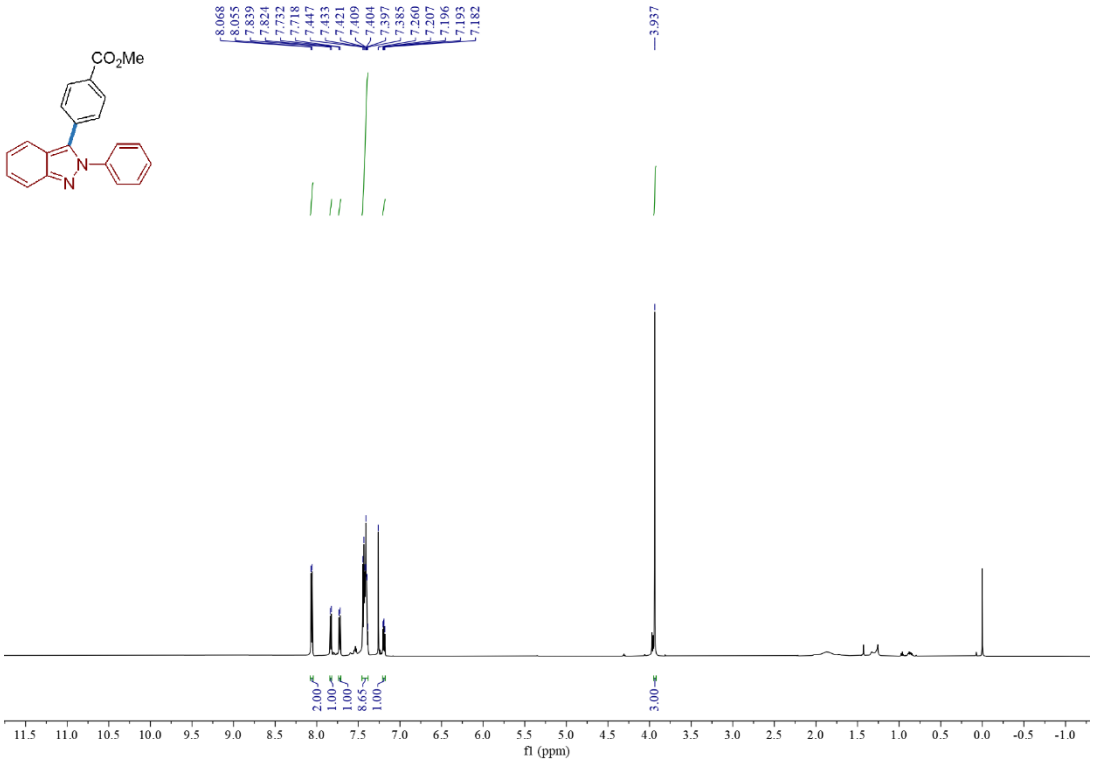


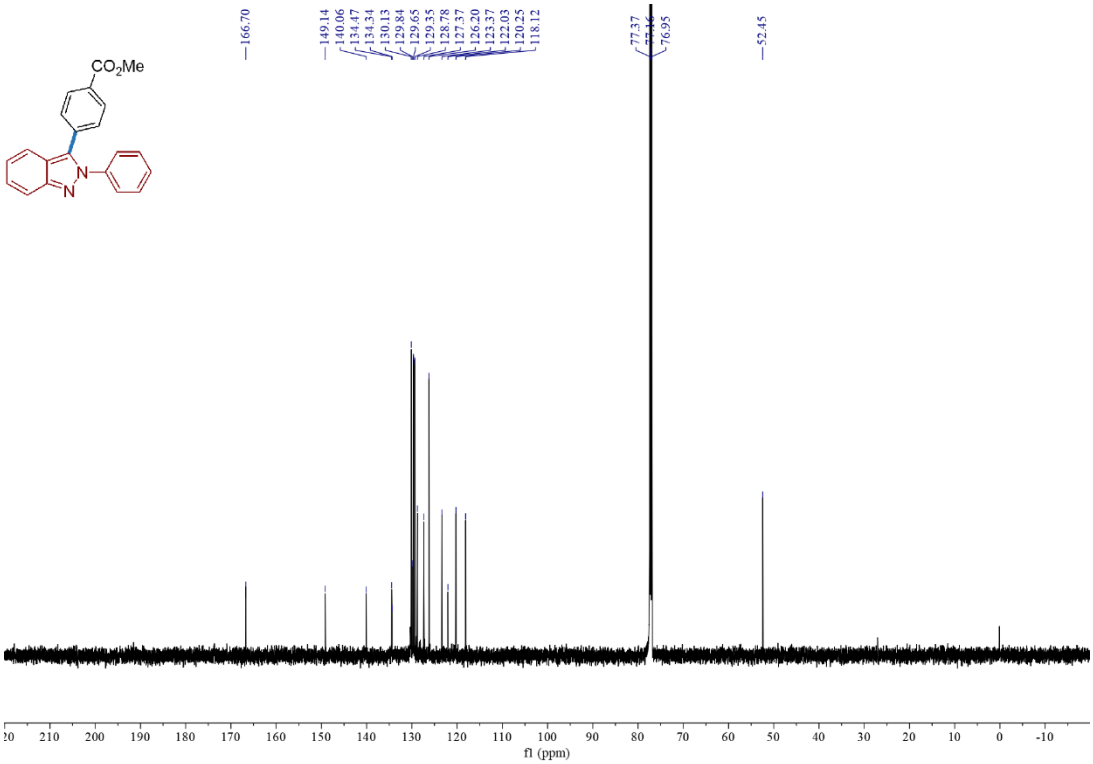
2-(4-Chlorophenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (9ce)



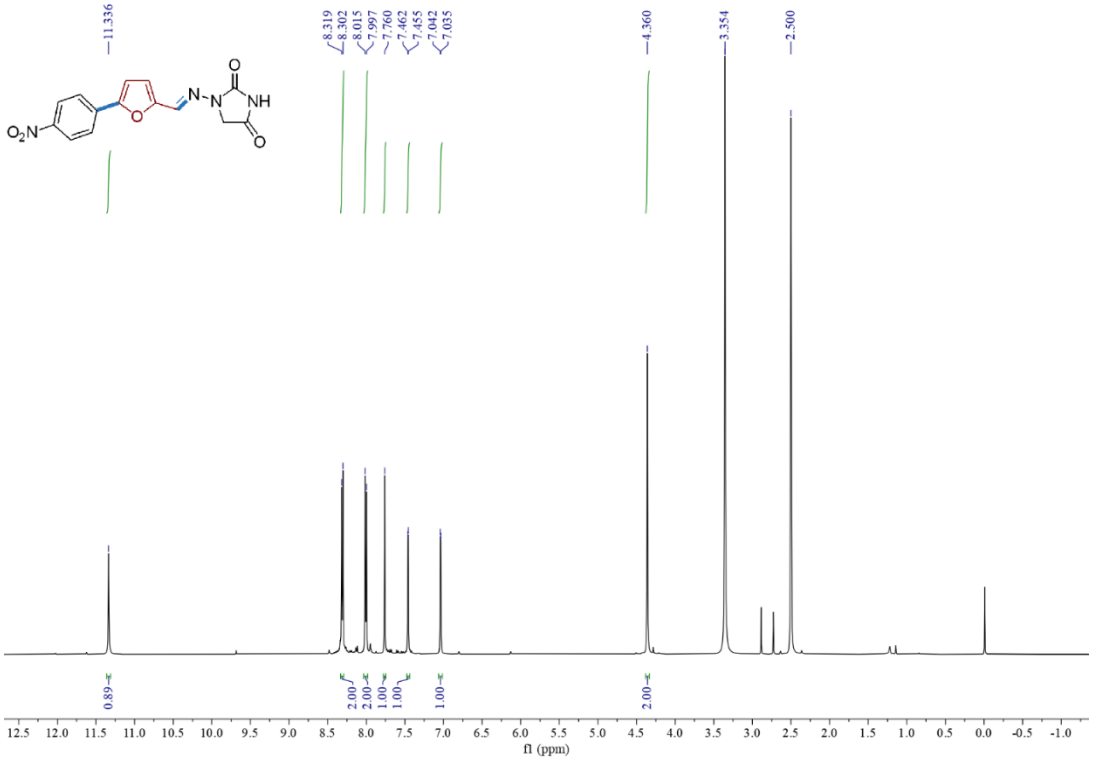


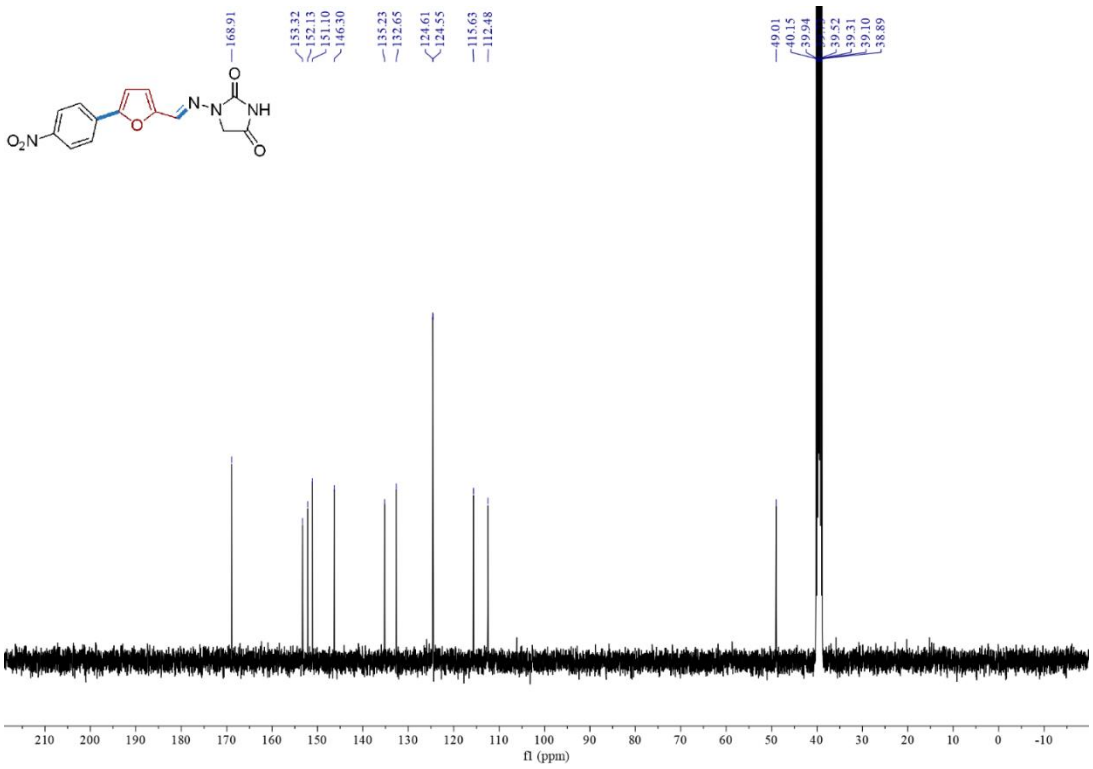
Methyl 4-(2-phenyl-2*H*-indazol-3-yl)benzoate (3qa)



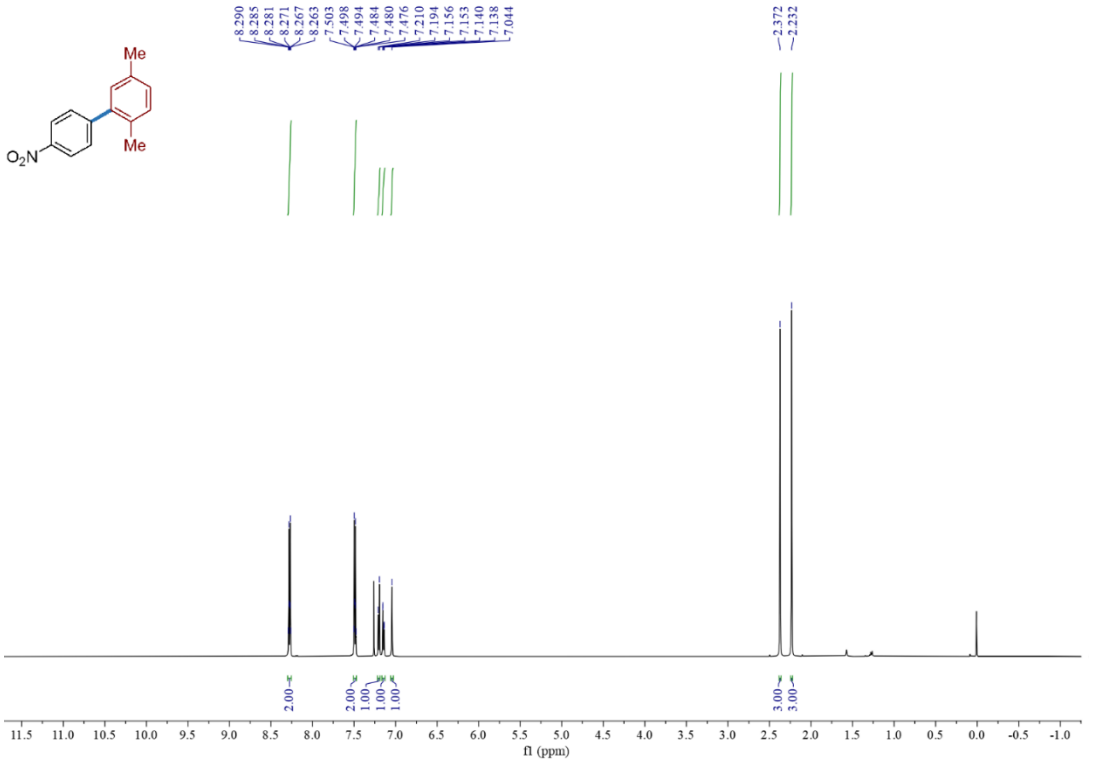


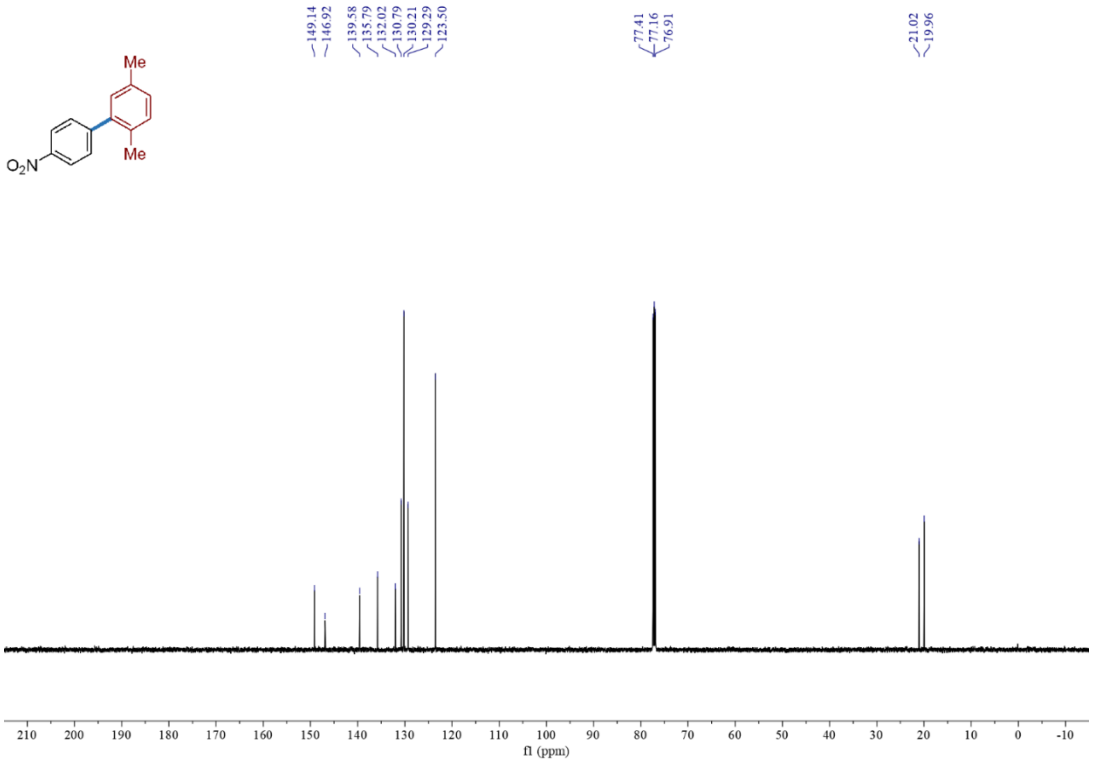
Dantrolene (11)



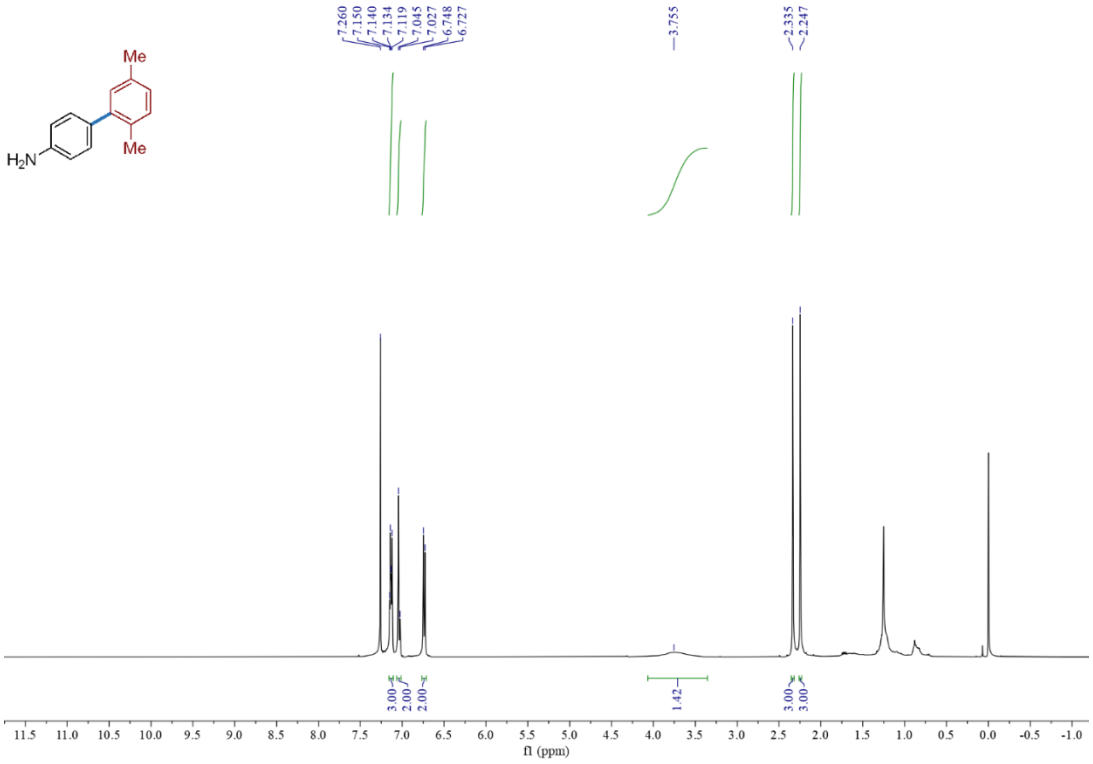


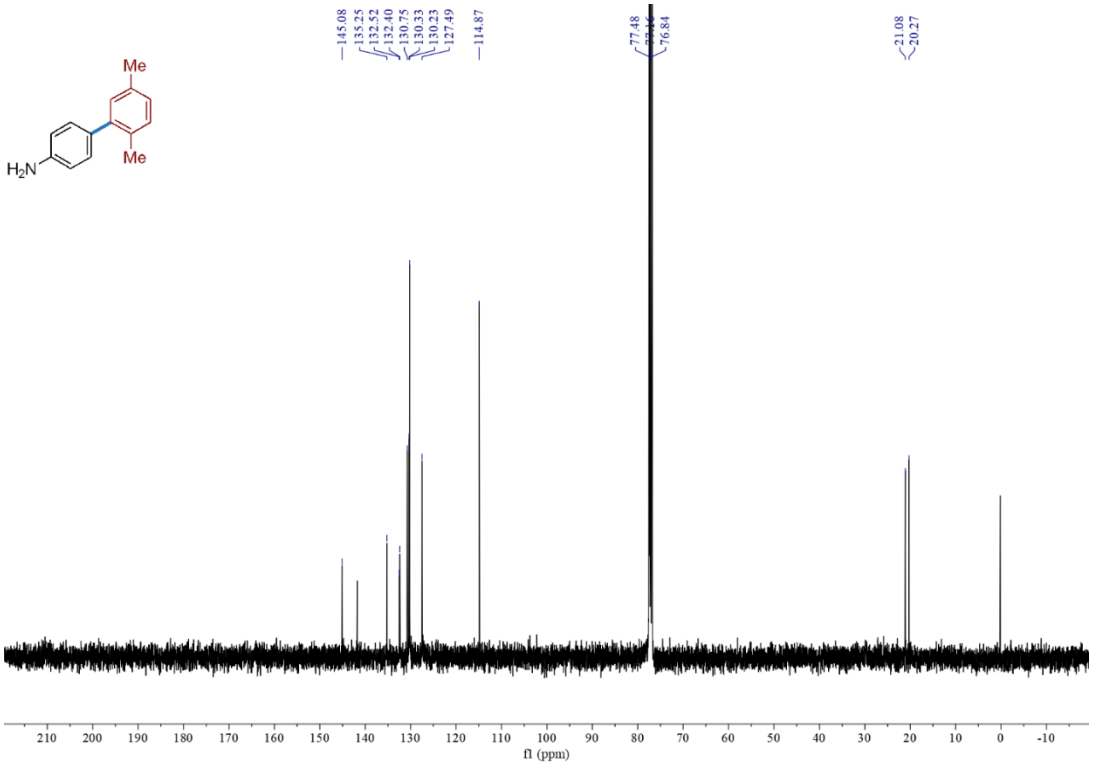
2,5-Dimethyl-4'-nitro-1,1'-biphenyl (3iq)



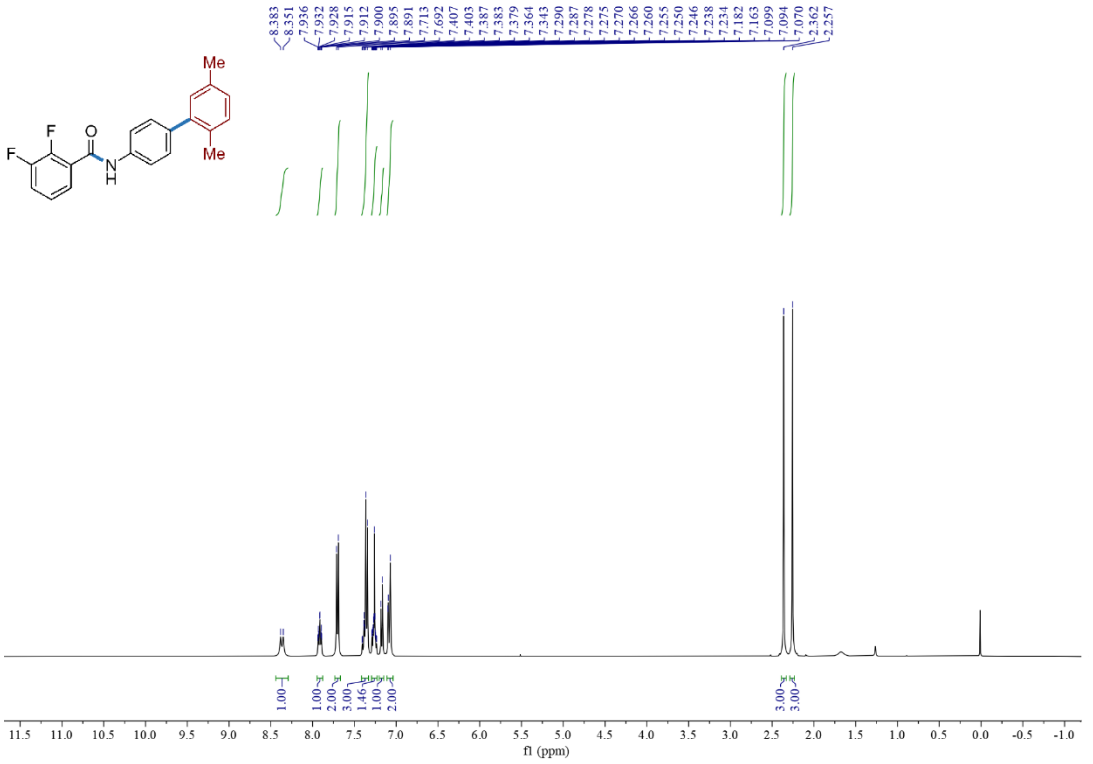


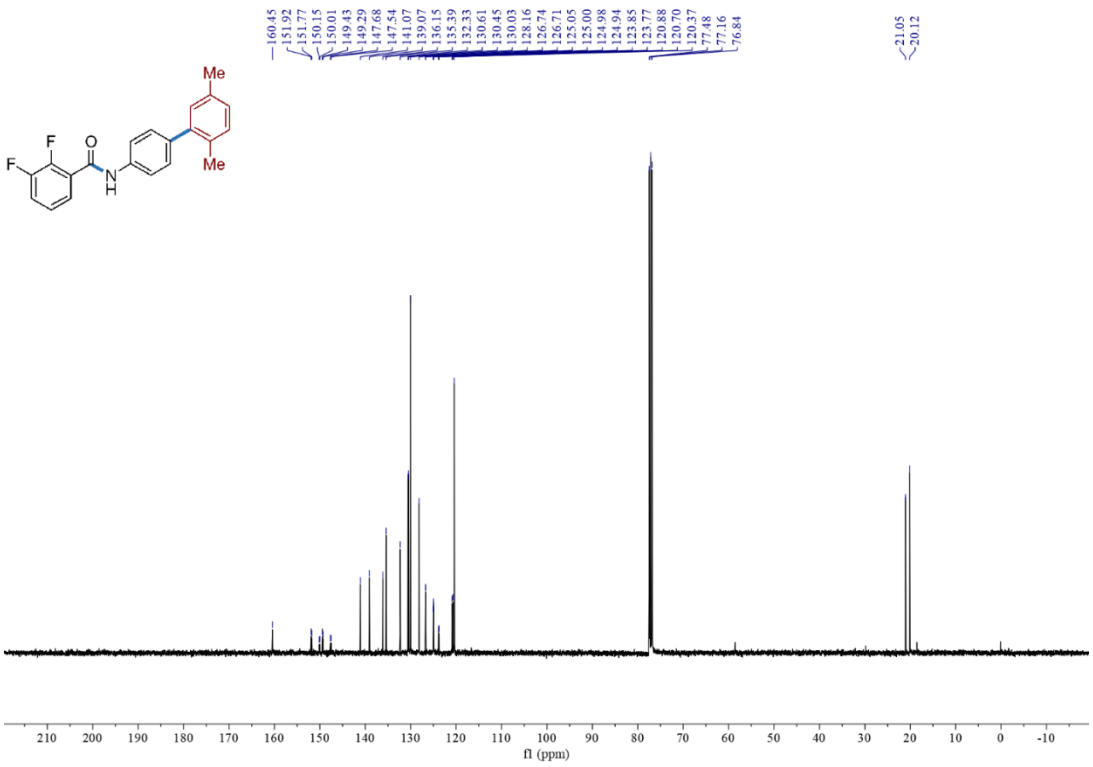
2',5'-Dimethyl-[1,1'-biphenyl]-4-amine (3iq')



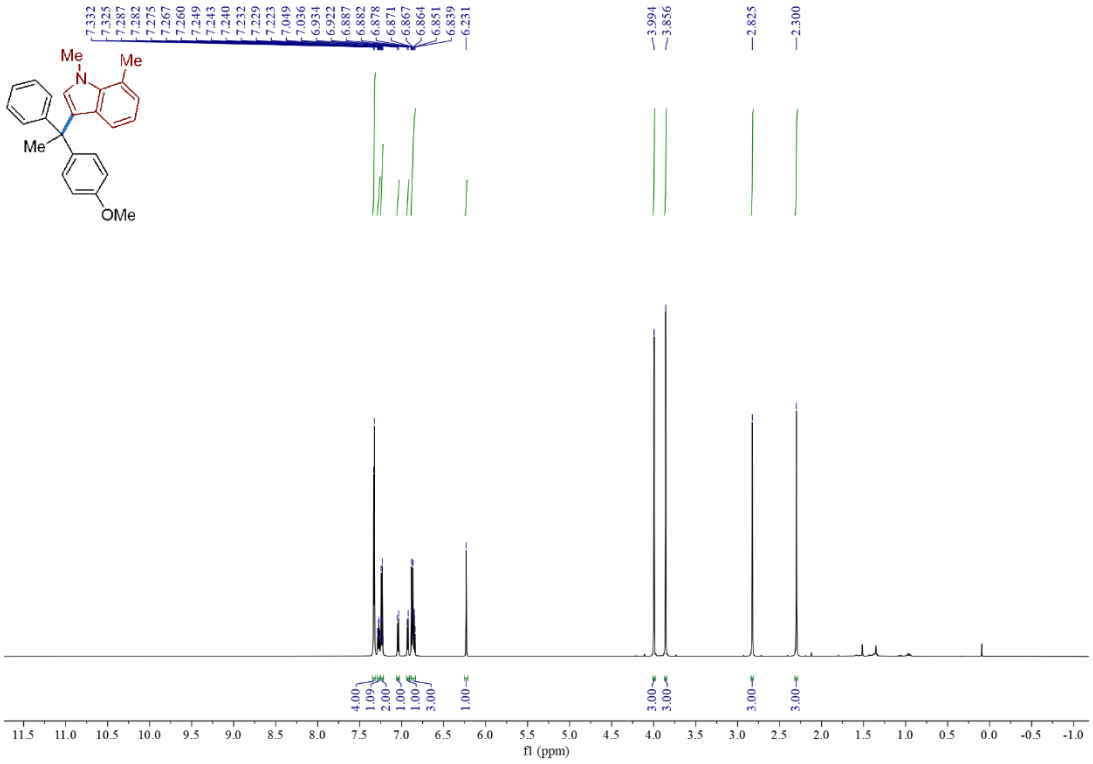


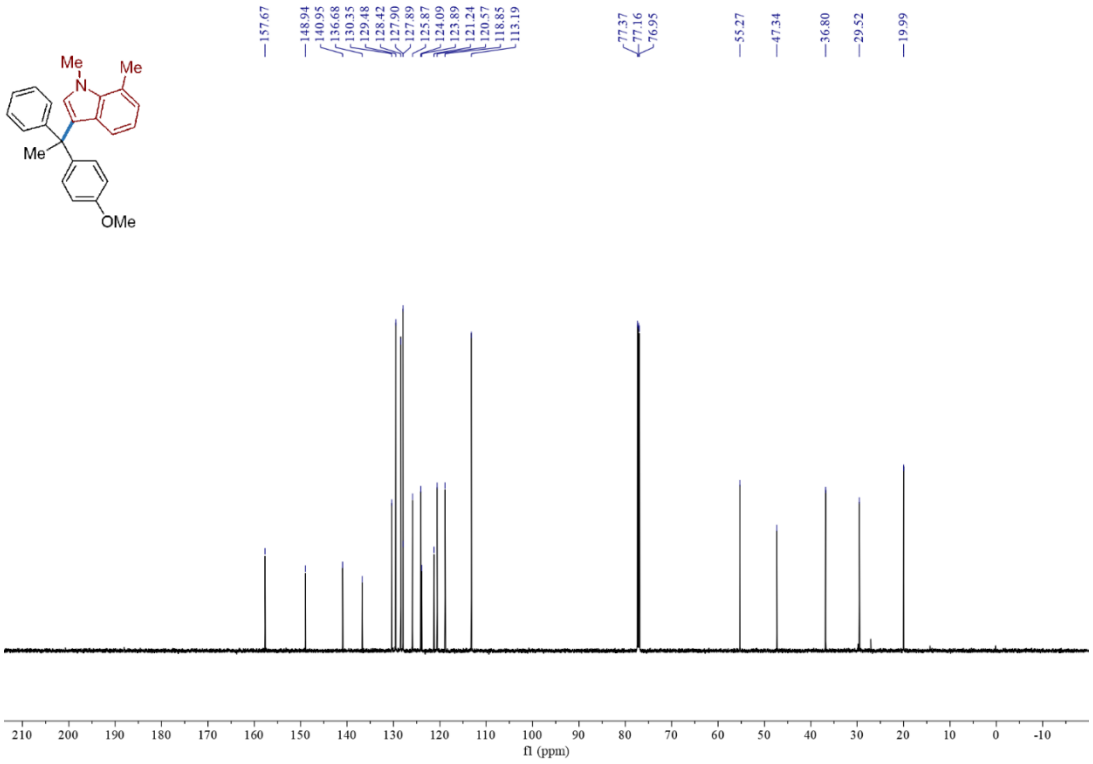
***N*-(2',5'-Dimethyl-[1,1'-biphenyl]-4-yl)-2,3-difluorobenzamide (12)**



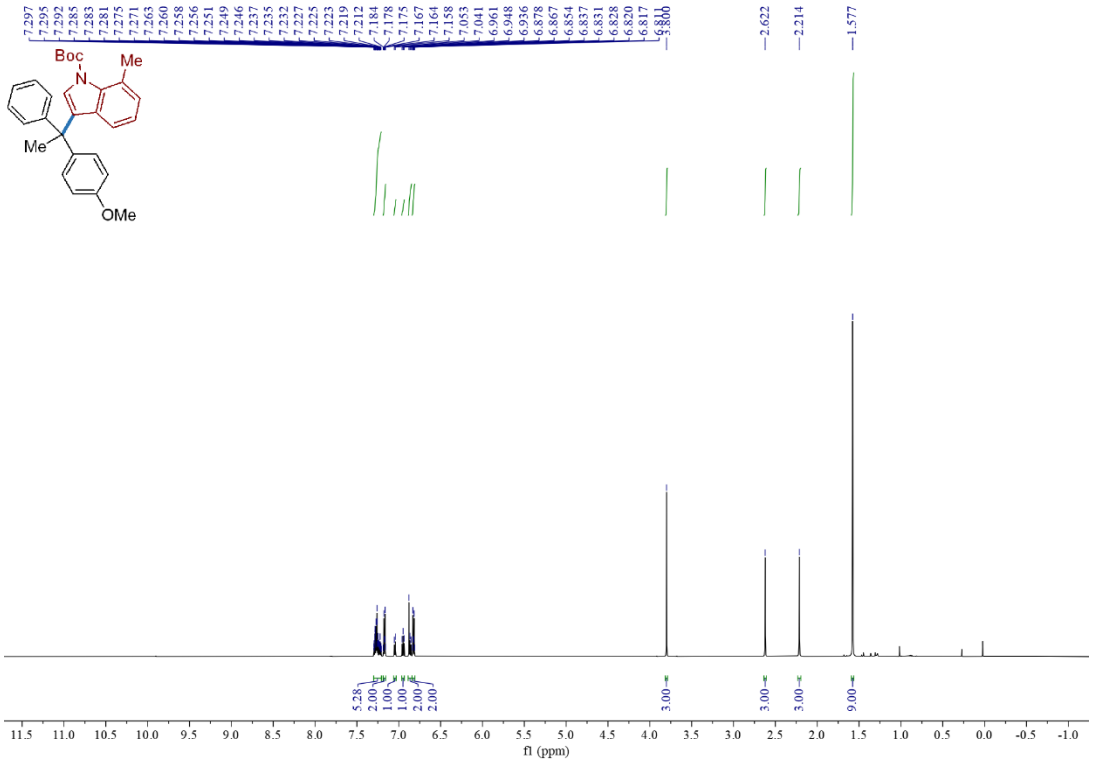


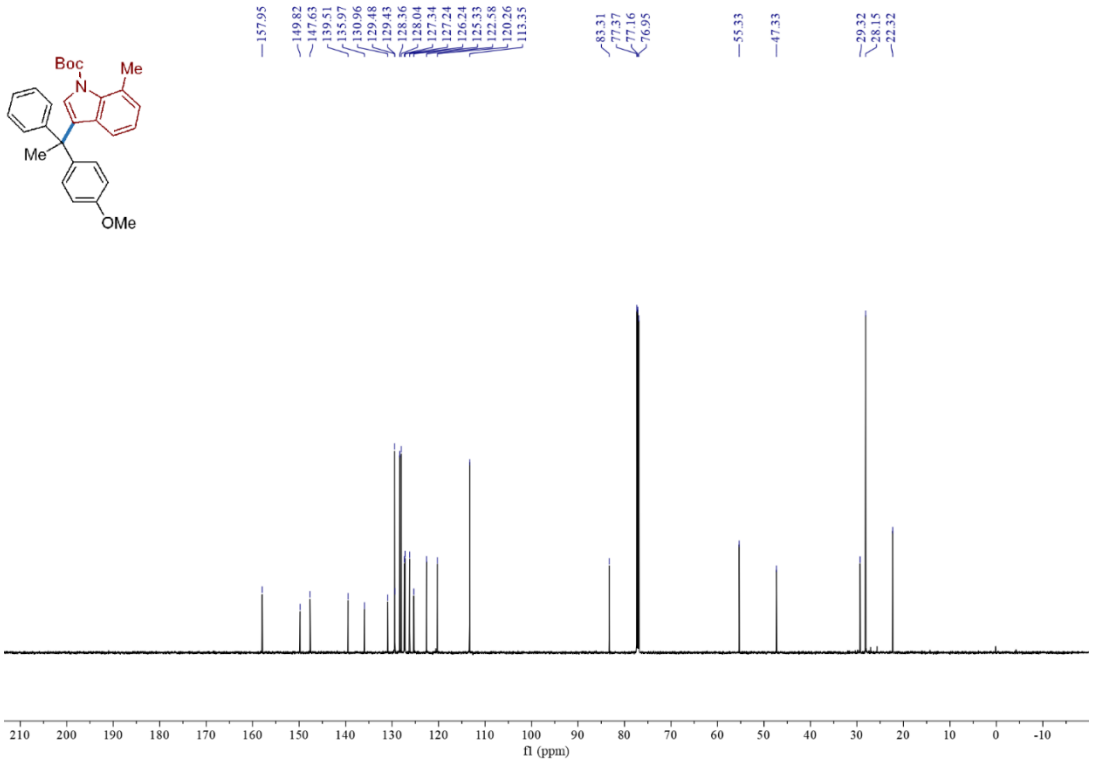
3-(1-(4-Methoxyphenyl)-1-phenylethyl)-1,7-dimethyl-1*H*-indole (13)



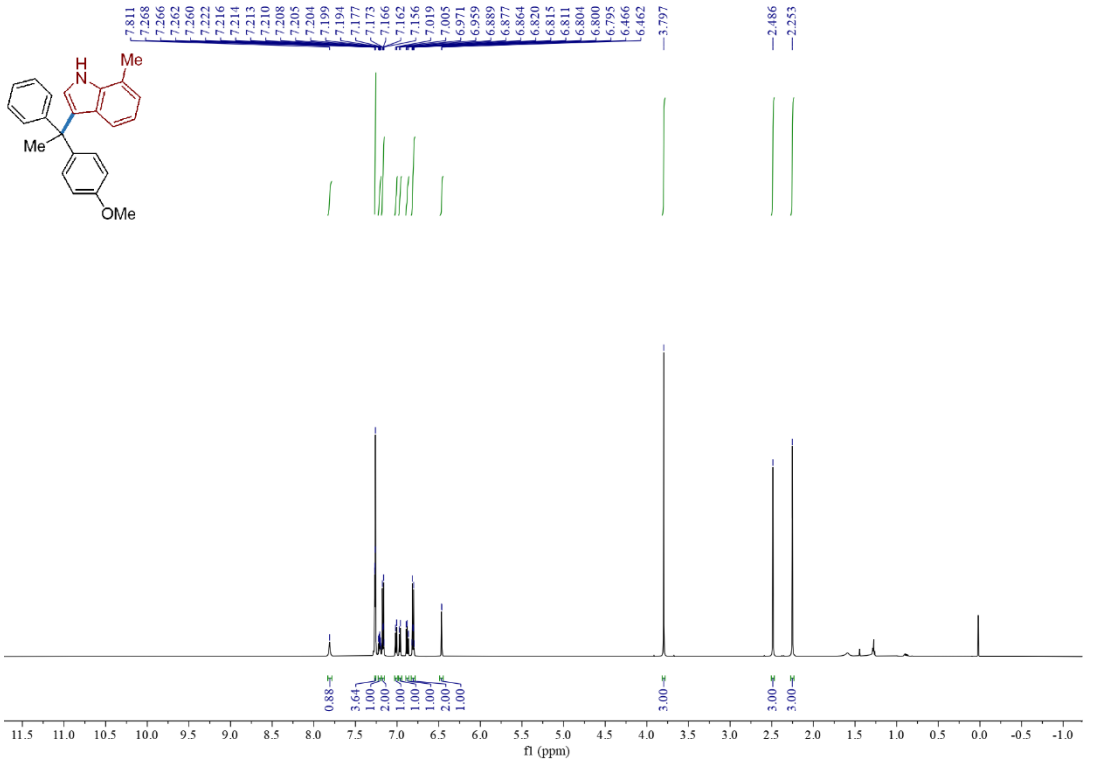


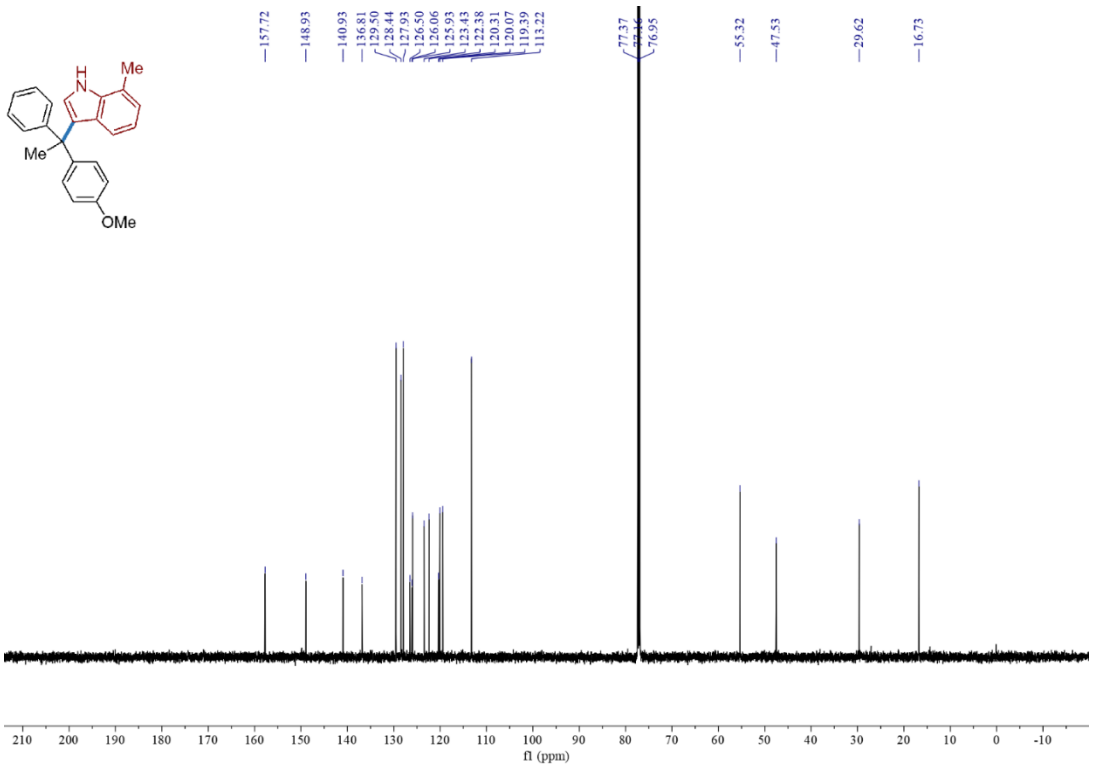
***tert*-Butyl 3-(1-(4-methoxyphenyl)-1-phenylethyl)-7-methyl-1*H*-indole-1-carboxylate (7fd')**



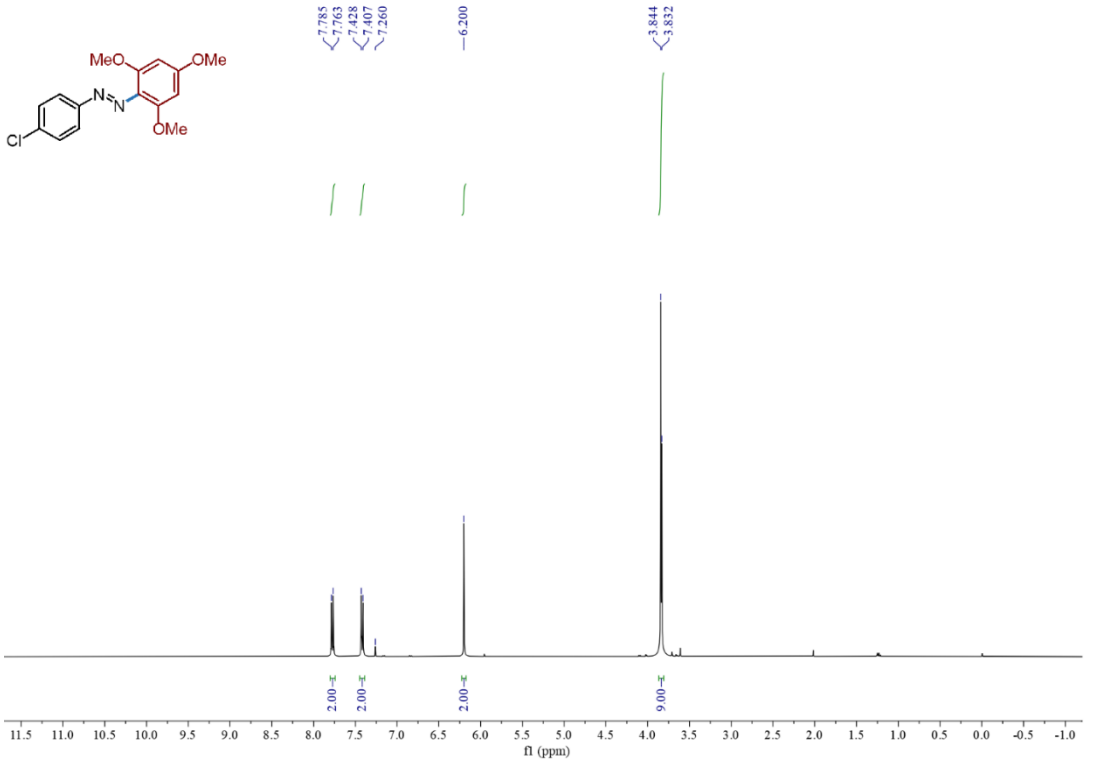


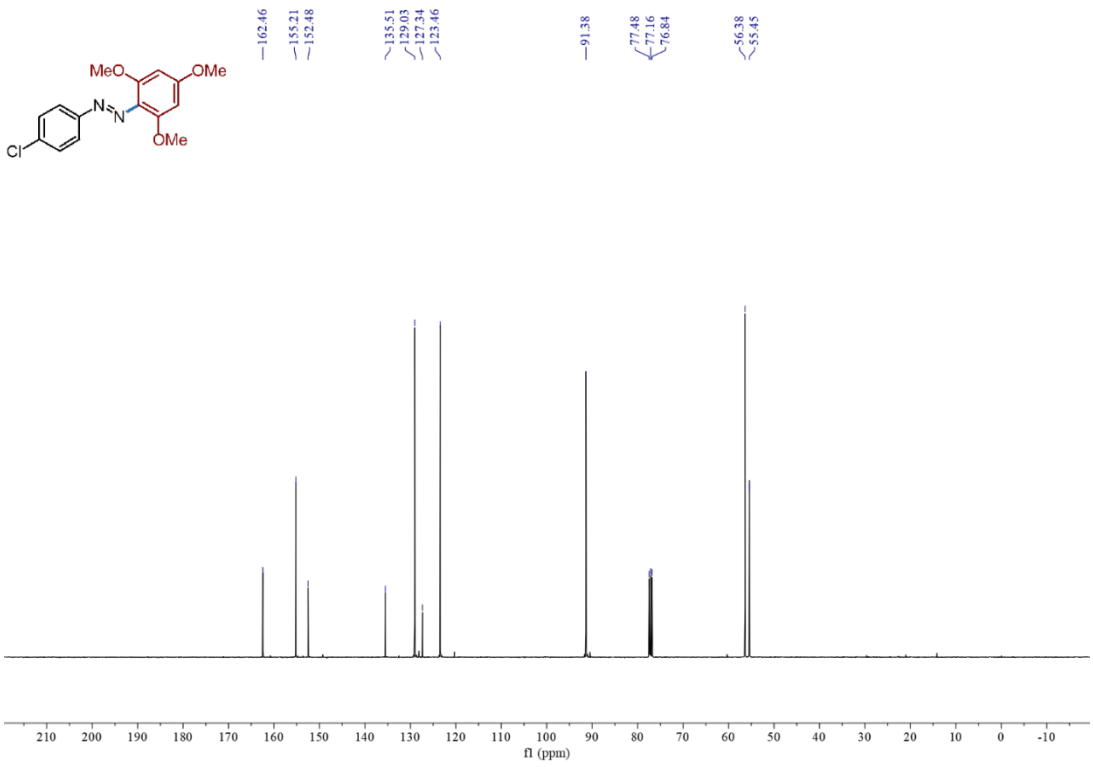
3-(1-(4-Methoxyphenyl)-1-phenylethyl)-7-methyl-1*H*-indole (14)



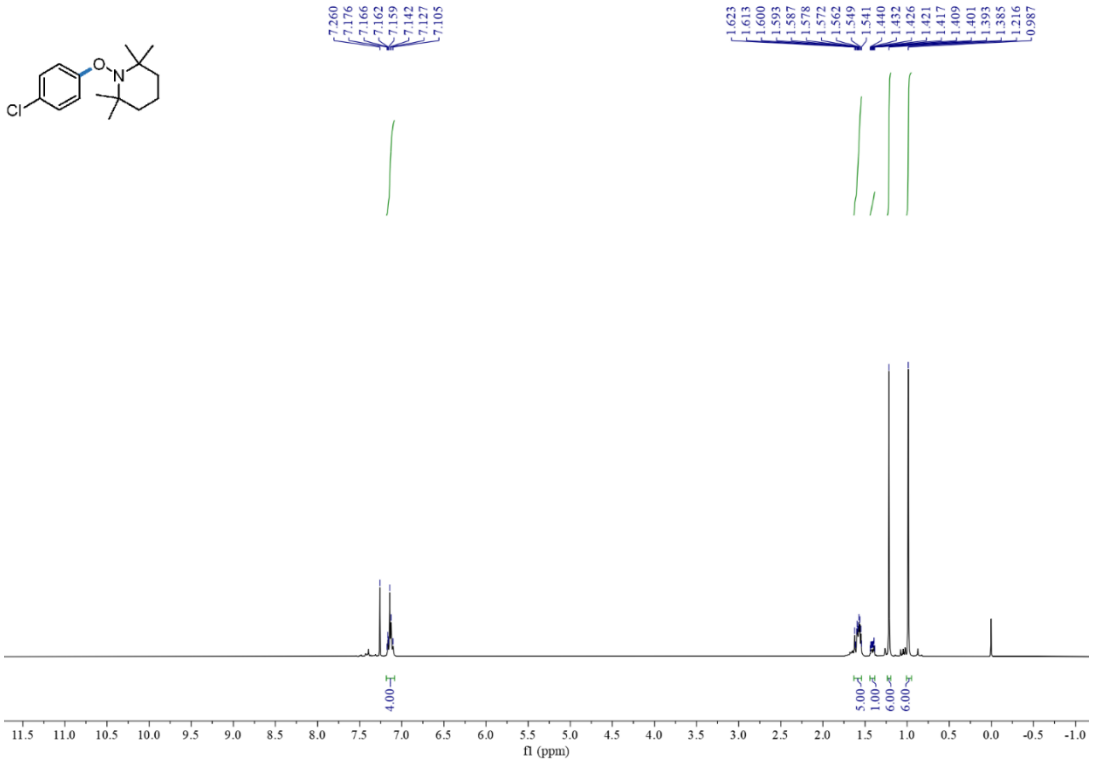


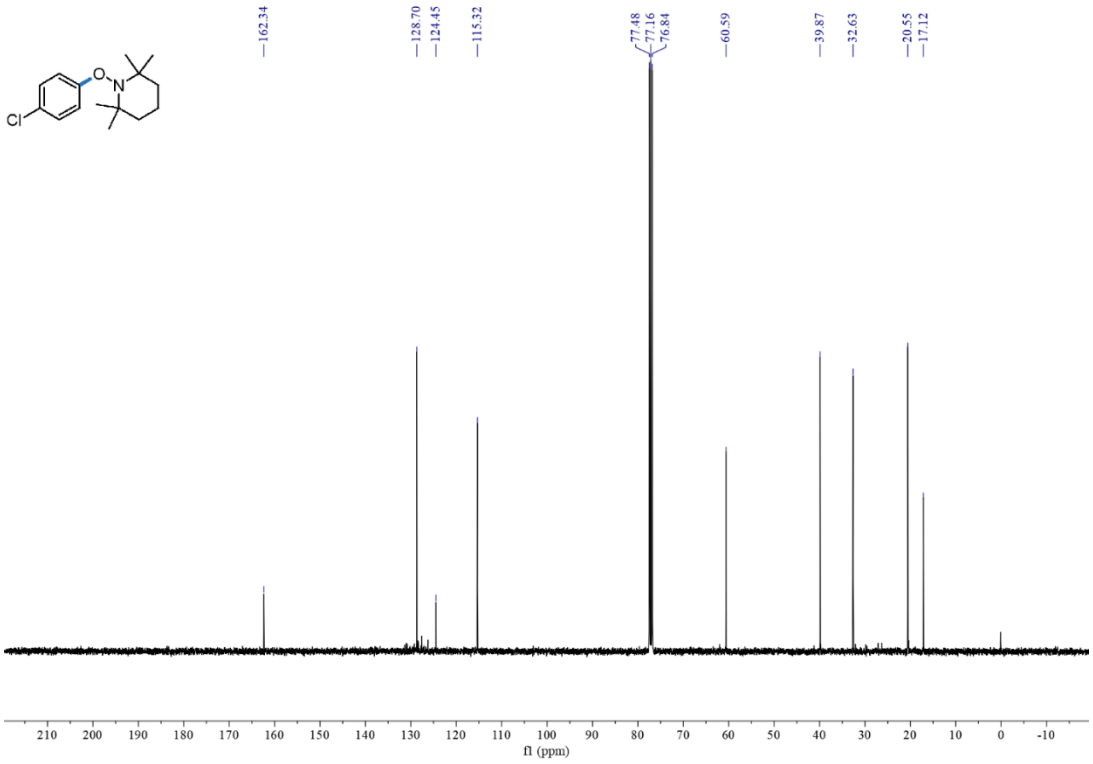
(*E*)-1-(4-Chlorophenyl)-2-(2,4,6-trimethoxyphenyl)diazene (3co')



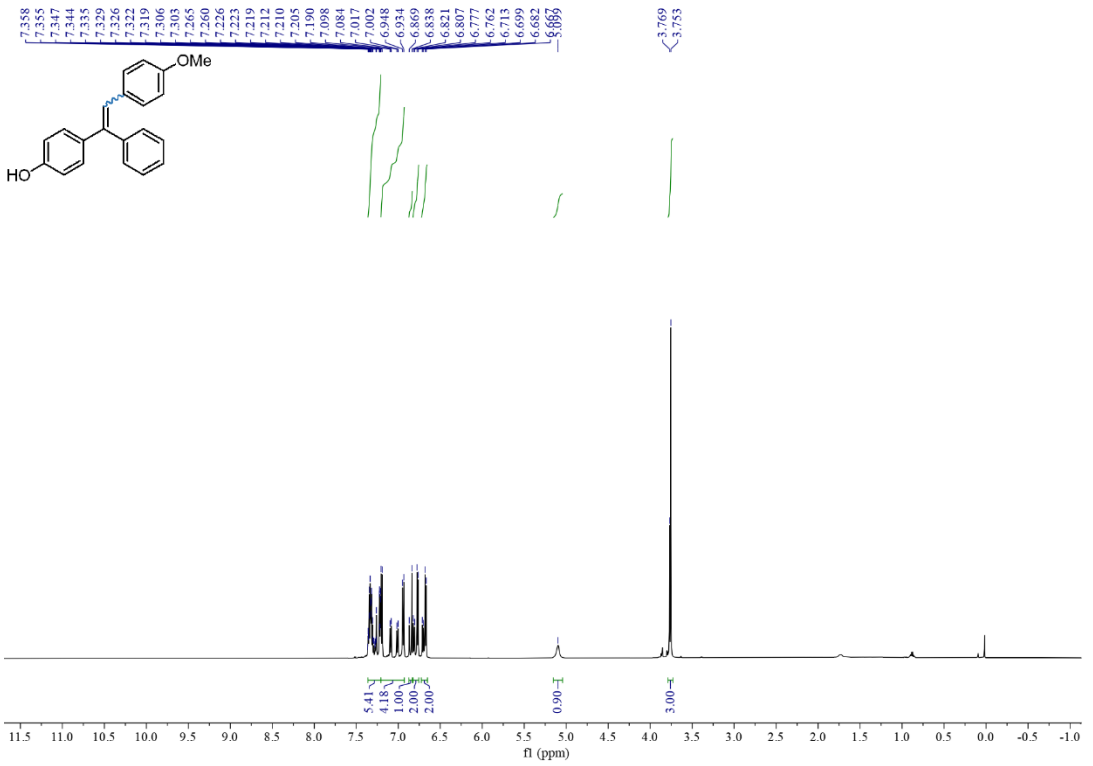


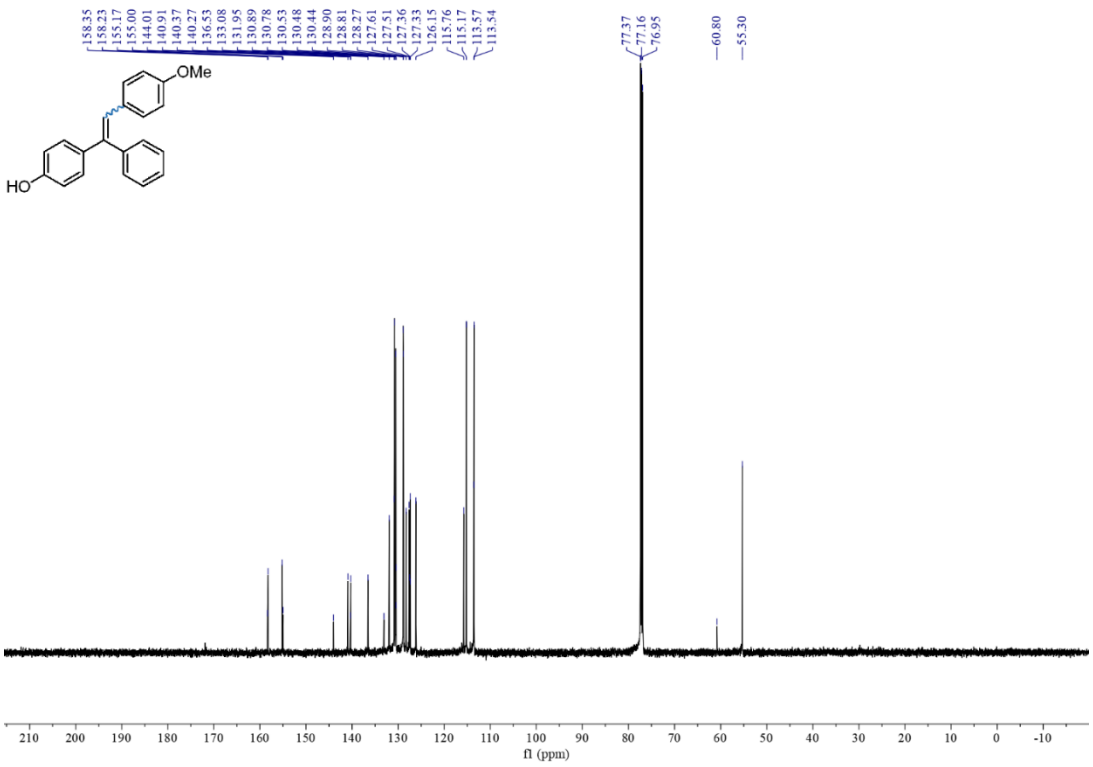
1-(4-Chlorophenoxy)-2,2,6,6-tetramethylpiperidine (1c-TEMPO)



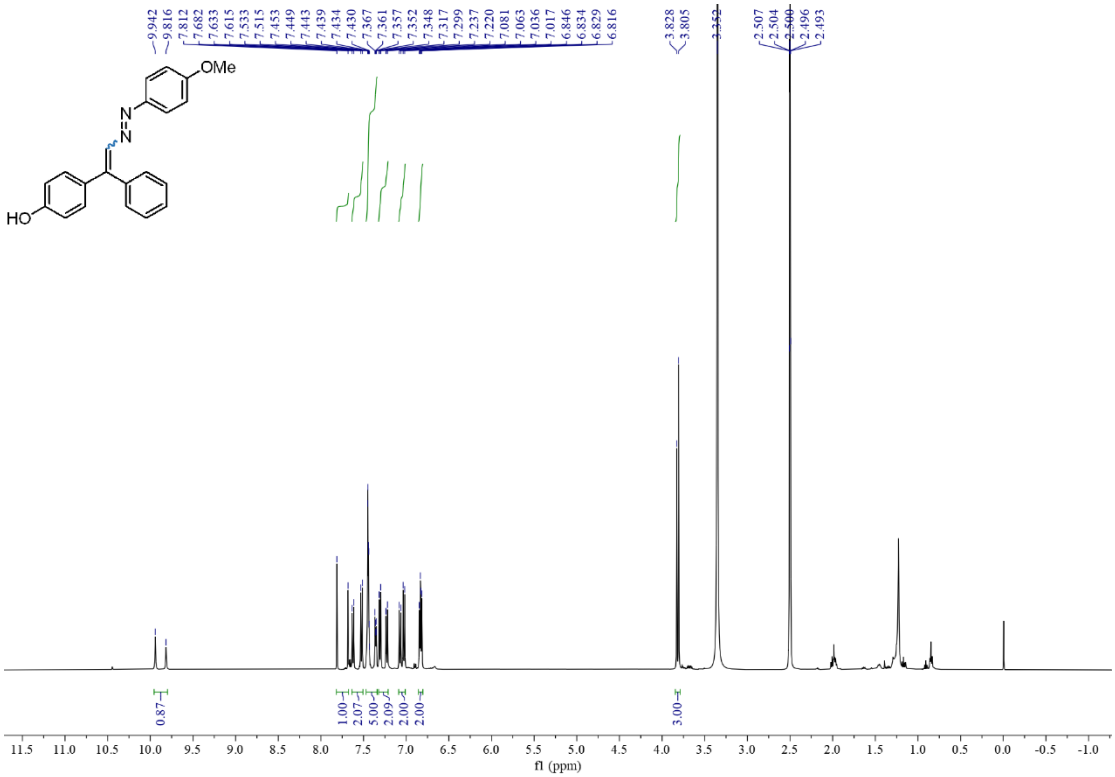


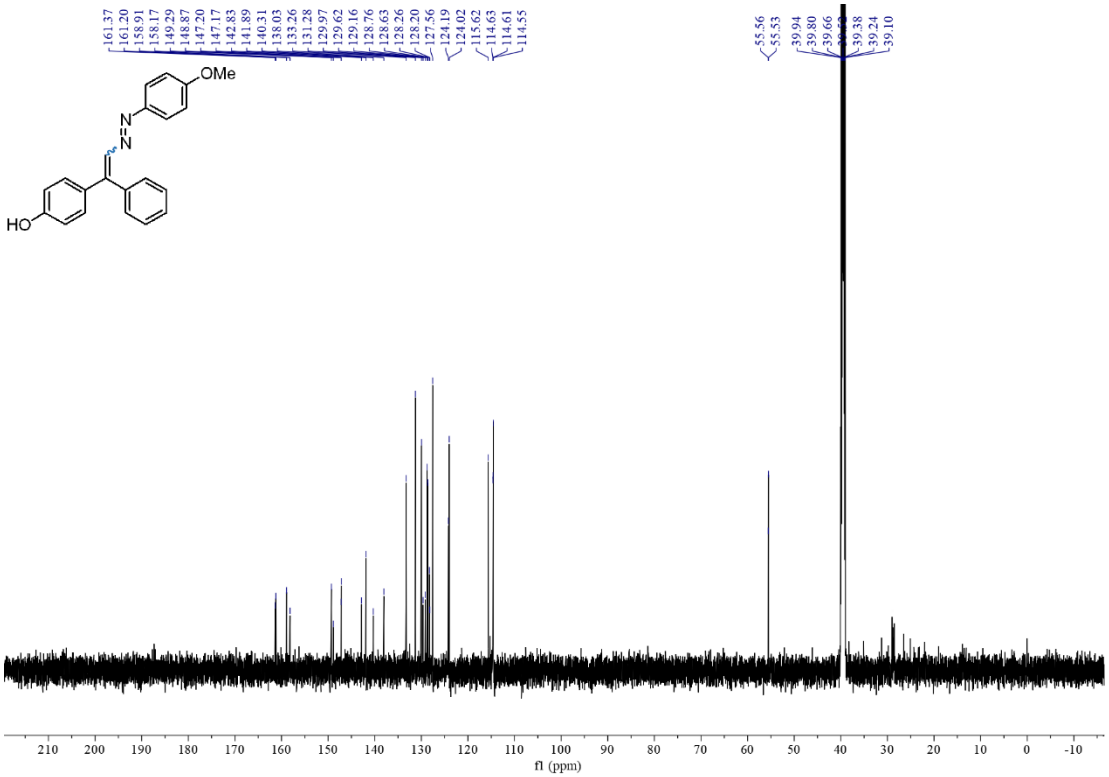
4-(2-(4-Methoxyphenyl)-1-phenylvinyl)phenol (5ad')



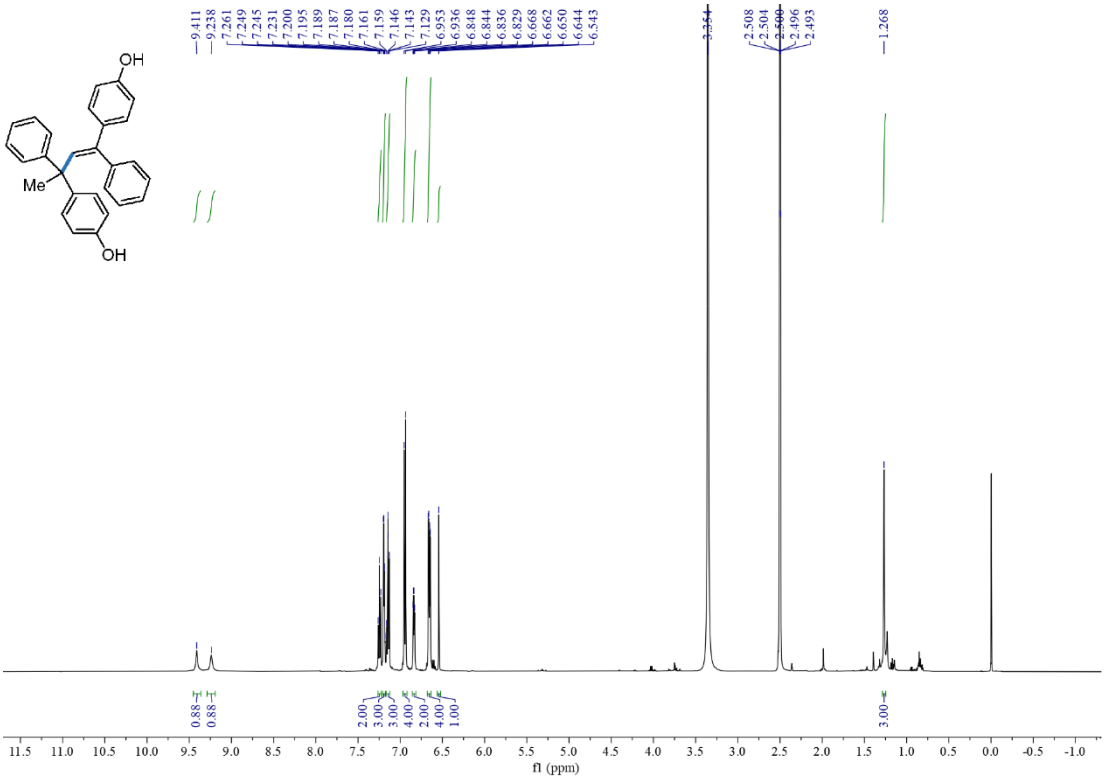


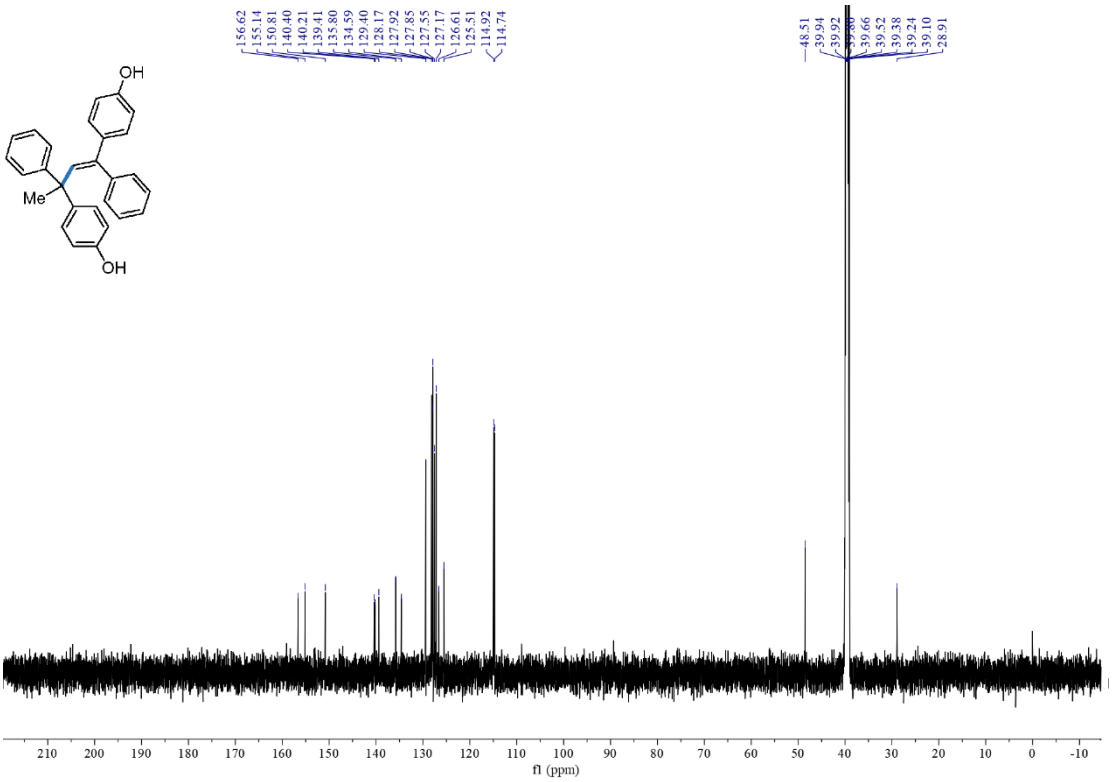
4-(2-((4-Methoxyphenyl)diazenyl)-1-phenylvinyl)phenol (5ad”)





(*E*)-4,4'-(1,3-Diphenylbut-1-ene-1,3-diyl)diphenol (15)





13. Computation study

13.1 1*H*-Indazole reactive site studies

Methods: all calculations were carried out with the Gaussian 09 software. The M06-2X functional[41] was adopted for all calculations. For geometry optimization and frequency calculations, the def2-SVP basis set[42] was used. The optimized structure has no imaginary frequency.

N*H*-Indazole optimized structures

C	-0.263413	-0.668639	-0.000061
C	-0.256806	0.744114	-0.000004
C	0.970237	1.434544	0.000143
C	2.139478	0.697780	0.000218
C	2.112173	-0.717745	0.000154
C	0.923550	-1.423005	0.000015
C	-1.647080	1.094746	-0.000158
H	0.995189	2.525107	0.000177
H	3.102638	1.209242	0.000322
H	3.055663	-1.265851	0.000212
H	0.909827	-2.513191	-0.000034
H	-2.098449	2.084477	-0.000167
N	-2.403116	0.023265	-0.000102
N	-1.578054	-1.030018	-0.000195
H	-1.965510	-1.963279	-0.000265

***N*-Acetyl-1*H*-indazole optimized structures**

C	-0.363950	-0.180524	0.000104
C	-1.133219	0.998076	0.000119
C	-2.535195	0.926838	0.000080
C	-3.121921	-0.326952	-0.000179
C	-2.333962	-1.498395	-0.000102
C	-0.948484	-1.455430	0.000185
C	-0.157679	2.058224	-0.000058
H	-3.141888	1.833355	0.000087
H	-4.208773	-0.416858	-0.000240
H	-2.831732	-2.469374	-0.000012
H	-0.333781	-2.351741	0.000407
H	-0.327617	3.133593	-0.000248
N	1.056129	1.587716	-0.000053
C	2.108581	-0.577371	-0.000031
O	1.994818	-1.774183	-0.000122
C	3.416830	0.164081	-0.000012
H	3.483904	0.814945	-0.881060
H	3.484640	0.813589	0.881973
H	4.221644	-0.577228	-0.000897
N	0.959449	0.235413	0.000101

_N_-Pivaloyl-1_H_-indazole optimized structures

C	1.258742	0.204719	0.000123
C	2.026354	-0.974975	0.000081
C	3.428511	-0.914482	-0.000069
C	4.024746	0.334353	-0.000181
C	3.242497	1.508712	-0.000130
C	1.856555	1.474769	0.000027
C	1.051621	-2.033189	0.000119
H	4.027163	-1.826335	-0.000113
H	5.112129	0.417465	-0.000319
H	3.744502	2.477543	-0.000224
H	1.253989	2.378047	0.000084
H	1.219532	-3.108907	0.000108
N	-0.160728	-1.561996	0.000258
C	-1.197482	0.645256	0.000240
O	-1.004102	1.833993	0.000565
C	-2.601195	0.029087	-0.000092
N	-0.071133	-0.207891	0.000218
C	-2.818578	-0.815385	1.266361
H	-3.868656	-1.142867	1.296097
H	-2.174064	-1.701122	1.279780
H	-2.626955	-0.219053	2.171180
C	-2.817830	-0.814607	-1.267226
H	-2.172989	-1.700113	-1.280982
H	-3.867769	-1.142479	-1.297574
H	-2.626076	-0.217567	-2.171550
C	-3.592443	1.196265	0.000004
H	-4.616964	0.798097	-0.000534
H	-3.458844	1.830332	0.886573
H	-3.458140	1.831079	-0.885913

_N_-Chloroacetyl-1_H_-indazole optimized structures

C	0.828600	0.469623	0.642165
C	-0.442831	0.764731	0.677766
C	-0.982233	2.020278	1.362844
C	-0.071574	2.891209	1.884582
C	1.454193	2.593070	1.763804
C	1.886748	1.440568	1.171967
C	-1.162892	-0.329691	-0.079430
H	-2.033160	2.211516	1.425140
H	-0.404546	3.782277	2.374508
H	2.165664	3.293296	2.149020
H	2.930500	1.220860	1.087054

H	-2.221025	-0.406249	-0.218686
N	-0.264171	-1.156833	-0.547842
C	2.429849	-1.185881	-0.183074
O	3.324253	-0.485506	0.358301
C	2.820644	-2.376399	-1.078365
H	2.060896	-3.127896	-1.024194
H	3.750905	-2.784846	-0.742677
N	1.012019	-0.867620	0.039115
Cl	2.986798	-1.829046	-2.742816

13.2 HAT-addition reaction transition state studies

Methods: all calculations were carried out with the Gaussian 16 software. The M06-2X functional[41] was adopted for all calculations. For geometry optimization and frequency calculations, the def2-SVP basis set[42] was used, and the optimal geometry for each compound was determined. The DFT-D3 dispersion correction[43] was applied to correct the weak interaction to improve the calculation accuracy.

Table S17. IRC data for the reaction profile reported in Fig. S10

REVERSE Direction		
# Point	**Reaction Coordinate**	**Electronic Energy (E), M06-2X/def2-SVP level of theory, [Hartree]**
TS	0.00000	-960.8842196
1	-0.10679	-960.8848453
2	-0.21354	-960.8870053
3	-0.32031	-960.8908057
4	-0.42707	-960.8955634
5	-0.53382	-960.9000362
6	-0.64046	-960.9032983
7	-0.74695	-960.9055824
8	-0.85364	-960.9074603
9	-0.96030	-960.9090202
10	-1.06693	-960.9103322
11	-1.17360	-960.9114795
12	-1.28031	-960.9125227
13	-1.38706	-960.9134928
14	-1.49381	-960.9144043
15	-1.60058	-960.9152647
16	-1.70734	-960.9160794
17	-1.81410	-960.9168523
18	-1.92087	-960.9175867
19	-2.02763	-960.9182854
20	-2.13440	-960.9189511
21	-2.24117	-960.9195857
22	-2.34793	-960.9201913
23	-2.45470	-960.9207695
24	-2.56146	-960.9213215
25	-2.66821	-960.9218487
26	-2.77494	-960.9223518
27	-2.88165	-960.9228319
28	-2.98832	-960.9232900
29	-3.09495	-960.9237281
30	-3.20160	-960.9241467

FORWARD Direction		
# Point	**Reaction Coordinate**	**Electronic Energy (E), M06-2X/def2-SVP level of theory, [Hartree]**
TS	0.00000	-960.8842196
1	0.10679	-960.8845703
2	0.21341	-960.8849813
3	0.31711	-960.8855176
4	0.42379	-960.8860153
5	0.52970	-960.8865268
6	0.63572	-960.8870443
7	0.74117	-960.8875520
8	0.84602	-960.8880748
9	0.95120	-960.8885667

10	1.05586	-960.8890702
11	1.16183	-960.8895303
12	1.26690	-960.8899831
13	1.37324	-960.8903884
14	1.47829	-960.8907893
15	1.58460	-960.8911452
16	1.68914	-960.8914924
17	1.79508	-960.8917867
18	1.89885	-960.8920813
19	2.00432	-960.8923200
20	2.10759	-960.8925632
21	2.21295	-960.8927573
22	2.31686	-960.8929533

23	2.42237	-960.8931148
24	2.52720	-960.8932737
25	2.63280	-960.8934152
26	2.73846	-960.8935524
27	2.84439	-960.8936819
28	2.95071	-960.8938052
29	3.05708	-960.8939220
30	3.16369	-960.8940320
31	2.84439	-960.8936819
32	2.95071	-960.8938052
33	3.05708	-960.8939220
34	3.16369	-960.8940320

TS optimized structures

C	-4.435126	-1.566528	1.120513
C	-3.475241	-0.842974	0.521766
C	-3.728672	0.566106	0.107451
C	-4.963330	0.943064	-0.438053
C	-5.213445	2.268153	-0.788916
C	-4.230545	3.239307	-0.603869
C	-2.994026	2.875298	-0.070267
C	-2.743325	1.550286	0.276895
C	-2.131856	-1.421925	0.252197
C	-1.532748	-2.310294	1.158812
C	-0.288733	-2.871403	0.896951
C	0.382215	-2.574220	-0.299699
O	1.568371	-3.144696	-0.552910
C	-0.207121	-1.681444	-1.211752
C	-1.439527	-1.108789	-0.930938
H	-4.274260	-2.614599	1.379039
H	-5.403685	-1.125681	1.362920
H	-5.725491	0.179985	-0.605867
H	-6.178298	2.541204	-1.219039
H	-4.424404	4.276360	-0.881652
H	-2.219120	3.629222	0.077036
H	-1.774215	1.269018	0.694091
H	-2.041402	-2.536037	2.097746
H	0.193976	-3.546507	1.604433
H	2.352951	-2.364062	-0.584345
H	0.326261	-1.449828	-2.135130
H	-1.888027	-0.414489	-1.644044
C	4.842367	3.275404	0.938561

O	5.353935	2.193615	0.207038
C	4.580029	1.096535	0.053828
C	5.148029	0.045005	-0.684012
C	4.434827	-1.130138	-0.899660
C	3.155181	-1.216630	-0.370943
C	2.566478	-0.212145	0.365307
C	3.289253	0.970309	0.580164
H	5.618878	4.047978	0.942567
H	3.930204	3.683552	0.472110
H	4.613968	2.988376	1.978524
H	6.156280	0.180243	-1.077410
H	4.877155	-1.947104	-1.471892
H	1.557680	-0.320976	0.773987
H	2.834997	1.774133	1.157886
H	6.156280	0.180243	-1.077410
H	4.877155	-1.947104	-1.471892
H	1.557680	-0.320976	0.773987
H	2.834997	1.774133	1.157886
Electronic energy		-961.949600	
Thermal correction to Gibbs Free Energy		0.282743	
Gibbs Free Energy		-961.666800	

MINIMA optimized structures

4-Methoxybenzene radical			
C	2.690012	0.274457	0.000774
O	1.674514	-0.691671	-0.000781
C	0.387615	-0.272650	-0.000396
C	-0.585553	-1.285292	-0.000045
C	-1.939941	-0.959813	0.000290
C	-2.272500	0.381312	0.000410
C	-1.359775	1.407522	-0.000081
C	0.003838	1.073647	-0.000475
H	3.641685	-0.268201	0.001628
H	2.641622	0.914778	-0.896040
H	2.639485	0.914019	0.898006
H	-0.245733	-2.321806	0.000039
H	-2.697621	-1.745770	0.000608
H	-1.665333	2.455691	-0.000065
H	0.747607	1.869568	-0.000796
Electronic energy		-346.062888	
Thermal correction to Gibbs Free Energy		0.090090	
Gibbs Free Energy		-345.972798	

4-(1-Phenylvinyl)phenol			
C	0.644418	2.589968	-0.041097
C	0.505594	1.254791	-0.012233
C	1.702259	0.367033	0.031384
C	2.848954	0.669842	-0.715409
C	3.981411	-0.138914	-0.643691
C	3.985254	-1.267983	0.174152
C	2.846981	-1.585299	0.915735
C	1.713985	-0.779061	0.840541
C	-0.838762	0.617084	-0.018605
C	-1.071212	-0.567742	-0.729428
C	-2.337420	-1.143057	-0.778959
C	-3.405698	-0.546378	-0.103212
O	-4.654596	-1.064022	-0.110614
C	-3.188927	0.628641	0.623583
C	-1.921622	1.195054	0.662097
H	-0.223541	3.246386	-0.125276
H	1.629714	3.055215	0.021645
H	2.839380	1.540591	-1.373529
H	4.862358	0.109334	-1.237778
H	4.870547	-1.903274	0.228704
H	2.841778	-2.466663	1.559035
H	0.825094	-1.029800	1.422843
H	-0.246404	-1.044042	-1.263061
H	-2.499608	-2.062373	-1.347593
H	-4.668444	-1.868381	-0.640544
H	-4.027900	1.072142	1.160134
H	-1.757485	2.099176	1.251183
Electronic energy		-615.892251	
Thermal correction to Gibbs Free Energy		0.182075	
Gibbs Free Energy		-615.710176	

4-(1-Phenylvinyl)phenol radical			
C	0.533969	2.579272	0.011595
C	0.419967	1.236214	0.021764
C	1.639259	0.378258	0.041558
C	2.742707	0.680929	-0.766324
C	3.896035	-0.099903	-0.715394
C	3.961817	-1.195974	0.143277
C	2.866642	-1.510028	0.948650
C	1.713158	-0.732046	0.895351
C	-0.901371	0.582277	-0.003790
C	-1.069197	-0.681693	-0.635840

C	-2.299425	-1.278911	-0.711432
C	-3.482344	-0.656363	-0.131343
O	-4.596663	-1.189545	-0.186821
C	-3.276165	0.629798	0.523868
C	-2.038724	1.211722	0.575628
H	-0.340924	3.227522	-0.056060
H	1.514946	3.055267	0.056489
H	2.684253	1.527003	-1.453637
H	4.744189	0.144851	-1.356477
H	4.863564	-1.808696	0.181799
H	2.911707	-2.365075	1.624699
H	0.859163	-0.978514	1.530082
H	-0.198389	-1.164434	-1.082607
H	-2.445194	-2.238148	-1.210181
H	-4.152437	1.093941	0.978771
H	-1.905547	2.161337	1.096291
Electronic energy		-615.244929	
Thermal correction to Gibbs Free Energy		0.168016	
Gibbs Free Energy		-615.076913	

4-Methoxybenzene			
C	2.747843	0.320603	0.000538
O	1.754054	-0.668020	-0.000676
C	0.459184	-0.277512	-0.000075
C	-0.496340	-1.304335	0.000028
C	-1.849194	-0.996040	0.000105
C	-2.274985	0.336191	0.000242
C	-1.324487	1.350705	-0.000156
C	0.042202	1.057424	-0.000265
H	3.711560	-0.200475	0.001143
H	2.684781	0.959786	-0.896057
H	2.683144	0.959009	0.897566
H	-0.140411	-2.334902	0.000116
H	-2.582797	-1.803983	0.000350
H	-1.641080	2.395140	-0.000171
H	0.765529	1.871423	-0.000508
H	-3.338493	0.575946	0.000474
Electronic energy		-346.750329	
Thermal correction to Gibbs Free Energy		0.103781	
Gibbs Free Energy		-346.646548	

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