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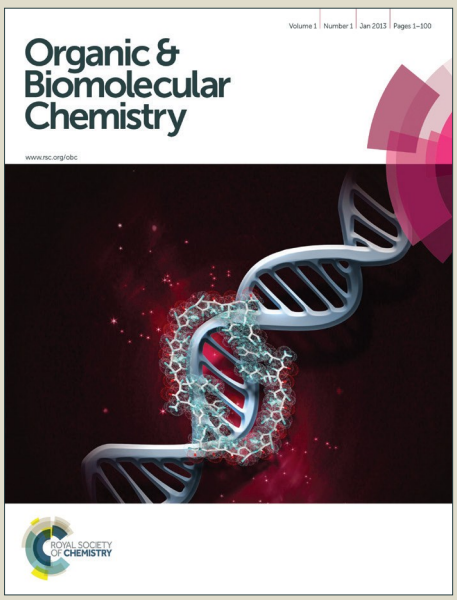

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ARTICLE

Intramolecular addition of diarylmethanols to imines promoted by KO*t*-Bu/DMF: a new synthetic approach to indole derivatives

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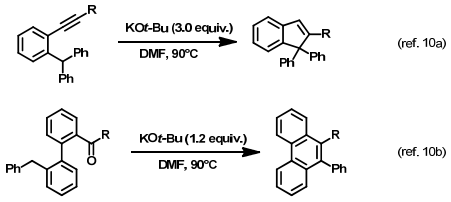
KO*t*-Bu/DMF promoted intramolecular addition of diarylmethanols to imines was developed. A series of 2,3-disubstituted indole was obtained in good yields. A reaction mechanism of radical cyclization and subsequent dehydration is proposed.

Introduction

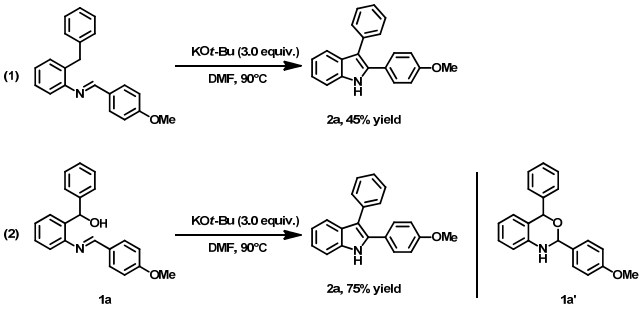
Indole derivatives are widely existed in natural products and many of them have valuable bioactivities.[1] Thus the development of new synthetic methods of indole derivatives is of great importance.[2-3] The unsymmetrical 2,3-disubstituted indole is usually prepared by multi-step reactions or by prefunctionalized substrates.[4] A more challenging approach is the direct annulation of unsymmetrical alkynes and anilines derivatives. However, the regioselectivity remains a major problem.[5] In the past decade, radical mediated indole synthesis has also been extensively studied.[6] Fukuyama and co-workers reported the synthesis of 2,3-disubstituted indole *via* intramolecular addition of α-stannoimidoyl radical to alkenes.[7] Rueping and Zhou reported the visible-light promoted radical addition of *N*,*N*-dimethyl-anilines to alkenes or alkynes.[8] However, the use of transition metal catalysts in the above cases hampered the further application. Recently, our group reported the synthesis of indole derivatives *via* the intramolecular coupling of tertiary amines with ketones or alkynes in the presence of KO*t*-Bu/DMF or KO*t*-Bu/DMSO.[9] We also found that KO*t*-Bu/DMF can promote the formation of triphenylmethyl and diphenylmethyl radicals, and the followed radical cyclization reactions (Scheme 1).[10] We speculate that diphenylmethyl radicals can also react with imines to give indole derivatives.

Initially, we examined the reaction of 2-benzyl-*N*-(4-methoxybenzylidene) aniline promoted by KO*t*-Bu/DMF. The expected 2-(*p*-methoxyphenyl)-3-phenylindole (2a) was obtained in 45% yield (Scheme 2, eq. 1). We also synthesized and examined the reaction of 1a (1a and benzoxazine 1a' are a pair of inseparable tautomers).[11] To our delight, 2a was obtained in an increased yield (Scheme 2, eq. 2). Because the hydroxyl substitution plays an important role in this reaction, we thought that a ketyl radical is generated.



Scheme 1 Previous studies of our group

The ketyl radicals are widely used as photomediators and intermediates of the C-C bond formation reactions.[11] They are formed mainly by the following three methods: (1) photo excitation of benzophenone derivatives;[12a-b] (2) reduction of the carbonyl group with SmI_2;[12c-f] (3) photoredox catalyzed reductive reactions.[12h-j] So far, the generation of ketyl radical



Scheme 2 Reactions of 2-benzyl-*N*-(4-methoxybenzylidene) aniline and **1a**/**1a'**promoted by KO*t*-Bu/DMF

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Electronic Supplementary Information (ESI) available: Synthetic procedures, analytical data and the NMR spectra of the substrates and products. See DOI: 10.1039/x0xx00000x

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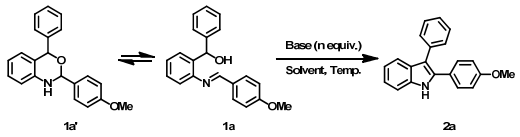
from substrates other than carbonyl compounds is less reported. In this paper, we report an efficient synthesis of 2,3-disubstituted indoles *via* intramolecular ketyl radical cyclization of diphenylmethanols with imines promoted by KO*t*-Bu/DMF.

Results and discussion

We optimized the reaction conditions and the results are summarized in Table 1. A variety of bases were examined. NaO*t*-Bu, KOH and KHMDS (Potassium hexamethyldisilazide) are also applicable, but lower yields were obtained (Table 1, entries 2, 4 and 5). LiO*t*-Bu is completely inefficient (Table 1, entry 3). The replacement of DMF with DMSO led to no reaction (Table 1, entry 6). Other solvents such as DMEU (1,3-Dimethyl-2-imidazolidinone), THF and 2-methyltetrahydrofuran are also applicable and low to moderate yields were obtained (Table 1, entries 7-9)[13]. The effect of KO*t*-Bu loading was also examined (Table 1, entries 10-12). The best result was obtained with 2.5 equiv. of KO*t*-Bu (Table 1, entry 11). The further decrease of the KO*t*-Bu loading (2.0 equiv) resulted in a slight loss of yield (Table 1, entry 10). Increasing the KO*t*-Bu loading to 4.0 equiv. led to a notable decrease of the yield (Table 1, entry 12). Increasing the temperature to 120℃ led to a better yield (Table 1, entry 13). The reaction at 60℃ provided the product **2a** in a lower yield (Table 1, entry 14). The sublimed KO*t*-Bu (>99.99% purity) was also examined and a similar yield was obtained (Table 1, entry 15). The fact demonstrated that the reaction is promoted by KO*t*-Bu itself, rather than the contaminated transition metals in KO*t*-Bu.

Table 1 Optimization of Reaction Conditions[a].

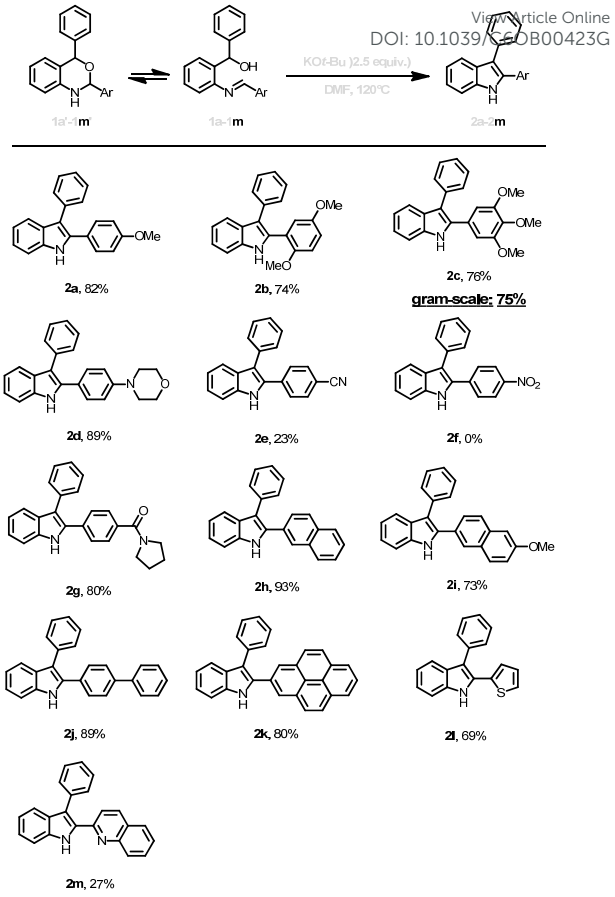


Entry	Base (equiv.)	Solvent	T (℃)	Yield[b]
1	KO*t*-Bu (3.0)	DMF	90	75
2	NaO*t*-Bu (3.0)	DMF	90	28
3	LiO*t*-Bu (3.0)	DMF	90	Trace
4	KHMDS (3.0)	DMF	90	60
5	KOH (3.0)	DMF	90	39
6	KO*t*-Bu (3.0)	DMSO	90	Trace
7	KO*t*-Bu (3.0)	DMEU	90	60
8	KO*t*-Bu (3.0)	THF	90	28
9	KO*t*-Bu (3.0)	2-MeTHF	90	50
10	KO*t*-Bu (2.0)	DMF	90	80
11	KO*t*-Bu (2.5)	DMF	90	88
12	KO*t*-Bu (4.0)	DMF	90	54
13	KO*t*-Bu (2.5)	DMF	120	93
14	KO*t*-Bu (2.5)	DMF	60	86
15[c]	KO*t*-Bu (2.5)	DMF	120	92

[a] Reaction conditions: **1a** (0.2 mmol), base (n equiv.), DMF (2.0 mL), at the indicated temperature for 2 hours under an argon atmosphere.

[b] Determined by GC using *n*-dodecane as the internal standard.

[c] 99.99% KOt-Bu was used.



[a] Reaction conditions: **1a**-**1m**/**1a'**-**1m'** (0.2 mmol), KO*t*-Bu (0.5 mmol), DMF (2.0 mL), argon atmosphere, 120 °C, 2 h. [b] Isolated yields.

Scheme 3 Intramolecular cyclization of **1a**-**1m**/**1a'**-**1m'**[a,b]

A series of 1,1-biaryl methanol imine derivatives **1a**-**1m** /**1a'** -**1m'** were prepared from substituted anilines and arylaldehydes. They were examined in the reaction and the results are summarized in Scheme 3. The substitutions with electron-donating groups such as methoxyl, morpholinyl were well tolerated. The substrates with single, double and triple methoxyl substitution gave the products **2a**-**2c** in good yields. However, the substitution with electron-withdrawing groups showed detrimental effect on the yield. The CN substituted substrate **1i**/**1i'** gave a 23% yield of **2i**. The substitution with NO_2 completely inhibited the reaction. The amide substituted substrate **1g**/**1g'** provided the product in a good yield. The substrates **1h**-**1k**/**1h'**-**1k'** with extended π-systems were also examined and the products were obtained in good to excellent

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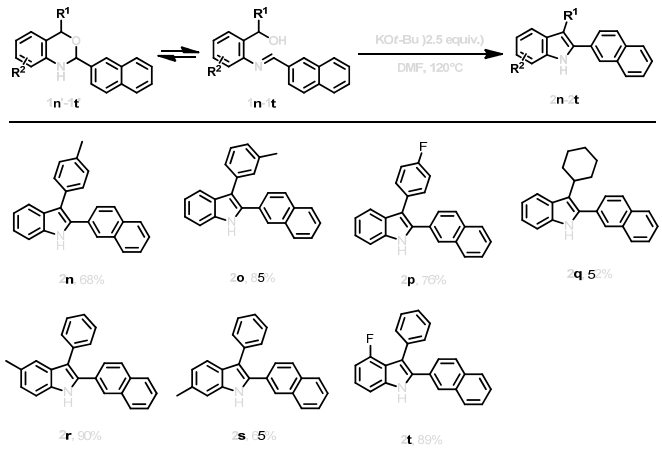
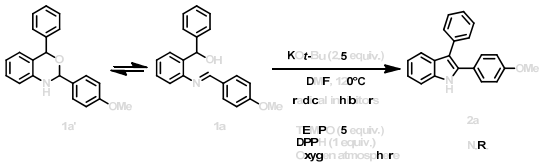


[a] Reaction conditions: **1n-1t/1n'-1t'** (0.2 mmol), KO*t*-Bu (0.5 mmol), DMF (2.0 mL), argon atmosphere, 120 °C, 2 h. [b] Isolated yields.

Scheme 4. Reactions of 1-aryl methanol with naphthyl imine derivatives **1n-1t/1n'-1t'** [a,b]



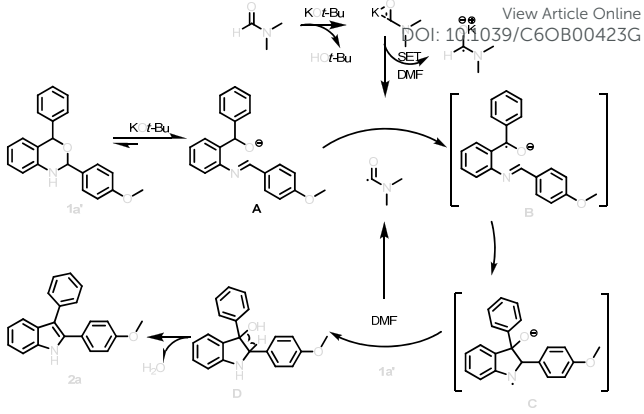
Scheme 5. Control experiments with free radical scavengers

yields. The substrates with heteroaryl groups were also applicable. The 2-thiophenyl substituted substrate **1l/1l'** gave the product **2l** in good yield, however 2-pyridyl substrate **1m/1m'** gave the product **2m** in a poor yield. To further demonstrate the utility of this reaction, a gram-scale reaction of **1c**/**1c'** was also examined. The product **2c** was obtained in a 75% yield.

The effect of the substitutions on the diaryl motif was also examined and the results are summarized in Scheme 4. The substitution at the phenyl ring with 4-methyl, 3-methyl and 4-fluoro was tolerated well. The products **2n**-**2p** were obtained in moderate to good yields. The replacement of the phenyl group with a cyclohexanyl group was also tolerated. The indole **2q** was obtained in a 52% yield. On the other hand, the substitution on the aniline motif with 5-methyl, 6-methyl and 4-fluoro was also applicable, the products **2r**-**2t** were obtained in good yields.

To explore the reaction mechanism, the control experiments with free radical scavengers such as TEMPO, DPPH (1,1-diphenyl-2-picrylhydrazyl radical) and O_2 were carried out (Scheme 5). The reaction was found to be inhibited completely. The results approve a free radical reaction pathway.

Based on our previous studies[14] and the present results, a tentative reaction mechanism is proposed in Scheme 6. In the presence of KO*t*-Bu, **1a'** can isomerize to the imine **A**.[15] DMF is



Scheme 6. Tentative reaction mechanism.

deprotonated by KO*t*-Bu to give the carbamoyl anion.[16] After a single-electron transfer (SET) step, the carbamoyl radical is generated. The carbamoyl radical removes a hydrogen from **A** to give the ketyl radical **B**.[17] **B** then undergoes an intramolecular radical addition to the imine. The resulted nitrogen radical anion **C** abstracts a hydrogen from DMF and a proton from **1a'** to provide the primary product **D**. After the subsequent dehydration, the final product **2a** is formed.

Conclusions

In summary, we have developed an efficient intramolecular cyclization of diarylmethanols to imines promoted by KO*t*-Bu/DMF. A number of 2,3-diarylindoles were prepared in good yields. A radical reaction pathway is proposed. The finding provides a new synthetic approach to indole derivatives.

Experimental

Representative experiment procedure

To a dried 10 mL reaction tube was added the mixture of **1a/1a'** (63.4 mg, 0.2 mmol), KO*t*-Bu (56.1 mg, 0.5 mmol) and dry DMF (2.0 mL). The mixture was stirred at 120℃ for 2 hours under argon atmosphere. After cooled down to room temperature, the reaction mixture was quenched with saturated NH_4Cl solution (1 mL) and was extracted with ethyl acetate (5 mL × 3). The combined organic layers was then washed with brine (5 mL) and dried over anhydrous $MgSO_4$. The residue was purified by column chromatography (petroleum ether/EtOAc = 10:1) to give **2a** as a light yellow solid (49.0 mg, 82% yield).

2-(4-Methoxyphenyl)-3-phenyl-1*H*-indole (2a). [18]

The product was obtained following the general procedure. Yield: 82%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.12 (br, 1H), 7.66 (d, *J* = 7.9 Hz, 1H), 7.45–7.41 (m, 2H), 7.39–7.31 (m, 5H), 7.26 (tt, *J* = 6.6, 1.4 Hz, 1H), 7.23–7.18 (m, 1H), 7.15–7.11 (m, 1H), 6.87–6.81 (m, 2H), 3.79 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 159.3, 135.8, 135.3, 134.2,

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130.2, 129.5, 128.9, 128.5, 126.1, 125.2, 122.4, 120.4, 119.5, 114.2, 110.8, 55.3. **HRMS** (ESI) calculated for $C_{24}H_{18}NO$ $[M+H]^+$: 300.1388, found: 300.1385.

2-(2,5-Dimethoxyphenyl)-3-phenyl-1*H*-indole (2b).

The product was obtained following the general procedure. Yield: 74%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 9.22 (br, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.47–7.43 (m, 2H), 7.42–7.35 (m, 3H), 7.29–7.19 (m, 2H), 7.11 (ddd, *J* = 8.0, 7.1, 1.0 Hz, 1H), 6.89 (d, *J* = 9.0 Hz, 1H), 6.80 (d, *J* = 3.2 Hz, 1H), 6.76 (dd, *J* = 8.9, 3.1 Hz, 1H), 3.80 (s, 3H), 3.36 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 153.5, 150.9, 136.0, 135.4, 131.1, 130.4, 128.6, 128.0, 126.3, 122.6, 121.5, 120.0, 119.4, 116.1, 115.9, 115.2, 113.4, 110.9, 56.6, 55.3. **HRMS** (ESI) calculated for $C_{22}H_{20}NO_2$, $[M+H]^+$: 330.1489, found: 330.1482.

3-Phenyl-2-(3,4,5-trimethoxyphenyl)-1*H*-indole (2c).

The product was obtained following the general procedure. Yield: 76%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.34 (br, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.50–7.33 (m, 5H), 7.32–7.20 (m, 2H), 7.15 (t, *J* = 7.6 Hz, 1H), 6.62 (s, 2H), 3.87 (s, 3H), 3.66 (s, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 153.3, 137.7, 135.8, 135.2, 134.0, 130.4, 128.9, 128.5, 128.0, 127.3, 126.4, 122.7, 120.5, 119.6, 115.2, 110.9, 105.3, 104.9, 61.0, 55.9. **HRMS** (ESI) calculated for $C_{23}H_{22}NO_3$, $[M+H]^+$: 360.1600, found: 360.1594.

4-(4-(3-Phenyl-1*H*-indol-2-yl)phenyl)morpholine (2d).

The product was obtained following the general procedure. Yield: 89%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.21 (br, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.47–7.32 (m, 7H), 7.30–7.25 (m, 2H), 7.24—7.19 (m, 1H), 7.16–7.10 (m, 1H), 6.85 (d, *J* = 8.4 Hz, 2H), 3.85 (t, *J* = 4.7 Hz, 4H), 3.18 (t, *J* = 4.8 Hz, 4H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 135.8, 135.4, 134.2, 130.2, 129.0, 128.9, 128.5, 126.0, 122.3, 120.3, 119.4, 115.3, 114.0, 110.7, 66.8, 48.8. **HRMS** (ESI) calculated for $C_{24}H_{21}N_2O$ $[M+H]^+$: 355.18109, found: 355.1802.

4-(3-Phenyl-1*H*-indol-2-yl)benzonitrile (2e). [19]

The product was obtained following the general procedure. Yield: 23%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.35 (br, 1H), 7.64 (d, *J* = 7.9 Hz, 1H), 7.57 (d, *J* = 8.2 Hz, 2H), 7.49 (d, *J* = 8.2 Hz, 2H), 7.47–7.32 (m, 6H), 7.29 (t, *J* = 7.4 Hz, 1H), 7.17 (t, *J* = 7.6 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 137.2, 136.4, 134.23, 132.4, 131.6, 130.1, 128.9, 128.8, 128.3, 127.0, 123.9, 120.9, 120.2, 118.8, 117.6, 111.2, 110.7. **HRMS** (ESI) calculated for , $C_{21}H_{15}N_2$ $[M+H]^+$: 292.1235, found: 292.1239.

(4-(3-Phenyl-1*H*-indol-2-yl)phenyl)(pyrrolidin-1-yl)methanone (2g).

The product was obtained following the general procedure. Yield: 80%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.90 (br, 1H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.48 (d, *J* = 8.2 Hz, 1H), 7.46–7.33 (m, 8H), 7.33–7.22 (m, 3H), 7.15 (t, *J* = 7.4 Hz, 1H), 3.67 (t, *J* = 7.0 Hz, 2H), 3.45 (t, *J* = 6.6 Hz, 2H), 2.00–1.84 (m, 4H). **^{13}C NMR** (100 MHz, DMSO): δ 167.7, 136.2, 135.8, 135.0, 133.7, 133.1, 129.8, 128.7, 128.0, 127.6, 127.3, 126.3, 122.3, 119.8, 118.7, 114.0, 111.5, 48.8, 45.9, 26.0, 23.9. **HRMS** (ESI) calculated for $C_{25}H_{23}N_2O$ $[M+H]^+$: 367.1805, found: 367.1809.

2-(Naphthalen-2-yl)-3-phenyl-1*H*-indole (2h). [20]

The product was obtained following the general procedure. Yield: 93%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.28 (br 1H), 7.92 (s, 1H), 7.80–7.73 (m, 2H), 7.73–7.68 (m, 2H), 7.47–7.40 (m, 6H), 7.38–7.33 (m, 2H), 7.30–7.23 (m, 2H), 7.16 (t, *J* = 7.6 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 136.2, 135.1, 134.1, 133.5, 132.7, 130.4, 130.3, 128.9, 128.6, 128.2, 128.1, 127.8, 126.7, 126.5, 126.4, 126.3, 122.9, 120.6, 119.8, 115.6, 111.0. **HRMS** (ESI) calculated for $C_{24}H_{18}N$, $[M+H]^+$: 320.1434, found: 320.1446.

2-(6-Methoxynaphthalen-2-yl)-3-phenyl-1*H*-indole (2i).

The product was obtained following the general procedure. Yield: 73%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.20 (br, 1H), 7.80 (s, 1H), 7.69 (t, *J* = 7.6 Hz, 1H), 7.63–7.53 (m, 2H), 7.44 (t, *J* = 7.5 Hz, 2H), 7.39–7.30 (m, 4H), 7.29–7.19 (m, 2H), 7.17–7.08 (m, 2H), 7.07–7.02 (m, 1H), 3.86 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 158.1, 136.1, 135.2, 134.4, 133.9, 130.3, 129.6, 128.9(4), 128.8(9), 128.6, 128.1, 127.0, 126.6, 126.3, 122.7, 120.5, 119.9, 119.3, 115.0, 111.0, 105.8, 55.4. **HRMS** (ESI) calculated for $C_{25}H_{20}NO$ $[M+H]^+$: 350.1539, found: 350.1531.

2-([1,1'-Biphenyl]-4-yl)-3-phenyl-1*H*-indole (2j). [19]

The product was obtained following the general procedure. Yield: 89%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.27 (br, 1H), 7.76 (d, *J* = 7.9 Hz, 1H), 7.68–7.63 (m, 2H), 7.63–7.59 (m, 2H), 7.58–7.35 (m, 11H), 7.32 (t, *J* = 7.6 Hz, 1H), 7.27–7.17 (m, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 140.4, 140.3, 136.0, 135.2, 133.7, 131.6, 130.3, 128.9(4), 128.9(0), 128.7, 128.5, 127.6, 127.3, 127.9, 126.4, 122.9, 120.6, 119.8, 115.4, 111.0. **HRMS** (ESI) calculated for $C_{26}H_{20}N$ $[M+H]^+$: 346.1590, found: 346.1580.

3-Phenyl-2-(pyren-2-yl)-1*H*-indole (2k).

The product was obtained following the general procedure. Yield: 80%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.20 (br, 1H), 8.13 (d, *J* = 7.6 Hz, 1H), 8.08–7.82 (m, 9H), 7.38 (d, *J* = 8.0 Hz, 1H), 7.34–7.20 (m, 4H), 7.10 (t, *J* = 7.4 Hz, 2H), 7.07–7.00 (m, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 136.3, 135.0, 133.8, 131.4, 131.3, 130.9, 129.8, 129.5, 129.0, 128.4, 128.0, 127.8, 127.7, 127.4, 126.2, 125.8, 125.5, 125.3, 125.2, 125.0, 124.7, 124.6, 122.8, 120.6, 119.9, 117.2, 111.1. **HRMS** (ESI) calculated for $C_{30}H_{20}N$ $[M+H]^+$: 394.1590, found: 394.1583.

3-Phenyl-2-(thiophen-2-yl)-1*H*-indole (2l). [21]

The product was obtained following the general procedure. Yield: 69%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.17 (br, 1H), 7.55 (d, *J* = 7.9 Hz, 1H), 7.52–7.47 (m, 2H), 7.45–7.32 (m, 4H), 7.27–7.19 (m, 2H), 7.14–7.09 (m, 1H), 7.06 (dd, *J* = 3.6, 1.1 Hz, 1H), 6.97 (dd, *J* = 5.1, 3.7 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 135.8, 134.6, 134.5, 130.6, 129.1, 128.6, 128.3, 127.5, 126.9, 125.4, 125.3, 123.1, 120.6, 119.7, 115.9, 110.8. **HRMS** (ESI) calculated for $C_{18}H_{14}NS$ $[M+H]^+$: 276.0841, found: 276.0845.

2-(3-Phenyl-1*H*-indol-2-yl)quinoline (2m).

The product was obtained following the general procedure. Yield: 27%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 9.92 (br, 1H), 8.11 (d, *J* = 8.4 Hz, 1H), 7.87 (d, *J* = 8.8 Hz, 1H), 7.75–7.68 (m, 2H), 7.60–7.42 (m, 9H),

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7.29 (ddd, *J* = 8.1, 7.0, 1.1 Hz, 1H), 7.11 (ddd, *J* = 8.0, 7.0, 1.0 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 150.6, 147.9, 135.8, 135.7, 135.2, 130.7, 129.8, 129.7, 128.9, 128.8, 127.6, 127.3, 127.2, 126.2, 124.1, 120.4, 120.2, 120.0, 111.3. **HRMS** (ESI) calculated for $C_{23}H_{17}N_2$ $[M+H]^+$: 321.1386, found: 321.1390.

2-(Naphthalen-2-yl)-3-(*p*-tolyl)-1*H*-indole (2n).

The product was obtained following the general procedure. Yield: 68%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.26 (br, 1H), 7.92 (s, 1H), 7.81–7.74 (m, 2H), 7.73–7.67 (m, 2H), 7.48–7.39 (m, 4H), 7.35 (d, *J* = 7.7 Hz, 2H), 7.24 (t, *J* = 7.3 Hz, 1H), 7.21–7.11 (m, 3H), 2.38 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 136.1, 135.9, 133.9, 133.5, 132.7, 132.0, 130.5, 130.1, 129.3, 129.0, 128.2, 128.1, 127.8, 126.5, 126.4, 126.3, 122.8, 120.4, 119.9, 115.5, 110.9, 21.3. **HRMS** (ESI) calculated for $C_{25}H_{20}N$ $[M+H]^+$: 334.1590, found: 334.1579.

2-(Naphthalen-2-yl)-3-(*m*-tolyl)-1*H*-indole (2o).

The product was obtained following the general procedure. Yield: 85%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.28 (br, 1H), 7.93 (s, 1H), 7.81–7.74 (m, 2H), 7.70 (dd, *J* = 7.8, 5.3 Hz, 2H), 7.49–7.40 (m, 4H), 7.32 (s, 1H), 7.28–7.20 (m, 3H), 7.16 (t, *J* = 7.5 Hz, 1H), 7.13–7.09 (m, 1H), 2.33 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 138.1, 136.1, 134.9, 134.0, 133.5, 132.7, 130.8, 130.4, 129.0, 128.5, 128.1, 128.0, 127.8, 127.4, 127.2, 126.5, 126.4(4), 126.3(8), 126.3, 122.9, 120.5, 119.9, 115.7, 110.9, 21.6. **HRMS** (ESI) calculated for $C_{25}H_{20}N$ $[M+H]^+$: 334.1590, found: 334.1581.

3-(4-Fluorophenyl)-2-(naphthalen-2-yl)-1*H*-indole (2p).

The product was obtained following the general procedure. Yield: 76%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.27 (br, 1H), 7.88 (s, 1H), 7.80–7.74 (m, 2H), 7.71 (d, *J* = 8.6 Hz, 1H), 7.65 (d, *J* = 7.9 Hz, 1H), 7.49–7.45 (m, 2H), 7.43–7.36 (m, 4H), 7.28–7.23 (m, 1H), 7.19–7.14 (m, 1H), 7.08–7.01 (m, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 161.7 (d, $^1J_{CF}$ = 244.2 Hz), 136.0, 134.2, 133.5, 132.7, 131.7 (d, $^3J_{CF}$ = 7.8 Hz), 131.0 (d, $^4J_{CF}$ = 3.2 Hz), 130.1, 129.6, 128.8, 128.3, 128.0, 127.8, 126.7, 126.6, 126.4, 126.3, 123.0, 120.6, 119.5, 115.6 (d, $^2J_{CF}$ = 21.1 Hz), 114.5, 111.0. **^{19}F NMR** (376 MHz, $CDCl_3$): δ –116.2. **HRMS** (ESI) calculated for $C_{24}H_{17}NF[M+H]^+$: 338.1345, found: 355.1346.

3-Cyclohexyl-2-(naphthalen-2-yl)-1*H*-indole (2q).

The product was obtained following the general procedure. Yield: 52%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.00 (br, 1H), 7.95–7.86 (m, 5H), 7.62 (dd, *J* = 8.5, 1.4 Hz, 1H), 7.56–7.49 (m, 2H), 7.38 (d, *J* = 8.0 Hz, 1H), 7.19 (t, *J* = 7.3 Hz, 1H), 7.12 (t, *J* = 7.7 Hz, 1H), 3.04 (tt, *J* = 12.3, 3.4 Hz, 1H), 2.15–2.05 (m, 2H), 1.94–1.83 (m, 4H), 1.79–1.73 (m, 1H), 1.42–1.32 (m, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 136.5, 133.7, 133.4, 132.7, 131.2, 128.3, 128.1, 127.8, 127.7, 127.5, 126.8, 126.6, 126.3, 121.9, 121.2, 119.3, 119.2, 111.1, 36.6, 33.2, 27.1, 26.4. **HRMS** (ESI) calculated for $C_{24}H_{24}N$ $[M+H]^+$: 326.1903, found: 326.1906.

5-Methyl-2-(naphthalen-2-yl)-3-phenyl-1*H*-indole (2r).

The product was obtained following the general procedure. Yield: 90%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.07 (br, 1H), 7.85 (s, 1H), 7.76–7.68 (m, 2H), 7.64 (d, *J* = 8.6 Hz, 1H), 7.48 (s, 1H), 7.46–7.39 (m, 4H), 7.39–7.31 (m, 3H), 7.31–7.24 (m, 2H), 7.06 (d, *J* = 8.3 Hz, 1H), 2.42 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 135.3, 134.5, 134.3, 133.5, 132.7, 130.5, 130.3, 129.9, 129.1, 128.6, 128.2, 128.1, 127.8, 126.5, 126.4, 126.3(9), 126.3(0), 124.5, 119.4, 115.2, 110.7, 21.7. **HRMS** (ESI) calculated for $C_{25}H_{20}N$ $[M+H]^+$: 334.1590, found: 334.1576.

6-Methyl-2-(naphthalen-2-yl)-3-phenyl-1*H*-indole (2s).

The product was obtained following the general procedure. Yield: 65%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.15 (br, 1H), 7.87 (s, 1H), 7.76–7.70 (m, 2H), 7.66 (d, *J* = 8.6 Hz, 1H), 7.55 (d, *J* = 8.2 Hz, 1H), 7.44–7.37 (m, 5H), 7.34–7.29 (m, 2H), 7.26–7.22 (m, 1H), 7.18 (s, 1H), 6.96 (d, *J* = 8.2 Hz, 1H), 2.45 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 136.6, 135.2, 133.5, 133.4, 132.8, 132.6, 130.5, 130.2, 128.5, 128.1, 128.0, 127.8, 126.7, 126.5, 126.4(3), 126.3(5), 126.3, 126.2, 122.3, 119.5, 115.4, 110.9, 21.8. **HRMS** (ESI) calculated for $C_{25}H_{20}N$ $[M+H]^+$: 334.1590, found: 334.1590.

4-Fluoro-2-(naphthalen-2-yl)-3-phenyl-1*H*-indole (2t).

The product was obtained following the general procedure. Yield: 89%. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.45 (br, 1H), 7.88 (s, 1H), 7.80–7.73 (m, 2H), 7.69 (d, *J* = 8.7 Hz, 1H), 7.50–7.43 (m, 4H), 7.35–7.28 (m, 4H), 7.23 (d, *J* = 8.1 Hz, 1H), 7.15 (td, *J* = 7.8, 4.8 Hz, 1H), 6.81 (dd, *J* = 11.3, 7.8 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 157.2 (d, $^1J_{CF}$ = 249.5 Hz), 138.5 (d, $^3J_{CF}$ = 10.2 Hz), 134.8, 134.5, 133.4, 132.7, 131.1, 129.8, 128.2, 128.1, 128.0, 127.8, 126.9, 126.6, 126.5(4), 126.4(8), 126.3, 123.1 (d, $^4J_{CF}$ = 8.0 Hz), 117.4 (d, $^2J_{CF}$ = 17.5 Hz), 113.8, 107.1, 106.0, 105.8. **^{19}F NMR** (376 MHz, $CDCl_3$): δ –118.7. **HRMS** (ESI) calculated for $C_{24}H_{17}NF$ $[M+H]^+$: 338.1345, found: 355.1350.

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