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Gold-catalyzed Michael addition/intramolecular annulation cascade: an effective pathway for the chemoselective- and regioselective synthesis of tetracyclic indole derivatives in water†

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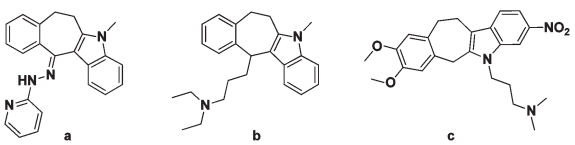
The report describes a gold(I) complex and trifluoroacetic acid (TFA) cocatalyzed one-pot, Michael addition/intramolecular cyclization cascade reaction for the synthesis of unusual tetracyclic indoles containing a seven-membered ring in water with microwave irradiation (MW). This protocol presents an operationally simple, rapid and environmentally friendly strategy for preparing potential biologically interesting fused-indole molecular architectures from some simple starting materials.

Introduction

Fused-indoles have received much attention because of the broad scope of their biological activities, and they are found in a large number of natural products and bioactive molecules.[1] In particular, tetracyclic indoles that contain a seven-membered ring represent a common structural motif present in a variety of bioactive compounds, such as anticancer compounds **a** and **b**,[2] and antimicrobial compound **c**[3] (Scheme 1). Therefore, developing efficient methods for the construction of these tetracyclic indoles is a priority. However, the available strategies for the synthesis of these compounds are limited,[4] and these synthetic challenges inspired us to explore various efficient strategies for achieving these intriguing molecules. It has been well documented that the C2- and C3-positions of an indole are the active positions for the reactivity,[5] which can serve as a double nucleophile in the proposed sequence and, therefore, provide many opportunities to construct diversified fused-indole derivatives. Commonly, indole 3-derivatization could be performed by the Michael addition[6] of indoles with α,β-unsaturated compounds in the presence of a protic or Lewis acid, such as SmI_3, $ScCO_2$, $CeCl_3{\cdot}7H_2O$–NaI/SiO_2, Yb(OTf)$_3$, $InCl_3$, $InBr_3$, and I_2. However, long reaction times are often required in these transformations,[7] and most of these reactions must be carried out in organic solvents.



Scheme 1 The active molecules of tetracyclic indoles.

Within the framework of green chemistry,[8] microwaves and water have emerged as attractive tools for the rapid and environmental friendly construction of these unusual compounds.[9] Water is one of the most benign solvents, and often has an unprecedented effect on the rate and selectivity of organic reactions through hydrophobic interactions and the enrichment of organic substrates in the local hydrophobic environment.[10] However, water is rarely used in transition metal catalysis because many catalysts are highly sensitive towards moisture.[11] In our previous research, we have successfully developed an efficient and regioselective method for the synthesis of indole derivatives *via* gold-catalyzed intramolecular hydroamination in water under microwave irradiation.[12] In the light of our ongoing efforts to develop new methods for synthesizing potential bioactive fused-polycyclic compounds using green reaction conditions, we here report our recent findings of the chemoselective- and regioselective synthesis of tetracyclic indole derivatives containing a seven-membered ring by means of a gold-catalyzed Michael addition/intramolecular annulation cascade in water using microwave irradiation.

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†Electronic supplementary information (ESI) available: Copies of ^{1}H and ^{13}C NMR spectra for target compounds. CCDC 894928 (**3Ba**). For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/c2gc36301a

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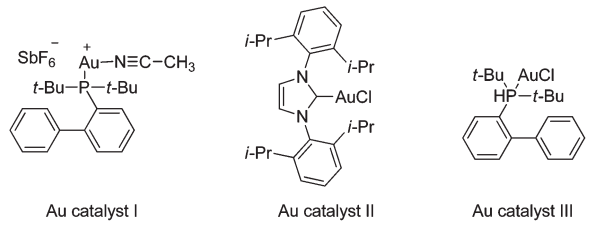
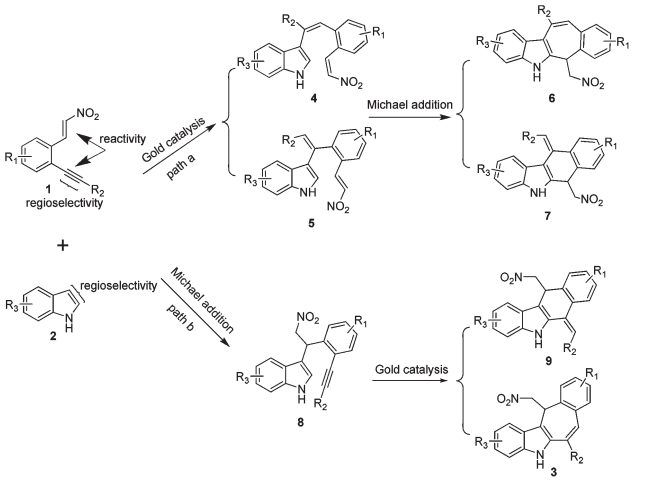
Results and discussion

We initiated our studies by examining catalyst and reaction conditions using the *ortho*-phenylethynyl substituted nitrostyrene **1A** and indole (**2a**) as a model substrate. As shown in Table 1, we firstly explored the reaction of the starting material **1A** with unsubstituted indole (**2a**) under the condition of using 10 mol% of Au catalyst I that is (acetonitrile)[(2-biphenyl)di-*tert*-butylphosphine]gold(I)hexafluoroantimonate (Scheme 2) as a catalyst at 100 °C for 20 min in water using microwave irradiation, but the desirable product **3Aa** was not detected (Table 1, entry 1). However, we were surprised to observe the expected fused-tetracyclic indole product with 27% yield when a catalytic amount of TFA (20 mol%) was used as an additive (Table 1, entry 2). The yield could be improved to 86% by increasing the reaction temperature to 120 °C (Table 1, entry 3).

However, a further elevation of the temperature to 140 °C did not improve the yield of this transformation (Table 1, entry 4). It was apparent that the reaction time had a significant influence on the yield of this reaction. Only 53% yield was obtained when the reaction time was shortened to 10 min (Table 1, entry 5). It was reported that the C3-position of an indole is the most reactive among three reactive positions (N1, C2, C3) of indole.[5] Therefore, in principle, as shown in Scheme 3, there are two possible reaction pathways to construct four products for this tandem cyclization from the starting material **1** and indole: (a) the formation of intermediates **4** and/or **5** *via* gold-catalyzed hydroarylation, which are subsequently cyclized to give products **6** and/or **7** *via* a further Michael addition; (b) the first formation of the key intermediate **8** *via* a Lewis acid mediated Michael addition, and further cyclizing to the compounds **3** and/or **9** *via* gold-catalyzed intramolecular hydroarylation. However, ^{1}H NMR, ^{13}C NMR, mass spectroscopy and X-ray crystallography (as shown in Fig. 1) demonstrated that the final product is the expected structure **3**, and no other products were detected. Subsequently, other protic acids, such as PhCOOH, $ClCH_2COOH$ and CH_3COOH, were screened as the additive for this transformation, and did not catalyze the cascade cyclization (Table 1, entries 6–8). However, it seems that TsOH was slightly effective for this reaction (Table 1, entry 9). Different gold catalysts such as AuCl(PPh_3), $NaAuCl_4$, Au catalyst II and Au catalyst III were also tested in this system (Table 1, entries 10–13), but Au catalyst I was proved to be the most effective catalyst for the transformation. In the absence of Au catalyst I, the product **3Aa** was not detected when only TFA was used as the catalyst (Table 1,

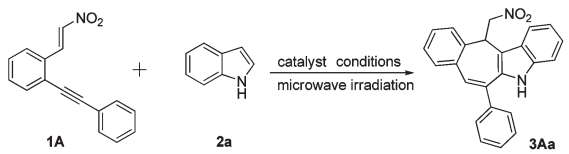


Scheme 2 The structure of the Au catalysts.



Scheme 3 The 6-*exo* and 7-*endo* cyclization pathways.

Table 1 Optimization of the reaction conditions[a]



Entry	Catalyst system	Additive	Solvent	Yield (%)
1	Au catalyst I	—	H_2O	0[b]
2	Au catalyst I	TFA	H_2O	27[c]
3	Au catalyst I	TFA	H_2O	86
4	Au catalyst I	TFA	H_2O	83[d]
5	Au catalyst I	TFA	H_2O	53[e]
6	Au catalyst I	PhCOOH	H_2O	0
7	Au catalyst I	$ClCH_2COOH$	H_2O	0
8	Au catalyst I	CH_3COOH	H_2O	0
9	Au catalyst I	TsOH	H_2O	52
10	AuCl(PPh_3)	TFA	H_2O	25
11	$NaAuCl_4 \cdot 2H_2O$	TFA	H_2O	5
12	Au catalyst II	TFA	H_2O	70[f]
13	Au catalyst III	TFA	H_2O	71[g]
14	—	TFA	H_2O	0
15	AgOTf	TFA	H_2O	0
16	$Yb(OTf)_3$	TFA	H_2O	0
17	$AgSbF_6$	TFA	H_2O	0
18	Au catalyst I	TFA	Toluene	74
19	Au catalyst I	TFA	DMF	30
20	Au catalyst I	TFA	THF	23
21	Au catalyst I	TFA	Toluene–H_2O	0[h]
22	Au catalyst I	TFA	H_2O	59[i]

[a] *Reaction conditions*: **1A** (0.2 mmol), **2a** (0.3 mmol), catalyst (0.02 mmol), additive (0.04 mmol), water (3 mL) under 120 °C for 20 min. [b] Au catalyst I = (acetonitrile)[(2-biphenyl)di-*tert*-butylphosphine]gold(I)hexafluoroantimonate. [c] Reaction was performed at 100 °C. [d] Reaction was performed at 140 °C. [e] The reaction time was shortened to 10 min. [f] Au catalyst II = 1,3-bis(2,6-diisopropylphenyl imidazol-2-ylidene)gold(I) chloride. [g] Au catalyst III = chloro[(1,1′-biphenyl-2-yl)di-*tert*-butylphosphine]gold(I). [h] Toluene–H_2O (v/v) = 1 : 1. [i] Reaction was performed at 120 °C in water using an oil bath for 14 h.

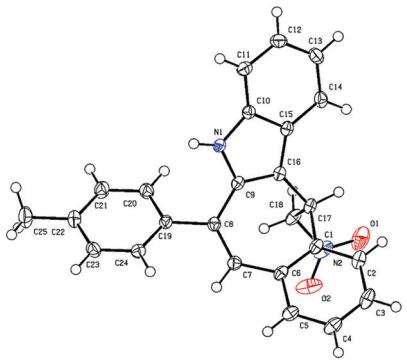


Fig. 1 X-ray crystal structure of **3Ba**.

entry 14). Some other Lewis acids, such as $AgSbF_6$, AgOTf and $Yb(OTf)_3$, were also considered, and the results demonstrated that they could not also catalyze this cascade cyclization to form the desired products either (Table 1, entries 15–17). It was also found that the reaction solvent has a significant action on the yield of this domino transformation. When toluene, DMF and THF were used as the solvent instead of H_2O, the yields of the desired product **3Aa** were decreased to 74%, 30% and 23%, respectively (Table 1, entries 18–20). This was most probably because the water facilitates the organic reaction by significant factors such as a hydrophobic effect, enhanced hydrogen bonding in the transition state and cohesive energy density.[13] When the reaction was performed in the mixed solvent of toluene–water (1 : 1, v/v), no product was detected (Table 1, entry 21), which was most likely due to the mixed solvent reducing the chemical interactions between reactants and catalysts. When we performed this transformation under the traditional heating condition, a long reaction time (14 h) was needed to finish this reaction, and only 59% of the target product was isolated (Table 1, entry 22).

After determining the optimized conditions (10 mol% Au catalyst I, 20 mol% TFA, H_2O, MW, 120 °C for 20 min), we examined the cascade process, as shown in Table 2. Firstly, a variety of *ortho*-alkyne substituted nitrostyrenes including aryl-alkyne substituted, heterocycle-alkyne substituted and alkyl-alkyne substituted nitrostyrenes were tolerant and could provide the desired products (**3Aa–3Ha**) in moderate to good yields (53–87%) (Table 2, entries 1–9). It seems that aryl-alkyne substituted nitrostyrenes are more suitable for the cyclization transformation (Table 2, entries 1–6). Moderate yields could be observed for heterocyclic and aliphatic alkyne substituted nitrostyrenes (Table 2, entries 7–9).

We further examined the extent of the action of the substrate using a variety of different indoles (Table 2, entries 10–16). These investigations revealed that the yield of the cascade cyclization was slightly affected by the electronic properties of the R_3 substituents of the indole ring. Relatively low yields were observed for the indoles bearing halogens (Table 2, entries 10–12).

When methoxy, methyl and cyano groups were introduced into the indole ring, the desired products were obtained with high yields (Table 2, entries 13–16). Subsequently, we prepared substrates **1J–1M** by introducing fluoro and methyl groups into the different positions of *ortho*-phenylethynyl substituted nitrostyrene (**1A**). Results of further investigations demonstrated that all the substrates tested were tolerated in this cascade transformation with good to excellent yields (Table 2, entries 17–28). However, treatment of substituted nitrostyrenes with 5-fluoro and 4-methyl indoles resulted in a slight reduction in the yield of the target compounds (Table 2, entries 18, 20 and 25). We speculate that it is due to electronic effects and/or steric effects of these substituents. In the light of these findings, this cascade transformation would be an effective and rapid strategy for the synthesis of intriguing fused tetracyclic indole molecular scaffolds.

Based on our previous knowledge and the results of our present study, we propose a plausible mechanism for construction of the tetracyclic indole frameworks. As shown in Scheme 4, TFA is a strong Lewis acid and it catalyzes the addition of indoles to nitroolefins first. The intermediate **8** which has been isolated by stopping the reaction at 5 min confirmed our conjecture. The results clearly showed that the Michael reaction selectively occurred at the C3-position of the indole ring. The intramolecular cyclization of **8** catalyzed by AuL/TFA proceeded smoothly to provide the desired product **3**. The results strongly supported our assumption that **3** was formed through Au(I)-catalyzed cyclization of enyne **8** in the one-pot procedure. We propose that the initial Au(I)-assisted electrophilic activation of the triple bond triggers a Friedel–Crafts-type alkylation at the C3-position of the indole ring, with the formation of spirocyclic derivative **11**.[14] The intermediate **11** can rearrange through a 1,2-shift to form the seven-membered-ring compound **12**, which would lose a proton, and then form compound **3** by protodemetalation.[15]

Conclusion

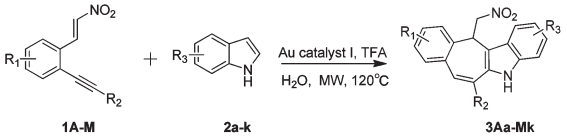
In summary, we have developed a new and environmentally friendly Au(I)/TFA-catalyzed regioselective one-pot cascade for the synthesis of tetracyclic indoles containing a seven-membered ring. The reaction can be performed in aqueous media using microwave irradiation, which reveals excellent tolerance to various substrates, and the target compounds can be obtained with good to excellent yields. In view of a large number of bioactivities involving fused-indole scaffolds, we expect that these potential special structures will have wide applicability in medicinal chemistry. Further studies are being undertaken, and the corresponding results will be reported in due course.

Experimental section

General experimental procedures

The reagents were purchased from commercial sources and used without further purification. Analytical thin layer

Table 2 Gold-mediated one-pot domino synthesis of target compounds[a]



1A-M 2a-k 3Aa-Mk

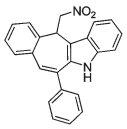
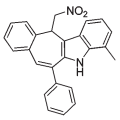
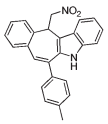
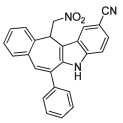
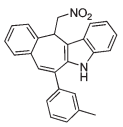
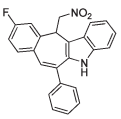
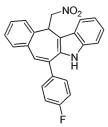
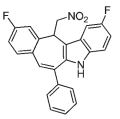
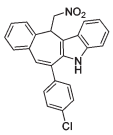
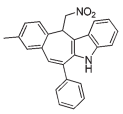
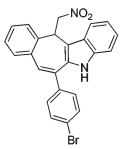
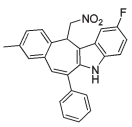
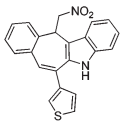
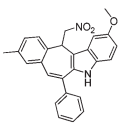
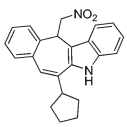
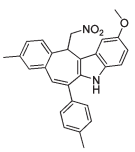
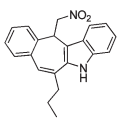
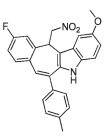
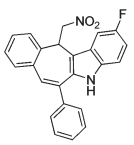
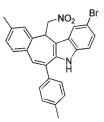
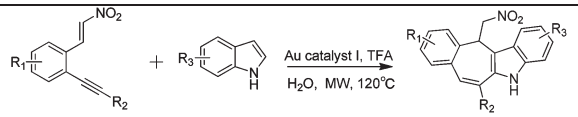
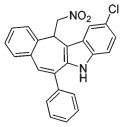
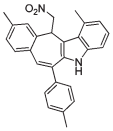
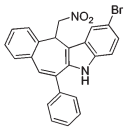
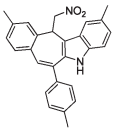
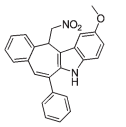
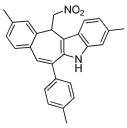
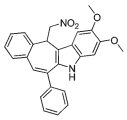
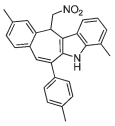
Entry	Product		Yield (%)	Entry	Product		Yield (%)
1		**3Aa**	86	15		**3Ah**	90
2		**3Ba**	84	16		**3Af**	85
3		**3Fa**	87	17		**3Ja**	94
4		**3Ca**	71	18		**3Jb**	71
5		**3Da**	64	19		**3Ka**	79
6		**3Ea**	74	20		**3Kb**	59
7		**3Ia**	63	21		**3Ke**	85
8		**3Ga**	76	22		**3Me**	95
9		**3Ha**	53	23		**3Le**	86
10		**3Ab**	65	24		**3Md**	86

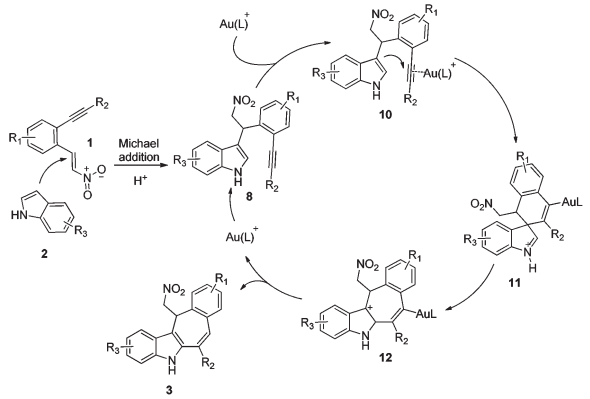
Table 2 *(Contd.)*



1A-M 2a-k 3Aa-Mk

Entry	Product		Yield (%)	Entry	Product		Yield (%)
11		**3Ac**	62	25		**3Mh**	66
12		**3Ad**	78	26		**3Mi**	91
13		**3Ae**	87	27		**3Mj**	84
14		**3Ag**	78	28		**3Mk**	87

[a] *Reagents and conditions*: **1A** (0.2 mmol), **2a** (0.3 mmol), Au catalyst I (10 mol%), TFA (20 mol%), H_2O (3–4 mL), M.W. irradiation (120 °C, 20 min).



Scheme 4 A proposed mechanism.

chromatography (TLC) was performed on HSGF 254 (0.15–0.2 mm thickness). All the microwave-assisted reactions were performed in an Initiator™ EXP microwave system (Biotage, Inc.) at the specified temperature using the standard mode of operation. Column chromatography was performed with a Combi*Flash*® Companion system (Teledyne Isco, Inc.). Proton and carbon magnetic resonance spectra (^{1}H NMR and ^{13}C NMR) were recorded using tetramethylsilane (TMS) in the solvent of $CDCl_3$ as the internal standard (^{1}H NMR: TMS at 0.00 ppm; $CHCl_3$ at 7.24 ppm; ^{13}C NMR: $CDCl_3$ at 77.0 ppm). Low- and high-resolution mass spectra (LRMS and HRMS) were measured on a Finnigan MAT 95 spectrometer.

Typical procedure for synthesis of the 12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indoles (3Aa as an example) in water. To a mixture of (*E*)-1-(2-nitrovinyl)-2-(phenylethynyl)benzene (**1A**, 0.2 mmol) and indole (**2a**, 0.3 mmol) in 3 mL of H_2O was added Au catalyst I (0.02 mmol) and trifluoroethanoic acid (0.04 mmol). The reaction vial was sealed and the mixture was then irradiated at 120 °C for 20 min. After cooling to ambient temperature, the mixture was concentrated in vacuum, and the resulting residue was purified by flash chromatography (petroleum ether–ethyl acetate = 10 : 1, v/v) to afford the expected product **3Aa** (64 mg, 87%) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (s, 1H), 7.86 (d, J = 3.2 Hz, 1H), 7.64–7.59 (m, 2H), 7.53–7.34 (m, 7H), 7.24–7.12 (m, 4H), 5.39 (t, J = 8.0 Hz, 1H), 4.64 (d, J = 8.4 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 145.0, 139.7, 136.8, 135.1, 134.3, 133.8, 131.8, 131.4, 129.9, 129.9, 129.6, 129.1, 128.9, 128.8, 127.3, 126.3, 123.5, 120.3, 118.2, 112.9, 111.0, 75.0, 41.4; LRMS (ESI) m/z 367 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{18}N_2O_2Na$ $[M + Na]^+$ 389.1266, found 389.1264.

12-(Nitromethyl)-6-(*p*-tolyl)-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Ba). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95–7.88 (m, 2H), 7.52–7.45 (m, 4H), 7.40–7.26 (m, 4H), 7.24–7.21 (m, 3H), 7.17 (s, 1H), 5.41 (t, J = 8.0 Hz, 1H), 4.64

(d, J = 8.0 Hz, 2H), 2.48 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.7, 136.7, 136.6, 135.0, 134.4, 133.6, 131.9, 131.2, 129.8, 129.6, 129.4, 129.3, 128.7, 127.2, 126.2, 123.4, 120.2, 118.1, 112.6, 110.9, 74.9, 41.4, 21.2; LRMS (ESI) m/z 381 $[M + H]^+$; HRMS (ESI) calcd for $C_{25}H_{20}N_2O_2Na$ $[M + Na]^+$ 403.1422, found 403.1435.

12-(Nitromethyl)-6-(4-fluorophenyl)-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ca). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88–7.86 (m, 2H), 7.58–7.56 (m, 2H), 7.51–7.45 (m, 2H), 7.42–7.39 (m, 2H) 7.26–7.21 (m, 5H), 7.13 (s, 1H), 5.41 (t, J = 8.4 Hz, 1H), 4.68–4.58 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.1 (d, J = 251 Hz), 136.8, 135.8 (d, J = 2.5 Hz), 135.1, 134.2, 132.7, 131.7, 131.3, 130.6 (d, J = 7.5 Hz), 129.9 (d, J = 12.5 Hz), 127.3, 126.3, 123.7, 120.5, 118.2, 116.2, 116.0, 113.0, 111.1, 74.9, 41.4; ^{19}F NMR (471 MHz, $CDCl_3$) δ = −112.65 ppm; LRMS (ESI) m/z 385 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{17}N_2O_2NaF$ $[M + Na]^+$ 407.1172, found 407.1183.

12-(Nitromethyl)-6-(4-chlorophenyl)-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Da). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.88–7.85 (m, 2H), 7.56–7.43 (m, 6H), 7.41–7.34 (m, 2H), 7.26–7.20 (m, 3H), 7.15 (s, 1H), 5.41 (t, J = 8.4 Hz, 1H), 4.62 (dd, J = 8.4, 3.0 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.1, 136.9, 135.2, 134.8, 134.1, 132.6, 131.4, 131.4, 130.2, 130.0, 129.9, 129.9, 129.3, 127.3, 126.3, 123.7, 120.5, 118.2, 113.2, 111.0, 75.0, 41.4; LRMS (ESI) m/z 401 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{17}N_2O_2NaCl$ $[M + Na]^+$ 423.0876, found 423.0896.

12-(Nitromethyl)-6-(4-bromophenyl)-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ea). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.88–7.86 (m, 2H), 7.66–7.63 (m, 2H), 7.51–7.34 (m, 6H), 7.26–7.20 (m, 3H), 7.15 (s, 1H), 5.41 (t, J = 8.4 Hz, 1H), 4.62 (dd, J = 8.4, 3.0 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.6, 136.9, 135.2, 134.1, 132.6, 132.2, 131.4, 131.3, 130.5, 130.0, 129.9, 127.3, 126.3, 123.8, 122.9, 120.5, 118.2, 113.3, 111.1, 75.0, 41.4; LRMS (ESI) m/z 445 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{17}N_2O_2NaBr$ $[M + Na]^+$ 467.0371, found 467.0353.

12-(Nitromethyl)-6-(*m*-tolyl)-5,12-dihydrobenzo[4,5]cyclo-hepta[1,2-*b*]indole (3Fa). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.94–7.87 (m, 2H), 7.53–7.40 (m, 2H), 7.39–7.30 (m, 6H), 7.26–7.21 (m, 3H), 7.17 (s, 1H), 5.42 (t, J = 8.1 Hz, 1H), 4.65 (d, J = 8.1 Hz, 2H), 2.47 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 139.7, 138.8, 136.8, 135.1, 134.4, 133.9, 132.0, 131.4, 129.9, 129.8, 129.6, 129.5, 129.5, 129.0, 127.3, 126.3, 126.0, 123.5, 120.3, 118.2, 112.7, 111.1, 75.0, 41.4, 21.6; LRMS (ESI) m/z 381 $[M + H]^+$; HRMS (ESI) calcd for $C_{25}H_{20}N_2O_2Na$ $[M + Na]^+$ 403.1422, found 403.1425.

2-Fluoro-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ab). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (s, 1H), 7.60 (d, J = 6.8 Hz, 2H), 7.56–7.30 (m, 8H), 7.26–7.17 (m, 2H), 6.93 (dd, J = 9.2, 2.4 Hz, 1H), 5.30 (t, J = 8.0 Hz, 1H), 4.67–4.56 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 158.2 (d, J = 235 Hz), 139.5, 135.0, 134.3, 133.6 (d, J = 8 Hz), 133.3, 131.5, 130.4, 129.8 (d, J = 2.5 Hz), 129.1, 128.9, 127.4, 126.8 (d, J = 10 Hz), 112.8 (d, J = 5 Hz), 112.2, 112.0, 111.8, 111.8, 103.2, 103.0, 75.0, 41.5; ^{19}F NMR (471 MHz, $CDCl_3$) δ = −122.99 ppm; LRMS (ESI) m/z 385 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{17}N_2O_2NaF$ $[M + Na]^+$ 407.1172, found 407.1164.

2-Chloro-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ac). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (s, 1H), 7.82 (s, 1H), 7.60–7.58 (m, 2H), 7.54–7.49 (m, 4H), 7.46–7.40 (m, 3H), 7.18 (s, 1H), 7.14 (t, J = 1.2 Hz, 2H), 5.31 (t, J = 8.4 Hz, 1H), 4.68–4.56 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 139.4, 135.0, 134.9, 134.2, 133.5, 133.2, 131.5, 130.6, 129.9, 129.8, 129.1, 128.9, 128.8, 127.5, 127.4, 126.1, 123.8, 117.7, 112.3, 112.1, 74.9, 41.4; LRMS (ESI) m/z 401 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{17}N_2O_2NaCl$ $[M + Na]^+$ 423.0876, found 423.0896.

2-Bromo-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ad). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99–7.97 (m, 2H), 7.60–7.58 (m, 2H), 7.54–7.42 (m, 4H), 7.40–7.35 (m, 3H), 7.27–7.25 (m, 1H), 7.19 (s, 1H), 7.07 (d, J = 8.4 Hz, 1H), 5.31 (t, J = 8.4 Hz, 1H), 4.68–4.56 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 139.4, 135.3, 134.9, 134.2, 133.4, 133.0, 131.5, 130.6, 129.9, 129.8, 129.2, 128.9, 128.8, 128.1, 127.5, 126.3, 120.8, 113.6, 112.5, 112.2, 74.8, 41.3; LRMS (ESI) m/z 445 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{17}N_2O_2NaBr$ $[M + Na]^+$ 467.0371, found 467.0371.

2-Methoxy-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ae). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (s, 1H), 7.61–7.60 (m, 2H), 7.53–7.47 (m, 5H), 7.40–7.34 (m, 2H), 7.27–7.26 (m, 1H), 7.14–7.11 (m, 2H), 6.89 (dd, J = 8.8, 2.4 Hz, 1H), 5.35 (t, J = 8.0 Hz, 1H), 4.64 (d, J = 8.0 Hz, 2H), 3.95 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 154.6, 139.8, 135.1, 134.4, 133.9, 132.6, 132.1, 131.4, 129.9, 129.6, 129.6, 129.0, 128.9, 128.7, 127.3, 126.7, 114.3, 112.6, 111.9, 99.4, 75.2, 56.0, 41.6; LRMS (ESI) m/z 397 $[M + H]^+$; HRMS (ESI) calcd for $C_{25}H_{20}N_2O_3Na$ $[M + Na]^+$ 419.1372, found 419.1368.

2-Carbonitrile-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo-[4,5]cyclohepta[1,2-*b*]indole (3Af). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.26 (s, 1H), 8.21 (s, 1H), 7.60–7.57 (m, 2H), 7.56–7.38 (m, 8H), 7.30–7.25 (m, 2H), 5.35 (t, J = 8.0 Hz, 1H), 4.74–4.55 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 139.0, 138.1, 134.6, 134.1, 134.0, 133.1, 131.6, 131.5, 130.3, 129.8, 129.3, 129.1, 128.8, 127.7, 126.4, 126.1, 123.9, 120.4, 113.0, 111.9, 103.6, 74.6, 41.1; LRMS (ESI) m/z 392 $[M + H]^+$; HRMS (ESI) calcd for $C_{25}H_{17}N_3O_2Na$ $[M + Na]^+$ 414.1218, found 414.1216.

2,3-Dimethoxy-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo-[4,5]cyclohepta[1,2-*b*]indole (3Ag). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (s, 1H), 7.61–7.59 (m, 2H), 7.52–7.48 (m, 5H), 7.39–7.33 (m, 2H), 7.26–7.22 (m, 1H), 7.06 (s, 1H), 6.74 (s, 1H), 5.31 (t, J = 8.0 Hz, 1H), 4.63 (dd, J = 8.4, 3.2 Hz, 2H), 4.04 (s, 3H), 3.86 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.3, 145.7, 140.0, 134.7, 134.6, 133.8, 131.6, 131.3, 130.6, 129.8, 129.3, 128.9, 128.9, 128.6, 128.1, 127.2, 119.1, 112.8, 99.4, 94.0, 75.1, 56.5, 56.1, 41.7, 30.9, 30.9; LRMS (ESI) m/z 427 $[M + H]^+$; HRMS (ESI) calcd for $C_{26}H_{22}N_2O_4Na$ $[M + Na]^+$ 449.1477, found 449.1456.

4-Methyl-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ah). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79–7.73 (m, 2H), 7.66–7.64 (m, 2H), 7.57–7.50 (m, 5H), 7.47–7.26 (m, 2H), 7.20–7.14 (m, 2H), 7.04–7.02 (m, 1H), 5.40

(t, J = 8.0 Hz, 1H), 4.65 (d, J = 8.4 Hz, 2H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.7, 136.4, 135.2, 134.3, 133.8, 131.4, 131.2, 129.8, 129.7, 129.5, 129.0, 128.7, 127.2, 125.8, 124.1, 120.5, 120.2, 115.8, 113.6, 74.9, 41.5, 16.5; LRMS (ESI) m/z 381 $[M + H]^+$; HRMS (ESI) calcd for $C_{25}H_{20}N_2O_2Na$ $[M + Na]^+$ 403.1422, found 403.1439.

12-(Nitromethyl)-6-(thiophen-3-yl)-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ia). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (s, 1H), 7.88–7.86 (m, 1H), 7.58 (dd, J = 3.0, 1.5 Hz, 1H), 7.51–7.39 (m, 5H), 7.38–7.22 (m, 5H), 5.39 (t, J = 8.0 Hz, 1H), 4.63–4.60 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 140.8, 136.6, 135.2, 134.2, 131.7, 131.3, 129.9, 129.6, 128.9, 128.2, 127.8, 127.2, 126.8, 126.3, 124.0, 123.6, 120.4, 118.2, 112.6, 111.0, 74.9, 41.3; LRMS (ESI) m/z 373 $[M + H]^+$; HRMS (ESI) calcd for $C_{22}H_{16}N_2O_2NaS$ $[M + Na]^+$ 395.0830, found 395.0841.

12-(Nitromethyl)-6-cyclopentyl-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Ga). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.22 (s, 1H), 7.86–7.83 (m, 1H), 7.43–7.19 (m, 7H), 6.95 (s, 1H), 5.30 (t, J = 8.1 Hz, 1H), 4.58–4.45 (m, 2H), 3.18–3.13 (m, 1H), 2.15 (t, J = 6.2 Hz, 2H), 1.99–1.77 (br, 5H), 1.58–1.55 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 136.7, 135.9, 134.8, 134.4, 133.3, 131.0, 129.6, 128.9, 127.0, 126.3, 125.5, 123.2, 120.3, 118.1, 112.1, 110.9, 74.6, 44.3, 41.2, 33.3, 31.6, 25.1, 24.8; LRMS (ESI) m/z 359 $[M + H]^+$; HRMS (ESI) calcd for $C_{23}H_{22}N_2O_2Na$ $[M + Na]^+$ 381.1579, found 381.1574.

12-(Nitromethyl)-6-propyl-5,12-dihydrobenzo[4,5]cyclohepta-[1,2-*b*]indole (3Ha). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.18 (s, 1H), 7.86–7.83 (m, 1H), 7.41–7.21 (m, 7H), 6.92 (s, 1H), 5.30 (t, J = 8.1 Hz, 1H), 4.60–4.45 (m, 2H), 2.83 (br, 1H), 2.64–2.54 (m, 1H), 1.70 (br, 2H), 1.08 (t, J = 7.2 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 136.8, 134.6, 134.3, 132.7, 132.4, 130.9, 129.8, 129.1, 128.8, 127.2, 126.5, 123.3, 120.3, 118.1, 112.1, 111.0, 74.8, 41.4, 38.1, 22.7, 14.1; LRMS (ESI) m/z 333 $[M + H]^+$; HRMS (ESI) calcd for $C_{21}H_{20}N_2O_2Na$ $[M + Na]^+$ 355.1422, found 355.1419.

10-Fluoro-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ja). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (s, 1H), 7.86–7.84 (m, 1H), 7.60–7.58 (m, 2H), 7.50–7.46 (m, 4H), 7.26–7.16 (m, 4H), 7.13 (s, 1H), 7.05–7.04 (m, 1H), 5.34 (t, J = 8.0 Hz, 1H), 4.66–4.63 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.2 (d, J = 257 Hz), 162.3, 139.5, 137.1, 137.0, 136.7, 133.3, 133.2, 133.1, 131.8, 130.6 (d, J = 3 Hz), 129.1, 128.8 (d, J = 9 Hz), 128.7, 126.1, 123.6, 120.4, 118.0, 116.5 (d, J = 22 Hz), 114.5 (d, J = 21 Hz), 111.9, 111.0, 74.6, 41.1; ^{19}F NMR (471 MHz, $CDCl_3$) δ = −112.25 ppm; LRMS (ESI) m/z 385 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{17}N_2O_2FNa$ $[M + Na]^+$ 407.1172, found 407.1187.

9-Methyl-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]-cyclohepta[1,2-*b*]indole (3Ka). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89–7.86 (m, 2H), 7.61–7.59 (m, 2H), 7.54–7.47 (m, 3H), 7.34–7.31 (m, 2H), 7.26–7.19 (m, 4H), 7.13 (s, 1H), 5.37 (t, J = 8.0 Hz, 1H), 4.61 (dd, J = 8.4, 1.2 Hz, 2H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.8, 136.8, 136.7, 134.1, 133.6, 132.4, 131.8, 130.5, 130.0, 129.8, 129.0, 128.8, 128.6, 126.3, 123.4, 120.2, 118.1, 113.0, 110.9, 75.2, 41.0, 20.9; LRMS (ESI) m/z 381 $[M + H]^+$; HRMS (ESI) calcd for $C_{25}H_{20}N_2O_2Na$ $[M + Na]^+$ 403.1422, found 403.1407.

2,10-Difluoro-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo-[4,5]cyclohepta[1,2-*b*]indole (3Jb). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (s, 1H), 7.59–7.46 (m, 7H), 7.26–7.13 (m, 3H), 7.07–7.03 (m, 1H), 6.99–6.94 (m, 1H), 5.23 (t, J = 8.0 Hz, 1H), 4.65–4.61 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.3 (d, J = 249 Hz), 158.4 (d, J = 235 Hz), 139.3, 136.9 (d, J = 7 Hz), 133.5, 133.3, 133.2 (d, J = 18 Hz), 130.5 (d, J = 3 Hz), 129.1, 129.0 (d, J = 24 Hz), 128.8, 126.6 (d, J = 10 Hz), 116.5 (d, J = 22 Hz), 114.6 (d, J = 22 Hz), 112.3, 112.1, 111.9 (d, J = 4 Hz), 111.9 (d, J = 8 Hz), 103.1, 102.9, 74.5, 41.2; ^{19}F NMR (471 MHz, $CDCl_3$) δ = −111.83, −122.69 ppm; LRMS (ESI) m/z 403 $[M + H]^+$; HRMS (ESI) calcd for $C_{24}H_{16}N_2O_2NaF_2$ $[M + Na]^+$ 425.1078, found 425.1096.

2-Bromo-10-methyl-12-(nitromethyl)-6-(*p*-tolyl)-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Md). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.97–7.94 (m, 2H), 7.48–7.46 (d, J = 7.8 Hz, 2H), 7.33–7.12 (m, 6H), 7.12–7.06 (m, 2H), 5.26 (t, J = 8.1 Hz, 1H), 4.63–4.58 (m, 2H), 2.46 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.9, 137.1, 136.6, 135.2, 134.1, 133.3, 133.1, 132.4, 131.9, 130.6, 130.3, 129.8, 129.8, 128.7, 128.1, 126.2, 120.8, 113.5, 112.4, 112.2, 75.1, 40.9, 21.3, 20.9; LRMS (ESI) m/z 473 $[M + H]^+$; HRMS (ESI) calcd for $C_{26}H_{21}N_2O_2NaBr$ $[M + Na]^+$ 495.0684, found 495.0710.

2-Fluoro-9-methyl-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Kb). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (s, 1H), 7.60–7.58 (m, 2H), 7.54–7.46 (m, 4H), 7.35–7.31 (m, 2H), 7.26–7.21 (m, 1H), 7.15–7.13 (m, 2H), 6.97–6.94 (m, 1H), 5.25 (t, J = 8.4 Hz, 1H), 4.68–4.55 (m, 2H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.1 (d, J = 235 Hz), 139.6, 137.0, 134.0, 133.5, 133.4 (d, J = 9 Hz), 132.3, 131.9, 130.5 (d, J = 19 Hz), 129.7, 129.1, 128.8 (d, J = 4 Hz), 126.8 (d, J = 9 Hz), 113.0 (d, J = 6 Hz), 112.0, 111.8, 111.7, 111.6, 103.2 (d, J = 23 Hz), 75.1, 41.1, 20.9; ^{19}F NMR (471 MHz, $CDCl_3$) δ = −123.09 ppm; LRMS (ESI) m/z 399 $[M + H]^+$; HRMS (ESI) calcd for $C_{25}H_{19}N_2O_2NaF$ $[M + Na]^+$ 421.1325, found 421.1328.

2-Methoxy-9-methyl-12-(nitromethyl)-6-phenyl-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Ke). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (s, 1H), 7.60–7.58 (m, 2H), 7.53–7.46 (m, 3H), 7.36–7.21 (m, 4H), 7.13–7.09 (m, 2H), 6.86 (dd, J = 8.8, 2.4 Hz, 1H), 5.31 (t, J = 8.4 Hz, 1H), 4.63 (d, J = 8.4 Hz, 2H), 4.95 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.5, 139.8, 136.8, 134.2, 133.7, 132.5, 132.4, 132.0, 131.8, 130.3, 129.8, 129.7, 128.9, 128.8, 128.6, 126.6, 114.1, 112.7, 111.8, 99.3, 75.3, 55.9, 41.1, 20.9; LRMS (ESI) m/z 411 $[M + H]^+$; HRMS (ESI) calcd for $C_{26}H_{22}N_2O_3Na$ $[M + Na]^+$ 433.1528, found 433.1507.

2-Methoxy-10-fluoro-12-(nitromethyl)-6-(*p*-tolyl)-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Le). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 (s, 1H), 7.48–7.44 (m, 3H), 7.32–7.30 (d, J = 7.6 Hz, 2H), 7.26–7.00 (m, 5H), 6.87 (dd, J = 8.8, 2.4 Hz, 1H), 5.27 (t, J = 8.4 Hz, 1H), 4.69–4.60 (m, 2H), 3.95 (s, 3H), 2.46 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.4 (d, J = 249 Hz), 154.7, 138.8, 137.0 (d, J = 7 Hz), 136.7, 133.3, 133.1 (d, J = 8 Hz), 132.7, 132.0, 130.8 (d, J = 3 Hz), 129.7, 128.8, 127.9, 126.5, 116.6 (d, J = 22 Hz), 114.5 (d, J = 23 Hz), 112.0, 111.6 (d, J = 5 Hz), 99.2, 74.7, 56.0, 41.2, 21.3; ^{19}F NMR (471 MHz, $CDCl_3$)

δ = −112.64 ppm; LRMS (ESI) *m*/*z* 429 $[M + H]^+$; HRMS (ESI) calcd for $C_{26}H_{21}N_2O_3NaF$ $[M + Na]^+$ 451.1434, found 451.1439.

2-Methoxy-9-methyl-12-(nitromethyl)-6-(*p*-tolyl)-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Me). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (s, 1H), 7.50–7.48 (m, 2H), 7.36–7.30 (m, 4H), 7.26–7.18 (m, 2H), 7.12–7.07 (m, 2H), 6.88–7.85 (dd, *J* = 8.8, 2.4 Hz, 1H), 5.30 (t, *J* = 8.4 Hz, 1H), 4.62 (d, *J* = 8.4 Hz, 2H), 3.95 (s, 3H), 2.46 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 154.6, 138.7, 137.0, 136.8, 134.3, 133.7, 132.8, 132.4, 132.0, 131.8, 130.3, 129.8, 129.7, 129.2, 128.8, 126.7, 114.0, 112.6, 111.8, 99.4, 75.3, 56.0, 41.2, 27.0, 21.3, 20.9; LRMS (ESI) *m*/*z* 425 $[M + H]^+$; HRMS (ESI) calcd for $C_{27}H_{24}N_2O_3Na$ $[M + Na]^+$ 447.1685, found 447.1669.

1-Methyl-9-methyl-12-(nitromethyl)-6-(*p*-tolyl)-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Mh). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (s, 1H), 7.52–7.50 (m, 2H), 7.38–7.32 (m, 4H), 7.21–7.19 (m, 1H), 7.13 (s, 1H), 7.06–7.05 (m, 2H), 6.89 (m, 1H), 5.84 (t, *J* = 8.0 Hz, 1H), 4.76–4.59 (m, 2H), 3.00 (s, 3H), 2.47 (s, 3H), 2.38 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.7, 137.1, 137.0, 136.8, 134.2, 133.9, 133.2, 132.1, 131.5, 130.6, 130.2, 129.7, 129.6, 129.1, 128.8, 124.5, 123.2, 122.4, 113.8, 109.1, 75.1, 42.3, 21.3, 21.0; LRMS (ESI) *m*/*z* 409 $[M + H]^+$; HRMS (ESI) calcd for $C_{27}H_{24}N_2O_2Na$ $[M + Na]^+$ 431.1735, found 431.1723.

2-Methyl-9-methyl-12-(nitromethyl)-6-(*p*-tolyl)-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Mi). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (s, 1H), 7.64 (s, 1H), 7.50–7.48 (m, 2H), 7.34–7.31 (m, 4H), 7.18 (dd, *J* = 7.2, 2.0 Hz, 1H), 7.13–7.02 (m, 3H), 5.33 (t, *J* = 8.0 Hz, 1H), 4.61 (dd, *J* = 8.0, 2.0 Hz, 2H), 2.52 (s, 3H), 2.47 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.6, 137.0, 136.8, 135.1, 134.3, 133.7, 132.5, 132.2, 131.8, 130.3, 129.8, 129.7, 129.5, 129.3, 128.8, 126.5, 125.1, 117.7, 112.4, 110.6, 75.3, 41.1, 21.6, 21.3, 21.0; LRMS (ESI) *m*/*z* 409 $[M + H]^+$; HRMS (ESI) calcd for $C_{27}H_{24}N_2O_2Na$ $[M + Na]^+$ 431.1735, found 431.1717.

3-Methyl-9-methyl-12-(nitromethyl)-6-(*p*-tolyl)-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Mj). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (s, 1H), 7.74–7.73 (m, 1H), 7.51–7.49 (m, 2H), 7.34–7.32 (m, 4H), 7.20–7.18 (m, 1H), 7.07–7.02 (m, 3H), 5.33 (t, *J* = 8.0 Hz, 1H), 4.61 (d, *J* = 8.0 Hz, 2H), 2.48 (s, 3H), 2.45 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.6, 137.2, 137.1, 136.8, 134.4, 133.7, 133.4, 132.4, 131.8, 131.5, 130.3, 129.8, 129.7, 129.0, 128.8, 124.3, 122.1, 117.9, 112.9, 110.8, 75.2, 41.2, 21.9, 21.3, 21.0; LRMS (ESI) *m*/*z* 409 $[M + H]^+$; HRMS (ESI) calcd for $C_{27}H_{25}N_2O_2$ $[M + H]^+$ 409.1916, found 409.1930.

4-Methyl-9-methyl-12-(nitromethyl)-6-(*p*-tolyl)-5,12-dihydrobenzo[4,5]cyclohepta[1,2-*b*]indole (3Mk). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (s, 1H), 7.72 (d, *J* = 8.4 Hz, 1H), 7.55–7.53 (m, 2H), 7.35–7.32 (m, 4H), 7.21–7.12 (m, 3H), 7.04–7.02 (m, 1H), 5.35 (t, *J* = 8.4 Hz, 1H), 4.63 (d, *J* = 8.4 Hz, 2H), 2.49 (s, 3H), 2.38 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.7, 137.0, 136.8, 136.4, 134.3, 133.6, 132.6, 131.8, 131.7, 130.2, 129.8, 129.5, 128.7, 125.9, 124.0, 120.5, 120.2, 115.9, 113.7, 75.2, 41.2, 21.3, 21.0, 16.6; LRMS (ESI) *m*/*z* 409 $[M + H]^+$; HRMS (ESI) calcd for $C_{27}H_{24}N_2O_2Na$ $[M + Na]^+$ 431.1735, found 431.1720.

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