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Metal-Free Dehydrogenative Double C-H Sulfuration to Access Thieno[2,3-*b*]indoles Using Elemental Sulfur

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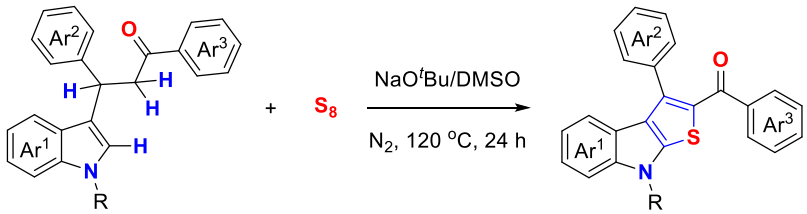


- Available materials
- Mild reaction condition
- Selective C-H bond cleavage
- Double C-S bond formation
- 37 Examples, up to 97% yield
- On a gram scale

Abstract: We reported a base-promoted metal-free approach for the synthesis of thieno[2,3-*b*]indole derivatives. This method combined four C-H σ-bonds cleavage reaction of two different kinds of C-H bonds and two C-S σ-bond formation process. Series of thieno[2,3-*b*]indoles were obtained starting from 3-benzyl indole derivatives with good yields and high regioselectivity with the elemental sulfur serving as the cheap and readily available sulfur source. Good efficiency could be kept even the reaction was performed on a gram scale. A plausible mechanism was proposed on the basis of mechanistic studies.

Keywords: C-H functionalization, cyclization, C-S bond formation, thienoindole

derivatives, elemental sulfur.

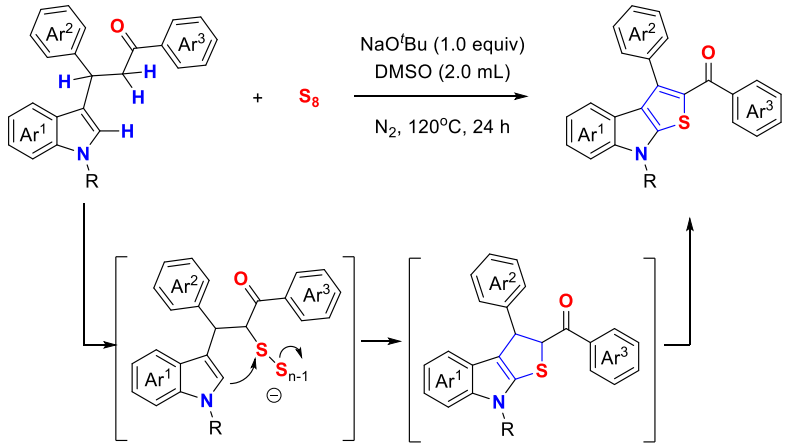
INTRODUCTION

Thieno[2,3-*b*]indole is one kind of important backbones, which is widely existed in a variety of natural products, biologically active agent and pharmaceutical molecules.[1-5] Hence, seeking efficient methodologies for facile access to the thieno[2,3-*b*]indoles has attracted a lot of attention in synthetic organic chemistry during the past decades.[6-10] It has been recognized as a powerful strategy to construct S-containing compounds by harnessing elemental sulfur as the sulfur source. It is common for numerous and mild oxidation states of elemental sulfur to select as a promising oxidant.[11-14] Meanwhile, elemental sulfur could incorporate ring systems to arrange functional components in the construction of heterocycles.[15-36] Recently, Li and Deng have developed an efficient approach for the construction of thienoindole derivatives starting from indole, ketone and sulfur powder.[37,38] Then, Deng *et al*. demonstrated the formation of the thieno[2,3-*b*]indoles by the reaction of indoles, alkenes or alkynes, and sulfur powder *via* a cascade reaction.[39] In above transformation, DMF played a vital role to convert the alkenes or alkynes into thioamides. Meanwhile, a tandem approach to substituted thienoindoles from indoles, α, β-unsaturated carboxylic acids, and elemental sulfur was also furnished by Fu and coworkers.[40] Despite these advances had been established, the incoprporation of elemental sulfur into substrate process hardly provided the thieno[2,3-*b*]indoles containing carbonyl groups. However, several challenges remained in choosing an efficient approach for the preparation of thieno[2,3-*b*]indoles contained containing carbonyl group. First, it

is a concern what materials could be chosen as the suitable substrates. Second, the scope of the transformation and the attractive and valuable route represents another difficulty.

Indole has proven to be ubiquitous scaffolds for enantioselective preparation of natural products, pharmaceuticals and agrochemicals.[41-43] Here, we discovered that β-indolylketone derivatives could serve as an effective and easily available substrates for making thieno[2,3-*b*]indoles contained carbonyl groups *via* a double C-S bond formation process. β-Indolylketone derivatives were easily obtained by the Friedel-Crafts alkylation of the available indoles with α, β-unsaturated ketones with the aid of Lewis acid.[44] The sulfur atom derived from elemental sulfur connect two different C-H bonds of substrate. Firstly, in the presence of base, the deprotonation of β-indolylketone gave the carbanion, followed by the electrophilic attack of elemental sulfur to form a β-indolylketone-sulfur species. After the elimination of elemental sulfur (S_{n-1}), the intermolecular nucleophilic cyclization occurred regiospecifically at the 2-position of the indole ring due to the indole C-H bond activity. Finally, the desired thienoindoles was released by the oxidative aromatization (Scheme 1). In above process, double C-S bond formation was achieved through cleavage four C-H σ-bonds in the presence of elemental sulfur and base. Herein, we reported a facile method for the construction of thienoindoles *via* the selective cleavage of C(sp^2)-H bonds and C(sp^3)-H bonds from easily available β-indolylketone, elemental sulfur, and base.

Scheme 1. Dual C-S Bond Formation *via* the Selective Cleavage of C(sp^2)-H Bonds and C(sp^3)-H Bonds.

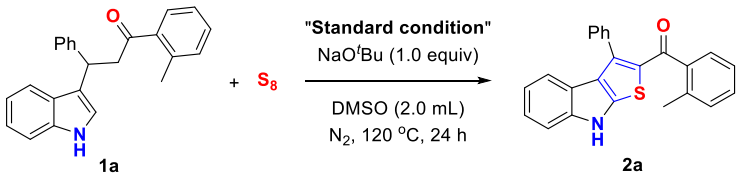


RESULTS AND DISCUSSION

To test our hypothesis, 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one (**1a**) was chosen as the model substrate to establish the optimized conditions of the dual C-S bond formation reaction. Firstly, a detailed survey of solvents revealed that other solvents afford the bad results in the similar condition. DMSO was the most suitable solvent, affording the desired product (**2a**) in 97% yield (Table 1, entries 1-6). Then we turned our investigation to explore the role of the base. It was noting that KO^{t}Bu, LiO^{t}Bu, Na_2CO_3, K_2CO_3, and K_3PO_4 provided positive results, and afforded moderate to good yields (Table 1, entries 7-11). Meanwhile, organic base, such as DBU and DABCO, provided the final product in trace and 90% yield, respectively (Table 1, entries 12 and 13). The amount of elemental sulfur did not affect the oxidative cyclization obviously. Both increasing and decreasing the mount of elemental sulfur generated the desired product **2a** in excellent yield (Table 1, entries 14-16). Neither at a lower temperature nor at a higher temperature influenced the yield of the final product (Table 1, entries 17-19). The optimized condition was shown as follow: **1a** (0.30 mmol), S_8 (0.20 mmol), NaO^{t}Bu (1.0 equiv), DMSO (2.0 mL), 120 °C, 24 h in

N_2 atmosphere.

Table1. Optimization of Reaction Conditions.[a]



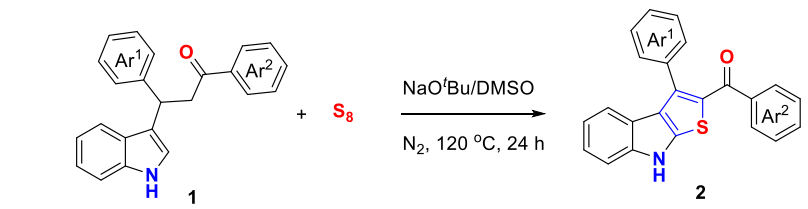
entry	S_8	base	solvent	tem. (°C)	yield (%)[b]
1	S_8 (0.20 mmol)	Na^{t}OBu	DMSO	120	97
2	S_8 (0.20 mmol)	Na^{t}OBu	1,4-dioxane	120	55
3	S_8 (0.20 mmol)	Na^{t}OBu	Toluene	120	17
4	S_8 (0.20 mmol)	Na^{t}OBu	Xylene	120	10
5	S_8 (0.20 mmol)	Na^{t}OBu	DMF	120	30
6	S_8 (0.20 mmol)	Na^{t}OBu	DMAc	120	52
7	S_8 (0.20 mmol)	K^{t}OBu	DMSO	120	89
8	S_8 (0.20 mmol)	Li^{t}OBu	DMSO	120	95
9	S_8 (0.20 mmol)	Na_2CO_3	DMSO	120	91
10	S_8 (0.20 mmol)	K_2CO_3	DMSO	120	51
11	S_8 (0.20 mmol)	K_3PO_4	DMSO	120	90
12	S_8 (0.20 mmol)	DABCO	DMSO	120	89
13	S_8 (0.20 mmol)	DABCO	DMSO	120	trace
14	S_8 (0.10 mmol)	Na^{t}OBu	DMSO	120	83
15	S_8 (0.30 mmol)	Na^{t}OBu	DMSO	120	94
16	S_8 (0.10 mmol)	Na^{t}OBu	DMSO	120	91
17	S_8 (0.20 mmol)	Na^{t}OBu	DMSO	100	87
18	S_8 (0.20 mmol)	Na^{t}OBu	DMSO	110	94
19	S_8 (0.20 mmol)	Na^{t}OBu	DMSO	130	86

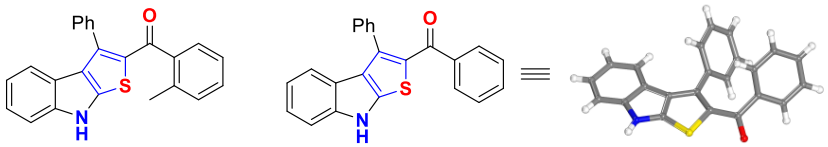
[a] Standard condition: **1a** (0.3 mmol), S_8 (0.20 mmol), NaO^{t}Bu (1.0 equiv), DMSO (2.0 mL), N_2, 120 °C, 24 h.

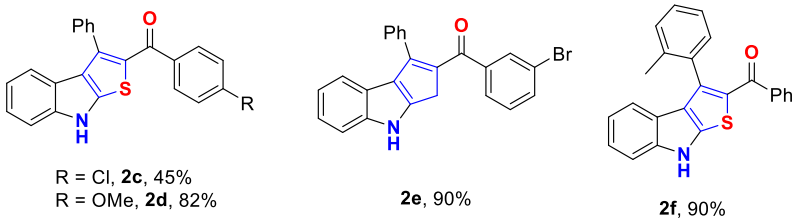
[b] Isolated yield.

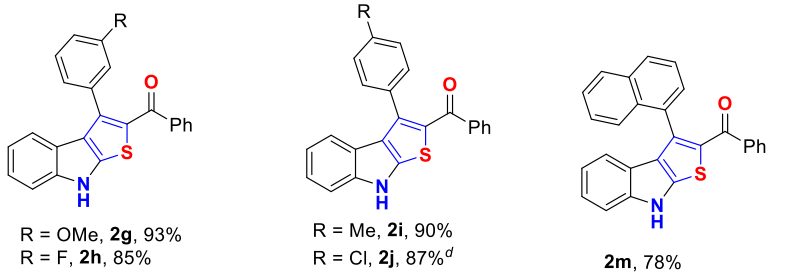
With the optimized double C-H sulfuration conditions in hand, we next examined the substrate scope of the β-indolylketones (Scheme 2). To our delight, 3-(1*H*-indol-3-yl)-1,3-diphenylpropan-1-one (**1b**) was well tolerated, and provided the desired product **2b** in 89% yield. The structure of **2b** was unambiguously confirmed by a single-crystal X-ray diffraction analysis.[42] The electron-donating group and electron-withdrawing group at the *para*-position of the aromatic ring could influence the yield of corresponding products dramatically (**2c** and **2d**). Notably, functionalized substrates bearing a bromide atom at the *meta*-position of the aromatic ring was compatible with the reaction conditions, affording the desired product in 90% yield (**2e**). Furthermore, β-indolylketones with different substituents such as methyl, methoxy and chloride groups at another aromatic ring converted to the corresponding products in good yields (**2f**-**2h**). In addition, a variety of functional groups at *para*-position of another aromatic ring, such as methyl, chloride, nitrile, and phenyl groups, were confirmed suitable to provide the final products from 74% to 92% yields (**2i**-**2l**). More importantly, the reaction of substrates containing naphthyl group also proceeded smoothly to deliver the desired thienoindoles from moderate to good yields (**2m**-**2o**). Finally, we further applied this approach to deliver the thienoindoles contained furan, thiophene and benzothiophene groups in 64-87% yields (**2p**-**2r**). Unfortunately, the reaction of substrates containing alky and pyridyl group was not compatible with the reaction (**2s**-**2t**). The desired products were not observed. The structures of **2o** and **2q** were unambiguously confirmed by a single-crystal X-ray diffraction analysis.[45]

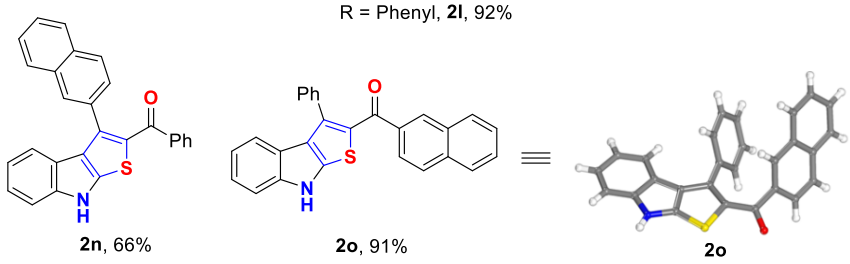
Scheme 2. Extension of the Reaction Scope.[a, b]

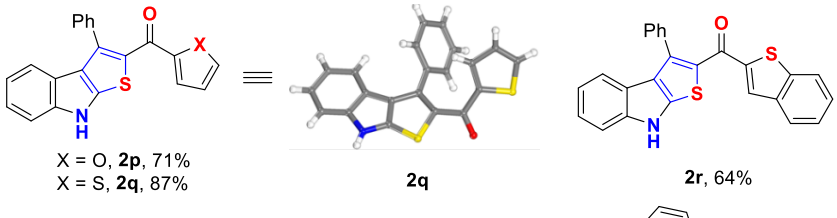


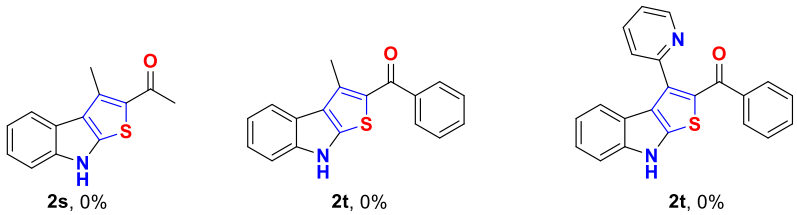












[a] Reaction conditions: **1** (0.30 mmol), S_8 (0.20 mmol), NaO^{t}Bu (1.0 equiv), DMSO (2.0 mL), N_2,

120 °C, 24 h.

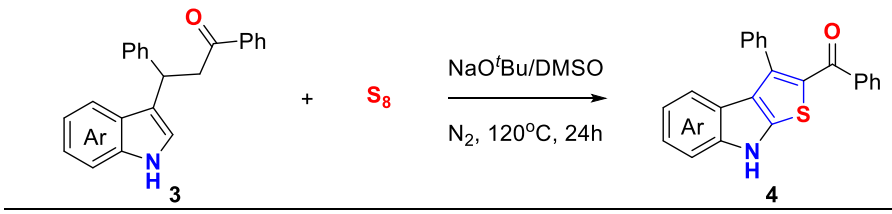
[b] Isolated yield.

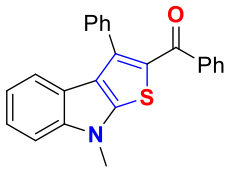
[c] NaO^{t}Bu (2.0 equiv), 100 °C.

[d] 120 °C, 36 h.

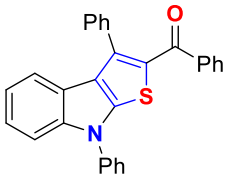
Next, we sought to examine the substituents of indole ring (Scheme 3). The substrates bearing methyl, phenyl and benzyl group at the α-position of the indole ring were well tolerated, furnishing the dual C-S bond formation in good yields (**4a**-**4c**). Meanwhile, β-indolylketones bearing the methyl and methoxy at the 4- and 5-positions of the indole were compatible with the optimized conditions, and the thienoindoles were achieved in high yields (**4d**-**4g**). As well, electron-withdrawing group at the 5-position of the indole ring smoothly reacted with the elemental sulfur, and afforded the corresponding products from 62% to 90% yields (**4h**-**4k**). Furthermore, the electron-donating groups and electron-withdrawing groups at the 6- and 7-position of the indole ring were also suitable substrates to generate the final products in excellent yields (**4l**-**4q**). In addition, indole bearing benzyl oxygen groups was conducted to undergo the transformation in 81% yield (**4r**). Notably, the substrate contained phenyl group at 2-position of indole ring could undergo the selective dual C-S bond formation reaction to generate the unexpected product **4s** in moderate yield. In the reaction system, the substrate **3s** underwent the cleavage of C-C bond to afford the byproduct **2a** in 40% yield. The structure of **4s** was unambiguously confirmed by a single-crystal X-ray diffraction analysis.[45]

Scheme 3. Scope of Dual C-S Bond Formation.[a]

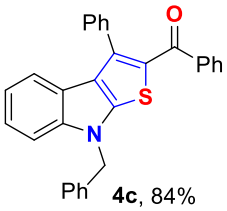




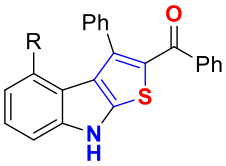
4a, 70%



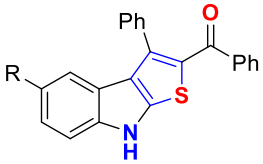
4b, 87%



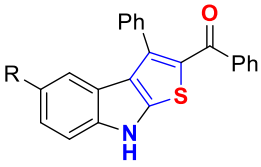
4c, 84%



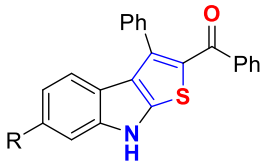
R = Me, **4d**, 78%
R = OMe, **4e**, 92%



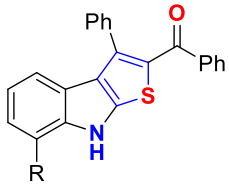
R = Me, **4f**, 95%
R = OMe, **4g**, 88%



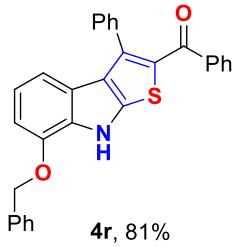
R = Cl, **4h**, 74%
R = F, **4i**, 90%
R = CN, **4j**, 62%
R = CO_2Me, **4k**, 62%



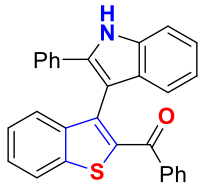
R = Me, **4l**, 90%
R = Cl, **4m**, 93%
R = F, **4n**, 90%



R = OMe, **4o**, 91%
R = Br, **4p**, 94%
R = Cl, **4q**, 90%

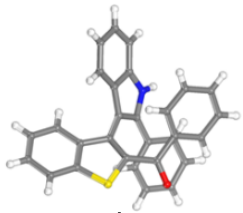


4r, 81%



4s, 45%

≡



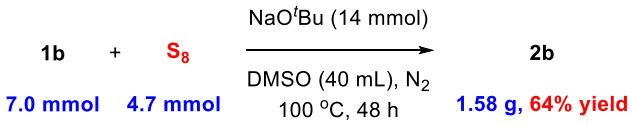
4s

[a] Reaction conditions: **3** (0.30 mmol), S_8 (0.20 mmol), NaO^tBu (1.0 equiv), DMSO (2.0 mL), N_2, 120 °C, 24 h.

[b] Isolated yield.

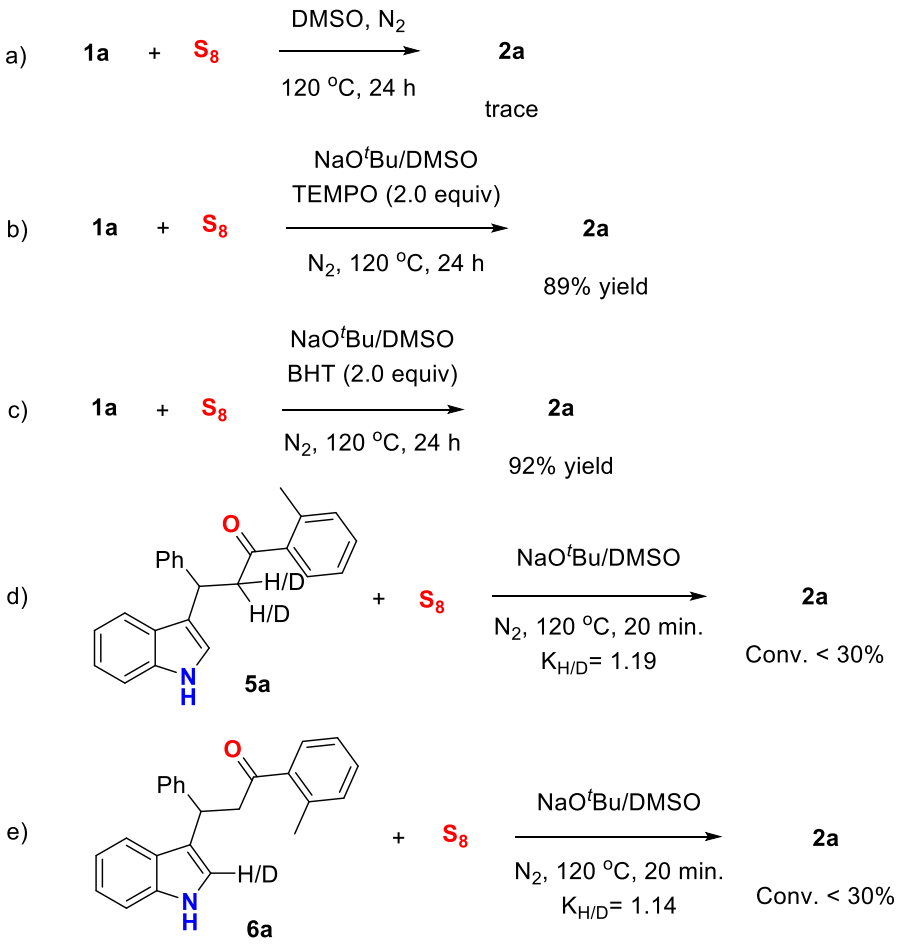
To demonstrate the practical of our method, the dual C-S bond formation was conducted in large scale synthesis (7.0 mmol). As a result, the desired product **2b** was isolated in 64% yield in 1.58 g (Scheme 4).

Scheme 4. Gram-Scale Experiment.



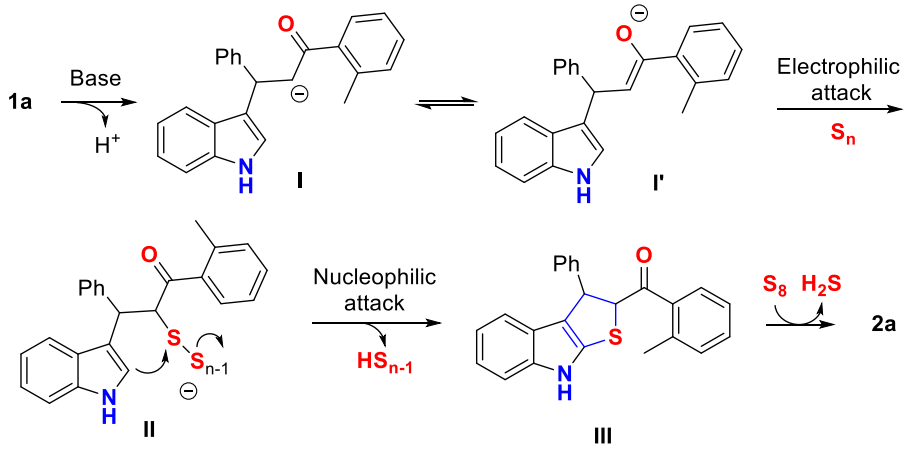
To gain some insight of the dual C-S bond formation, several control experiments were explored in different conditions. In the absence of base, only a trace of product was obtained in standard condition (Scheme **5a**). This result demonstrated that base played a decisive role and captured the hydrogen at the α-position of the carbonyl group. Hence, radical trapping experiments were conducted under the optimized conditions to probe whether a radical process was involved or not (Scheme **5b** and **5c**). The dual C-S bond formations were not completely suppressed by TEMPO and BHT. These results showed that the radical process maybe involved in the dual C-S bond formation reaction. In addition, the intramolecular kinetic isotope effect was applied to conduct under the optimized conditions on a 0.3 mmol scale with 88% D content starting material **5a**. The result exhibited that the cleavage of C-H bond at the α-position of the carbonyl group was not the rate-limiting step (Scheme **5d**). Subsequently, another intramolecular kinetic isotope effect carried out with a 0.30 mmol starting material was also investigated under the optimized conditions. The observed isotopic effect (k_H/k_D = 1.14) demonstrated that the cleavage of C-H bond at the 2-position of the indole ring was not the rate-limiting step (Scheme **5e**).

Scheme 5. Mechanistic Experiments



Based on the results and some previous reports,[11, 20, 23, 32] we proposed the mechanism of the dual C-S bond formations (Scheme 6). The substrate **1a** converted to intermediate **I** and its proper tautomeric equilibrium **I'**, followed by the lose hydrogen proton with the help of base. Subsequently, an intermediate **II** was formed by an electrophilic attack of the elemental sulfur at the α-position of the carbonyl group. The intramolecular nucleophilic cyclization of the intermediate **II** provided an intermediate **III** by elimination of the elemental sulfur (S_{n-1}). Finally, the desired thienoindole was released by the oxidative aromatization of elemental sulfur.[12,13]

Scheme 6. Proposed Reaction Mechanism for the Formation of 2a.



CONCLUSION

In summary, we have achieved a novel process of elemental sulfur promoted the dual C-S bond formation that proceeded smoothly to afford poly-substituted thienoindoles. This approach could be extended to explore the dual C-S bond formation of broad range of β-indolylketones. Importantly, the approach is suitable for larger scale synthesis without decreasing the yield of the desired product. In this transformation, the dual C-S bonds are prepared by the selective cleavage of the C(sp^2)-H bond and C(sp^3)-H bonds with the aid of base. Furthermore, the dual C-S bond formation underwent the electrophilic attack of elemental sulfur and intramolecular nucleophilic cyclization to form the corresponding product.

EXPERIMENTAL SECTION

General Information. All the solvents and other reagents were purchased from commercial suppliers without the purification. All reactions were performed in N_2 atmosphere unless otherwise. The **1** and **3** were prepared by the reported literatures.[44] ^1H and $^{13}C\{^1H\}$ NMR spectra were recorded on Bruker Avance/600 (^1H: 600 MHz,

$^{13}C\{^{1}H\}$: 150 MHz at 25 ºC) or Bruker Avance/400 (^{1}H: 400 MHz, $^{13}C\{^{1}H\}$: 100 MHz at 25 ºC) and TMS as internal standard. ^{1}H and ^{19}F NMR multiplicities are reported as follows: singlet (s), doublet (d), doublet of doublets (dd), quartet (q), multiplet (m), and broad resonance (br). All high-resolution mass spectra (HRMS) were measured on a mass spectrometer by using electrospray ionization (ESI-oa-TOF). Melting points were measured on a melting point apparatus equipped with a thermometer and were uncorrected. All reactions were monitored by thin-layer chromatography (TLC) through GF254 silica gel-coated plates. Flash chromatography was conducted on neutral aluminum oxide (200-300 mesh, purchased from Sinopharm Chemical Reagent Co., Ltd).

General procedure for the synthesis of β-indolylketones (1 and 3): In a 25 mL flame-dried Schlenk tube equipped with a stir bar, indole (0.50 mmol, 58.6 mg), chalcone (0.55 mmol, 114.5 mg) and $TsOH\cdot H_2O$ (5.0 mol%, 4.8 mg) were combined and the tube was then sealed. The Schlenk tube was purged three times with N_2. Then, CH_3CN (2.5 mL) was injected into the Schlenk tube with a syringe under N_2 atmosphere. The Schlenk tube contents were then allowed to stir at 50 ºC by heating mantle for 24 h. After cooling to room temperature, the residue was concentrated in *vacuum*. The residue was neutralized by $NaHCO_3$ and then the aqueous phase was extracted by ethyl acetate (5×25 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by column chromatography on silica gel to afford the desired starting materials **1** and **3**

3-(1H-indol-3-yl)-3-phenyl-1-(o-tolyl)propan-1-one (1a).[44] The title compound

was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 152.7 mg, 90% yield; m.p. 110-113 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (br, 1H), 7.51 (d, J = 8.0 Hz, 1H), 7.40 (d, J = 8.0 Hz, 1H), 7.33-7.25 (m, 5H), 7.23-7.10 (m, 6H), 7.01-6.92 (m, 1H), 4.95 (t, J = 8.0 Hz, 1H), 3.73-3.59 (m, 2H), 2.20 (s, 3H).

3-(1H-indol-3-yl)-1,3-diphenylpropan-1-one (1b).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 149.7 mg, 92% yield; m.p. 115-118 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.79 (br, 1H), 7.90 (d, J = 8.0 Hz, 2H), 7.46 (td, J = 8.0, 4.0 Hz, 1H), 7.38-7.30 (m, 5H), 7.25 (dd, J = 8.0, 4.0 Hz, 2H), 7.11 (t, J = 6.0 Hz, 2H), 7.00-6.91 (m, 2H), 6.80 (t, J = 8.0 Hz, 1H), 4.83 (t, J = 6.0 Hz, 1H), 3.83 (q, J = 8.0 Hz, 1H), 3.71 (q, J = 8.0 Hz, 1H).

1-(4-Chlorophenyl)-3-(1H-indol-3-yl)-3-phenylpropan-1-one (1c).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the pink solid, 161.9 mg, 90% yield; m.p. 144-147 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.80 (br, 1H), 7.88 (d, J = 8.0 Hz, 2H), 7.40-7.25 (m, 7H), 7.09 (t, J = 8.0 Hz, 2H), 6.99-6.92 (m, 2H), 6.80 (t, J = 8.0 Hz, 1H), 4.82 (t, J = 8.0 Hz, 1H), 3.82 (q, J = 8.0 Hz, 1H), 3.69 (q, J = 8.0 Hz, 1H).

3-(1H-indol-3-yl)-1-(4-methoxyphenyl)-3-phenylpropan-1-one (1d).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 20:1, v/v) to give the pink

solid, 159.9 mg, 90% yield; m.p. 162-169 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.87 (br, 1H), 8.00 (d, J = 8.0 Hz, 2H), 7.42 (td, J = 10.0, 4.0 Hz, 3H), 7.33 (d, J = 8.0 Hz, 2H), 7.21 (t, J = 8.0 Hz, 2H), 7.10-6.99 (m, 4H), 6.90 (t, J = 8.0 Hz, 1H), 4.90 (t, J = 8.0 Hz, 1H), 3.85 (q, J = 8.0 Hz, 1H), 3.79 (s, 3H), 3.73 (q, J = 8.0 Hz, 1H).

1-(3-Bromophenyl)-3-(1H-indol-3-yl)-3-phenylpropan-1-one (1e). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 194.1 mg, 96% yield; m.p. 128-131 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.91 (br, 1H), 8.17 (d, J = 4.0 Hz, 1H), 7.98 (d, J = 8.0 Hz, 1H), 7.75 (d, J = 8.0 Hz, 1H), 7.49-7.35 (m, 6H), 7.22 (t, J = 6.0 Hz, 2H), 7.11-7.03 (m, 2H), 6.92 (t, J = 8.0 Hz, 1H), 4.92 (t, J = 8.0 Hz, 1H), 3.98 (q, J = 8.0 Hz, 1H), 3.85 (q, J = 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 197.8, 145.7, 139.4, 136.9, 136.2, 131.3, 131.1, 128.6, 128.3, 127.5, 126.9, 126.3, 126.8, 122.5, 121.5, 119.3, 118.8, 118.5, 111.9, 44.9, 38.1. HRMS (ESI-TOF) m/z: [M+Na]$^+$ Calcd for $C_{23}H_{18}BrNONa$ (M+Na$^+$): 426.0464; Found 426.0464.

3-(1H-indol-3-yl)-1-phenyl-3-(o-tolyl)propan-1-one (1f).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the yellow solid, 166.3 mg, 98% yield; m.p. 92-96 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.02 (br, 1H), 8.09 (d, J = 8.0 Hz, 2H), 7.60-7.45 (m, 6H), 7.30-7.02 (m, 6H), 5.33 (t, J = 8.0 Hz, 1H), 4.05-3.81 (m, 2H), 2.58 (s, 3H).

3-(1H-indol-3-yl)-3-(3-methoxyphenyl)-1-phenylpropan-1-one (1g).[47] The title

compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 20:1, v/v) to give the yellow solid, 168.8 mg, 95% yield; m.p. 121-124 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.92 (br, 1H), 8.02 (d, J = 8.0 Hz, 2H), 7.53 (d, J = 8.0 Hz, 2H), 7.45-7.37 (m, 4H), 7.14 (t, J = 6.0 Hz, 1H), 7.08-7.02 (m, 3H), 6.94 (t, J = 8.0 Hz, 1H), 6.67 (d, J = 8.0 Hz, 1H), 4.97 (t, J = 8.0 Hz, 1H), 3.96 (q, J = 8.0 Hz, 1H), 3.83 (q, J = 8.0 Hz, 1H), 3.63 (s, 3H).

3-(3-Fluorophenyl)-3-(1H-indol-3-yl)-1-phenylpropan-1-one (1h).[49] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the pink solid, 168.3 mg, 98% yield; m.p. 123-125 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (br, 1H), 7.92 (d, J = 8.0 Hz, 2H), 7.53 (td, J = 6.0, 4.0 Hz, 1H), 7.44-7.40 (m, 3H), 7.30 (d, J = 8.0 Hz, 1H), 7.21-7.13 (m, 3H), 7.04-7.00 (m, 2H), 6.97 (d, J = 4.0 Hz, 1H), 6.84 (td, J = 8.0, 4.0 Hz, 1H), 5.07 (t, J = 6.0 Hz, 1H), 3.80 (q, J = 6.7 Hz, 1H), 3.70 (q, J = 9.3 Hz, 1H).

3-(1H-indol-3-yl)-1-phenyl-3-(p-tolyl)propan-1-one (1i).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the pink solid, 156.1 mg, 92% yield; m.p. 118-122 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 10.82 (br, 1H), 8.00 (d, J = 6.0 Hz, 2H), 7.62 (td, J = 9.0, 6.0 Hz, 1H), 7.51 (t, J = 9.0 Hz, 2H), 7.39 (d, J = 12.0 Hz, 1H), 7.31-7.25 (m, 4H), 7.01 (td, J = 9.0, 6.0 Hz, 3H), 6.88 (td, J = 9.0, 6.0 Hz, 1H), 4.82 (t, J = 6.0 Hz, 1H), 3.87 (q, J = 8.0 Hz, 1H), 3.78 (q, J = 8.0

Hz, 1H), 2.19 (s, 3H).

3-(4-Chlorophenyl)-3-(1H-indol-3-yl)-1-phenylpropan-1-one (1j).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the pink solid, 152.9 mg, 85% yield; m.p. 116-119 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.90 (br, 1H), 8.02 (dd, J = 8.0, 4.0 Hz, 2H), 7.62 (td, J = 8.0, 4.0 Hz, 1H), 7.51 (td, J = 8.0, 4.0 Hz, 2H), 7.44-7.41 (m, 3H), 7.37 (d, J = 8.0 Hz, 1H), 7.32 (d, J = 8.0 Hz, 1H), 7.27 (dd, J = 8.0, 4.0 Hz, 2H), 7.03 (t, J = 8.0 Hz, 1H), 6.90 (t, J = 8.0 Hz, 1H), 4.88 (t, J = 8.0 Hz, 1H), 3.93 (q, J = 8.0 Hz, 1H), 3.83 (q, J = 8.0 Hz, 1H).

4-(1-(1H-indol-3-yl)-3-oxo-3-phenylpropyl)benzonitrile (1k).[47] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 15:1, v/v) to give the white solid, 162.9 mg, 93% yield; m.p. 116-119 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.97 (br, 1H), 8.03 (d, J = 8.0 Hz, 2H), 7.69 (dd, J = 8.0, 4.0 Hz, 2H), 7.65-7.60 (m, 3H), 7.53-7.43 (m, 4H), 7.34 (d, J = 8.0 Hz, 1H), 7.05 (t, J = 8.0 Hz, 1H), 6.92 (t, J = 8.0 Hz, 1H), 4.98 (t, J = 8.0 Hz, 1H), 4.06-3.90 (m, 2H).

3-([1,1'-Biphenyl]-4-yl)-3-(1H-indol-3-yl)-1-phenylpropan-1-one (1l).[47] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the light pink solid, 58.2 mg, 29% yield; m.p. 219-223 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.90 (br, 1H), 8.05 (d, J = 8.0 Hz, 2H), 7.65-7.58 (m, 3H), 7.54-7.49 (m, 7H), 7.41 (t, J = 8.0 Hz, 3H), 7.34-7.29 (m, 2H), 7.05 (t, J = 6.0 Hz, 1H), 6.92 (t, J = 8.0 Hz, 1H),

4.95 (t, *J* = 8.0 Hz, 1H), 4.01-3.86 (m, 2H).

3-(1H-indol-3-yl)-3-(naphthalen-1-yl)-1-phenylpropan-1-one (1m).[48] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 176.5 mg, 94% yield; m.p. 73-79 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.88 (br, 1H), 8.40 (d, *J* = 8.0 Hz, 1H), 8.01 (d, *J* = 8.0 Hz, 2H), 7.90 (d, *J* = 8.0 Hz, 1H), 7.74 (d, *J* = 8.0 Hz, 1H),7.61-7.45 (m, 6H), 7.40-7.32 (m, 3H), 7.24 (d, *J* = 4.0 Hz, 1H), 7.02 (t, *J* = 8.0 Hz, 1H), 6.85 (t, *J* = 8.0 Hz, 1H), 5.80 (td, *J* = 8.0, 4.0 Hz, 1H), 4.09 (q, *J* = 8.0 Hz, 1H), 3.89 (q, *J* = 8.0 Hz, 1H).

3-(1H-indol-3-yl)-3-(naphthalen-2-yl)-1-phenylpropan-1-one (1n).[49] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the pink solid, 178.3 mg, 95% yield; m.p. 155-158 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.95 (br, 1H), 8.03 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.96 (d, *J* = 4.0 Hz, 1H), 7.83-7.75 (m, 3H), 7.61-7.56 (m, 2H), 7.50-7.34 (m, 7H), 7.04 (t, *J* = 6.0 Hz, 1H), 6.89 (t, *J* = 8.0 Hz, 1H), 5.11 (t, *J* = 8.0 Hz, 1H), 4.05 (q, *J* = 8.0 Hz, 1H), 3.95 (q, *J* = 8.0 Hz, 1H).

3-(1H-indol-3-yl)-1-(naphthalen-2-yl)-3-phenylpropan-1-one (1o).[47] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 180.2 mg, 96% yield; m.p. 151-155 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.87 (br, 1H), 8.80 (s, 1H), 8.13 (d, *J* = 8.0 Hz, 1H), 8.00-7.95 (m, 3H), 7.68-7.60 (m, 2H), 7.45 (d, *J* = 8.0 Hz, 3H), 7.38 (s, 1H), 7.32 (dd, *J* = 8.0, 4.0 Hz, 1H), 7.23 (dd, *J* = 6.0,

4.0 Hz, 2H), 7.10 (td, *J* = 6.0, 4.0 Hz, 1H), 7.03 (t, *J* = 8.0 Hz, 1H), 6.90 (t, *J* = 8.0 Hz, 1H), 4.95 (t, *J* = 8.0 Hz, 1H), 4.10 (q, *J* = 8.0 Hz, 1H), 3.93 (q, *J* = 8.0 Hz, 1H).

1-(Furan-2-yl)-3-(1H-indol-3-yl)-3-phenylpropan-1-one (1p). [44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the green solid, 140.2 mg, 89% yield; m.p. 117-121 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.88 (br, 1H), 7.95 (s, 1H), 7.60 (d, *J* = 4.0 Hz, 1H), 7.44-7.39 (m, 3H), 7.33 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.23 (t, *J* = 8.0 Hz, 2H), 7.11 (t, *J* = 8.0 Hz, 1H), 7.04 (t, *J* = 8.0 Hz, 1H), 6.91 (t, *J* = 6.0 Hz, 1H), 6.89 (d, *J* = 4.0 Hz, 1H), 4.87 (t, *J* = 8.0 Hz, 1H), 3.73 (q, *J* = 8.0 Hz, 1H), 3.58 (q, *J* = 6.7 Hz, 1H).

3-(1H-indol-3-yl)-3-phenyl-1-(thiophen-2-yl)propan-1-one (1q).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the purple solid, 140.9 mg, 85% yield; m.p. 116-119 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.86 (br, 1H), 8.13 (d, *J* = 4.0 Hz, 1H), 7.95 (dd, *J* = 8.0, 4.0 Hz, 1H), 7.41 (t, *J* = 8.0 Hz, 3H), 7.34 (s, 1H), 7.30 (d, *J* = 8.0 Hz, 1H), 7.24-7.20 (m, 3H), 7.10 (td, *J* = 8.0, 4.0 Hz, 1H), 7.02 (dd, *J* = 8.0, 4.0 Hz, 1H), 6.89 (td, *J* = 8.0, 4.0 Hz, 1H), 4.86 (t, *J* = 8.0 Hz, 1H), 3.86 (q, *J* = 8.0 Hz, 1H), 3.70 (q, *J* = 8.0 Hz, 1H).

1-(Benzo[b]thiophen-2-yl)-3-(1H-indol-3-yl)-3-phenylpropan-1-one (1r). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the red solid, 177.4 mg, 93% yield; m.p. 187-191 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (br,

1H), 7,89 (s, 1H), 7.82 (d, J = 8.0 Hz, 2H), 7.43 (dd, J = 8.0, 4.0 Hz, 2H), 7.39-7.35 (m, 3H), 7.30-7.23 (m, 4H), 7.17-7.12 (m, 2H), 7.01 (td, J = 8.0, 4.0 Hz, 2H), 5.09 (t, J = 6.0 Hz, 1H), 3.85 (q, J = 8.0 Hz, 1H), 3.72 (q, J = 6.7 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 193.0, 143.9, 143.9, 142.6, 139.1, 136.7, 129.0, 128.5, 127.8, 127.4, 126.6, 126.5, 126.0, 125.0, 123.0, 122.2, 121.5, 119.6, 119.5, 119.0, 111.2, 45.8, 38.7. HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{25}H_{19}NOSNa$ ($M+Na^+$): 404.1080; Found 404.1080.

3-(1-Methyl-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3a).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 161.2 mg, 95% yield; m.p. 168-174 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.00 (d, J = 8.0 Hz, 2H), 7.62 (t, J = 6.0 Hz, 1H), 7.50 (t, J = 8.0 Hz, 2H), 7.45 (d, J = 8.0 Hz, 1H), 7.40 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 7.22 (t, J = 6.0 Hz, 2H), 7.09 (t, J = 8.0 Hz, 2H), 6.93 (t, J = 8.0 Hz, 1H), 4.87 (t, J = 8.0 Hz, 1H), 3.92-3.80 (m, 2H), 3.71 (s, 3H).

1,3-Diphenyl-3-(1-phenyl-1H-indol-3-yl)propan-1-one (3b).[48] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give orange oil, 170.6 mg, 85% yield; m.p. 101-104 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (d, J = 8.0 Hz, 2H), 7.51-7.43 (m, 3H), 7.41-7.38 (m, 6H), 7.33 (td, J = 8.0, 4.0 Hz, 2H), 7.23 (td, J = 8.0, 4.0 Hz, 3H), 7.15-7.09 (m, 3H), 7.04 (t, J = 6.0 Hz, 1H), 5.12 (td, J = 8.0, 4.0 Hz, 1H), 3.84-3.71 (m, 2H).

3-(1-Benzyl-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3c).[50] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the pink solid, 162.1 mg, 78% yield; m.p. 139-141 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (dd, J = 8.0, 4.0 Hz, 2H), 7.52 (td, J = 8.0, 4.0 Hz, 1H), 7.46-7.35 (m, 5H), 7.29-7.23 (m, 5H), 7.21-7.09 (m, 3H), 7.05-6.98 (m, 3H), 6.94 (s,1H), 5.25 (s, 2H), 5.08 (t, J =8.0 Hz, 1H), 3.83-3.69 (m, 2H).

3-(4-Methyl-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3d).[51] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the yellow solid, 146.0 mg, 86% yield; m.p. 134-136 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (br, 1H), 7.91 (dd, J = 8.0, 4.0 Hz, 2H), 7.52 (td, J = 8.0, 4.0 Hz, 1H), 7.41 (t, J = 6.0 Hz, 2H), 7.23-7.19 (m, 4H), 7.15-7.10 (m, 2H), 7.00 (t, J = 8.0 Hz, 1H), 6.92 (d, J = 4.0 Hz, 1H), 6.74 (dd, J = 8.0, 4.0 Hz, 1H), 5.40 (t, J = 8.0 Hz, 1H), 3.73 (q, J = 8.0 Hz, 1H), 3.60 (q, J = 8.0 Hz, 1H), 2.50 (s, 3H).

3-(4-Methoxy-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3e).[52] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 20:1, v/v) to give the yellow solid, 172.4 mg, 97% yield; m.p. 139-142 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95-7.91 (m, 3H), 7.52 (td, J = 8.0, 4.0 Hz, 1H), 7.41 (td, J = 8.0, 4.0 Hz, 2H), 7.35 (dd, J = 8.0, 4.0 Hz, 2H), 7.23 (dd, J = 8.0, 4.0 Hz, 2H), 7.14 (td, J = 8.0, 4.0 Hz, 1H), 7.06 (t, J = 8.0 Hz, 1H), 6.91 (d, J = 8.0 Hz, 1H), 6.66 (d, J = 4.0 Hz, 1H), 6.44 (d, J = 8.0 Hz, 1H),

5.39 (q, *J* = 4.0 Hz, 1H), 3.88 (q, *J* = 8.0 Hz, 1H), 3.77 (s, 3H), 3.70 (q, *J* = 8.0 Hz, 1H).

3-(5-Methyl-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3f).[47] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the brown solid, 149.4 mg, 88% yield; m.p. 170-171 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.70 (br, 1H), 8.00 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.62 (td, *J* = 8.0, 4.0 Hz, 1H), 7.51 (td, *J* = 8.0, 4.0 Hz, 2H), 7.39 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.27 (d, *J* = 4.0 Hz, 1H), 7.24-7.17 (m, 4H), 7.10 (td, *J* = 8.0, 4.0 Hz, 1H), 6.84 (d, *J* = 8.0 Hz, 1H), 4.83 (t, *J* = 8.0 Hz, 1H), 3.88 (q, *J* = 8.0 Hz, 1H), 3.78 (q, *J* = 8.0 Hz, 1H), 2.30 (s, 3H).

3-(5-Methoxy-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3g).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 20:1, v/v) to give the brown solid, 145.7 mg, 82% yield; m.p. 138-141 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 10.70 (br, 1H), 8.02 (d, *J* = 6.0 Hz, 2H), 7.63 (td, *J* = 9.0, 6.0 Hz, 1H), 7.52 (td, *J* = 9.0, 6.0 Hz, 2H), 7.42 (dd, *J* = 12.0, 6.0 Hz, 2H), 7.29 (s, 1H), 7.24-7.19 (m, 3H), 7.11 (td, *J* = 9.0, 6.0 Hz, 1H), 6.87 (s, 1H), 6.68 (dd, *J* = 12.0, 6.0 Hz, 1H), 4.83 (t, *J* = 6.0 Hz, 1H), 3.91 (q, *J* = 8.0 Hz, 1H), 3.81 (q, *J* = 8.0 Hz, 1H), 3.68 (s, 3H).

3-(5-Chloro-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3h).[47] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the pink solid, 170.9 mg, 95% yield; m.p. 148-150 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (br, 1H),

7.91 (d, *J* = 8.0 Hz, 2H), 7.53 (t, *J* = 8.0 Hz, 1H), 7.42 (t, *J* = 8.0 Hz, 2H), 7.37 (d, *J* = 4.0 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.24 (d, *J* = 8.0 Hz, 2H), 7.17 (td, *J* = 6.0, 4.0 Hz, 2H), 7.06 (dd, *J* = 8.0, 4.0 Hz, 1H), 6.97 (d, *J* = 8.0 Hz, 1H), 4.99 (t, *J* = 6.0 Hz, 1H), 3.76 (q, *J* = 8.0 Hz, 1H), 3.68 (q, *J* = 8.0 Hz, 1H).

3-(5-Fluoro-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3i).[47] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 164.8 mg, 96% yield; m.p. 149-152 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.99 (br, 1H), 8.02 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.61 (t, *J* = 8.0 Hz, 1H), 7.50 (t, *J* = 8.0 Hz, 2H), 7.44 (td, *J* = 8.0, 4.0 Hz, 3H), 7.31 (q, *J* = 5.3 Hz, 1H), 7.23 (t, *J* = 8.0 Hz, 2H), 7.17 (dd, *J* = 10.0, 4.0 Hz, 1H), 7.11 (t, *J* = 8.0 Hz, 1H), 6.88 (td, *J* = 10.0, 4.0 Hz, 1H), 4.85 (t, *J* = 8.0 Hz, 1H), 3.94 (q, *J* = 8.0 Hz, 1H), 3.82 (q, *J* = 8.0 Hz, 1H).

3-(3-Oxo-1,3-diphenylpropyl)-1H-indole-5-carbonitrile (3j).[51] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 15:1, v/v) to give the white solid, 119.1 mg, 68% yield; m.p. 164-167 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (br, 1H), 7.93 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.72 (s, 1H), 7.56 (td, *J* = 8.0, 4.0 Hz, 1H), 7.44 (td, *J* = 8.0, 4.0 Hz, 2H), 7.33-7.27 (m, 6H), 7.21-7.17 (m, 1H), 7.14 (dd, *J* = 4.0, 4.0 Hz, 1H), 5.03 (t, *J* = 8.0 Hz, 1H), 3.80 (q, *J* = 8.0 Hz, 1H), 3.69 (q, *J* = 8.0 Hz, 1H).

Methyl 3-(3-oxo-1,3-diphenylpropyl)-1H-indole-5-carboxylate (3k). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 20:1, v/v) to give the pink

solid, 153.4 mg, 80% yield; m.p. 228-230 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.32 (br, 1H), 8.12 (d, J = 4.0 Hz, 1H), 8.01 (td, J = 8.0, 4.0 Hz, 2H), 7.69 (dd, J = 8.0, 4.0 Hz, 1H), 7.62 (td, J = 8.0, 4.0 Hz, 1H), 7.51 (td, J = 8.0, 4.0 Hz, 3H), 7.41 (dd, J = 8.0, 4.0 Hz, 3H), 7.25 (t, J = 6.0 Hz, 2H), 7.12 (td, J = 8.0, 4.0 Hz, 1H), 4.93 (t, J = 8.0 Hz, 1H), 3.96 (q, J = 9.3 Hz, 1H), 3.81 (s, 3H), 3.80 (q, J = 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 198.7, 167.7, 145.4, 139.4, 137.3, 133.6, 129.2, 128.7, 128.5, 128.2, 126.5, 126.5, 124.4, 122.6, 121.6, 120.3, 120.0, 111.8, 52.1, 45.1, 37.8. HRMS (ESI-TOF) m/z: [M+Na]$^+$ Calcd for $C_{25}H_{21}NO_3Na$ (M+Na$^+$): 406.1414; Found 406.1414.

3-(6-Methyl-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3l).[52] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the yellow solid, 152.7 mg, 90% yield; m.p. 161-163 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (dd, J = 8.0, 4.0 Hz, 2H), 7.82 (br, 1H), 7.53 (td, J = 8.0, 4.0 Hz, 1H), 7.42 (td, J = 8.0, 4.0 Hz, 2H), 7.34 (dd, J = 8.0, 4.0 Hz, 2H), 7.29 (d, J = 12.0 Hz, 1H), 7.25-7.22 (m, 2H), 7.15 (td, J = 8.0, 4.0 Hz, 1H), 7.11 (d, J = 4.0 Hz, 1H), 6.92 (d, J = 4.0 Hz, 1H), 6.84 (d, J = 8.0 Hz, 1H), 5.04 (t, J = 6.0 Hz, 1H), 3.80 (q, J = 8.0 Hz, 1H), 3.71 (q, J = 8.0 Hz, 1H), 2.40 (s, 3H).

3-(6-Chloro-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3m).[44] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the brown solid, 142.1 mg, 79% yield; m.p. 156-158 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.02 (br,

1H), 8.01 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.61 (td, *J* = 8.0, 4.0 Hz, 1H), 7.50 (t, *J* = 8.0 Hz, 2H), 7.41 (td, *J* = 8.0, 4.0 Hz, 4H), 7.36 (d, *J* = 4.0 Hz, 1H), 7.22 (td, *J* = 8.0, 4.0 Hz, 2H), 7.10 (td, *J* = 6.0, 4.0 Hz, 1H), 6.91 (d, *J* = 8.0, 1H), 4.86 (t, *J* = 8.0 Hz, 1H), 3.92 (q, *J* = 8.0 Hz, 1H), 3.81 (q, *J* = 8.0 Hz, 1H).

3-(6-Fluoro-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3n). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 128.8 mg, 75% yield; m.p. 122-124 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (br, 1H), 7.91 (d, *J* = 8.0 Hz, 2H), 7.52 (td, *J* = 8.0, 4.0 Hz, 1H), 7.41 (t, *J* = 8.0 Hz, 2H), 7.31 (td, *J* = 8.0, 4.0 Hz, 2H), 7.28-7.22 (m, 3H), 7.15 (td, *J* = 8.0, 4.0 Hz, 1H), 6.93 (dd, *J* = 10.0, 4.0 Hz, 2H), 6.75 (td, *J* = 10.0, 4.0 Hz, 1H), 5.01 (t, *J* = 8.0 Hz, 1H), 3.76 (q, *J* = 8.0 Hz, 1H), 3.66 (q, *J* = 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 198.7, 160.0 (*J* = 241 Hz), 144.2, 137.1, 136.6 (*J* = 13.6 Hz), 133.2, 128.6 (*J* = 16.6 Hz), 128.1, 127.8, 126.5, 123.3, 121.6 (*J* = 3.0 Hz), 120.3 (*J* = 10.6 Hz), 119.3 (*J* = 3.0 Hz), 108.3, 108.1, 97.6, 97.4, 45.3, 38.2. HRMS (ESI-TOF) m/z: [M+ Na]$^+$ Calcd for $C_{23}H_{18}FNONa$ (M+Na$^+$): 366.1265; Found 366.1266.

3-(7-Methoxy-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3o).[48] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 20:1, v/v) to give the brown solid, 163.5 mg, 92% yield; m.p. 132-135 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (br, 1H), 7.92 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.52 (td, *J* = 8.0, 4.0 Hz, 1H), 7.42 (td *J* = 8.0, 4.0 Hz, 2H), 7.34 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.23 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.15 (td, *J* = 8.0,

4.0 Hz, 1H), 7.04 (d, *J* = 8.0 Hz, 1H), 6.96 (dd, *J* = 4.0, 4.0 Hz, 1H), 6.93 (t, *J* = 8.0 Hz, 1H), 6.59 (d, *J* = 8.0 Hz, 1H), 5.04 (t, *J* = 8.0 Hz, 1H), 3.91 (s, 3H), 3.80 (q, *J* = 8.0 Hz, 1H), 3.72 (q, *J* = 8.0 Hz, 1H).

3-(7-Bromo-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3p). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the yellow solid, 196.1 mg, 97% yield; m.p. 117-120 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.12 (br, 1H), 8.02 (d, *J* = 8.0 Hz, 2H), 7.61 (t, *J* = 8.0 Hz, 1H), 7.51 (d, *J* = 8.0 Hz, 2H), 7.48-7.46 (m, 2H), 7.42 (d, *J* = 8.0 Hz, 2H), 7.22 (t, *J* = 8.0 Hz, 3H), 7.10 (td, *J* = 8.0, 4.0 Hz, 1H), 6.86 (t, *J* = 8.0 Hz, 1H), 4.89 (t, *J* = 6.0 Hz, 1H), 3.97 (q, *J* = 8.0 Hz, 1H), 3.84 (q, *J* = 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 198.7, 145.4, 137.3, 135.0, 133.6, 129.1, 128.6, 128.5, 128.2, 126.4, 124.0, 123.8, 120.3, 120.0, 118.8, 104.6, 44.6, 38.1. HRMS (ESI-TOF) m/z: [M+Na]$^+$ Calcd for $C_{23}H_{18}BrNONa$ (M+Na$^+$): 426.0464; Found 426.0464.

3-(7-Chloro-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3q). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 30:1, v/v) to give the white solid, 170.9 mg, 95% yield; m.p. 99-100 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (br, 1H), 7.92 (dd, *J* = 8.0, 4.0 Hz, 2H), 7.54 (td, *J* = 8.0, 4.0 Hz, 1H), 7.42 (td, *J* = 8.0, 4.0 Hz, 2H), 7.32 (td, *J* = 8.0, 4.0 Hz, 3H), 7.26 (dd, *J* = 8.0, 4.0 Hz, 1H), 7.24 (d, *J* = 4.0 Hz, 1H), 7.17 (dd, *J* = 8.0, 4.0 Hz, 1H), 7.14 (dd, *J* = 10.0, 4.0 Hz, 1H), 7.06 (dd, *J* = 4.0, 4.0 Hz, 1H), 6.93 (t, *J* = 8.0 Hz, 1H), 5.05 (t, *J* = 6.0 Hz, 1H), 3.80 (q, *J* = 8.0 Hz, 1H),

3.70 (q, J = 8.0 Hz, 1H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 198.3, 143.9, 137.1, 133.9, 133.1, 128.6, 128.5, 128.1, 127.8, 126.5, 121.9, 121.6, 120.5, 120.3, 118.3, 116.6, 45.1, 38.2. HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{18}ClNONa$ ($M+Na^+$): 382.0969; Found 382.0969.

3-(7-(Benzyloxy)-1H-indol-3-yl)-1,3-diphenylpropan-1-one (3r). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 20:1, v/v) to give the pink solid, 161.8 mg, 75% yield; m.p. 139-142 °C. ^1H NMR (400 MHz, DMSO-d_6) δ 10.96 (br, 1H), 8.01 (dd, J = 8.0, 4.0 Hz, 2H), 7.61 (td, J = 8.0, 4.0 Hz, 1H), 7.51 (q, J = 8.0 Hz, 4H), 7.41-7.37 (m, 4H), 7.32 (td, J = 8.0, 4.0 Hz, 1H), 7.27 (d, J = 4.0 Hz, 1H), 7.21 (td, J = 8.0, 4.0 Hz, 2H), 7.09 (td, J = 8.0, 4.0 Hz, 1H), 7.02 (d, J = 8.0 Hz, 1H), 6.79 (t, J = 8.0 Hz, 1H), 6.67 (d, J = 8.0 Hz, 1H), 5.21 (s, 2H), 4.84 (t, J = 6.0 Hz, 1H), 3.91 (q, J = 8.0 Hz, 1H), 3.81 (q, J = 9.3 Hz, 1H); $^{13}C\{^1H\}$ NMR (151 MHz, DMSO-d_6) δ 198.9, 145.8, 145.5, 137.9, 137.3, 133.6, 129.1, 128.9, 128.6, 128.5, 128.2, 128.2, 128.0, 127.0, 126.2, 122.2, 119.2, 119.1, 112.3, 103.4, 69.6, 44.7, 38.2. HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{18}ClNONa$ ($M+Na^+$): 382.0969; Found 382.0969.

1,3-Diphenyl-3-(2-phenyl-1H-indol-3-yl)propan-1-one (3s).[53] The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 20:1, v/v) to give the white solid, 174.7 mg, 87% yield; m.p. 114-116 °C ^1H NMR (400 MHz, $CDCl_3$) δ 8.08 (br, 1H), 7.70 (d, J = 8.0 Hz, 2H), 7.57-7.52 (m, 1H), 7.32 (t, J = 8.0 Hz, 5H), 7.20-7.13 (m,

8H), 7.07-6.99 (m, 3H), 5.28 (t, J = 6.0 Hz, 1H), 3.88-3.78 (m, 2H).

The general procedure for the synthesis of 2 and 4 (2a as example): In a 25 mL Schlenk equipped with a magnetic stirrer, 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one (**1a**) (0.30 mmol, 101.8 mg), elemental sulfur (S_8) (0.20 mmol, 51.3 mg) and NaO^{t}Bu (0.30 mmol, 28.8 mg) was combined and the Schenk tube was sealed. Then anhydrous dimethyl sulfoxide (DMSO) (2.0 mL) was injected in tube under N_2 atmosphere. After this, the Schlenk tube was conducted at 120 ^{o}C by heating mantle for 24 h. After cooling to room temperature, water (30 mL) was added and the aqueous phase was extracted by EtOAc (5×30 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by chromatography (petroleum ether/ethyl acetate = 7:1, v/v) on neutral aluminum oxide to afford the desired product **2a** in 97% yield.

The general procedure for the gram scale synthesis of 2b. In a 100 mL Schlenk equipped with a magnetic stirrer, 3-(1*H*-indol-3-yl)-1,3-diphenylpropan-1-one (**1b**) (7.0 mmol, 2.28 g), elemental sulfur (S_8) (4.7 mmol, 1.21 g) and NaO^{t}Bu (14 mmol, 1.35 g) was combined and the Schenk tube was sealed. Then anhydrous dimethyl sulfoxide (DMSO) (40 mL) was injected in tube under N_2 atmosphere. After this, the Schlenk tube was conducted at 100 ^{o}C by heating mantle for 48 h. After cooling to room temperature, water (100 mL) was added and the aqueous phase was extracted by EtOAc (5×100 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by chromatography (petroleum

ether/ethyl acetate = 7:1, v/v) on neutral aluminum oxide to afford the desired product **2b** in 64% yield.

The dual C-S bond formation of 1a in the absence of NaO^{t}Bu. In a 25 mL Schlenk equipped with a magnetic stirrer, 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one (**1a**) (0.30 mmol, 101.8 mg) and elemental sulfur (S_8) (0.20 mmol, 51.3 mg) was combined and the Schenk tube was sealed. Then anhydrous dimethyl sulfoxide (DMSO) (2.0 mL) was injected in tube under N_2 atmosphere. After this, the Schlenk tube was conducted at 120 °C by heating mantle for 24 h. After cooling to room temperature, water (30 mL) was added and the aqueous phase was extracted by EtOAc (5×30 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. Only a trace of product was observed in residue.

The dual C-S bond formation of 1a in the presence of TEMPO. In a 25 mL Schlenk equipped with a magnetic stirrer, 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one (**1a**) (0.30 mmol, 101.8 mg), elemental sulfur (S_8) (0.20 mmol, 51.3 mg), NaO^{t}Bu (0.30 mmol, 28.8 mg) and TEMPO (0.60 mmol, 93.8 mg) was combined and the Schenk tube was sealed. Then anhydrous dimethyl sulfoxide (DMSO) (2.0 mL) was injected in tube under N_2 atmosphere. After this, the Schlenk tube was conducted at 120 °C by heating mantle for 24 h. After cooling to room temperature, water (30 mL) was added and the aqueous phase was extracted by EtOAc (5×30 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by chromatography (petroleum ether/ethyl acetate = 7:1, v/v) on neutral aluminum oxide

to afford the desired product **2a** in 89% yield.

The dual C-S bond formation of 1a in the presence of BHT. In a 25 mL Schlenk equipped with a magnetic stirrer, 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one (**1a**) (0.30 mmol, 101.8 mg), elemental sulfur (S_8) (0.20 mmol, 51.3 mg), NaO^{t}Bu (0.30 mmol, 28.8 mg) and BHT (0.60 mmol, 132.2 mg) was combined and the Schenk tube was sealed. Then anhydrous dimethyl sulfoxide (DMSO) (2.0 mL) was injected in tube under N_2 atmosphere. After this, the Schlenk tube was conducted at 120 ^{o}C by heating mantle for 24 h. After cooling to room temperature, water (30 mL) was added and the aqueous phase was extracted by EtOAc (5×30 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by chromatography (petroleum ether/ethyl acetate = 7:1, v/v) on neutral aluminum oxide to afford the desired product **2a** in 92% yield.

The general procedure for the synthesis of 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one-2,2-d_2 (5a). To a solution of 10 mol % of TBD (0.072 mmol, 10 mg) in $CDCl_3$ (3.0 mL) was added 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one (0.72 mmol, 244 mg). The reaction mixture was stirred at room temperature for 24 h and quenched with 1 N HCl (1.0 mL). The organic layer was washed with water (2×2.0 mL) and brine (1.0 mL). The mixture was dried over anhydrous Na_2SO_4, concentrated in *vacuum*. The residue was purified by chromatography (petroleum ether/ethyl acetate = 3:1, v/v) on silica gel to gain the desired product in 86% yield.

3-(1H-indol-3-yl)-3-phenyl-1-(o-tolyl)propan-1-one-2,2-d_2 (5a, 88% D content). ^{1}H

NMR (400 MHz, $CDCl_3$) δ 7.98 (br, 1H), 7.51 (dd, J = 8.0, 4.0 Hz, 1H), 7.39 (d, J = 8.0 Hz, 1H), 7.33-7.28 (m, 4H), 7.23 (d, J = 8.0 Hz, 2H), 7.20 (dd, J = 8.0, 4.0 Hz, 1H), 7.15 (dd, J = 8.0, 4.0 Hz, 2H), 7.10 (d, J = 8.0 Hz, 1H), 6.99 (t, J = 6.0 Hz, 1H), 6.90 (d, J = 4.0 Hz, 1H), 4.94 (d, J = 8.0 Hz, 1H), 3.72-3.58 (m, 0.24H), 2.20 (s, 3H).

The general procedure for the synthesis of 3-(1*H*-indol-3-yl-2-*d*)-3-phenyl-1-(*o*-tolyl)propan-1-one (6a). $FeCl_3$ (0.025 mmol, 4.1 mg), $PdCl_2$ (0.025 mmol, 4.4 mg), and acetylacetone (0.075 mmol, 7.5 mg) were added into a solution of (*E*)-1-phenyl-3-(*o*-tolyl)prop-2-en-1-one (0.50 mmol) and 2-*d*-indole (0.55 mmol)[46] in anhydrous CH_3OH (2.0 mL). After stirring at room temperature for 24 h, the mixture was diluted with H_2O (10 mL) and extracted with EtOAc (3×20 mL). The combined organic layers were over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by chromatography (petroleum ether/ethyl acetate = 30:1, v/v) on silica gel to gain the desired product in 86% yield.

3-(1H-indol-3-yl-2-d)-3-phenyl-1-(o-tolyl)propan-1-one (6a). ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.90 (br, 1H), 7.75 (d, J = 8.0 Hz, 1H), 7.39-7.32 (m, 5H), 7.27 (t, J = 8.0 Hz, 1H), 7.23-7.18 (m, 3H), 7.10 (t, J = 8.0 Hz, 1H), 7.03 (t, J = 8.0 Hz, 1H), 6.88 (t, J = 8.0 Hz, 1H), 4.80 (t, J = 8.0 Hz, 1H), 3.79 (q, J = 8.0 Hz, 1H), 3.71 (q, J = 8.0 Hz, 1H), 2.10 (s, 3H).

The general procedure for KIE. In a 25 mL Schlenk equipped with a magnetic stirrer, 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one (**1a**) (0.30 mmol, 101.8 mg), elemental sulfur (S_8) (0.20 mmol, 51.3 mg) and NaO^{t}Bu (0.30 mmol, 28.8 mg) was combined and the Schenk tube was sealed. Then anhydrous dimethyl sulfoxide

(DMSO) (2.0 mL) was injected in tube under N_2 atmosphere. After this, the Schlenk tube was conducted at 120 °C by heating mantle for 20 min. After cooling to room temperature, water (30 mL) was added and the aqueous phase was extracted by EtOAc (5×30 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by chromatography (petroleum ether/ethyl acetate = 30:1, v/v) on neutral aluminum oxide to afford the desired product **2a** in 25% yield.

In a 25 mL Schlenk equipped with a magnetic stirrer, 3-(1*H*-indol-3-yl-2-*d*)-3-phenyl-1-(*o*-tolyl)propan-1-one (0.30 mmol, 102.1 mg), elemental sulfur (S_8) (0.20 mmol, 51.3 mg) and NaO^{t}Bu (0.30 mmol, 28.8 mg) was combined and the Schenk tube was sealed. Then anhydrous dimethyl sulfoxide (DMSO) (2.0 mL) was injected in tube under N_2 atmosphere. After this, the Schlenk tube was conducted at 120 °C by heating mantle for 20 min. After cooling to room temperature, water (30 mL) was added and the aqueous phase was extracted by EtOAc (5×30 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by chromatography (petroleum ether/ethyl acetate = 30:1, v/v) on neutral aluminum oxide to afford the desired product **2a** in 22% yield.

In a 25 mL Schlenk equipped with a magnetic stirrer, 3-(1*H*-indol-3-yl)-3-phenyl-1-(*o*-tolyl)propan-1-one-2,2-d_2 (88% D content) (0.30 mmol, 102.4 mg), elemental sulfur (S_8) (0.20 mmol, 51.3 mg) and NaO^{t}Bu (0.30 mmol, 28.8 mg) was combined and the Schenk tube was sealed. Then anhydrous

dimethyl sulfoxide (DMSO) (2.0 mL) was injected in tube under N_2 atmosphere. After this, the Schlenk tube was conducted at 120 °C by heating mantle for 20 min. After cooling to room temperature, water (30 mL) was added and the aqueous phase was extracted by EtOAc (5×30 mL). The combined organic phases were dried over Na_2SO_4, and concentrated in *vacuum*. The residue was purified by chromatography (petroleum ether/ethyl acetate = 30:1, v/v) on neutral aluminum oxide to afford the desired product **2a** in 21% yield.

(3-Phenyl-8H-thieno[2,3-b]indol-2-yl)(o-tolyl)methanone (2a). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 106.9 mg, 97% yield; m.p. 170-180 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 12.21 (br, 1H), 7.55 (dd, J = 12.0, 6.0 Hz, 1H), 7.27-7.22 (m, 3H), 7.17 (q, J = 6.0 Hz, 4H), 7.06 (td, J = 9.0, 6.0 Hz, 2H), 6.99-6.94 (m, 2H), 6.84 (td, J = 9.0, 6.0 Hz, 1H), 2.23 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 191.0, 146.6, 143.3, 142.3, 139.8, 135.2, 134.6, 131.7, 130.3, 129.7, 129.5, 128.3, 128.2, 128.0, 126.2, 125.2, 124.1, 122.5, 120.5, 118.9, 112.7, 19.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NOS$ ($M+H^+$): 368.1103; Found 368.1101.

Phenyl(3-phenyl-8H-thieno[2,3-b]indol-2-yl)methanone (2b). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 94.4 mg, 89% yield; m.p. 214-217 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 12.20 (br, 1H), 7.56 (d, J = 12.0 Hz, 1H), 7.40 (d, J = 6.0 Hz, 2H), 7.34-7.32 (m, 3H), 7.27 (q, J

= 8.0 Hz, 2H), 7.21 (t, *J* = 6.0 Hz, 3H), 7.11 (t, *J* = 6.0 Hz, 2H), 7.02 (t, *J* = 6.0 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (151 MHz, DMSO-d_6) δ 189.8, 146.0, 143.3, 141.7, 138.9, 135.1, 131.3, 130.3, 130.2, 129.1, 128.4, 128.3, 127.9, 125.6, 124.0, 122.4, 120.4, 119.0, 112.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{16}NOS$ ($M+H^+$): 354.0947; Found 354.0949.

(4-Chlorophenyl)(3-phenyl-8H-thieno[2,3-b]indol-2-yl)methanone (2c). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 52.4 mg, 45% yield; m.p. 222-230 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 12.25 (br, 1H), 7.57 (d, *J* = 12.0 Hz, 1H), 7.37 (dd, *J* = 12.0, 6.0 Hz, 2H), 7.33 (dd, *J* = 12.0, 6.0 Hz, 3H), 7.28 (d, *J* = 6.0 Hz, 2H), 7.25 (td, *J* = 9.0, 6.0 Hz, 2H), 7.14 (d, *J* = 6.0 Hz, 2H), 7.03 (t, *J* = 6.0 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (151 MHz, DMSO-d_6) δ 188.6, 146.2, 143.3, 142.0, 137.7, 135.9, 134.9, 130.9, 130.4, 130.2, 128.5, 128.4, 128.0, 125.7, 124.1, 122.3, 120.5, 119.0, 112.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}ClNOS$ ($M+H^+$): 388.0557; Found 388.0560.

(4-Methoxyphenyl)(3-phenyl-8H-thieno[2,3-b]indol-2-yl)methanone (2d). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 6:1, v/v) to give the yellow solid, 94.3 mg, 82% yield; m.p. 255-260 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 12.14 (br, 1H), 7.56 (dd, *J* = 12.0 , 6.0 Hz, 1H), 7.44 (dd, *J* = 12.0, 6.0 Hz, 2H), 7.39-7.37 (m, 3H), 7.30-7.25 (m, 4H), 7.04 (td, *J* = 9.0, 6.0 Hz, 1H), 6.67 (dd, *J* = 12.0 , 6.0 Hz, 2H), 3.71 (s, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, DMSO-d_6) δ 188.5, 162.1, 145.3, 143.2,

140.7, 135.4, 131.6, 131.2, 130.3, 130.2, 128.5, 128.3, 125.3, 123.9, 122.3, 120.3, 119.0, 113.4, 112.7, 55.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NO_2S$ ($M+H^+$): 384.1052; Found 384.1051.

(3-Bromophenyl)(3-phenyl-8H-thieno[2,3-b]indol-2-yl)methanone (2e). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 116.7 mg, 90% yield; m.p. 243-249 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.23 (br, 1H), 7.57 (d, J = 8.0 Hz, 1H), 7.46-7.42 (m, 2H), 7.39-7.34 (m, 3H), 7.31 (t, J = 6.0 Hz, 1H), 7.27-7.23 (m, 4H), 7.09-7.01 (m, 2H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 188.1, 146.5, 143.3, 142.3, 141.0, 134.9, 133.8, 131.7, 130.2, 130.1, 130.1, 128.6, 128.4, 127.8, 125.8, 124.2, 122.4, 121.2, 120.6, 119.0, 112.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}BrNOS$ ($M+H^+$): 432.0052; Found 432.0058.

Phenyl(3-(o-tolyl)-8H-thieno[2,3-b]indol-2-yl)methanone (2f). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 99.2 mg, 90% yield; m.p. 180-184 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 12.20 (br, 1H), 7.56 (dd, J = 12.0, 6.0 Hz, 1H), 7.43 (d, J = 6.0 Hz, 2H), 7.29 (t, J = 9.0 Hz, 1H), 7.25 (td, J = 9.0, 6.0 Hz, 1H), 7.14 (t, J = 6.0 Hz, 4H), 7.11 (d, J = 6.0 Hz, 1H), 7.03-6.97 (m, 2H), 6.91 (dd, J = 12.0, 6.0 Hz, 1H), 2.13 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 189.7, 146.1, 143.2, 140.9, 139.2, 135.9, 135.3, 131.2, 130.9, 130.4, 130.2, 128.4, 127.8, 126.2, 125.8, 124.0, 122.5, 120.6, 118.7, 112.7, 20.0.

HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NOS$ ($M+H^+$): 368.1103; Found 368.1105.

(3-(3-Methoxyphenyl)-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (2g). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 6:1, v/v) to give the yellow solid, 107.0 mg, 93% yield; m.p. 202-206 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.20 (br, 1H), 7.57 (d, J = 8.0 Hz, 1H), 7.43-7.38 (m, 3H), 7.32-7.25 (m, 2H), 7.18 (t, J = 8.0 Hz, 1H), 7.13 (t, J = 6.0 Hz, 2H), 7.04 (td, J = 8.0, 4.0 Hz, 1H), 7.00 (dd, J = 12.0, 4.0 Hz, 1H), 6.83 (d, J = 4.0 Hz, 1H), 6.79 (dd, J = 8.0, 4.0 Hz, 1H), 3.62 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.9, 159.1, 146.0, 143.3, 141.5, 139.1, 136.4, 131.3, 130.5, 129.5, 129.0, 127.9, 125.6, 124.0, 122.5, 122.4, 120.4, 119.1, 115.5, 114.7, 112.7, 55.4. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NO_2S$ ($M+H^+$): 384.1052; Found 384.1051.

(3-(3-Fluorophenyl)-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (2h). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 94.7 mg, 85% yield; m.p. 187-191 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.30 (br, 1H), 7.58 (d, J = 8.0 Hz, 1H), 7.43 (d, J = 8.0 Hz, 2H), 7.35-7.27 (m, 4H), 7.24 (td, J = 8.0, 4.0 Hz, 1H), 7.18-7.13 (m, 3H), 7.10-7.02 (m, 2H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.6, 162.0 (J = 245 Hz), 146.1, 143.3, 140.0, 139.1, 137.5 (J =

9.1 Hz), 131.4, 130.7, 130.4 (J = 9.1 Hz), 129.0, 128.0, 126.4 (J = 3.0 Hz), 125.5, 124.1, 122.2, 120.5, 118.9, 117.2 (J = 22 Hz), 115.2 (J = 21 Hz), 112.8; ^{19}F NMR (376 MHz, DMSO-d_6) δ -113.6 ppm. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}FNOS$ ($M+H^+$): 372.0852; Found 372.0851.

Phenyl(3-(p-tolyl)-8H-thieno[2,3-b]indol-2-yl)methanone (2i). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 99.2 mg, 90% yield; m.p. 261-265 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 12.16 (br, 1H), 7.55 (d, J = 6.0 Hz, 1H), 7.38 (q, J = 6.0 Hz, 3H), 7.30-7.23 (m, 2H), 7.22 (d, J = 6.0 Hz, 2H), 7.12 (t, J = 9.0 Hz, 2H), 7.02 (t, J = 9.0 Hz, 3H), 2.24 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 189.8, 146.0, 143.2, 141.9, 139.0, 137.7, 132.2, 131.2, 130.2, 129.9, 129.1, 128.9, 127.9, 125.6, 124.0, 122.4, 120.4, 119.1, 112.7, 21.3. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NOS$ ($M+H^+$): 368.1103; Found 368.1106.

(3-(4-Chlorophenyl)-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (2j). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 101.2 mg, 87% yield; m.p. 264-270 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 12.20 (br, 1H), 7.57 (dd, J = 12.0, 6.0 Hz, 1H), 7.41 (d, J = 12.0 Hz, 2H), 7.37-7.31 (m, 4H), 7.28 (d, J = 6.0 Hz, 3H), 7.18 (td, J = 9.0, 6.0 Hz, 2H), 7.05 (td, J = 9.0, 6.0 Hz, 1H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 189.6, 146.1, 143.3, 140.2, 139.0, 134.1,

133.2, 132.0, 131.4, 130.4, 129.1, 128.4, 128.1, 125.5, 124.1, 122.2, 120.6, 119.0, 112.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}ClNOS$ ($M+H^+$): 388.0557; Found 388.0556.

4-(2-Benzoyl-8H-thieno[2,3-b]indol-3-yl)benzonitrile (2k). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 5:1, v/v) to give the orange solid, 84.0 mg, 74% yield; m.p. 255-259 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.24 (br, 1H), 7.70 (dd, J = 12.0, 4.0 Hz, 2H), 7.60- 7.55 (m, 3H), 7.42 (d, J = 8.0 Hz, 2H), 7.36 (td, J = 8.0, 4.0 Hz, 1H), 7.31-7.25 (m, 2H), 7.18 (td, J = 8.0, 4.0 Hz, 2H), 7.04 (t, J = 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.4, 146.2, 143.3, 140.4, 139.5, 138.9, 132.2, 131.5, 131.2, 130.8, 129.1, 128.1, 125.3, 124.3, 121.9, 120.6, 119.1, 119.0, 112.9, 110.9. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{15}N_2OS$ ($M+H^+$): 379.0899; Found 379.0897.

(3-([1,1'-Biphenyl]-4-yl)-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (2l). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 118.6 mg, 92% yield; m.p. 252-255 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.26 (br, 1H), 7.59 (d, J = 8.0 Hz, 1H), 7.56 (d, J = 8.0 Hz, 2H), 7.45 (td, J = 8.0, 4.0 Hz, 4H), 7.40 (d, J = 4.0 Hz, 2H), 7.38-7.34 (m, 4H), 7.27 (t, J = 8.0 Hz, 1H), 7.21 (t, J = 8.0 Hz, 1H), 7.09-7.01 (m, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.8, 146.2, 143.3, 141.4, 140.1, 140.0, 139.1, 134.2, 131.0, 130.8, 130.4, 129.4, 129.1, 128.1, 127.9, 127.0, 126.4, 125.5, 124.1, 122.4, 120.5, 119.2, 112.8. HRMS (ESI-TOF) m/z:

$[M+H]^+$ Calcd for $C_{29}H_{20}NOS$ ($M+H^+$): 430.1260; Found 430.1261.

(3-(Naphthalen-1-yl)-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (2m). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 94.4 mg, 78% yield; m.p. 236-239 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.28 (br, 1H), 7.89 (d, J = 8.0 Hz, 1H), 7.78 (d, J = 8.0 Hz, 1H), 7.72 (d, J = 8.0 Hz, 1H), 7.56 (d, J = 8.0 Hz, 1H), 7.49 (td, J = 8.0, 4.0 Hz, 1H), 7.40 (td, J = 8.0, 4.0 Hz, 1H), 7.34 (dd, J = 8.0, 4.0 Hz, 1H), 7.28 (t, J = 8.0 Hz, 1H), 7.23 (d, J = 8.0 Hz, 2H), 7.17 (td, J = 8.0, 4.0 Hz, 1H), 7.05 (td, J = 8.0, 4.0 Hz, 1H), 6.77 (t, J = 8.0 Hz, 3H), 6.42 (d, J = 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.9, 146.1, 143.2, 139.5, 139.2, 133.3, 133.1, 132.0, 131.6, 131.0, 128.8, 128.7, 128.0, 127.3, 127.1, 126.9, 126.4, 125.8, 125.5, 123.9, 122.3, 120.3, 119.2, 112.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{27}H_{18}NOS$ ($M+H^+$): 404.1103; Found 404.1102.

(3-(Naphthalen-2-yl)-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (2n). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 79.9 mg, 66% yield; m.p. 202-210 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.34 (br, 1H), 8.33 (d, J = 8.0 Hz, 1H), 8.10 (d, J = 8.0 Hz, 1H), 7.91 (d, J = 8.0 Hz, 1H), 7.78-7.69 (m, 3H), 7.54 (d, J = 8.0 Hz, 2H), 7.44 (d, J = 4.0 Hz, 1H), 7.35 (dd, J = 8.0, 4.0 Hz, 2H), 7.29 (t, J = 8.0 Hz, 1H), 7.12 (td, J = 8.0, 4.0 Hz, 1H), 7.07-7.00 (m, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 191.2, 139.1, 137.8, 137.8, 137.3, 136.4, 135.9, 132.5, 132.2, 129.5, 129.1, 128.4, 128.0, 128.0, 127.9, 127.4, 127.1, 126.7,

124.3, 123.1, 122.0, 120.0, 119.3, 112.2, 109.1. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{27}H_{18}NOS$ ($M+H^+$): 404.1103; Found 404.1107.

Naphthalen-2-yl(3-phenyl-8H-thieno[2,3-b]indol-2-yl)methanone (2o). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the red solid, 110.2 mg, 91% yield; m.p. 228-235 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.23 (br, 1H), 8.04 (s, 1H), 7.80 (q, J = 8.0 Hz, 2H), 7.71 (d, J = 8.0 Hz, 1H), 7.59 (td, J = 8.0, 4.0 Hz, 2H), 7.53 (td, J = 8.0, 4.0 Hz, 1H), 7.46 (td, J = 8.0, 4.0 Hz, 1H), 7.41 (dd, J = 12.0, 4.0 Hz, 2H), 7.36 (d, J = 8.0 Hz, 1H), 7.28 (t, J = 8.0 Hz, 1H), 7.10-7.02 (m, 3H), 6.98 (td, J = 8.0, 4.0 Hz, 1H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.6, 145.9, 143.3, 141.7, 136.0, 135.4, 134.3, 131.9, 130.8, 130.4, 130.1, 129.3, 128.3, 128.2, 128.1, 127.8, 127.8, 126.7, 125.7, 125.4, 124.0, 122.4, 120.4, 119.0, 112.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{27}H_{18}NOS$ ($M+H^+$): 404.1103; Found 404.1102.

Furan-2-yl(3-phenyl-8H-thieno[2,3-b]indol-2-yl)methanone (2p). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 73.1 mg, 71% yield; m.p. 175-183 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.16 (br, 1H), 7.66 (s, 1H), 7.58 (d, J = 8.0 Hz, 1H), 7.53 (dd, J = 8.0, 4.0 Hz, 2H), 7.47-7.39 (m, 4H), 7.28 (td, J = 8.0, 4.0 Hz, 1H), 7.05 (t, J = 8.0 Hz, 1H), 6.97 (d, J = 4.0 Hz, 1H), 6.49 (d, J = 4.0 Hz, 1H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 175.2, 151.7, 147.2, 145.6, 143.3, 141.2, 136.0, 129.7, 128.7, 128.5, 127.6, 125.4, 124.0,

122.1, 120.4, 119.1, 119.0, 112.8, 112.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{21}H_{14}NO_2S$ ($M+H^+$): 344.0739; Found 344.0745.

(3-Phenyl-8H-thieno[2,3-b]indol-2-yl)(thiophen-2-yl)methanone (2q). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 93.8 mg, 87% yield; m.p. 188-194 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 12.24 (br, 1H), 7.82 (d, J = 6.0 Hz, 1H), 7.60 (d, J = 6.0 Hz, 1H), 7.53 (dd, J = 12.0, 6.0 Hz, 2H), 7.44-7.36 (m, 4H), 7.35 (dd, J = 6.0, 6.0 Hz, 1H), 7.29 (td, J = 9.0, 6.0 Hz, 1H), 7.06 (t, J = 9.0 Hz, 1H), 6.88 (t, J = 6.0 Hz, 1H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 180.5, 145.2, 143.6, 143.3, 140.6, 135.7, 134.3, 133.9, 130.1, 128.7, 128.6, 128.2, 128.1, 125.3, 124.0, 122.2, 120.4, 119.1, 112.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{21}H_{14}NOS_2$ ($M+H^+$): 360.0511; Found 360.0510.

Benzo[b]thiophen-2-yl(3-phenyl-8H-thieno[2,3-b]indol-2-yl)methanone (2r). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow liquid, 78.6 mg, 64% yield. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.21 (br, 1H), 7.96 (d, J = 8.0 Hz, 1H), 7.72 (td, J = 6.0, 4.0 Hz, 2H), 7.59 (td, J = 8.0, 4.0 Hz, 3H), 7.44 (t, J = 8.0 Hz, 2H), 7.39 (t, J = 4.0 Hz, 1H), 7.37-7.34 (m, 2H), 7.31-7.24 (m, 2H), 7.06 (t, J = 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 181.5, 145.7, 143.4, 143.0, 141.3, 141.1, 139.0, 135.7, 131.6, 129.9, 128.7, 128.7, 127.9, 127.5, 126.2, 125.7, 125.4, 124.2, 123.2, 122.2, 120.5, 119.1, 112.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{25}H_{16}NOS_2$ ($M+H^+$): 410.0667; Found 410.0666.

(8-Methyl-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4a). The title compound was prepared according to the general procedure and purified by flash column chromatography(petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 77.2 mg, 70% yield; m.p. 183-186 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.65 (dd, J = 8.0, 4.0 Hz, 1H), 7.40 (d, J = 8.0 Hz, 2H), 7.36-7.32 (m, 4H), 7.29 (td, J = 8.0, 4.0 Hz, 1H), 7.25-7.20 (m, 3H), 7.14-7.06 (m, 3H), 3.95 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 194.3, 153.1, 148.3, 146.8, 143.6, 139.8, 136.1, 135.1, 135.0, 133.8, 133.3, 133.1, 132.7, 128.8, 127.0, 125.5, 123.8, 115.8, 37.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NOS$ ($M+H^+$): 368.1103; Found 368.1102.

(3,8-Diphenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4b). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 112.1 mg, 87% yield; m.p. 167-176 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.83 (d, J = 8.0 Hz, 2H), 7.73 (td, J = 8.0, 4.0 Hz, 2H), 7.58 (t, J = 8.0 Hz, 2H), 7.45-7.40 (m, 5H), 7.36 (d, J = 8.0 Hz, 1H), 7.33 (d, J = 12.0, 4.0 Hz, 1H), 7.29-7.25 (m, 3H), 7.19-7.12 (m, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.8, 146.8, 142.4, 141.8, 138.5, 137.5, 134.7, 131.7, 131.1, 130.2, 129.1, 128.7, 128.5, 128.1, 125.7, 124.9, 124.4, 122.9, 121.9, 119.5, 111.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{29}H_{20}NOS$ ($M+H^+$): 430.1260; Found 430.1262.

(8-Benzyl-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4c). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow

solid, 111.8 mg, 84% yield; m.p. 131-139 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.79 (d, J = 8.0 Hz, 1H), 7.41-7.34 (m, 8H), 7.30 (t, J = 8.0 Hz, 3H), 7.25-7.15 (m, 4H), 7.08-7.03 (m, 3H), 5.56 (s, 2H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.7, 147.1, 143.2, 141.7, 138.7, 135.9, 134.9, 131.3, 131.1, 130.3, 129.3, 129.1, 128.7, 128.6, 128.5, 128.3, 127.9, 124.8, 124.2, 122.5, 120.9, 119.2, 111.3, 49.4. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{30}H_{22}NOS$ ($M+H^+$): 444.1416; Found 444.1420.

(4-Methyl-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4d). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 86.0 mg, 78% yield; m.p. 215-220 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.25 (br, 1H), 7.36 (dd, J = 8.0, 4.0 Hz, 3H), 7.33-7.28 (m, 2H), 7.27 (d, J = 4.0 Hz, 1H), 7.21-7.14 (m, 5H), 7.12 (t, J = 8.0 Hz, 1H), 6.75 (d, J = 8.0 Hz, 1H), 1.59 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.9, 146.5, 143.5, 142.3, 139.9, 137.2, 131.1, 130.9, 130.8, 130.0, 128.4, 128.1, 128.0, 127.6, 127.3, 124.0, 122.6, 122.2, 110.0, 21.9. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NOS$ ($M+H^+$): 368.1103; Found 368.1104.

(4-Methoxy-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4e). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 6:1, v/v) to give the yellow solid, 105.8 mg, 92% yield; m.p. 226-229 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.24 (br, 1H), 7.33 (d, J = 8.0 Hz, 2H), 7.25 (t, J = 8.0 Hz, 1H), 7.19-7.15 (m, 4H), 7.12-7.04 (m, 5H), 6.50 (d, J = 8.0 Hz, 1H), 3.23 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz,

DMSO-d_6) δ 190.1, 153.7, 145.1, 144.5, 142.6, 139.4, 136.3, 131.3, 130.9, 130.8, 128.7, 127.8, 127.3, 126.4, 126.0, 125.1, 112.5, 105.3, 101.8, 54.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NO_2S$ ($M+H^+$): 384.1052; Found 384.1053.

(5-Methyl-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4f). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 104.7 mg, 95% yield; m.p. 239-241 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.16 (br, 1H), 7.45 (d, J = 8.0 Hz, 1H), 7.39 (dd, J = 8.0, 4.0 Hz, 2H), 7.33 (t, J = 4.0 Hz, 2H), 7.28 (td, J = 8.0, 4.0 Hz, 1H), 7.24-7.19 (m, 3H), 7.12 (s, 1H), 7.09 (t, J = 8.0 Hz, 3H), 2.27 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.7, 146.1, 141.8, 141.6, 139.0, 135.2, 131.2, 130.3, 130.0, 129.0, 128.4, 128.3, 127.9, 125.3, 125.3, 122.6, 118.9, 112.4, 21.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NOS$ ($M+H^+$): 368.1103; Found 368.1104.

(5-Methoxy-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4g). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 6:1, v/v) to give the yellow solid, 101.2 mg, 88% yield; m.p. 198-203 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.04 (br, 1H), 7.50 (d, J = 8.0 Hz, 1H), 7.42 (d, J = 8.0 Hz, 2H), 7.36 (td, J = 4.0, 4.0 Hz, 2H), 7.30 (td, J = 8.0, 4.0 Hz, 1H), 7.27-7.24 (m, 3H), 7.14 (td, J = 8.0, 4.0 Hz, 2H), 6.95 (dd, J = 8.0, 4.0 Hz, 1H), 6.83 (s, 1H), 3.64 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 194.5, 158.7, 151.2, 146.5, 143.7, 142.9, 139.8, 136.0, 135.0, 134.6, 133.8, 133.2, 133.0, 132.7, 130.2, 127.7, 118.0, 116.9, 107.5, 60.4. HRMS (ESI-TOF)

m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NO_2S$ ($M+H^+$): 384.1052; Found 384.1050.

(5-Chloro-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4h). The title compound was prepared according to the general procedure and purified by flash column chromatography(petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 86.1 mg, 74% yield; m.p. 238-243 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.33 (br, 1H), 7.60 (d, J = 8.0 Hz, 1H), 7.41 (dd, J = 8.0, 4.0 Hz, 2H), 7.35-7.31 (m, 2H), 7.30 (d, J = 4.0 Hz, 1H), 7.28 (d, J = 4.0 Hz, 1H), 7.26 (d, J = 4.0 Hz, 2H), 7.24 (d, J = 4.0 Hz, 2H), 7.12 (td, J = 8.0, 4.0 Hz, 2H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.9, 146.9, 141.7, 141.3, 138.7, 134.8, 131.5, 130.9, 130.1, 129.1, 128.6, 128.5, 128.0, 124.8, 123.7, 123.4, 118.1, 114.2. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}ClNOS$ ($M+H^+$): 388.0557; Found 388.0553.

(5-Fluoro-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4i). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 100.3 mg, 90% yield; m.p. 191-195 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.27 (br, 1H), 7.60 (q, J = 4.0 Hz, 1H), 7.41 (dd, J = 8.0, 4.0 Hz, 2H), 7.32 (t, J = 4.0 Hz, 2H), 7.30-7.22 (m, 4H), 7.16-7.10 (m, 3H), 6.98 (dd, J = 8.0, 4.0 Hz, 1H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.8, 157.2 (J = 235 Hz), 147.3, 141.4, 139.7, 138.8, 134.8, 131.4, 130.6, 130.1, 129.1, 128.5, 128.4, 127.9, 125.2 (J = 4.0 Hz), 122.6 (J = 11.1 Hz), 113.7 (J = 10.1 Hz), 111.5 (J = 25.3 Hz), 104.3 (J = 25.3 Hz); ^{19}F NMR (376 MHz, DMSO-d_6) δ -123.0 ppm. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}FNOS$ ($M+H^+$): 372.0852; Found 372.0853.

2-Benzoyl-3-phenyl-8H-thieno[2,3-b]indole-5-carbonitrile (4j). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 5:1, v/v) to give the yellow liquid, 70.4 mg, 62% yield. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.86 (br, 1H), 7.76 (d, J = 8.0 Hz, 1H), 7.64 (d, J = 8.0 Hz, 1H), 7.59 (s, 1H), 7.42 (dd, J = 8.0, 4.0 Hz, 2H), 7.36-7.33 (m, 2H), 7.31-7.24 (m, 4H), 7.14 (td, J = 8.0, 4.0 Hz, 2H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.9, 147.3, 145.0, 141.0, 138.5, 134.6, 131.9, 131.7, 130.1, 129.2, 128.8, 128.6, 128.0, 126.9, 124.9, 123.2, 122.1, 120.5, 114.0, 102.3. HRMS (ESI-TOF) m/z: [M+H]$^+$ Calcd for $C_{24}H_{15}N_2OS$ (M+H$^+$): 379.0899; Found 379.0900.

Methyl-2-benzoyl-3-phenyl-8H-thieno[2,3-b]indole-5-carboxylate (4k). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 5:1, v/v) to give the yellow liquid, 76.5 mg, 62% yield. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.66 (br, 1H), 8.05 (s, 1H), 7.89 (dd, J = 8.0, 4.0 Hz, 1H), 7.66 (d, J = 8.0 Hz, 1H), 7.42 (dd, J = 8.0, 4.0 Hz, 2H), 7.36 (dd, J = 8.0, 4.0 Hz, 2H), 7.33-7.26 (m, 3H), 7.24-7.22 (m, 1H), 7.13 (td, J = 8.0, 4.0 Hz, 2H), 3.78 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.9, 167.1, 147.0, 145.8, 141.3, 138.7, 134.8, 131.5, 131.3, 130.2, 129.1, 128.7, 128.4, 128.0, 125.7, 124.9, 122.0, 121.6, 120.9, 112.6, 52.3. HRMS (ESI-TOF) m/z: [M+H]$^+$ Calcd for $C_{25}H_{18}NO_3S$ (M+H$^+$): 412.1001; Found 412.1002.

(6-Methyl-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4l). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow

solid, 99.2 mg, 90% yield; m.p. 216-222 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.08 (br, 1H), 7.37 (t, J = 8.0 Hz, 3H), 7.31 (t, J = 4.0 Hz, 2H), 7.27 (t, J = 8.0 Hz, 1H), 7.21 (t, J = 4.0 Hz, 4H), 7.10 (t, J = 8.0 Hz, 2H), 6.84 (d, J = 8.0 Hz, 1H), 2.40 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.7, 145.7, 143.7, 141.5, 139.0, 135.2, 133.5, 131.2, 130.2, 130.0, 129.1, 128.3, 128.3, 127.9, 125.7, 121.8, 120.2, 118.7, 112.7, 21.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NOS$ ($M+H^+$): 368.1103; Found 368.1105.

(6-Chloro-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4m). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the orange solid, 108.2 mg, 93% yield; m.p. 268-270 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.43 (br, 1H), 7.67 (d, J = 2.0 Hz, 1H), 7.40 (d, J = 8.0 Hz, 2H), 7.33-7.27 (m, 4H), 7.24-7.19 (m, 3H), 7.11 (t, J = 8.0 Hz, 2H), 7.06 (dd, J = 8.0, 4.0 Hz, 1H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.8, 146.5, 143.6, 141.2, 138.8, 134.9, 131.4, 130.9, 130.2, 129.1, 128.5, 128.4, 128.4, 127.9, 125.1, 121.1, 120.5, 119.9, 112.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}ClNOS$ ($M+H^+$): 388.0557; Found 388.0555.

(6-Fluoro-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4n). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 100.3 mg, 90% yield; m.p. 239-244 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.23 (br, 1H), 7.43-7.39 (m, 3H), 7.33 (t, J = 4.0 Hz, 2H), 7.31-7.26 (m, 2H), 7.25-7.21 (m,

3H), 7.12 (td, J = 8.0, 4.0 Hz, 2H), 6.90 (td, J = 8.0, 4.0 Hz, 1H); $^{13}C\{^1H\}$ NMR (101 MHz, DMSO-d_6) δ 189.8, 160.0 (J = 239 Hz), 146.2, 143.4 (J = 13.1 Hz), 141.2, 138.8, 135.0, 131.4, 130.6, 130.19, 129.1, 128.4 (J = 5.1 Hz), 128.0, 125.2, 119.8 (J = 10.1 Hz), 119.1, 108.4 (J = 24.2 Hz), 99.5 (J = 26.3 Hz). ^{19}F NMR (376 MHz, DMSO-d_6) δ -118.1 ppm. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}FNOS$ ($M+H^+$): 372.0852; Found 372.0851.

(7-Methoxy-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4o). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 6:1, v/v) to give the yellow solid, 104.7 mg, 91% yield; m.p. 186-195 ^oC. ^1H NMR (400 MHz, DMSO-d_6) δ 12.30 (br, 1H), 7.40 (d, J = 4.0 Hz, 2H), 7.32 (t, J = 4.0 Hz, 2H), 7.28 (t, J = 8.0 Hz, 1H), 7.21 (d, J = 8.0 Hz, 3H), 7.11 (t, J = 6.0 Hz, 2H), 6.98-6.91 (m, 2H), 6.88 (d, J = 8.0 Hz, 1H), 3.97 (s, 3H); $^{13}C\{^1H\}$ NMR (101 MHz, DMSO-d_6) δ 189.8, 146.2, 145.4, 141.7, 138.9, 135.1, 132.7, 131.4, 130.4, 130.3, 129.1, 128.4, 128.3, 127.9, 126.1, 123.5, 121.1, 111.8, 105.2, 56.0. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{18}NO_2S$ ($M+H^+$): 384.1052; Found 384.1050.

***(7-Bromo-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4p*).** The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 121.9 mg, 94% yield; m.p. 197-199 ^oC. ^1H NMR (400 MHz, DMSO-d_6) δ 12.38 (br, 1H), 7.45 (d, J = 8.0 Hz, 1H), 7.37 (d, J = 8.0 Hz, 2H), 7.30-7.24 (m, 4H), 7.20 (t, J = 6.0 Hz, 3H), 7.08 (t, J = 8.0 Hz, 2H), 6.94 (t, J = 8.0 Hz, 1H); $^{13}C\{^1H\}$ NMR (101

MHz, DMSO-d_6) δ 189.9, 146.4, 141.5, 141.1, 138.6, 134.7, 131.5, 131.4, 130.2, 129.1, 128.5, 128.4, 128.0, 126.4, 125.9, 124.0, 121.8, 118.3, 104.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}BrNOS$ ($M+H^+$): 432.0052; Found 432.0051.

(7-Chloro-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4q). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the orange solid, 104.7 mg, 90% yield; m.p. 198-202 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.57 (br, 1H), 7.41 (d, J = 8.0 Hz, 2H), 7.36-7.28 (m, 6H), 7.22 (d, J = 8.0 Hz, 2H), 7.12 (t, J = 8.0 Hz, 2H), 7.03 (t, J = 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.9, 146.4, 141.4, 139.7, 138.6, 134.7, 131.5, 131.4, 130.2, 129.1, 128.5, 128.4, 127.9, 125.9, 124.1, 123.4, 121.4, 117.8, 116.4. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{15}ClNOS$ ($M+H^+$): 388.0557; Found 388.0554.

(7-(Benzyloxy)-3-phenyl-8H-thieno[2,3-b]indol-2-yl)(phenyl)methanone (4r). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 6:1, v/v) to give the orange solid, 111.7 mg, 81% yield; m.p. 207-213 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.35 (br, 1H), 7.59 (d, J = 8.0 Hz, 2H), 7.45-7.35 (m, 5H), 7.32 (t, J = 8.0 Hz, 2H), 7.26 (t, J = 8.0 Hz, 1H), 7.19 (t, J = 6.0 Hz, 3H), 7.09 (t, J = 8.0 Hz, 2H), 6.98-6.90 (m, 3H), 5.29 (s, 2H); ^{13}C{^{1}H} NMR (101 MHz, DMSO-d_6) δ 189.8, 145.6, 145.2, 141.7, 138.9, 137.5, 135.1, 133.0, 131.3, 130.5, 130.3, 129.1, 128.9, 128.4, 128.3, 128.2, 127.9, 126.1, 123.7, 121.0, 112.1, 106.5, 69.9. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{30}H_{22}NO_2S$ ($M+H^+$): 460.1365; Found 460.1362.

Phenyl(3-(2-phenyl-1H-indol-3-yl)benzo[b]thiophen-2-yl)methanone (4s). The title compound was prepared according to the general procedure and purified by flash column chromatography (petroleum ether/ethyl acetate = 7:1, v/v) to give the yellow solid, 58.0 mg, 45% yield; m.p. 152-159 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 11.44 (br, 1H), 8.17 (d, J = 12.0 Hz, 1H), 7.59-7.54 (m, 2H), 7.39 (td, J = 9.0, 6.0 Hz, 1H), 7.33 (d, J = 6.0 Hz, 1H), 7.28 (td, J = 9.0, 6.0 Hz, 2H), 7.25 (d, J = 6.0 Hz, 1H), 7.23-7.19 (m, 3H), 7.18 (t, J = 1.2 Hz, 1H), 7.14 (td, J = 9.0, 6.0 Hz, 1H), 7.09 (dd, J = 12.0, 6.0 Hz, 2H), 7.02 (t, J = 6.0 Hz, 1H), 6.89 (t, J = 9.0 Hz, 2H); ^{13}C{^{1}H} NMR (151 MHz, DMSO-d_6) δ 191.0, 140.7, 139.9, 138.6, 137.5, 137.4, 136.5, 136.1, 132.3, 131.8, 129.1, 129.0, 128.5, 128.1, 127.9, 127.8, 127.4, 125.9, 125.6, 123.7, 122.6, 120.4, 119.3, 111.9, 106.2. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{29}H_{20}NOS$ ($M+H^+$): 430.1260; Found 430.1263.

Associated content

Supporting Information

X-ray crystallography data and CIF file, ^{1}H and ^{13}C{^{1}H} NMR spectra of all compounds. The SI is available free of charge on the ACS Publications website.

Crystal structure data for **2b** (CIF)

Crystal structure data for **2o** (CIF)

Crystal structure data for **2q** (CIF)

Crystal structure data for **4s** (CIF)

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