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Diastereoselective *trans* Cyclopropanation of 3-Alkylidene Oxindoles with In Situ Generated α-Diazo Carbonyls or α,β-Unsaturated Diazo Compounds

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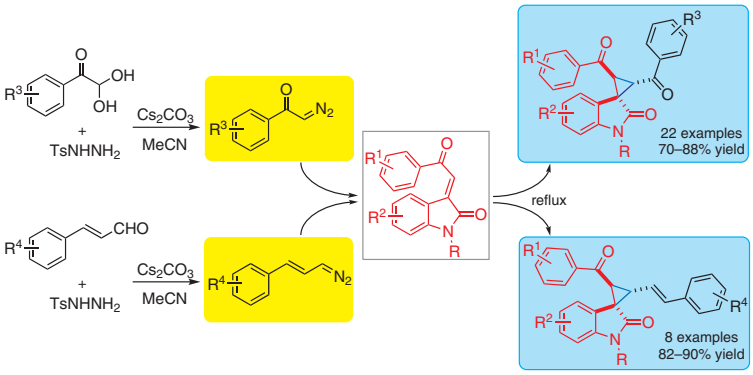

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Abstract An efficient diastereoselective *trans* cyclopropanation of 3-alkylidene oxindoles with in situ generated α-diazo carbonyl compounds or α,β-unsaturated diazo compounds under metal-free conditions has been developed to synthesize 3-spirocyclopropyl-2-oxindole derivatives. The procedure is based on the 1,3-dipolar character of the corresponding diazo compounds under base-catalyzed conditions. The method has a wide substrate scope and uses easily available starting materials.

Key words diastereoselectivity, *trans* cyclopropanation, diazo compounds, 1,3-dipoles, spiro compounds, oxindoles

There is a great demand for structurally complex cyclopropane scaffolds, which have extensive applications in the pharmaceutical area. Therefore, there is interest in designing and developing expeditious strategies towards the construction of these compounds.[1] Among them, the spiro-oxindole skeleton is widely found in both natural alkaloids and synthetic therapeutic agents.[2,3] Over the past few decades, numerous elegant transformations have been developed for the construction of these structures, which usually employ multistep reactions to construct the spiro-oxindole skeletons.[4]

Among the spiro-oxindoles, 3-spirocyclopropyl-2-oxindole is a privileged scaffold with an attractive framework for both medicinal research and synthetic chemistry. 3-Spirocyclopropyl-2-oxindoles possess a wide spectrum of biological activities, such as inotropic[3c] and herbicidal[5,6] properties. They are also useful in the treatment of congestive heart failure, hypertension, edema, and hyponatremia.[7] Spirocyclopropyl oxindole derivatives are extensively applied, e.g. in kinase 4 inhibitor as an orally bioavailable antitumor agent, as an EP4 receptor antagonist, as antagonists for vasopressin, and for the treatment of congestive heart failure.[8] These unique chemical and biological characteristics of spirocyclopropyl oxindoles have stimulated the development of new synthetic strategies towards their synthesis.

In the last few decades, great efforts have been devoted to develop efficient methods for cyclopropanation reactions.[9] 3-Spirocyclopropyl-2-oxindoles can be traditionally synthesized in a diastereoselective and enantioselective manner by treating oxindoles with bromonitroolefins,[10] with α-chloroacetoacetate esters,[11] with pyridinium salts in the presence of base,[12] and with ethyl diazoacetate.[13] 3-Chlorooxindole can also be used as a nucleophile, performing Michael-initiated ring closure between α,β-unsaturated carbonyl compounds, resulting in spirocyclopropyl oxindoles.[14] Recently, Marinia et al. reported the synthesis of spirocyclopropyl oxindoles by using vinyl selenone and substituted and unsubstituted oxindoles.[15] In the last few years, many synthetic approaches have been used for spirocyclopropyl oxindoles, e.g. a 1,3-dipolar cycloaddition reaction of substituted methyleneindolinones with α-diazomethylphosphonate (Scheme 1a),[16] a ring opening/cyclopropanation reaction of cyclic sulfur ylides with (*E*)-3-(oxyethylidene)-2-oxoindolines (Scheme 1b),[17] a sequential [3 + 2] cycloaddition/ring contraction reaction of 3-ylideneoxindoles with 2,2,2-trifluorodiazoethane (Scheme 1c).[18] However, the aforementioned strategies use transition metals, which results in limited diversification points in the product. Of environmental concern, CF_3CHN_2 is explosive and toxic. Therefore, an alternate approach avoiding the use of expensive and explosive diazo compounds for the synthesis of these scaffolds is still in great demand. In the last

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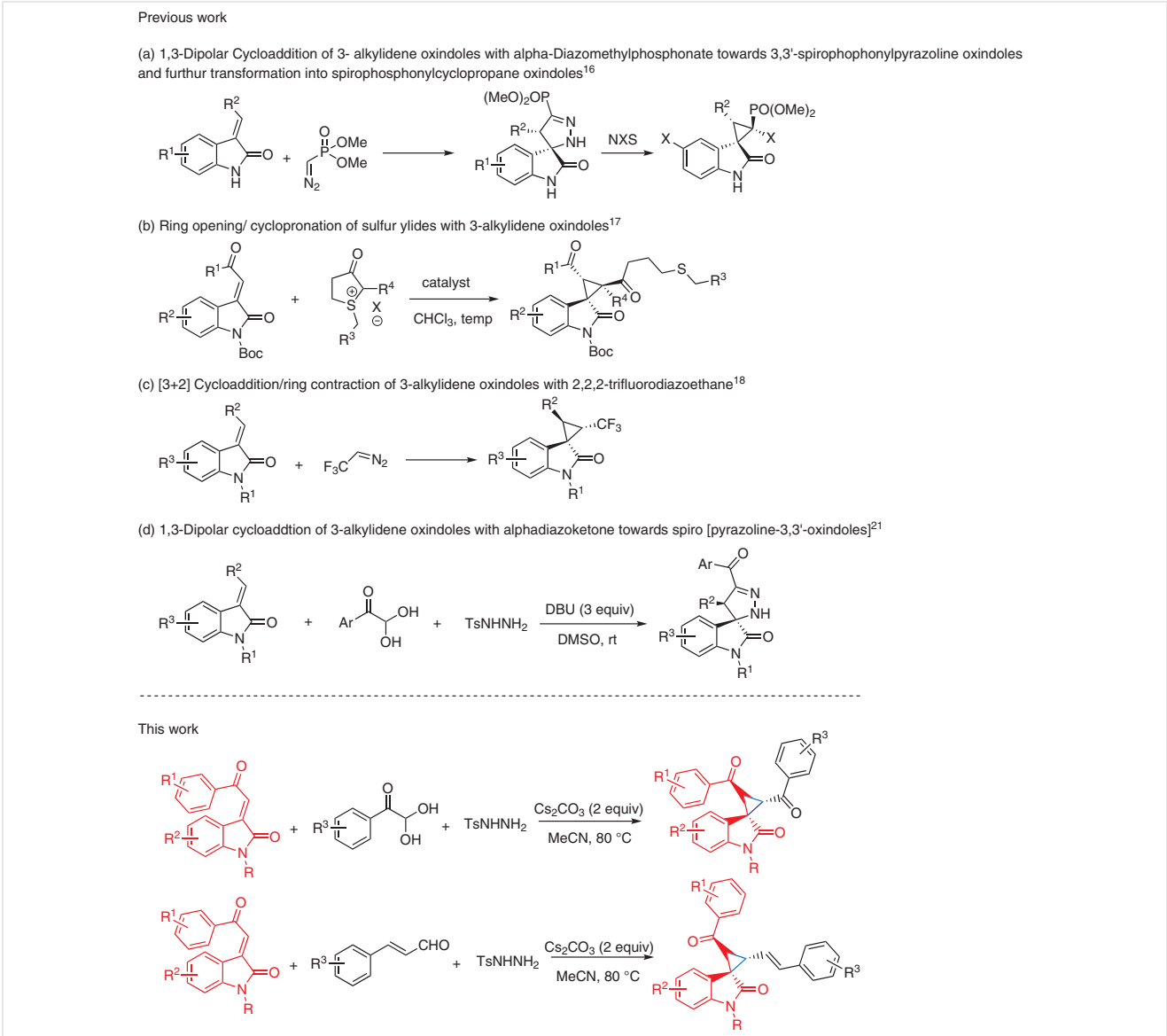
few decades, α-diazo carbonyl compounds have been widely utilized as 1,3-dipoles in a variety of useful chemical transformations.[19] Construction of α-diazo carbonyl compounds from readily available aryl glyoxal monohydrate and tosylhydrazine encouraged us to further develop an effective synthetic approach towards spirocyclopropyl oxindole derivatives.[20] However, recently, Xiao et al.[21] reported the synthesis of spiro[pyrazolin-3,3′-oxindoles] and 3-arylcarbonylmethyl-substituted 3-ylideneoxindoles using the same starting materials (Scheme 1d); Babu et al.[22] also utilized in situ generated α-aryldiazomethane with 3-ylideneoxindoles towards the synthesis of 3-spirocyclopropyl-2-oxindole. In continuation to our efforts towards the generation of new cascade reactions to construct carbo- and heterocyclic moieties, we report here the synthesis of 2,3-dibenzoylspirocyclopropyl oxindole derivatives in a sequential [3 + 2] cycloaddition/ring contraction strategy[23] starting from 3-ylidene oxindoles and α-diazo carbonyl obtained from aryl glyoxal monohydrate. We also noticed that α,β-unsaturated diazoalkanes (generated in situ from tosylhydrazine and α,β-unsaturated aldehydes) act as 1,3-dipoles and take part in a similar reaction, providing good access to 2-benzoyl-3-styrylspirocyclopropyl oxindoles.

Our preliminary investigation shown in Table 1 commenced with the in situ generation of α-diazoacetophenone from phenylglyoxal monohydrate (**2a**) and $TsNHNH_2$ (**3**) in acetonitrile as solvent at room temperature in the presence of Et_3N as base, followed by treatment of this



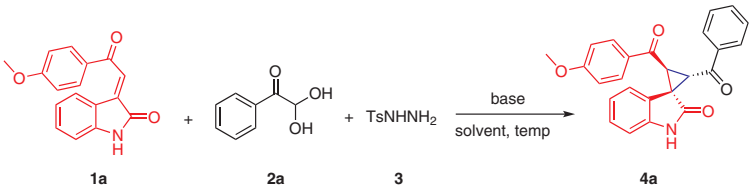
Scheme 1 Cyclopropanation of 3-alkylidene oxindoles and α-diazo compounds for the synthesis of 3-spirocyclopropyl-2-oxindoles

reaction mixture with **1a** under reflux. To our delight, cyclopropanation occur smoothly to give the corresponding product **4a** in 68% isolated yield with excellent regioselectivity and diastereoselectivity (entry 1). The structure of the corresponding cyclopropanation product **4a** was confirmed by NMR and HRMS analyses.

This interesting result encouraged us to scrutinize other parameters such as temperature, base and solvent to increase the efficiency of the reaction. Different reaction temperatures were examined and it was found that the reaction at 80 °C gave a satisfying yield (80%) with reduced reaction time (Table 1, entry 3). The base used has a remarkable effect on the reaction efficiency; the reaction occurs in the presence of various organic and inorganic bases, such as Et_3N, pyridine, DBU, Cs_2CO_3, and K_2CO_3, giving the desired product in moderate to good yield. After optimization using different bases, Cs_2CO_3 was shown to be superior, providing the best yield of **4a** (entry 3). Furthermore, a survey was conducted using solvents such as EtOH, MeCN, MeOH, THF, DCM, and toluene, which revealed that MeCN is the optimal solvent. Hence, after a brief screening, the optimal conditions were concluded to be the following: **1a** (0.5 mmol), **2a** (0.5 mmol), **3** (0.5 mmol) and Cs_2CO_3 (1 mmol) in MeCN under reflux (80 °C) (Table 1, entry 3).

With these optimized reaction conditions in hand, we then investigated the substrate scope of this cyclopropanation reaction by varying the substitution pattern of alkylidene oxindole **1** and aryl glyoxal monohydrate **2** (Scheme 2). Initially, various aryl glyoxal monohydrates **2** substituted with different functional groups were screened; these undergo cyclopropanation through 1,3-dipolar cycloaddition/ring contraction strategy quite easily and provided the corresponding 3-spirocyclopropyl-2-oxindole scaffolds **4**. It was found that both electron-donating (Me, MeO) and electron-withdrawing (Cl) groups were well tolerated under the reaction conditions along with phenyl glyoxal monohydrate (without substitution), affording good yields. Aryl glyoxal monohydrates **2** with electron-donating groups provide comparably better yields (**4e**, **4h**, **4i**, **4m**, **4r**, **4v**) than those with electron-withdrawing groups (**4j**, **4s**). When both the 3-alkylidene oxindole **1** and aryl glyoxal **2** are substituted with strong electron-withdrawing groups, a

Table 1 Optimization Study for the Formation of **4a**[a]

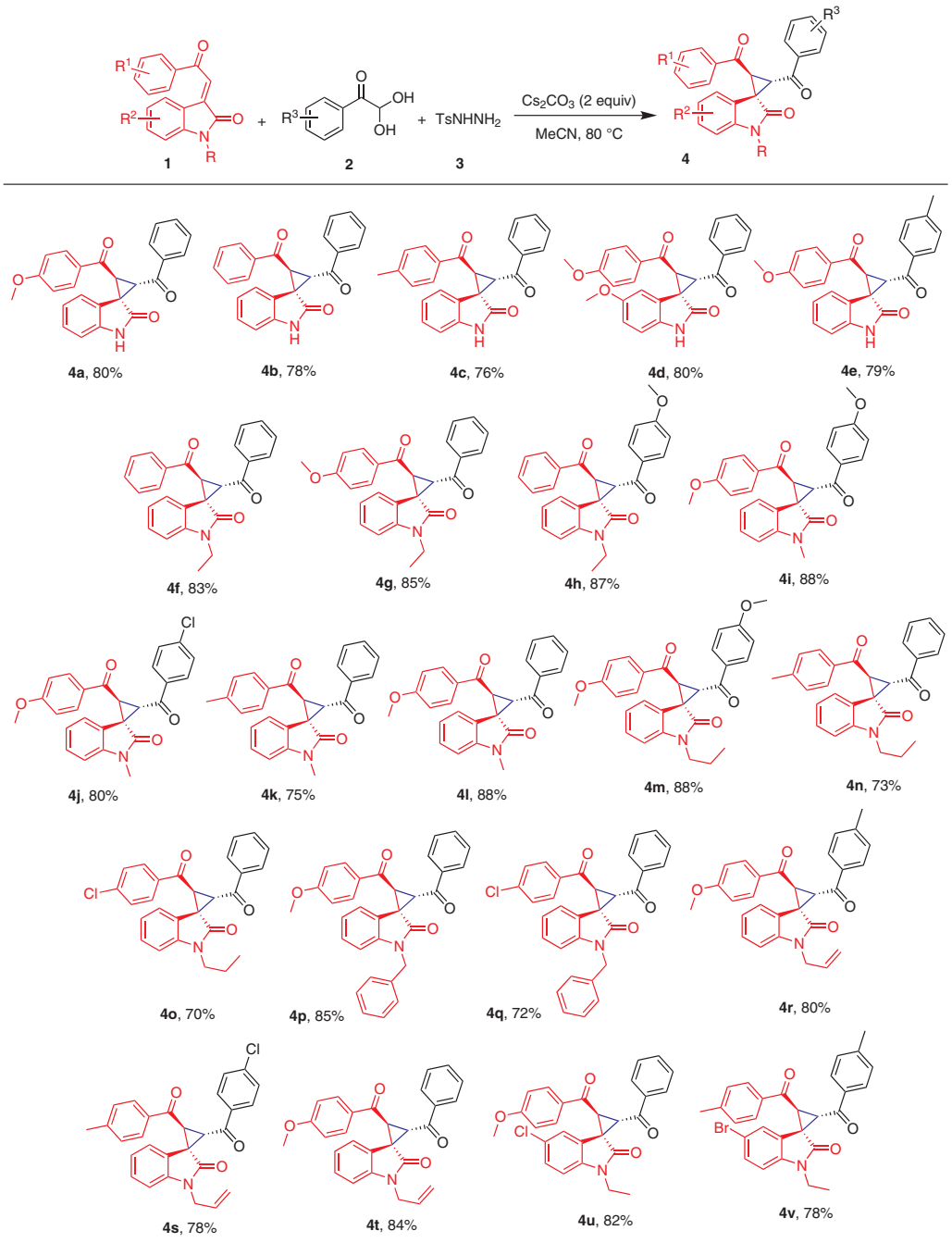


1a **2a** **3** **4a**

Entry	Solvent	Base (equiv)	Temp (°C)	Time (h)	Yield (%)[b]
1	EtOH	Et_3N (2)	80	9	68
2	EtOH	pyridine (2)	80	9	31
3	MeCN	Cs_2CO_3 (2)	80	5	80
4	MeCN	Cs_2CO_3 (2)	rt	10	–
5	MeCN	K_2CO_3 (2)	80	8	60
6	MeCN	DBU (2)	80	6	42
7	MeCN	Et_3N (1)	80	6	65
8	MeCN	Cs_2CO_3 (1)	50	8	52
9	THF	pyridine (2)	100	9	trace
10	THF	K_2CO_3 (1)	100	9	34
11	THF	Cs_2CO_3 (2)	80	9	40
12	toluene	Cs_2CO_3 (2)	100	8	–
13	MeOH	Cs_2CO_3 (2)	80	9	65
14	MeOH	K_2CO_3 (1)	80	9	53
15	MeOH	Et_3N (2)	80	9	50
16	DCM	Cs_2CO_3 (1)	rt	6	–
17	MeCN	Cs_2CO_3 (1)	80	5	68

[a] Reaction conditions: **1a** (0.5 mmol), **2a** (0.5 mmol), **3** (0.5 mmol), base, solvent.
[b] Isolated yields.

negligible amount of product is formed, which is too little to isolate. It is worth mentioning that halo-substituted products are useful for further functional group interconversions. Products **4** are obtained in excellent diastereoselectivity, i.e. >95:5 dr towards *trans* orientation of the cyclopropane ring. This was shown by ^{1}H NMR spectroscopy of pure compound **4j** having two doublets at δ = 4.37, 4.12 with coupling constant J = 7.6 Hz as measured by a 400 MHz spectrometer (see Supporting Information, SI), ideal for *trans*-oriented CH groups of cyclopropane.[24] Additionally, the HPLC data of compound **4j** was recorded, ensuring the good diastereoselectivity (see SI). We also checked a ^{1}H NMR spectrum of the crude product **4j** and noticed a similar coupling constant of the two cyclopropane CH groups



Scheme 2 Substrate scope for the formation of product **4**. *Reagents and conditions*: **1** (0.5 mmol), **2** (0.5 mmol), **3** (0.5 mmol), anhyd Cs_2CO_3 (1 mmol), MeCN (6 mL), 70–80 °C, 5 h.

compared with the pure compound's ^{1}H NMR data (Figure 1). X-ray crystallographic analysis of compound **4j** confirmed the *trans* orientation of the cyclopropane group (Figure 2)

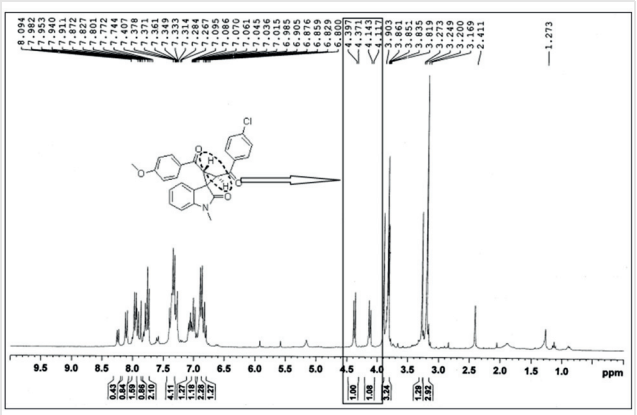


Figure 1 Crude NMR spectrum of compound **4j**

With these satisfactory results in hand, we then investigated the substrate variation of alkylidene oxindoles **1** in this cyclopropanation reaction (Scheme 2). Both electron-withdrawing (**4u**, **4v**) and electron-donating (**4d**) substitution on the indoline ring were compatible with the reaction

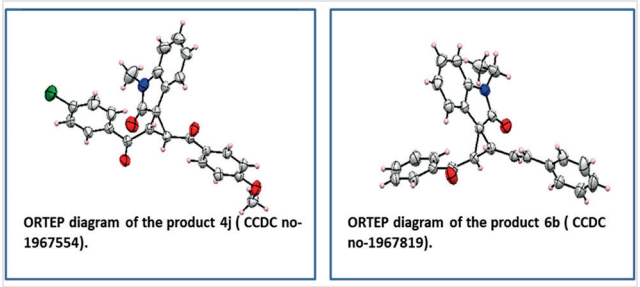
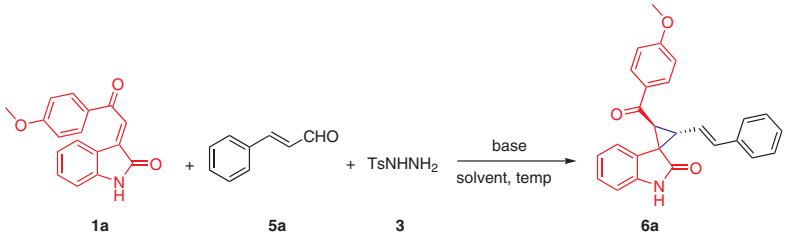


Figure 2 ORTEP diagrams of **4j** and **6b**

conditions. In addition, the electronic nature of the substituent on the aryl ring of **1** appears to have a subtle influence on the yield of product **4**. It was observed, here also, that an electron-donating group (MeO) on the aryl ring produced higher yields (**4a**, **4d**, **4e**, **4g**, **4i**, **4j**, **4l**, **4m**, **4p**, **4r**, **4t**, **4u**) compared to an electron-withdrawing group (**4o**, **4q**). Then the effect of N-protecting groups on the indoline ring was also investigated. Various N-protected (Me, Et, Pr, Bn, All) alkylidene oxindoles **1** were used; N-protected oxindoles **1** gave better yields compared to the unprotected substrates (**4f–v**). Moreover, the halo-substituted products **4** can be further used for transition-metal catalyzed cross-coupling reactions, thus allowing further application of such products. In all cases, the functional complexity of the resulting products demonstrates the remarkable chemo- and

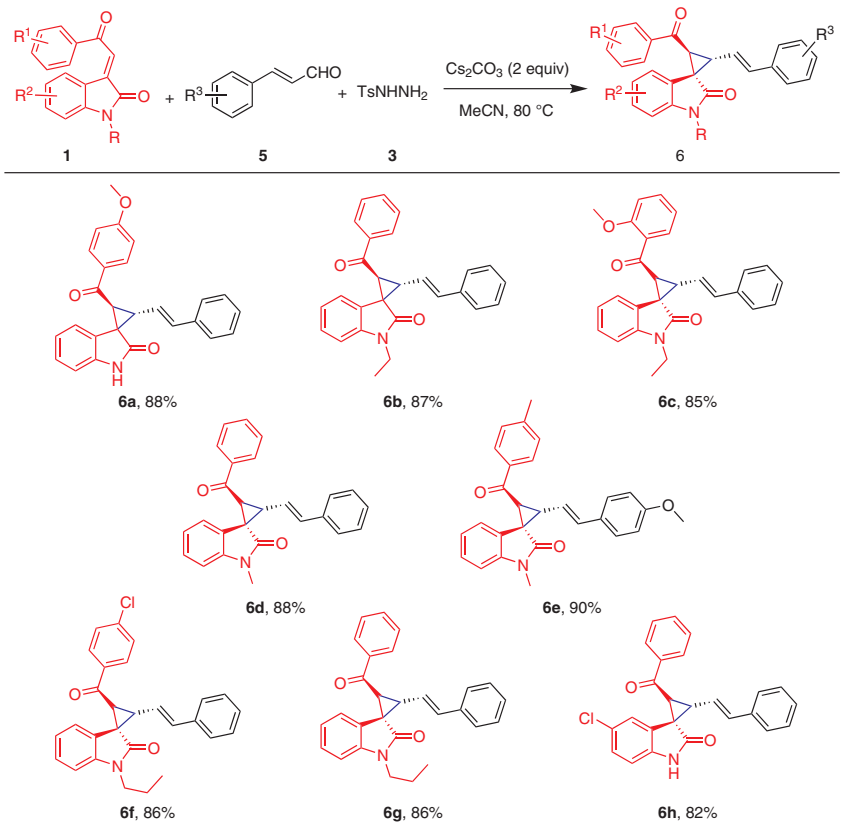
Table 2 Optimization Study for the Formation of **6a**[a]



1a **5a** **3** **6a**

Entry	Solvent	Base (equiv)	Temp (°C)	Time (h)	Yield (%)[b]
1	MeCN	Cs_2CO_3 (2)	80	4	88
2	MeCN	K_2CO_3 (2)	80	6	72
3	MeCN	Cs_2CO_3 (2)	80	12	70
4	MeCN	Cs_2CO_3 (2)	rt	9	–
5	MeCN	Cs_2CO_3 (2)	50	4	57
6	EtOH	K_2CO_3 (1)	80	6	62
7	EtOH	Cs_2CO_3 (1)	80	6	74
8	MeOH	Et_3N (2)	80	6	56
9	toluene	Et_3N (2)	110	7	30
10	DCM	Cs_2CO_3 (2)	rt	6	–
11	MeCN	Cs_2CO_3 (1)	80	4	73

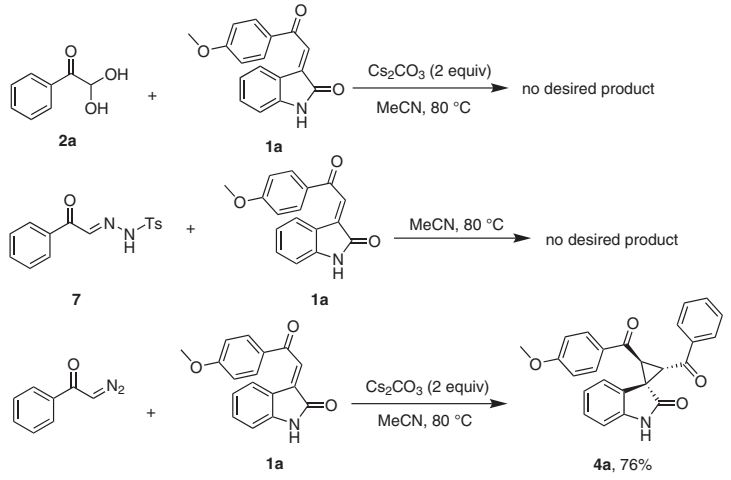
[a] Reaction conditions: **1a** (0.5 mmol), **5a** (0.5 mmol), **3** (0.5 mmol), base, solvent.
[b] Isolated yields.



Scheme 3 Substrate scope for the formation of product **6**. *Reagents and conditions*: **1** (0.5 mmol), **5** (0.5 mmol), **3** (0.5 mmol), anhyd Cs_2CO_3 (1 mmol), MeCN (6 mL), 70–80 °C, 4–6 h.

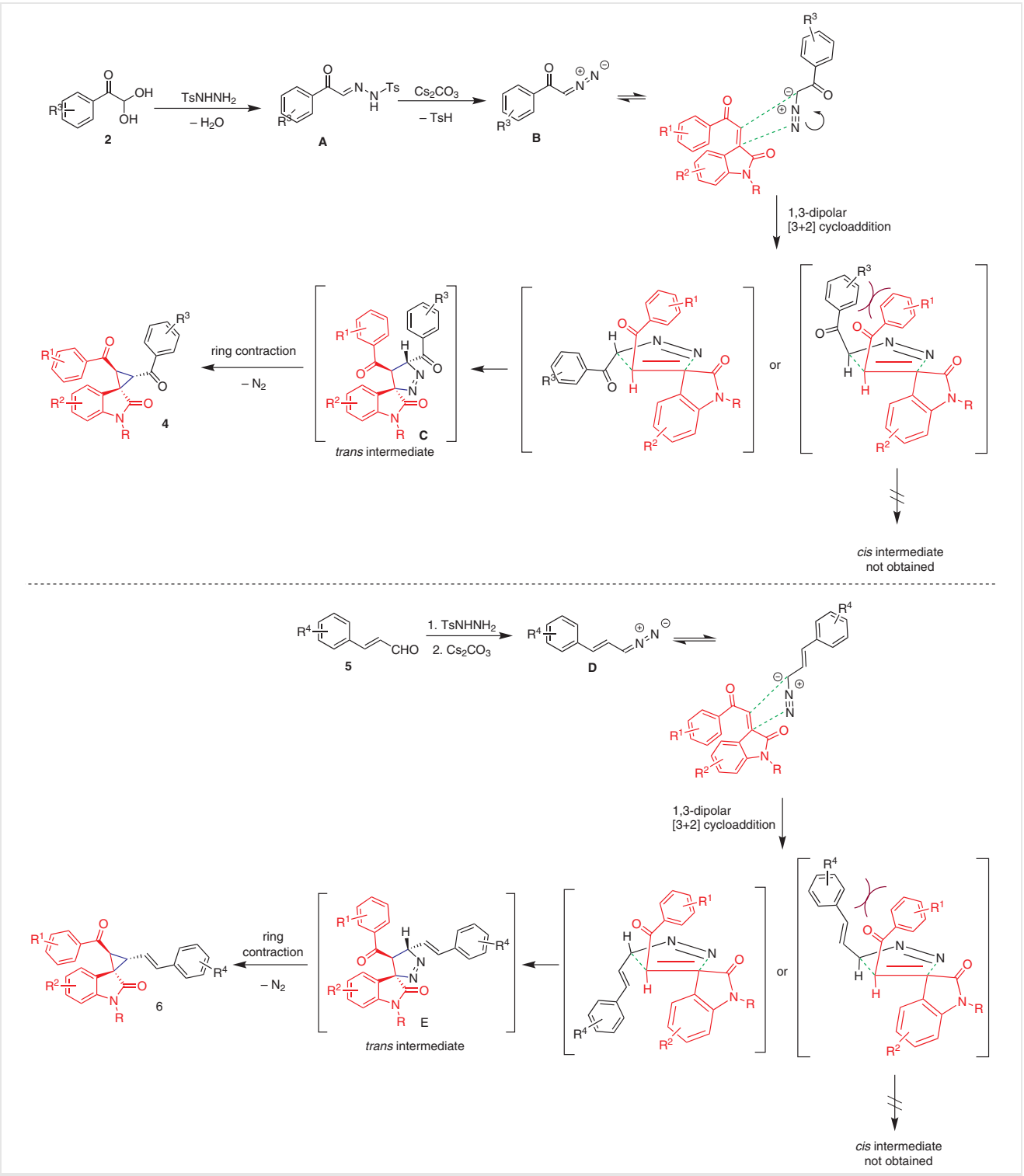
regiospecificity of the sequence starting from easily accessible starting materials. The structures were unambiguously elucidated by NMR spectroscopic analysis. A single crystal of **4j** was successfully obtained by slow evaporation of the solvent and the structure was unequivocally confirmed by X-ray diffraction analysis (Figure 2).

During further study of the reaction, we observed that (*E*)-(3-diazoprop-1-enyl)benzene, which is generated in situ from *trans*-cinnamaldehyde and $TsNHNH_2$ under base



Scheme 4 Control experiments

catalysis, can also perform similar cyclopropanation with alkylidene oxindoles **1** (Table 2). In our preliminary investigation we treated *trans*-cinnamaldehyde (**5a**) and $TsNHNH_2$ (**3**) in acetonitrile at room temperature in the presence of Cs_2CO_3 as base with alkylidene oxindole **1a** under reflux. As expected, cyclopropanation occurred, to give the corre-



Scheme 5 Plausible mechanism of the reaction

sponding spiro[cyclopropane-1,3′-indolin]-2′-one **6a** in 88% yield with excellent regiospecificity and diastereoselectivity (entry 1). The structure of the corresponding product **6a** was confirmed by NMR and HRMS analysis (see SI). Therefore, we investigated other reaction parameters for further improvement. After a brief optimization of temperature, solvent, and base, the optimal conditions were determined to be the following: **1a** (0.5 mmol), **5a** (0.5 mmol), **3** (0.5 mmol), Cs_2CO_3 (1 mmol), in MeCN as medium under refluxing conditions (80 °C) (entry 1).

Next, we examined the substrate scope by varying both alkylidene oxindole **1** and α,β-unsaturated aldehyde **5** (Scheme 3). We found that α,β-unsaturated aldehyde **5** with 4-MeO substitution gave the corresponding cyclopropanation product **6e** in good yield. Different substituents R^1 and R^2 on **1** were also investigated. All the products **6** were obtained in >95:5 dr, as confirmed by NMR and single-crystal X-ray analysis of **6b** (Figure 2).

To gain some insight into the mechanism of this reaction, we conducted some control experiments as shown in Scheme 4. In our first experiment, the reaction was carried out with **2a** (0.5 mmol) and **1a** (0.5 mmol) in the presence of Cs_2CO_3 (2 equiv) in refluxing MeCN; we did not obtain our desired product and both starting materials remained unchanged. Therefore, we can say that this cyclopropanation requires a 1,3-dipole to initiate a dipolar cycloaddition and subsequent ring contraction. Then, tosylhydrazone **7** of phenyl glyoxal monohydrate (0.5 mmol) was subjected to **1a** (0.5 mmol) in MeCN as medium without any base, and, as expected, we did not obtain the cyclopropanation product. Therefore, base-catalyzed elimination of the tosyl group is required to generate the active diazo compound. We also carried out the reaction with α-diazoacetophenone, instead of in situ generation of this, under the optimal conditions; the desired product **4a** was obtained in 76% yield.

On the basis of the above results and some previous reports,[18,21,22] a plausible mechanism of the reaction is shown in Scheme 5. Initially, the condensation of arylglyoxal monohydrate **2** and tosylhydrazine afforded the corresponding tosylhydrazone intermediate **A**, which subsequently generated α-diazoarylethanone **B** in the presence of Cs_2CO_3 by elimination of the tosyl group. Then alkylidene oxindole **1**, which has dual Michael acceptor ability, undergoes 1,3-dipolar cycloaddition with α-diazoarylethanone, acting as 1,3-dipolarophile. The observed diastereoselectivity of the reaction might be explained by severe steric repulsion in the formation of a *cis* five-membered intermediate, rejecting the possibility of *cis* cyclopropanation. The intermediate **C** decomposes under refluxing conditions by elimination of N_2 to deliver the corresponding *trans*-spirocyclopropyl oxindole derivative **4**. In a similar mechanistic pathway, **6** can be generated from **D** (formed in situ from *trans*-cinnamaldehyde **5** and $TsNHNH_2$) (Scheme 5).

In conclusion, we have successfully developed a simple and efficient methodology for the one-pot synthesis of spirocyclopropyl oxindole derivatives through 1,3-dipolar cycloaddition/ring contraction of in situ generated α-diazocarbonyl or α,β-unsaturated diazo compounds with 3-alkylidine oxindoles, which were synthesized by a reported procedure.[25] The notable advantage of this method is that cyclopropanation is achieved without the use of transition metals or expensive reagents. Further studies towards the application of this methodology and structural diversification of this moiety are underway in our laboratory.

All commercially available chemicals were purchased from Aldrich, USA, or Spectrochem, India, and used without further purification. All solvents were used as received. The progress of the reactions were monitored by TLC (glass sheets pre-coated with silica gel, with binder, 300 mesh, Spectrochem) and column chromatography was performed using silica gel (100–200 mesh). Bruker instruments were used for ^1H (300 and 400 MHz) and ^{13}C (75 and 100 MHz) NMR spectroscopy. Chemical shifts are reported in ppm downfield from an internal TMS reference. HRMS with an ESI source was carried out on a Waters XEVO-G2S Q TOF mass spectrometer. A 2400 Series II CHNS Analyzer, Perkin Elmer, USA, was used for elemental analyses. HPLC spectra were recorded by using an Agilent 1200 Series auto sampler HPLC system. Melting points were recorded with an open capillary on an electrical melting point apparatus and the single-crystal structures of the synthesized compounds were confirmed by an X-ray crystallography experiment on a Bruker SMART diffractometer.

CCDC 1967554 (**4j**) and 1967819 (**6b**) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/structures.

Spiro[cyclopropane-1,3′-indolin]-2′-ones 4 and 6; General Procedure

The appropriate 3-alkylidene oxindole **1** (0.5 mmol), aryl glyoxal monohydrate **2** or *trans*-cinnamaldehyde **5** (0.5 mmol), tosylhydrazine (**3**; 0.5 mmol), and Cs_2CO_3 (1 mmol) were added with MeCN (6 mL) to a dry 10 mL round-bottomed flask equipped with a reflux condenser. Then the reaction mixture was stirred under reflux for 5 h. After the reaction had reached completion, as monitored by TLC, the reaction mixture was cooled to rt, diluted with water (10 mL), and extracted with EtOAc (3 × 10 mL). The organic layer was combined, washed with brine, and dried over anhyd Na_2SO_4. After the solvent had been removed under reduced pressure, the crude product was purified by column chromatography (silica gel, PE–EtOAc); this afforded the desired product **4** or **6**.

2-Benzoyl-3-(4-methoxybenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4a)

White solid; yield: 158.8 mg, 80%; R_f = 0.3 (EtOAc–PE, 25:75); mp 198–200 °C.

^1H NMR (300 MHz, $CDCl_3$): δ = 8.91 (br s, 1 H), 7.85–7.73 (m, 4 H), 7.43–7.36 (m, 1 H), 7.27–7.15 (m, 4 H), 6.96–6.88 (m, 2 H), 6.70 (d, *J* = 8.4 Hz, 2 H), 4.29 (d, *J* = 8.7 Hz, 1 H), 4.09 (d, *J* = 8.7 Hz, 1 H), 3.70 (s, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 190.3, 190.1, 164.2, 141.2, 136.2, 133.6, 131.0, 129.8, 128.8, 128.4, 124.6, 122.8, 122.7, 114.4, 114.0, 110.1, 55.5, 40.8, 39.7, 38.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{25}H_{19}NO_4$: 398.1392; found: 398.1376.

2′-Oxospiro[cyclopropane-1,3′-indoline]-2,3-diylbis(phenylmethanone) (4b)

White solid; yield: 143.7 mg, 78%; R_f = 0.3 (EtOAc–PE, 25:75); mp 200–202 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.76 (s, 1 H), 7.98 (d, *J* = 7.8 Hz, 2 H), 7.83 (d, *J* = 7.8 Hz, 2 H), 7.57–7.33 (m, 7 H), 7.28–7.23 (m, 1 H), 7.04 (t, *J* = 7.5 Hz, 1 H), 6.95 (d, *J* = 7.5 Hz, 1 H), 4.43 (d, *J* = 7.8 Hz, 1 H), 4.19 (d, *J* = 7.8 Hz, 1 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 192.0, 190.4, 173.3, 141.4, 136.7, 136.1, 133.8, 133.6, 128.8, 128.6, 128.5, 128.4, 124.3, 122.8, 122.6, 110.3, 41.1, 39.6, 38.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{24}H_{17}NO_3$: 368.1287; found: 368.1299.

2-Benzoyl-3-(4-methylbenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4c)

White solid; yield: 144.0 mg, 76%; R_f = 0.3 (EtOAc–PE, 25:75); mp 201–203 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.45 (s, 1 H), 7.87–7.81 (m, 4 H), 7.49 (t, *J* = 7.2 Hz, 1 H), 7.42–7.30 (m, 3 H), 7.24–7.18 (m, 3 H), 7.02 (t, *J* = 7.6 Hz, 1 H), 6.90 (d, *J* = 8 Hz, 1 H), 4.38 (d, *J* = 8 Hz, 1 H), 4.16 (d, *J* = 8 Hz, 1 H), 2.35 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.5, 190.5, 173.2, 144.9, 141.2, 136.1, 134.2, 133.6, 131.2, 129.4, 128.7, 128.6, 128.5, 128.4, 124.4, 122.8, 122.6, 110.2, 40.9, 39.5, 38.7, 21.6.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{25}H_{19}NO_3$: 382.1443; found: 382.1496.

2-Benzoyl-5′-methoxy-3-(4-methoxybenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4d)

White solid; yield: 171.1 mg, 80%; R_f = 0.3 (EtOAc–PE, 3:7); mp 194–196 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.26 (br s, 1 H), 7.99–7.94 (m, 2 H), 7.83–7.78 (m, 2 H), 7.52–7.48 (m, 1 H), 7.43–7.39 (m, 1 H), 7.36–7.34 (m, 1 H), 6.94–6.92 (m, 1 H), 6.86–6.81 (m, 2 H), 6.79–6.77 (m, 2 H), 4.37 (d, *J* = 7.6 Hz, 1 H), 4.12 (d, *J* =48 Hz, 1 H), 3.85–3.83 (m, 6 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 192.1, 190.1, 173.1, 163.9, 155.8, 136.7, 136.1, 134.5, 133.8, 130.7, 129.7, 128.7, 128.6, 128.4, 125.7, 125.6, 114.0, 110.5, 109.2, 55.7, 55.4, 41.0, 39.8, 38.5.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{26}H_{21}NO_5$: 428.1498; found: 428.1465.

2-(4-Methoxybenzoyl)-3-(4-methylbenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4e)

White solid ; yield: 162.0 mg, 79%; R_f = 0.3 (EtOAc–PE, 25:75); mp 196–198 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.87 (br s, 1 H), 7.90 (d, *J* = 8.8 Hz, 1 H), 7.81 (dd, J_1 = 8 Hz, J_2 = 22.8 Hz, 2 H), 7.71 (d, *J* = 8 Hz, 1 H), 7.29 (d, *J* = 7.6 Hz, 1 H), 7.23–7.19 (m, 1 H), 7.15–7.11 (m, 2 H), 7.02–6.98 (m, 1 H), 6.91 (d, *J* = 7.6 Hz, 1 H), 6.80–6.76 (m, 3 H), 4.35 (d, *J* = 7.6 Hz, 1 H), 4.14 (d, *J* = 7.6 Hz, 1 H), 3.77 (s, 3 H), 2.31 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.3, 190.2, 173.6, 164.0, 144.6, 141.3, 133.6, 132.3, 130.9, 130.7, 129.6, 129.4, 129.3, 128.6, 128.5, 124.5, 122.6, 122.5, 113.8, 110.3, 55.5, 40.9, 39.5, 38.7, 21.6.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{26}H_{21}NO_4$: 412.1549; found: 412.1583.

1′-Ethyl-2′-oxospiro[cyclopropane-1,3′-indoline]-2,3-diylbis(phenylmethanone) (4f)

White solid; yield: 163.3 mg, 83%; R_f = 0.3 (EtOAc–PE, 2:8); mp 208–210 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.00 (d, *J* = 7.8 Hz, 2 H), 7.80 (d, *J* = 7.8 Hz, 2 H), 7.59–7.28 (m, 8 H), 7.06 (t, *J* = 7.8 Hz, 1 H), 6.92 (d, *J* = 7.8 Hz, 1 H), 4.42 (d, *J* = 7.8 Hz, 1 H), 4.13 (d, *J* = 7.8 Hz, 1 H), 3.82–3.63 (m, 2 H), 1.10 (t, *J* = 7.2 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 192.4, 190.7, 170.8, 143.3, 136.8, 136.3, 135.8, 133.4, 128.7, 128.6, 128.5, 128.4, 124.2, 122.6, 122.5, 108.4, 40.8, 39.7, 38.5, 35.1, 12.6.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{26}H_{21}NO_3$: 396.1600; found: 396.1680.

2-Benzoyl-1′-ethyl-3-(4-methoxybenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4g)

White solid; yield: 180.9 mg, 85%; R_f = 0.3 (EtOAc–PE, 2:8); mp 204–206 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.98 (d, *J* = 8.4 Hz, 2 H), 7.80 (d, *J* = 7.5 Hz, 2 H), 7.52 (t, *J* = 6.3 Hz, 2 H), 7.39–7.28 (m, 4 H), 7.05 (t, *J* = 7.8 Hz, 1 H), 6.92–6.89 (m, 3 H), 4.4 (d, *J* = 7.5 Hz, 1 H), 4.12 (d, *J* = 7.5 Hz, 1 H), 3.85–3.65 (m, 1 H), 1.09 (t, *J* = 6.6 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): 190.8, 190.5, 170.9, 164.1, 143.2, 136.3, 133.4, 131.0, 129.9, 128.6, 128.4, 124.4, 122.6, 122.5, 113.9, 108.4, 55.5, 40.5, 39.6, 38.3, 35.0, 12.5.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{27}H_{23}NO_4$: 426.1706; found: 426.1757.

2-Benzoyl-1′-ethyl-3-(4-methoxybenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4h)

White solid; yield: 185.8 mg, 87%; R_f = 0.3 (EtOAc–PE, 2:8); mp 180–182 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.97 (d, *J* = 7.6 Hz, 2 H), 7.76 (d, *J* = 8.8 Hz, 2 H), 7.54–7.52 (m, 1 H), 7.44–7.26 (m, 4 H), 7.03 (t, *J* = 7.6 Hz, 1 H), 6.90–6.81 (m, 3 H), 4.39 (d, *J* = 8 Hz, 1 H), 4.08 (d, *J* = 8 Hz, 1 H), 3.83–3.76 (m, 4 H), 3.70–3.66 (m, 1 H), 1.13–1.06 (m, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 192.6, 189.3, 171.0, 164.0, 143.4, 137.0, 133.9, 130.8, 129.8, 128.9, 128.8, 128.5, 124.5, 122.8, 114.1, 108.6, 55.7, 40.9, 39.9, 38.8, 35.2, 12.8.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{27}H_{23}NO_4$: 426.1706; found: 426.1708.

1′-Methyl-2′-oxospiro[cyclopropane-1,3′-indoline]-2,3-diylbis((4-methoxyphenyl)methanone) (4i)

White solid; yield: 194.2 mg, 88%; R_f = 0.3 (EtOAc–PE, 25:75); mp 178–180 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.90 (d, *J* = 8.8 Hz, 2 H), 7.71 (d, *J* = 8.8 Hz, 2 H), 7.28 (d, *J* = 7.6 Hz, 1 H), 7.23–7.19 (m, 1 H), 6.97 (t, *J* = 7.6 Hz, 1 H), 6.81–6.74 (m, 5 H), 4.31 (d, *J* = 7.6 Hz, 1 H), 4.05 (d, *J* = 7.6 Hz, 1 H), 3.76–3.73 (m, 6 H), 3.11 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.4, 189.0, 171.4, 164.0, 163.7, 144.1, 131.0, 130.7, 129.8, 129.3, 128.3, 124.2, 122.6, 122.3, 113.9, 113.8, 108.2, 55.5, 40.5, 39.4, 38.5, 30.9, 26.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{27}H_{23}NO_5$: 4412.1654; found: 4412.1693.

2-(4-Chlorobenzoyl)-3-(4-methoxybenzoyl)-1′-methylspiro[cyclopropane-1,3′-indolin]-2′-one (4j)

White solid; yield: 178.0 mg, 80%; R_f = 0.3 (EtOAc–PE, 25:75); mp 204–206 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.95 (d, *J* = 9.2 Hz, 1 H), 7.79–7.73 (m, 2 H), 7.38 (d, *J* = 8.4 Hz, 1 H), 7.35–7.31 (m, 3 H), 7.30–7.28 (m, 1 H), 7.07–7.03 (m, 1 H), 6.89–6.82 (m, 3 H), 4.37 (d, *J* = 7.6 Hz, 1 H), 4.12 (d, *J* = 7.6 Hz, 1 H), 3.83 (s, 3 H), 3.18 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.1, 189.5, 171.2, 164.1, 163.9, 144.1, 140.0, 134.9, 131.0, 130.7, 130.0, 129.8, 129.1, 128.5, 123.8, 122.8, 113.9, 108.3, 55.5, 40.5, 39.1, 38.4, 26.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{26}H_{21}ClNO_4$: 446.1160; found: 446.1199.

2-Benzoyl-1′-methyl-3-(4-methylbenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4k)

White solid; yield: 148.5 mg, 75%; R_f = 0.3 (EtOAc–PE, 2:8); mp 190–192 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.98 (d, *J* = 7.6 Hz, 1 H), 7.85 (dd, J_1 = 8 Hz, J_2 = 24 Hz, 2 H), 7.71 (d, *J* = 8 Hz, 1 H), 7.52–7.51 (m, 2 H), 7.42–7.35 (m, 2 H), 7.32–7.26 (m, 1 H), 7.22–7.15 (m, 2 H), 7.05–7.04 (m, 1 H), 6.87 (t, *J* = 7.6 Hz, 1 H), 4.44 (d, *J* = 8 Hz, 1 H), 4.18 (d, *J* = 8 Hz, 1 H), 3.18 (s, 3 H), 2.36 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.6, 190.5, 171.3, 144.9, 144.1, 136.0, 134.1, 133.8, 133.6, 129.4, 128.7, 128.6, 128.5, 128.4, 123.9, 122.7, 122.4, 108.3, 40.7, 39.3, 38.5, 26,7, 21.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{26}H_{21}NO_3$: 396.1599; found: 396.1676.

2-Benzoyl-3-(4-methoxybenzoyl)-1′-methylspiro[cyclopropane-1,3′-indolin]-2′-one (4l)

White solid; yield: 180.8 mg, 88%; R_f = 0.3 (EtOAc–PE, 2:8); mp 199–201 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.98–7.95 (m, 2 H), 7.82–7.77 (m, 2 H), 7.53–7.49 (m, 1 H), 7.43–7.39 (m, 1 H), 7.38–7.34 (m, 2 H), 7.31–7.26 (m, 1 H), 7.05 (t, *J* = 7.6 Hz, 1 H), 6.90–6.82 (m, 3 H), 4.40 (d, *J* = 8 Hz, 1 H), 4.16 (d, *J* = 8 Hz, 1 H), 3.88 (s, 3 H), 3.18 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.5, 190.3, 171.3, 164.1, 144.1, 136.1, 133.5, 131.0, 130.7, 128.7, 128.4, 124.0, 122.7, 122.4, 113.9, 108.2, 55.5, 40.6, 39.4, 38.4, 26.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{26}H_{21}NO_4$: 412.1550; found: 412.1584.

2′-Oxo-1′-propylspiro[cyclopropane-1,3′-indoline]-2,3-diylbis((4-methoxyphenyl)methanone (4m)

White solid; yield: 206.3 mg, 88%; R_f = 0.3 (EtOAc–PE, 2:8); mp 188–190 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.87 (d, *J* = 8.8 Hz, 2 H), 7.69 (d, *J* = 8.8 Hz, 2 H), 7.25 (d, *J* = 7.2 Hz, 1 H), 7.18 (t, *J* = 7.2 Hz, 1 H), 6.93 (t, *J* = 7.6 Hz, 1 H), 6.80–6.77 (m, 3 H), 6.73 (d, *J* = 8.8 Hz, 2 H), 4.27 (d, *J* = 7.6 Hz, 1 H), 4.01 (d, *J* = 7.6 Hz, 1 H), 3.73–3.71 (m, 6 H), 3.61 (q, *J* = 7.2 Hz, 1 H), 3.42 (q, *J* = 6.8 Hz, 1 H), 1.54–1.41 (m, 2 H), 0.68 (t, *J* = 7.2 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 183.5, 182.2, 164.3, 157.0, 156.6, 136.5, 123.9, 123.6, 122.8, 122.4, 121.2, 117.2, 115.3, 106.8, 106.7, 101.4, 48.4, 48.3, 34.7, 33.3, 32.3, 31.5, 13.6, 4.0.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{29}H_{27}NO_5$: 470.1968; found: 470.1983.

2-Benzoyl-3-(4-methylbenzoyl)-1′-propylspiro[cyclopropane-1,3′-indolin]-2′-one (4n)

White solid; yield: 158.6 mg, 73%; R_f = 0.3 (EtOAc–PE, 15:85); mp 200–202 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.99 (d, *J* = 7.5 Hz, 1 H), 7.89 (d, *J* = 8.1 Hz, 1 H), 7.82 (d, *J* = 7.8 Hz, 1 H), 7.71 (d, *J* = 8.1 Hz, 1 H), 7.54–7.15 (m, 7 H), 7.07–7.04 (m, 1 H), 6.89 (d, *J* = 7.8 Hz, 1 H), 4.41 (d, *J* = 7.8 Hz, 1 H), 4.15 (d, *J* = 7.8 Hz, 1 H), 3.71–3.66 (m, 2 H), 2.38 (s, 3 H), 1.59–1.55 (m, 2 H), 0.77 (t, *J* = 7.2 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 191.7, 190.7, 171.3, 144.8, 143.7, 136.3, 134.3, 133.7, 133.4, 129.4, 128.9, 128.7, 128.6, 128.5, 128.4, 124.2, 122.5, 108.5, 41.8, 40.5, 39.4, 38.7, 21.6, 20.6, 11.0.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{28}H_{25}NO_3$: 424.1912; found: 424.2745.

2-Benzoyl-3-(4-chlorobenzoyl)-1′-propylspiro[cyclopropane-1,3′-indolin]-2′-one (4o)

Yellow liquid; yield: 70%; R_f = 0.3 (EtOAc–PE, 15:85).

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.99–7.91 (m, 1 H), 7.82–7.73 (m, 1 H), 7.61 (d, *J* = 8.4 Hz, 1 H), 7.57–7.53 (m, 1 H), 7.50–7.34 (m, 7 H), 7.06 (t, *J* = 7.5 Hz, 1 H), 6.91 (d, *J* = 7.8 Hz, 1 H), 4.39 (t, *J* = 8.1 Hz, 1 H), 4.13 (t, *J* = 7.5 Hz, 1 H), 3.74–3.59 (m, 2 H), 1.63–1.52 (m, 2 H), 0.76 (q, *J* = 9 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 191.2, 190.5, 171.0, 143.7, 140.4, 136.1, 135.0, 133.5, 130.1, 130.0, 129.7, 129.1, 129.0, 128.9, 128.7, 128,6, 128,5, 123.8, 122.6, 108.7, 41.9, 40.7, 39.5, 38.5, 30.9, 20.6, 11.0.

2-Benzoyl-1′-benzyl-3-(4-methoxybenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4p)

White solid; yield: 206.9 mg, 85%; R_f = 0.3 (EtOAc–PE, 2:8); mp 172–174 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.99 (d, *J* = 7.8 Hz, 2 H), 7.88–7.81 (m, 2 H), 7.58 (t, *J* = 7.5 Hz, 1 H), 7.47–7.35 (m, 3 H), 7.21–7.16 (m, 4 H), 7.07–6.99 (m, 3 H), 6.90 (d, *J* = 9 Hz, 2 H), 6.78–6.74 (m, 1 H), 5.09 (d, *J* = 15.6 Hz, 1 H), 4.69 (d, *J* = 15.6 Hz, 1 H), 4.46 (d, *J* = 7.8 Hz, 1 H), 4.22 (d, *J* = 7.8 Hz, 1 H), 3.86 (s, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 190.7, 190.3, 171.5, 164.1, 143.2, 136.2, 135.5, 133.5, 131.0, 130.8, 129.8, 128.8, 128.5, 128.3, 127.5, 127.1, 127.0, 124.1, 122.8, 122.4, 114.0, 109.3, 55.5, 44.0, 40.3, 39.6, 38.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{32}H_{25}NO_4$: 488.1862; found: 488.1889.

2-Benzoyl-1′-benzyl-3-(4-chlorobenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4q)

Yellow liquid; yield: 176.7 mg, 72%; R_f = 0.3 (EtOAc–PE, 2:8).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.96 (d, *J* = 7.6 Hz, 1 H), 7.91 (d, *J* = 8.8 Hz, 1 H), 7.75 (d, *J* = 7.6 Hz, 1 H), 7.72 (d, *J* = 8.8 Hz, 1 H), 7.45–7.29 (m, 6 H), 7.22–7.14 (m, 4 H), 7.03–7.01 (m, 1 H), 6.97–6.96 (m, 2 H), 6.76 (t, *J* = 7.6 Hz, 1 H), 5.27 (d, *J* = 15 Hz, 1 H), 5.08 (d, *J* = 15 Hz, 1 H), 4.44 (d, *J* = 8 Hz, 1 H), 4.15 (d, *J* = 8 Hz, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.2, 190.8, 175.0, 143.1, 138.7, 138.1, 136.0, 133.2, 133.1, 132.5, 129.5, 129.4, 129.3, 129.2, 129.0, 128.1, 127.6, 127.3, 124.2, 123.0, 122.5, 114.0, 109.3, 44.5, 40.2, 39.5, 38.7.

1′-Allyl-2-(4-methoxybenzoyl)-3-(4-methylbenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4r)

White solid; yield: 180.4 mg, 80%; R_f = 0.3 (EtOAc–PE, 2:8); mp 191–192 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.99–7.97 (m, 1 H), 7.84 (dd, J_1 = 8.4 Hz, J_2 = 36.8 Hz, 1 H), 7.72 (d, J = 8 Hz, 1 H), 7.37–7.34 (m, 1 H), 7.28–7.27 (m, 1 H), 7.26–7.21 (m, 1 H), 7.17 (d, J = 8 Hz, 1 H), 7.06–7.02 (m, 1 H), 6.89 (d, J = 9.2 Hz, 2 H), 6.87–6.83 (m, 2 H), 5.70–5.66 (m, 1 H), 5.10–5.07 (m, 1 H), 5.03–4.99 (m, 1 H), 4.42 (d, J = 8 Hz, 1 H), 4.36–4.35 (m, 1 H), 4.28–4.26 (m, 1 H), 4.15 (d, J = 8 Hz, 1 H), 3.84 (s, 3 H), 2.36 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.4, 190.3, 171.2, 164.1, 144.4, 143.3, 131.1, 130.8, 129.9, 129.4, 128.8, 128.6, 128.3, 124.2, 122.7, 122.5, 117.2, 113.9, 109.2, 55.5, 42.6, 40.6, 40.4, 39.6, 38.8, 38.6, 21.7.

HRMS (ESI): m/z [M + H]$^+$ calcd for $C_{29}H_{25}NO_4$: 452.1863; found: 452.1898.

1′-Allyl-2-(4-chlorobenzoyl)-3-(4-methylbenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4s)

White solid; yield: 177.4 mg, 78%; R_f = 0.3 (EtOAc–PE, 2:8); mp 205–207 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.98 (d, J = 7.6 Hz, 1 H), 7.84 (dd, J_1 = 7.6 Hz, J_2 = 27.2 Hz, 2 H), 7.70 (d, J = 8 Hz, 1 H), 7.55–7.49 (m, 1 H), 7.44–7.34 (m, 2 H), 7.23–7.15 (m, 2 H), 7.05–7.03 (m, 1 H), 6.84 (d, J = 8 Hz, 1 H), 5.69–5.62 (m, 1 H), 5.08–4.97 (m, 2 H), 4.42–4.34 (m, 2 H), 4.26–4.15 (m, 2 H), 2.37 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.8, 190.7, 171.2, 145.1, 144.6, 143.5, 136.5, 134.5, 133.6, 131.2, 129.6, 128.9, 128.8, 128.7, 128.6, 128.5, 124.2, 122.6, 117.4, 109.3, 42.7, 40.7, 39.8, 39.0, 21.8.

HRMS (ESI): m/z [M + H]$^+$ calcd for $C_{28}H_{22}ClNO_3$: 456.1366; found: 456.1476.

1′-Allyl-2-benzoyl-3-(4-methoxybenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4t)

White solid; yield: 183.5 mg, 84%; R_f = 0.3 (EtOAc–PE, 25:75); mp 195–196 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.99 (d, J = 8.7 Hz, 2 H), 7.85–7.79 (m, 2 H), 7.53 (t, J = 7.2 Hz, 1 H), 7.40–7.37 (m, 3 H), 7.28 (t, J = 6.6 Hz, 1 H), 7.03–6.99 (m, 1 H), 6.90–6.84 (m, 3 H), 5.72–5.63 (m, 1 H), 5.12–4.97 (m, 2 H), 4.46–4.38 (m, 2 H), 4.28–4.15 (m, 2 H), 3.85 (s, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 190.7, 190.3, 171.1, 164.1, 143.3, 136.1, 133.5, 131.0, 130.7, 129.8, 128.7, 128.6, 128.4, 128.3, 124.0, 122.7, 122.4, 117.2, 113.9, 109.2, 55.5, 55.4, 42.5, 40.4, 39.5, 38.5.

HRMS (ESI): m/z [M + H]$^+$ calcd for $C_{28}H_{23}NO_4$: 438.1705; found: 438.1761.

2-Benzoyl-5′-chloro-1′-ethyl-3-(4-methoxybenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4u)

White solid; yield: 188.2 mg, 82%; R_f = 0.3 (EtOAc–PE, 2:8); mp 211–213 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.92–7.90 (m, 2 H), 7.68 (d, J = 7.2 Hz, 2 H), 7.43 (t, J = 7.2 Hz, 1 H), 7.31–7.26 (m, 3 H), 7.19–7.17 (m, 1 H), 6.83–6.80 (m, 2 H), 6.74–6.70 (m, 1 H), 4.29 (d, J = 8 Hz, 1 H), 4.00 (d, J = 8 Hz, 1 H), 3.76 (s, 3 H), 3.68–3.60 (m, 1 H), 3.55–3.51 (m, 1 H), 2.08 (s, 3 H), 0.95 (t, J = 7.2 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.5, 190.1, 170.5, 164.2, 141.7, 136.1, 134.6, 132.3, 131.1, 128.7, 128.6, 128.4, 128.3, 126.1, 123.2, 113.9, 109.3, 55.4, 39.9, 38.3, 35.1, 30.9, 12.4.

HRMS (ESI): m/z [M + H]$^+$ calcd for $C_{27}H_{22}ClNO_4$: 460.1315; found: 460.1341.

2-Benzoyl-5′-bromo-1′-ethyl-3-(4-methylbenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (4v)

White solid; yield: 189.9 mg, 78%; R_f = 0.3 (EtOAc–PE, 2:8); mp 214–215 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.90 (d, J = 8.4 Hz, 2 H), 7.77 (d, J = 8 Hz, 2 H), 7.54–7.45 (m, 3 H), 7.40–7.26 (m, 4 H), 6.80 (d, J = 8.4 Hz, 1 H), 4.39 (d, J = 8 Hz, 1 H), 4.08 (d, J = 8 Hz, 1 H), 3.78–3.73 (m, 1 H), 3.64–3.59 (m, 1 H), 2.39 (s, 3 H), 1.06 (t, J = 7.2 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.7, 190.1, 170.5, 164.2, 141.8, 136.1, 134.1, 133.6, 129.5, 128.8, 128.7, 128.4, 128.3, 128.0, 126.0, 123.2, 113.9, 113.2, 109.2, 40.3, 39.9, 38.5, 35.2, 21.7, 12.4.

HRMS (ESI): m/z [M + H]$^+$ calcd for $C_{28}H_{24}BrNO_3$: 502.1018; found: 502.1139.

2-(4-Methoxybenzoyl)-3-styrylspiro[cyclopropane-1,3′-indolin]-2′-one (6a)

White solid; yield: 173.8 mg, 88%; R_f = 0.3 (EtOAc–PE, 15:85); mp 165–166 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.61 (br s, 1 H), 7.89 (d, J = 8.7 Hz, 2 H), 7.33 (d, J = 7.5 Hz, 2 H), 7.29–7.25 (m, 3 H), 7.19 (t, J = 7.2 Hz, 1 H), 7.14 (t, J = 7.6 Hz, 1 H), 6.96 (t, J = 7.6 Hz, 1 H), 6.90 (d, J = 7.6 Hz, 1 H), 6.80–6.70 (m, 4 H), 3.98 (d, J = 7.6 Hz, 1 H), 3.77 (s, 3 H), 3.59 (t, J = 7.9 Hz, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.8, 175.4, 163.8, 140.9, 136.7, 133.7, 130.6, 129.9, 128.5, 127.5, 126.3, 126.2, 123.2, 122.3, 113.8, 109.8, 55.4, 42.8, 41.8, 39.1.

HRMS (ESI): m/z [M + H]$^+$ calcd for $C_{26}H_{21}NO_3$: 396.1599; found: 396.1671.

2-Benzoyl-1′-ethyl-3-styrylspiro[cyclopropane-1,3′-indolin]-2′-one (6b)

White solid; yield: 170.9 mg, 87%; R_f = 0.3 (EtOAc–PE, 15:85); mp 162–164 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.93 (d, J = 7.6 Hz, 2 H), 7.53 (t, J = 7.2 Hz, 1 H), 7.44–7.39 (m, 4 H), 7.33–7.20 (m, 5 H), 6.99 (t, J = 7.6 Hz, 1 H), 6.88–6.81 (m, 2 H), 6.73 (d, J = 16 Hz, 1 H), 4.03 (d, J = 7.6 Hz, 1 H), 3.88 (q, J = 7.2 Hz, 2 H), 3.60 (t, J = 8.4 Hz, 1 H), 1.31 (t, J = 7.2 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 193.0, 172.5, 142.9, 137.3, 137.0, 133.8, 133.7, 128.8, 128.7, 128.5, 127.6, 127.5, 126.4, 125.9, 123.6, 122.6, 122.4, 108.3, 43.0, 42.0, 39.4, 35.3, 13.1.

HRMS (ESI): m/z [M + H]$^+$ calcd for $C_{27}H_{23}NO_2$: 394.1808; found: 394.1832.

1′-Ethyl-2-(2-methoxybenzoyl)-3-styrylspiro[cyclopropane-1,3′-indolin]-2′-one (6c)

White solid; yield: 179.7 mg, 85%; R_f = 0.3 (EtOAc–PE, 15:85); mp 174–175 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.74 (d, *J* = 7.6 Hz, 1 H), 7.44–7.39 (m, 3 H), 7.35 (d, *J* = 7.2 Hz, 1 H), 7.29 (t, *J* = 7.6 Hz, 2 H), 7.24–7.18 (m, 2 H), 7.02–7.00 (m, 1 H), 6.98–6.94 (m, 1 H), 6.90–6.89 (m, 1 H), 3.87 (dd, J_1 = 2.4 Hz, J_2 = 6.4 Hz, 2 H), 3.84 (s, 1 H), 6.71 (d, *J* = 16 Hz, 1 H), 4.11 (d, *J* = 8 Hz, 1 H), 3.93–3.85 (m, 2 H), 3.75 (s, 3 H), 3.67 (dd, J_1 = 8 Hz, J_2 = 9.2 Hz, 1 H), 1.35–1.27 (m, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 192.6, 172.8, 159.2, 152.8, 142.5, 136.8, 134.3, 132.7, 131.1, 130.7, 130.5, 128.9, 127.3, 127.2, 127.0, 126.3, 124.0, 122.3, 121.9, 120.4, 111.5, 107.8, 55.4, 48.4, 41.5, 39.6, 34.9, 12.9.

2-Benzoyl-1′-methyl-3-styrylspiro[cyclopropane-1,3′-indolin]-2′-one (6d)

White solid; yield: 166.7 mg, 88%; R_f = 0.3 (EtOAc–PE, 15:85); mp 167–168 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.84–7.82 (m, 2 H), 7.42–7.38 (m, 1 H), 7.31–7.28 (m, 4 H), 7.23–7.20 (m, 2 H), 7.17 (d, *J* = 8 Hz, 1 H), 7.12–7.09 (m, 2 H), 6.91–6.89 (m, 1 H), 6.76–6.70 (m, 2 H), 6.62 (d, *J* = 16 Hz, 1 H), 3.95 (d, *J* = 7.6 Hz, 1 H), 3.51 (dd, J_1 = 7.6 Hz, J_2 = 9.2 Hz, 1 H), 3.24 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 192.7, 172.6, 143.6, 136.9, 136.7, 133.6, 133.5, 128.6, 128.4, 128.3, 127.4, 126.2, 125.5, 123.3, 122.4, 122.2, 107.9, 42.6, 41.8, 39.2, 26.6.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{26}H_{21}NO_2$: 380.1651; found: 380.1705.

2-(4-Methoxystyryl)-1′-methyl-3-(4-methylbenzoyl)spiro[cyclopropane-1,3′-indolin]-2′-one (6e)

White solid; yield: 190.3 mg, 90%; R_f = 0.3 (EtOAc–PE, 15:85); mp 162–164 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.85 (d, *J* = 6.4 Hz, 2 H), 7.36–7.30 (m, 3 H), 7.22–7.16 (m, 3 H), 6.99 (t, *J* = 7.2 Hz, 1 H), 6.85–6.83 (m, 3 H), 6.70–6.69 (m, 2 H), 4.04 (d, *J* = 7.2 Hz, 1 H), 3.79 (s, 3 H), 3.62–3.60 (m, 1 H), 3.24 (s, 3 H), 2.37 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 192.2, 172.5, 159.0, 144.5, 142.6, 134.5, 133.0, 131.4, 129.6, 129.3, 128.4, 127.4, 127.2, 125.6, 122.3, 122.1, 120.9, 117.4, 113.8, 108.8, 55.2, 42.9, 42.6, 41.5, 39.4, 21.6.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{28}H_{25}NO_3$: 424.1913; found: 424.1942.

2-(4-Chlorobenzoyl)-1′-propyl-3-styrylspiro[cyclopropane-1,3′-indolin]-2′-one (6f)

White solid; yield: 189.6 mg, 86%; R_f = 0.3 (EtOAc–PE, 15:85); mp 177–178 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.86 (d, *J* = 8.8 Hz, 2 H), 7.39–7.34 (m, 1 H), 7.31–7.19 (m, 5 H), 6.98 (t, *J* = 7.6 Hz, 1 H), 6.87–6.84 (m, 1 H), 6.82–6.78 (m, 1 H), 6.72 (d, *J* = 16 Hz, 1 H), 3.96 (d, *J* = 7.6 Hz, 1 H), 3.83–3.74 (m, 2 H), 3.58 (dd, J_1 = 7.6 Hz, J_2 = 8.8 Hz, 1 H), 1.77–1.70 (m, 2 H), 0.97 (t, *J* = 7.6 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.7, 172.6, 143.0, 140.1, 136.7, 135.3, 133.7, 129.7, 129.0, 128.5, 127.5, 126.3, 125.4, 123.1, 122.2, 122.1, 108.4, 42.8, 42.0, 41.7, 39.1, 20.9, 11.3.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{28}H_{24}ClNO_2$: 442.1574; found: 442.1590.

2-Benzoyl-1′-propyl-3-styrylspiro[cyclopropane-1,3′-indolin]-2′-one (6g)

White solid; yield: 175.0 mg, 86%; R_f = 0.3 (EtOAc–PE, 15:85); mp 163–164 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.94 (d, *J* = 7.8 Hz, 2 H), 7.55–7.51 (m, 1 H), 7.44–7.40 (m, 4 H), 7.33–7.29 (m, 3 H), 7.24–7.19 (m, 2 H), 7.01–6.98 (m, 1 H), 6.89–6.83 (m, 2 H), 6.74 (d, *J* = 16 Hz, 1 H), 4.06 (d, *J* = 7.6 Hz, 1 H), 3.85–3.75 (m, 2 H), 3.63 (dd, J_1 = 7.6 Hz, J_2 = 9.2 Hz, 1 H), 1.78–1.71 (m, 2 H), 0.99 (t, *J* = 7.2 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 192.8, 172.6, 143.0, 136.9, 136.8, 133.5, 133.4, 128.6, 128.4, 128.3, 127.4, 127.3, 126.2, 125.6, 123.3, 122.2, 122.1, 108.3, 42.9, 41.9, 39.1, 30.8, 20.8, 11.3.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{28}H_{25}NO_2$: 408.1964; found: 408.1987.

2-Benzoyl-5′-chloro-3-styrylspiro[cyclopropane-1,3′-indolin]-2′-one (6h)

White solid; yield: 163.5 mg, 82%; R_f = 0.3 (EtOAc–PE, 15:85); mp 195–196 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.62 (s, 1 H), 7.96 (d, *J* = 7.2 Hz, 2 H), 7.56 (t, *J* = 7.6 Hz, 1 H), 7.44 (t, *J* = 7.6 Hz, 2 H), 7.37 (d, *J* = 7.2 Hz, 2 H), 7.32–7.31 (m, 1 H), 7.29–7.26 (m, 2 H), 7.23–7.20 (m, 1 H), 7.13 (dd, J_1 = 2 Hz, J_2 = 8.4 Hz, 1 H), 6.82 (d, *J* = 8.4 Hz, 1 H), 6.74–6.70 (m, 2 H), 4.05 (d, *J* = 8 Hz, 1 H), 3.61–3.57 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 192.4, 174.4, 139.2, 136.8, 136.6, 134.3, 128.8, 128.6, 128.4, 127.9, 127.8, 127.7, 127.5, 126.3, 123.1, 122.5, 110.6, 42.9, 42.0, 40.0.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{25}H_{18}ClNO_2$: 400.1104; found: 400.1159.

Conflict of Interest

The authors declare no conflict of interest.

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