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Phosphorus-Containing Lewis Base Catalyzed Cascade Reactions of Isatin-Derived Oximes with Allenic Esters and Further Transformations

Cheng-Kui Pei,[a] Yu Jiang,[a] and Min Shi*[a,b]

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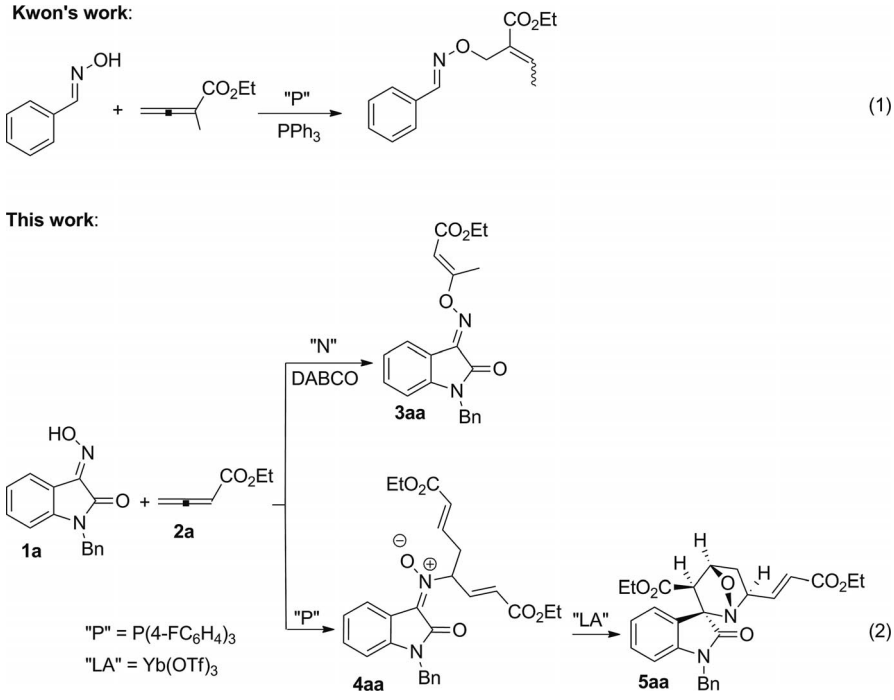
Phosphorus containing Lewis base catalyzed cascade reactions of isatin-derived oximes with allenic esters afford the corresponding functionalized nitrones. Further Lewis acid catalyzed highly regioselective intramolecular [3+2] cycliza-tions give the corresponding bridged cycloadducts. Moreover, a combined "one-pot" reaction is also feasible for the above two catalytic reactions.

Introduction

Oximes and their derivatives are valuable synthetic building blocks,[1] and they are well-known for their dehydration reactions to produce nitriles,[2] for their Beckmann rearrangement reactions to prepare amides,[3] and as precursors of 1,3-dipolar addition reactions.[4] Recently, allenoates have served as an attractive substrate class for Lewis base catalyzed reactions, and they have attracted much synthetic interest because of their facile preparation and diverse reactivity.[5] To our surprise, the reactions of oximes as substrates with allenoates have been seldom mentioned. The only example was reported by Kwon in 2011, providing β′-umpolung addition products due to the nucleophilicity of the oximes [Scheme 1, Equation (1)].[6] Herein, we wish to report the discovery of the reaction of oximes derived from



Scheme 1. Reaction modes of oximes and allenoates.

[a] Key Laboratory for Advanced Materials and Institute of Fine Chemicals, East China University of Science and Technology, 130 Mei Long Road, Shanghai 200237, China
[b] State Key Laboratory of Organometallic Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences, 354 Fenglin Lu, Shanghai 200032, China
Fax: +86-21-64166128
E-mail: Mshi@mail.sioc.ac.cn

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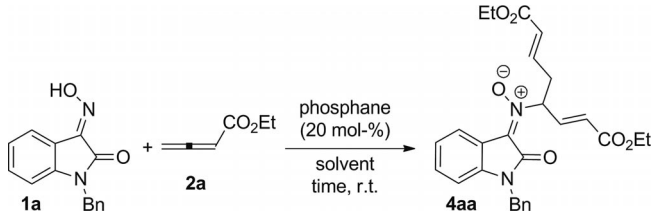
isatins with allenic esters catalyzed by phosphorus-containing Lewis bases ("P" catalytic cycle)[7–9] to give functionalized nitrones as the products, and we will also disclose that these nitrones as 1,3-dipoles can undergo highly regioselective intramolecular [3+2] cycloaddition reactions[10,11] in the presence of a Lewis acid ("LA" catalytic cycle) to afford bridged-ring compounds, which are structural subunits in many natural products and biologically active molecules[11] [Scheme 1, Equation (2)].

Results and Discussion

We initially utilized (*E*)-1-benzyl-3-(hydroxyimino)-indolin-2-one (**1a**; 0.1 mmol, 1.0 equiv.) and ethyl 2,3-butadienoate (**2a**; 0.2 mmol, 2.0 equiv.) as substrates to investigate their reaction behavior in THF at room temperature in the presence of nitrogen-containing Lewis bases such as 1,4-diazabicyclo[2,2,2]octane (DABCO) ("N" catalytic cycle, 20 mol-%). It was found that the reaction took place smoothly to give the corresponding addition product **3aa** in 87% yield [Scheme 1, Equation (2)]. Considering the different reaction profiles of phosphorus- and nitrogen-containing Lewis bases, we changed the Lewis base from DABCO to PPh_3 and were pleased to find that nitrone product **4aa** had been afforded in 62% yield. These results attracted our attention. Subsequently, we chose PPh_3 as a Lewis base and screened various solvents for this reaction. We found that toluene was the best solvent for this reaction, affording **4aa** in 65% yield (Table 1, Entry 6). In acetonitrile (CH_3CN), *N*,*N*-dimethylformamide (DMF), and dimethyl sulfoxide (DMSO), only addition product **3aa** was produced without the formation of **4aa** (Table 1, Entries 7–9), and in dioxane, no reaction occurred (Table 1, Entry 10). We next attempted to screen other phosphorus-containing Lewis base catalysts and found that tris(4-fluorophenyl)-phosphane [$P(4\text{-}FC_6H_4)_3$] was the best Lewis base for the reaction (Table 1, Entries 11–14). Lowering the reaction temperature to 0 or –10 °C did not improve the yield of **4aa** (Table 1, Entries 15 and 16). Raising the reaction temperature to 50 °C furnished **4aa** in 72% yield (Table 1, Entry 17), but further increase in the reaction temperature did not improve the reaction outcome (Table 1, Entry 18). Increasing the amount of allenoate employed to 3.0 equiv. produced **4aa** in 78% yield (Table 1, Entry 19), and a further increase in the amount of allenoate employed did not give a better reaction outcome (Table 1, Entry 20). We also confirmed that no product was formed in the absence of $P(4\text{-}FC_6H_4)_3$ (Table 1, Entry 21). Thus, we established the optimal conditions for this reaction: 20 mol-% $P(4\text{-}FC_6H_4)_3$ as the catalyst and toluene as a solvent with 3.0 equiv. allenoate at 50 °C.

Under the optimized reaction conditions, the reaction generality was investigated by using various oximes **1** in the reaction with several allenic esters **2**, and the results of these experiments are summarized in Table 2. With oximes **1b–d** bearing different N-protecting groups, the reactions proceeded smoothly to produce the corresponding nitrone products **4ba–da** in good to high yields (up to 90%; Table 2, Entries 1–3). Changing the ester moiety of allenic esters **2** from OEt to OBn provided a similar reaction outcome, affording desired product **4ab** in 72% yield (Table 2, Entry 4). As for substrates **1e–m**, regardless of whether an electron-donating or electron-withdrawing group was introduced at the 5-, 6-, or 7-position of the benzene ring of the *N*-allyl-protected oximes, the reactions proceeded smoothly to give the corresponding products **4** in good yields (Table 2, Entries 5–13). The use of oxime **1n** (R^1 = 5-Me, PG = Bn) as the substrate afforded desired product **4na** in 88% yield (Table 2, Entry 14). However, as for oxime **1o** having a bromine atom at the 4-position of the benzene ring, only addition product **3oa** was formed rather than the nitrone product, perhaps due to steric effects (Table 2, Entry 15). The allenic ester α-methylallenoate was also used in the reaction. However, the corresponding β′-umpolung addition product was formed, which is similar to the finding of Kwon[6] (Supporting Information, Scheme S1). The structure of **4da** was unambiguously determined by X-ray diffraction. The ORTEP drawing is shown in the Supporting Information.[12]

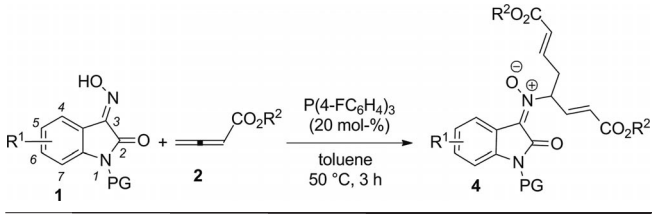
Table 1. Optimization of the conditions for the reaction of (*E*)-1-benzyl-3-(hydroxyimino)indolin-2-one (**1a**) and ethyl 2,3-butadienoate (**2a**).[a]



Entry	Solvent	Phosphane	*T* [°C]	Time [h]	Yield [%][b]
1	THF	PPh_3	r.t.	12	62
2	Et_2O	PPh_3	r.t.	12	53
3	DCM	PPh_3	r.t.	12	46
4	DCE	PPh_3	r.t.	12	48
5	$CHCl_3$	PPh_3	r.t.	12	63
6	toluene	PPh_3	r.t.	12	65
7	CH_3CN	PPh_3	r.t.	12	–[e]
8	DMF	PPh_3	r.t.	12	–[e]
9	DMSO	PPh_3	r.t.	12	–[e]
10	dioxane	PPh_3	r.t.	12	NR
11	toluene	PBu_3	r.t.	12	disorder
12	toluene	$PMePh_2$	r.t.	12	disorder
13	toluene	$P(4\text{-}MeOC_6H_4)_3$	r.t.	12	45
14	toluene	$P(4\text{-}FC_6H_4)_3$	r.t.	12	68
15	toluene	$P(4\text{-}FC_6H_4)_3$	0	24	68
16	toluene	$P(4\text{-}FC_6H_4)_3$	–10	24	68
17	toluene	$P(4\text{-}FC_6H_4)_3$	50	3	72
18	toluene	$P(4\text{-}FC_6H_4)_3$	60	3	70
19[c]	toluene	$P(4\text{-}FC_6H_4)_3$	50	3	78
20[d]	toluene	$P(4\text{-}FC_6H_4)_3$	50	3	78
21	toluene	–	50	r.t.	NR

[a] All reactions were carried out with **1a** (0.10 mmol) and **2a** (0.20 mmol) in solvent (2.0 mL) for 24 h. [b] Isolated yield. [c] Compound **2a** was used as 3.0 equiv. [d] Compound **2a** was used as 4.0 equiv. [e] Only **3aa** was formed.

Table 2. Substrate scope of the cascade reactions of oximes **1** and allenic esters **2**.[a]



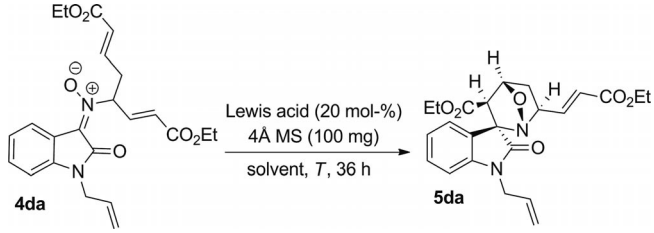
Entry	1	R^1	PG	R^2	Product	Yield [%][b]
1	**1b**	H	Me	Et (**2a**)	**4ba**	89
2	**1c**	H	CPh_3	Et (**2a**)	**4ca**	70
3	**1d**	H	1-allyl	Et (**2a**)	**4da**	90
4	**1a**	H	Bn	Bn (**2b**)	**4ab**	72
5	**1e**	5-Me	1-allyl	Et (**2a**)	**4ea**	89
6	**1f**	5-Br	1-allyl	Et (**2a**)	**4fa**	83
7	**1g**	5-Cl	1-allyl	Et (**2a**)	**4ga**	85
8	**1h**	6-Me	1-allyl	Et (**2a**)	**4ha**	87
9	**1i**	6-Br	1-allyl	Et (**2a**)	**4ia**	80
10	**1j**	7-Cl	1-allyl	Et (**2a**)	**4ja**	87
11	**1k**	7-Br	1-allyl	Et (**2a**)	**4ka**	77
12	**1l**	7-F	1-allyl	Et (**2a**)	**4la**	90
13	**1m**	7-CF_3	1-allyl	Et (**2a**)	**4ma**	80
14	**1n**	5-Me	Bn	Et (**2a**)	**4na**	88
15	**1o**	4-Br	1-allyl	Et (**2a**)	**4oa**	–[c]

[a] All reactions were carried out with **1** (0.10 mmol) and **2** (0.30 mmol) in toluene (2.0 mL) for 3 h. [b] Isolated yield. [c] Only addition product **3oa** was formed.

Next, we utilized nitrone product **4da** as the substrate to investigate its intramolecular [3+2] cycloaddition reaction behavior in the presence of $Yb(OTf)_3$ as the Lewis acid and 4 Å molecular sieves (100 mg for 0.1 mmol of **4da**). The results are summarized in Table 3. We found that the cyclization gave a trace amount of **5da** in conventional solvents, such as toluene, DCM, and THF, at room temperature (Table 3, Entries 1–3). An increase in the reaction temperature to 80 and 100 °C in toluene resulted in smooth cycloaddition to afford **5da** in 50 and 65% yield, respectively, in a highly regioselective manner (Table 3, Entries 4 and 5). A further increase in the reaction temperature to 120 °C did not improve the reaction outcome (Table 3, Entry 6). Other Lewis acids such as $BF_3{\cdot}OEt_2$ and $Sc(OTf)_3$ were also tested in the above reaction; a complex mixture of products was obtained in the former and a 51% yield of **5da** was obtained in the latter (Table 3, Entries 7 and 8). We also found that the use of $Yb(OTf)_3$ as a Lewis acid is essential for this transformation (Table 4, Entry 9). Therefore, $Yb(OTf)_3$ was used as the catalyst in this cyclization reaction.

Under the optimized reaction conditions, we found that nitrone products **4** could undergo intramolecular [3+2] cycloaddition to afford bridged-ring compounds **5** in good yields with high regioselectivities (Table 4, Entries 1–5), thus opening up a new route to synthesize bridged-ring compounds. Compound **5ca** was characterized by spectroscopy and the structure was confirmed by single-crystal X-ray diffraction.[13] Next, under the optimized reaction conditions, we carried out the one-pot reaction of oximes

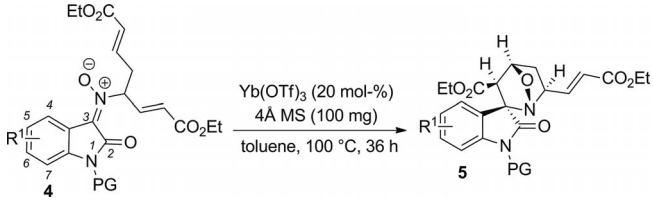
Table 3. Optimization of the reaction conditions for the intramolecular [3+2] cycloaddition of **4aa**.[a]



Entry	Lewis acid	Solvent	T [°C]	Yield [%][b]
1	$Yb(OTf)_3$	toluene	r.t.	trace
2	$Yb(OTf)_3$	DCM	r.t.	trace
3	$Yb(OTf)_3$	THF	r.t.	trace
4	$Yb(OTf)_3$	toluene	80	50
5	$Yb(OTf)_3$	toluene	100	65
6	$Yb(OTf)_3$	toluene	100	60
7	$BF_3{\cdot}Et_2O$	toluene	100	disorder
8	$Sc(OTf)_3$	toluene	100	51
9	–	toluene	100	–

[a] All reactions were carried out with **4da** (0.10 mmol) catalyzed by Lewis acid (20 mol-%) with the addition of 4 Å MS (100 mg) in solvent (2.0 mL) for 36 h. [b] Isolated yield.

Table 4. Intramolecular [3+2] cycloaddition reaction of **4**.[a]

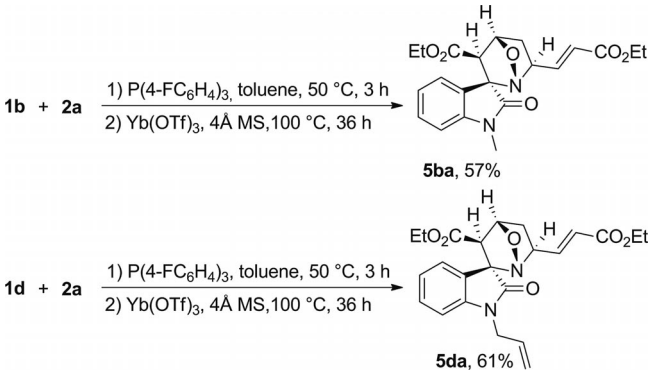


Entry	Substrate	R^1	PG	Product	Yield [%][b]
1	**4aa**	H	Bn	**5aa**	65
2	**4ca**	H	CPh_3	**5ca**	60
3	**4ga**	5-Cl	1-allyl	**5ga**	68
4	**4ha**	6-Me	1-allyl	**5ha**	65
5	**4na**	5-Me	Bn	**5na**	70

[a] All reactions were carried out at 100 °C by using **4** (0.10 mmol) catalyzed by $Yb(OTf)_3$ (20 mol-%) with the addition of 4 Å MS (100 mg) in toluene (2.0 mL) for 3 h, unless otherwise specified. [b] Isolated yield.

1b and **1d** with allenoate **2a** by adding $P(4\text{-}FC_6H_4)_3$ (20 mol-%) in toluene and performing the reaction at 50 °C for 3 h, followed by the addition of $Yb(OTf)_3$ (20 mol-%) and 4 Å molecular sieves without purification upon heating the reaction mixtures at 100 °C for 36 h. The corresponding bridged-ring compounds **5ba** and **5da** could be obtained in 57 and 61% yield, respectively (Scheme 2).

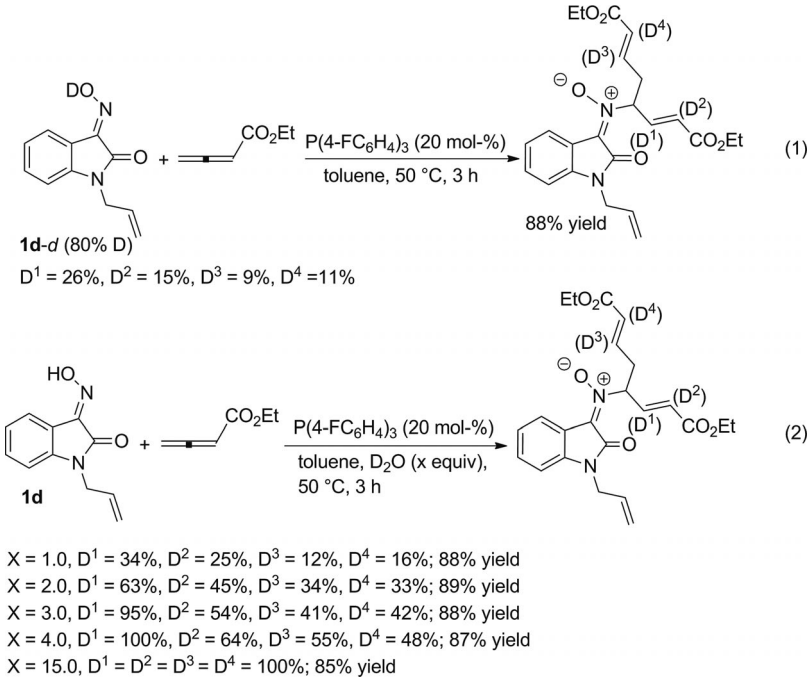
To clarify the reaction mechanism, several deuterium labeling experiments were conducted, and the results are summarized in Scheme 3. The first experiment was carried out with **1d**-*d* (80%D) and **2a** under the standard reaction conditions to afford crude product **4da** in 88% yield along with 26, 15, 9, and 11% D content[14] incorporated at the D^1, D^2, D^3, and D^4 positions, respectively [Scheme 3, Equation (1)], after silica gel column chromatography. Consider-



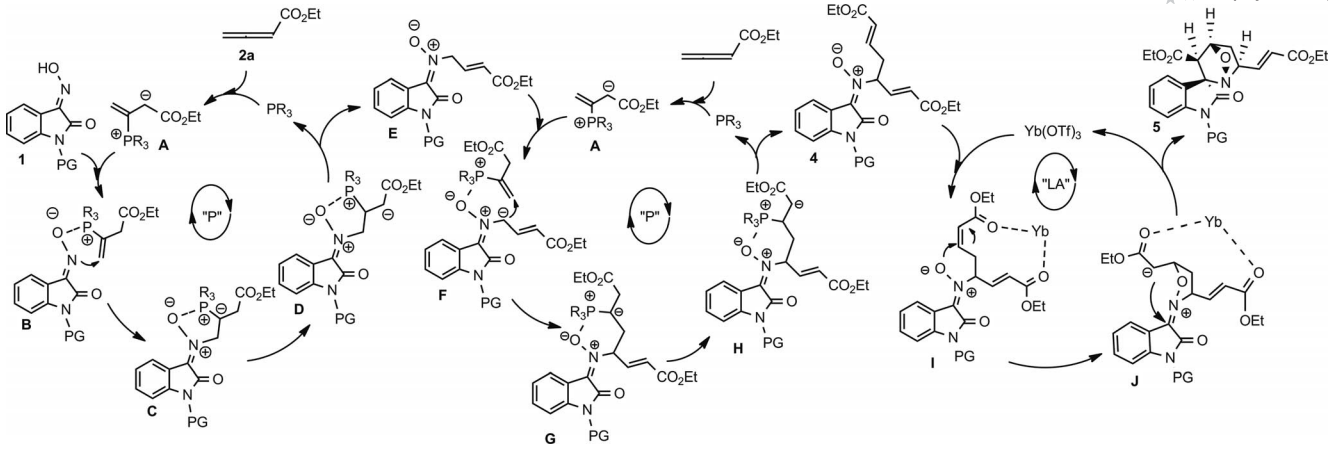
Scheme 2. One-pot reaction of oximes **1b** and **1c** with allenoate **2a**.

ing that a trace amount of H_2O would assist the 1,2-proton transfer and affect the D content of **4da**[15] that and **1d**-*d* could be also generated in situ from **1d** and D_2O, we carried out the same reaction with **1d** in toluene/D_2O (1.0 equiv.) and found that **4da** was formed in 88% yield along with 38, 25, 15, and 17%D content incorporated at the D^1, D^2, D^3, and D^4 positions, respectively [Scheme 3, Equation (2)]. Increasing the employed amount of D_2O could improve the D content incorporated at the D^1, D^2, D^3, and D^4 positions [Scheme 3, Equation (2)]. Increasing the employed amount of D_2O to 15.0 equiv., we observed 100%D content incorporated at the D^1, D^2, D^3, and D^4 positions [Scheme 3, Equation (2)]. These deuterium labeling experiments indicate that proton transfer between the oxime or water and the allenic ester can occur in the presence of a tertiary phosphane and several intermolecular proton transfers can take place at the same time in the catalytic cycle.

The mechanism for the reactions has not been unequivocally established, but one rational explanation is shown in Scheme 4 based on earlier reports[7] and our own deuterium labeling investigations. Addition of phosphane to allenoate **2a** delivers zwitterionic intermediate **A**. Deprotonation of pronucleophile **1** by zwitterionic intermediate **A** forms intermediate **B**. The negatively charged oxygen ion of the oxime can coordinate with the phosphate ion of the phosphonium enolate,[7e,7f,15] which precludes addition of the negative oxygen ion to the enolate, and the following conjugate addition of the nitrogen atom of the oxime to the enolate forms intermediate **C**. Subsequently, facile 1,2-proton transfer affords intermediate **D**, and then elimination takes place to give intermediate **E**. The existence of the positively charged nitrogen ion of intermediate **E** makes deprotonation from the active methylene feasible by zwitterionic intermediate **A** to give intermediate **F**, which undergoes conjugate addition to give intermediate **G**, and then facile 1,2-proton transfer affords intermediate **H**. Finally, elimination takes place to give the corresponding product **4** and regenerates the phosphane catalyst. In the "LA" catalytic cycle, the two esters of nitrone **4** can be activated by $Yb(OTf)_3$ to give intermediate **I**, which undergoes cyclization regioselectively to give intermediate **J**. Intermediate **J** undergoes another cyclization to furnish cycloaddition product **5** and regenerates the $Yb(OTf)_3$ catalyst, presumably through an asynchronous concerted process. Therefore, the one-pot synthetic sequence can be also summarized as a cascade process including two phosphane-catalyzed cascade catalytic cycles ("P" cycle) combined with a Lewis acid catalyzed catalytic cycle ("LA" cycle) (Scheme 4). From what has been discussed above, we can easily draw a conclusion



Scheme 3. Deuterium labeling experiments.



Scheme 4. A plausible reaction mechanism.

about the possible details on the formation of D^1, D^2, D^3, and D^4 incorporated products. In the first "P" cycle, D^2 incorporation could be obtained by proton transfer between the deuterium atom at the hydroxy group of the oxime with intermediate **A**, and 1,2-proton transfer of intermediate **C** gives D^1 incorporation. Intermediates **G** and **H** in the second "P" cycle could also undergo intermolecular proton transfer with the deuterium atom at the hydroxy group of the remaining oxime or D_2O to provide D^3 and D^4 incorporated products, suggesting that the corresponding deuterated intermediate **H** could be regenerated through deprotonation by the in situ generated counteranion to participate in the catalytic cycle.[15]

Conclusions

In summary, we have found and developed an interesting phosphorus-containing Lewis base catalyzed cascade reactions of isatin-derived oximes with allenic esters to give the corresponding functionalized nitrones in good to excellent yields under mild conditions. The obtained nitrones could further undergo intramolecular [3+2] cycloaddition to afford bridged-ring compounds in good yields with high regioselectivities, and these compounds are useful building blocks in the organic synthesis of biologically useful compounds.[11] Furthermore, a combined "one-pot" reaction is also feasible for the above two catalytic reactions. A plausible reaction mechanism has also been proposed on the basis of previous literature and our own deuterium labeling investigations. Efforts are in progress to elucidate further mechanistic details of these reactions and to understand their scope and limitations.

Experimental Section

General Procedure for 1: To a solution of *N*-Bn-protected isatin (1.2 g, 0.50 mmol) in MeOH (10 mL) was added hydroxylamine hydrochloride (0.41 g, 0.60 mmol) and potassium carbonate (0.83 g, 0.60 mmol). The resulting mixture was stirred under reflux overnight. The reaction mixture was concentrated under reduced pressure, and the residue was purified by column chromatography on silica gel (pentane/EtOAc, 2:1) to give **1a** as a yellow solid (1.13 g, 90% yield).

(*E*)-1-Benzyl-3-(hydroxyimino)indolin-2-one (1a): A yellow solid (1.13 g, 90% yield); m.p. 219–220 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 4.94 (s, 2 H), 6.96 (d, J = 7.6 Hz, 1 H), 7.05 (t, J = 7.6 Hz, 1 H), 7.21–7.26 (m, 1 H), 7.29–7.35 (m, 5 H), 8.02 (d, J = 7.6 Hz, 1 H), 13.6 (s, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 42.6, 109.6, 115.4, 122.8, 127.0, 127.2, 127.5, 128.7, 132.0, 136.3, 142.8, 143.5, 163.3 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2982, 2933, 1717, 1655, 1595, 1558, 1442, 1369, 1040, 964, 786, 730 cm^{-1}. MS (ESI): m/z = 275.0 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{15}H_{12}N_2O_2Na$ [M + Na]$^+$ 275.0791; found 275.0797.

(*E*)-3-(Hydroxyimino)-1-methylindolin-2-one (1b): A yellow solid (0.79 g, 90% yield); m.p. 209–210 °C. ^{1}H NMR (400 MHz, [D_6]-DMSO, TMS): δ = 3.14 (s, 3 H), 7.01–7.07 (m, 2 H), 7.40 (t, J = 7.6 Hz, 1 H), 7.95 (d, J = 7.6 Hz, 1 H), 13.4 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D_6]DMSO, TMS): δ = 25.8, 109.0, 115.2, 122.6, 126.8, 132.0, 143.7, 143.8, 163.1 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3213, 2926, 2851, 1716, 1609, 1558, 1457, 1374, 1329, 1071, 1015, 969, 801, 697, 541 cm^{-1}. MS (ESI): m/z = 177.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_9H_9N_2O_2$ [M + H]$^+$ 177.0659; found 177.0657.

(*E*)-3-(Hydroxyimino)-1-tritylindolin-2-one (1c): A yellow solid (1.62 g, 80% yield); m.p. 263–265 °C. ^{1}H NMR (400 MHz, [D_6]-DMSO, TMS): δ = 6.24 (d, J = 7.6 Hz, 1 H), 6.98 (t, J = 7.6 Hz, 1 H), 7.07 (t, J = 7.6 Hz, 1 H), 7.20 (t, J = 7.2 Hz, 3 H), 7.28 (t, J = 7.2 Hz, 6 H), 7.47 (d, J = 7.2 Hz, 6 H), 8.04 (d, J = 7.6 Hz, 1 H), 13.4 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D_6]DMSO, TMS): δ = 73.9, 115.3, 116.9, 122.4, 126.5, 126.8, 127.8, 128.7, 130.3, 142.1, 143.0, 143.3, 164.0 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3213, 2926, 2851, 1716, 1609, 1558, 1457, 1374, 1329, 1071, 1015, 969, 801, 697, 541 cm^{-1}. MS (ESI): m/z = 427.0 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{27}H_{20}N_2O_2Na$ [M + Na]$^+$ 427.1417; found 427.1426.

(*E*)-1-Allyl-3-(hydroxyimino)indolin-2-one (1d): A yellow solid (0.90 g, 89% yield); m.p. 215–217 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 4.34 (dt, J = 5.2, 1.5 Hz, 2 H), 5.23 (dd, J = 10.0, 1.5 Hz, 1 H), 5.25 (dd, J = 17.2, 1.5 Hz, 1 H), 5.79–5.87 (m, 1 H), 6.80 (d, J = 8.0 Hz, 1 H), 7.03 (dt, J = 8.0, 1.0 Hz, 1 H), 7.32 (dt, J = 8.0, 1.0 Hz, 1 H), 8.07 (dd, J = 8.0, 1.0 Hz, 1 H), 11.48 (br. s, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 42.2, 109.2, 115.6, 117.9, 123.2, 128.1, 130.9, 132.1, 143.2, 144.1, 164.0 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3219, 2924, 1716, 1608, 1465, 1378, 1352, 1194, 1043, 1017, 949, 751, 705 cm^{-1}. MS (ESI): m/z = 224.9 [M +

Na]$^+$. HRMS (ESI): calcd. for $C_{11}H_{10}N_2O_2Na$ [M + Na]$^+$ 225.0635; found 225.0641.

(*E*)-1-Allyl-3-(hydroxyimino)-5-methylindolin-2-one (1e): A yellow solid (0.97 g, 90% yield); m.p. 189–190 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 2.29 (s, 3 H), 4.37 (d, J = 5.2 Hz, 2 H), 5.23 (d, J = 10.0 Hz, 1 H), 5.24 (d, J = 17.2 Hz, 1 H), 5.79–5.88 (m, 1 H), 6.70 (d, J = 8.0 Hz, 1 H), 7.13 (d, J = 8.0 Hz, 1 H), 7.92 (s, 1 H), 11.2 (s, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 20.9, 42.2, 109.0, 115.6, 117.8, 128.8, 131.1, 132.5, 132.8, 141.1, 144.4, 164.0 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3282, 2904, 1716, 1616, 1456, 1328, 1195, 1076, 1041, 802, 729 cm^{-1}. MS (ESI): m/z = 217.1 [M + H]$^+$. HRMS (ESI): calcd. for $C_{12}H_{12}N_2O_2Na$ [M + Na]$^+$ 239.0791; found 239.0794.

(*E*)-1-Allyl-5-bromo-3-(hydroxyimino)indolin-2-one (1f): A yellow solid (1.18 g, 85% yield); m.p. 237–238 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 4.31 (s, 2 H), 5.14 (d, J = 15.6 Hz, 1 H), 5.15 (d, J = 11.2 Hz, 1 H), 5.78–5.87 (m, 1 H), 6.94 (d, J = 8.4 Hz, 1 H), 7.55 (d, J = 8.4 Hz, 1 H), 8.05 (s, 1 H), 13.78 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 41.5, 111.6, 114.2, 116.9, 117.1, 129.0, 131.7, 134.3, 142.0, 142.6, 162.4 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3143, 2857, 1725, 1603, 1559, 1430, 1369, 1329, 1263, 1039, 1011, 816, 712, 689 cm^{-1}. MS (ESI): m/z = 280.9 [M + H]$^+$. HRMS (ESI): calcd. for $C_{11}H_{10}O_2N_2Br$ [M + H]$^+$ 280.9920; found 280.9921.

(*E*)-1-Allyl-5-chloro-3-(hydroxyimino)indolin-2-one (1g): A yellow solid (1.03 g, 87% yield); m.p. 188–190 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 4.33 (d, J = 4.4 Hz, 2 H), 5.15 (d, J = 16.8 Hz, 1 H), 5.16 (d, J = 10.4 Hz, 1 H), 5.78–5.88 (m, 1 H), 7.01 (d, J = 8.4 Hz, 1 H), 7.46 (dd, J = 8.4, 2.4 Hz, 1 H), 7.94 (d, J = 2.4 Hz, 1 H), 13.80 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 41.6, 111.2, 116.5, 117.2, 126.3, 126.6, 131.5, 131.7, 141.7, 142.8, 162.5 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3298, 2982, 2926, 1723, 1606, 1467, 1436, 1324, 1191, 1069, 1042, 999, 924, 813 cm^{-1}. MS (ESI): m/z = 237.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{11}H_9N_2O_2ClNa$ [M + Na]$^+$ 259.0245; found 259.0240.

(*E*)-1-Allyl-3-(hydroxyimino)-6-methylindolin-2-one (1h): A yellow solid (0.96 g, 89% yield); m.p. 227–229 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 2.33 (s, 3 H), 4.32 (d, J = 5.2 Hz, 2 H), 5.13 (d, J = 17.2 Hz, 1 H), 5.15 (d, J = 10.4 Hz, 1 H), 5.80–5.90 (m, 1 H), 6.84 (s, 1 H), 6.89 (d, J = 8.0 Hz, 1 H), 7.86 (d, J = 8.0 Hz, 1 H), 13.38 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 22.0, 41.4, 110.2, 113.0, 116.9, 123.3, 126.8, 132.0, 142.6, 143.2, 143.5, 163.3 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2981, 2928, 1717, 1658, 1614, 1558, 1485, 1455, 1368, 1335, 1262, 1182, 1040, 978, 810, 730, 699 cm^{-1}. MS (ESI): m/z = 239.0 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{12}H_{12}N_2O_2Na$ [M + Na]$^+$ 239.0791; found 239.0789.

(*E*)-1-Allyl-5-bromo-3-(hydroxyimino)indolin-2-one (1i): A yellow solid (1.19 g, 85% yield); m.p. 190–191 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 4.34 (d, J = 4.8 Hz, 2 H), 5.15 (d, J = 16.4 Hz, 1 H), 5.16 (d, J = 11.2 Hz, 1 H), 5.79–5.88 (m, 1 H), 7.22–7.24 (m, 2 H), 7.88 (d, J = 7.6 Hz, 1 H), 13.65 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 41.5, 112.7, 114.4, 117.1, 125.1, 125.4, 128.2, 131.7, 142.8, 144.2, 162.8 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3144, 2856, 1725, 1603, 1558, 1430, 1369, 1328, 1263, 1040, 1011, 817, 712, 689 cm^{-1}. MS (ESI): m/z = 281.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{11}H_{10}N_2O_2Br$ [M + H]$^+$ 280.9920; found 280.9928.

(*E*)-1-Allyl-7-chloro-3-(hydroxyimino)indolin-2-one (1j): (1.04 g, 88% yield): a yellow solid; m.p. 226–228 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 4.63 (d, J = 1.6 Hz, 2 H), 4.99 (d, J = 17.6 Hz, 1 H), 5.12 (d, J = 10.4 Hz, 1 H), 5.92–6.01 (m, 1 H), 7.08 (t, J = 8.0 Hz, 1 H), 7.40 (d, J = 8.0 Hz, 1 H), 8.04 (d, J = 8.0 Hz, 1 H), 13.83 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 42.8, 114.6, 115.5, 118.1, 124.2, 125.9, 133.6, 133.9, 138.6, 142.2, 163.4 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2915, 2851, 1717, 1600, 1442, 1329, 1175, 1035, 931, 795, 729, 519 cm^{-1}. MS (ESI): m/z = 237.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{11}H_9N_2O_2ClNa$ [M + Na]$^+$ 259.0245; found 259.0242.

(*E*)-1-Allyl-7-bromo-3-(hydroxyimino)indolin-2-one (1i): A yellow solid (1.16 g, 83% yield); m.p. 219–221 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 4.68 (d, J = 4.0 Hz, 2 H), 4.97 (d, J = 17.2 Hz, 1 H), 5.12 (d, J = 10.4 Hz, 1 H), 5.92–6.01 (m, 1 H), 7.00–7.04 (m, 1 H), 7.55 (d, J = 8.4 Hz, 1 H), 8.10 (dd, J = 8.4, 1.2 Hz, 1 H), 13.83 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 42.5, 102.1, 115.5, 118.4, 124.5, 126.4, 133.6, 137.2, 140.0, 142.1, 163.6 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2920, 2856, 1723, 1595, 1558, 1440, 1365, 1338, 1261, 1178, 1041, 931, 729, 507 cm^{-1}. MS (ESI): m/z = 281.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{11}H_{10}N_2O_2Br$ [M + H]$^+$ 280.9920; found 280.9926.

(*E*)-1-Allyl-7-fluoro-3-(hydroxyimino)indolin-2-one (1l): A yellow solid (0.88 g, 80% yield); m.p. 220–222 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 4.39 (d, J = 3.6 Hz, 2 H), 5.06 (d, J = 17.6 Hz, 1 H), 5.12 (d, J = 11.6 Hz, 1 H), 5.87–6.95 (m, 1 H), 7.06–7.11 (m, 1 H), 7.29–7.32 (m, 1 H), 7.86 (d, J = 7.6 Hz, 1 H), 13.77 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 43.3 (d, $J_{C\text{-}F}$ = 4.8 Hz), 116.1, 118.0 (d, $J_{C\text{-}F}$ = 3.0 Hz), 120.0 (d, $J_{C\text{-}F}$ = 19.8 Hz), 123.3, 123.9 (d, $J_{C\text{-}F}$ = 6.0 Hz), 129.2 (d, $J_{C\text{-}F}$ = 8.4 Hz), 132.9, 142.8, 146.6 (d, $J_{C\text{-}F}$ = 242.0 Hz), 162.7 ppm. ^{19}F NMR (376 MHz, [D$_6$]DMSO, $CFCl_3$): δ = –130.065 to –130.027 (m, 1 F) ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3207, 2936, 2851, 1724, 1622, 1447, 1340, 1197, 952, 937, 797, 726 cm^{-1}. MS (ESI): m/z = 221.1 [M + H]$^+$. HRMS (ESI): calcd. for $C_{11}H_9N_2O_2FNa$ [M + Na]$^+$ 243.0540; found 243.0540.

(*E*)-1-Allyl-3-(hydroxyimino)-7-(trifluoromethyl)indolin-2-one (1m): A yellow solid (1.08 g, 80% yield); m.p. 245–247 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 4.43 (d, J = 4.0 Hz, 2 H), 4.90 (d, J = 17.2 Hz, 1 H), 5.04 (d, J = 10.4 Hz, 1 H), 5.78–5.87 (m, 1 H), 7.21 (t, J = 8.0 Hz, 1 H), 7.66 (d, J = 8.0 Hz, 1 H), 8.35 (d, J = 8.0 Hz, 1 H), 14.02 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 43.7 (q, $J_{C\text{-}F}$ = 3.4 Hz), 111.3 (q, $J_{C\text{-}F}$ = 31.9 Hz), 115.2, 118.0, 122.8, 123.3 (q, $J_{C\text{-}F}$ = 270.1 Hz), 129.0 (q, $J_{C\text{-}F}$ = 5.9 Hz), 130.9, 132.3, 140.6, 141.1, 164.1 ppm. ^{19}F NMR (376 MHz[D$_6$]DMSO, $CFCl_3$): δ = –49.83 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3227, 3069, 2872, 1731, 1636, 1592, 1447, 1420, 1330, 1177, 1079, 811, 744, 701, 506 cm^{-1}. MS (ESI): m/z = 271.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{12}H_{10}N_2O_2F_3$ [M + H]$^+$ 271.0689; found 271.0696.

(*E*)-1-Benzyl-3-(hydroxyimino)-5-methylindolin-2-one (1n): A yellow solid (1.14 g, 86% yield); m.p. 209–211 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 2.22 (s, 3 H), 4.94 (s, 2 H), 6.58 (d, J = 8.4 Hz, 1 H), 7.03 (d, J = 8.4 Hz, 1 H), 7.25–7.28 (m, 1 H), 7.30–7.31 (m, 4 H), 7.88 (s, 1 H), 11.06 (s, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 20.8, 43.7, 109.1, 115.7, 127.3, 127.7, 128.8, 132.4, 132.8, 135.4, 141.0, 144.4, 164.4 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3223, 2884, 1716, 1616, 1594, 1481, 1455, 1339, 1275, 1260, 1190, 949, 809, 749, 699 cm^{-1}. MS (ESI): m/z = 267 [M + H]$^+$. HRMS (ESI): calcd. for $C_{16}H_{14}O_2N_2Na$ [M + Na]$^+$ 289.0946; found 289.0952.

(*E*)-1-Allyl-4-bromo-3-(hydroxyimino)indolin-2-one (1o): A yellow solid (1.16 g, 83% yield); m.p. 211–213 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO, TMS): δ = 4.32 (s, 2 H), 5.13 (d, J = 10.4 Hz, 1 H), 5.14 (d, J = 16.8 Hz, 1 H), 5.78–5.87 (m, 1 H), 6.98–7.01 (m, 1 H), 7.25–7.27 (m, 2 H), 13.68 (s, 1 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO, TMS): δ = 41.2, 108.7, 115.0, 117.1, 117.7, 126.9,

131.6, 131.7, 141.7, 143.8, 155.5 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3011, 1675, 1605, 1444, 1350, 1247, 1216, 1170, 1101, 981, 948, 930, 791, 768 cm^{-1}. MS (ESI): *m/z* = 281.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{11}H_{10}N_2O_2Br$ [M + H]$^+$ 280.9920; found 280.9926.

General Procedure for 4: A solution of **1a** (25.2 mg, 0.10 mmol), ethyl 2,3-butadienoate (**2a**; 36 μL, 0.30 mmol), and P(4-FC_6H_4)$_3$ (6.2 mg, 20 mol-%) in toluene (2.0 mL) was stirred at 50 °C for 3 h. The reaction was monitored by TLC. When **1a** disappeared, the solvent was removed under reduced pressure, and the residue was purified by flash chromatography on silica gel (pentane/EtOAc, 4:1) to give **4aa** as a deep red oil (37.1 mg, 78% yield).

(2*E*,6*E*,*NE*)-*N*-(1-Benzyl-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine Oxide (4aa): A deep red oil (37.1 mg, 78% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.23 (t, *J* = 7.2 Hz, 3 H), 1.28 (t, *J* = 7.2 Hz, 3 H), 2.75–2.81 (m, 1 H), 3.10–3.18 (m, 1 H), 4.14 (q, *J* = 7.2 Hz, 2 H), 4.20 (q, *J* = 7.2 Hz, 2 H), 4.94 (d, *J* = 15.6 Hz, 1 H), 5.00 (d, *J* = 15.6 Hz, 1 H), 5.96 (d, *J* = 15.6 Hz, 1 H), 6.18 (d, *J* = 14.8 Hz, 1 H), 6.74 (d, *J* = 7.6 Hz, 1 H), 6.83–6.90 (m, 1 H), 7.06–7.14 (m, 3 H), 7.28–7.36 (m, 6 H), 8.35 (d, *J* = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.8, 43.8, 60.4, 60.8, 68.4, 108.9, 117.8, 123.3, 125.2, 125.3, 125.5, 127.2, 127.9, 128.9, 132.0, 134.3, 135.2, 140.3, 141.4, 141.8, 160.4, 165.3, 165.8 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2973, 2924, 1719, 1608, 1466, 1380, 1348, 1265, 1176, 1082, 1044, 878, 748, 697 cm^{-1}. MS (ESI): *m/z* = 477.1 [M + H]$^+$. HRMS (ESI): calcd. for $C_{27}H_{28}O_6N_2Na$ [M + Na]$^+$ 499.1840; found 499.1844.

(2*E*,6*E*,*NE*)-*N*-(1-Benzyl-2-oxoindolin-3-ylidene)-1,8-bis(benzyloxy)-1,8-dioxoocta-2,6-dien-4-amine Oxide (4ab): A deep red oil (43.2 mg, 72% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 2.73–2.80 (m, 1 H), 3.10–3.17 (m, 1 H), 4.93 (s, 2 H), 5.12 (s, 2 H), 5.17 (s, 2 H), 6.01 (d, *J* = 15.6 Hz, 1 H), 6.22 (d, *J* = 14.4 Hz, 1 H), 6.72 (d, *J* = 8.0 Hz, 1 H), 6.87–6.95 (m, 1 H), 7.04–7.15 (m, 3 H), 7.25–7.36 (m, 15 H), 8.33 (d, *J* = 8.0 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 34.8, 43.8, 66.2, 66.7, 68.3, 108.9, 117.7, 123.3, 125.0, 125.2, 127.2, 127.8, 128.07, 128.13, 128.3, 128.4, 128.49, 128.55, 128.9, 132.0, 134.3, 135.2, 135.5, 135.8, 140.3, 142.1, 142.3, 160.3, 165.1, 165.5 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 3063, 3032, 2929, 1718, 1693, 1657, 1607, 1556, 1496, 1465, 1379, 1347, 1263, 1173, 1077, 972, 771, 735, 697 cm^{-1}. MS (ESI): *m/z* = 601.1 [M + H]$^+$. HRMS (ESI): calcd. for $C_{37}H_{32}O_6N_2Na$ [M + Na]$^+$ 623.2153; found 623.2164.

(2*E*,6*E*,*NE*)-1,8-Diethoxy-*N*-(1-methyl-2-oxoindolin-3-ylidene)-1,8-dioxoocta-2,6-dien-4-amine Oxide (4ba): A deep red oil (35.6 mg, 89% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.23 (t, *J* = 7.2 Hz, 3 H), 1.27 (t, *J* = 7.2 Hz, 3 H), 2.71–2.78 (m, 1 H), 3.10–3.17 (m, 1 H), 3.28 (s, 3 H), 4.13 (q, *J* = 7.2 Hz, 2 H), 4.18 (q, *J* = 7.2 Hz, 2 H), 5.95 (d, *J* = 15.6 Hz, 1 H), 6.15 (d, *J* = 14.8 Hz, 1 H), 6.80–6.87 (m, 2 H), 7.02–7.13 (m, 3 H), 7.40 (t, *J* = 7.6 Hz, 1 H), 8.33 (d, *J* = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 26.2, 34.5, 60.4, 60.8, 68.3, 107.9, 117.6, 123.2, 125.1, 125.2, 125.5, 132.1, 134.4, 141.1, 141.4, 141.8, 160.2, 165.3, 165.8 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2981, 1718, 1655, 1609, 1559, 1471, 1374, 1330, 1022, 979, 852, 774, 730, 699, 543 cm^{-1}. MS (ESI): *m/z* = 423.0 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{21}H_{24}N_2O_6Na$ [M + Na]$^+$ 423.1527; found 423.1523.

(2*E*,6*E*,*NE*)-1,8-Diethoxy-1,8-dioxo-*N*-(2-oxo-1-tritylindolin-3-ylidene)octa-2,6-dien-4-amine Oxide (4ca): A yellow solid (45.5 mg, 70% yield); m.p. 108–110 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.23 (t, *J* = 7.2 Hz, 3 H), 1.29 (t, *J* = 7.2 Hz, 3 H), 2.61–2.68 (m, 1 H), 3.02–3.10 (m, 1 H), 4.15 (q, *J* = 7.2 Hz, 2 H), 4.19 (q, *J* = 7.2 Hz, 2 H), 5.91 (d, *J* = 15.6 Hz, 1 H), 6.06 (d, *J* = 14.4 Hz, 1 H), 6.21–6.24 (m, 1 H), 6.79–6.86 (m, 1 H), 6.97–6.76 (m, 4 H), 7.20–7.30 (m, 9 H), 7.44–7.46 (m, 6 H), 8.40–8.42 (m, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.6, 60.3, 60.7, 67.6, 74.9, 115.1, 118.7, 122.7, 124.4, 125.08, 125.13, 127.0, 127.7, 129.1, 130.7, 134.4, 140.7, 141.5, 141.7, 142.2, 161.4, 165.3, 165.7 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2980, 2902, 2884, 1714, 1659, 1626, 1476, 1372, 1262, 1171, 1108, 1041, 992, 804, 700 cm^{-1}. MS (ESI): *m/z* = 651.2 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{39}H_{36}O_6N_2Na$ [M + Na]$^+$ 651.2466; found 651.2460.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine Oxide (4da): A yellow solid (38.3 mg, 90% yield); m.p. 108–110 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.23 (t, *J* = 7.2 Hz, 3 H), 1.28 (t, *J* = 7.2 Hz, 3 H), 2.73–2.79 (m, 1 H), 3.08–3.16 (m, 1 H), 4.13 (q, *J* = 7.2 Hz, 2 H), 4.19 (q, *J* = 7.2 Hz, 2 H), 4.39–4.41 (m, 2 H), 5.25 (d, *J* = 16.8 Hz, 1 H), 5.26 (d, *J* = 11.2 Hz, 1 H), 5.81–5.91 (m, 1 H), 5.95 (d, *J* = 15.6 Hz, 1 H), 6.16 (d, *J* = 14.8 Hz, 1 H), 6.80–6.87 (m, 2 H), 7.03–7.12 (m, 3 H), 7.37 (t, *J* = 7.6 Hz, 1 H), 8.35 (d, *J* = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.09, 14.14, 34.7, 42.4, 60.3, 60.8, 68.3, 108.8, 117.8, 118.0, 123.2, 125.1, 125.3, 125.5, 130.9, 132.0, 134.3, 140.3, 141.4, 141.7, 159.9, 165.3, 165.7 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2980, 2902, 2884, 1714, 1659, 1626, 1476, 1372, 1262, 1171, 1108, 1041, 992, 804, 700 cm^{-1}. MS (ESI): *m/z* = 427.2 [M + H]$^+$. $C_{23}H_{26}N_2O_6$ (426.46): calcd. C 64.78, H 6.15, N 6.57; found C 64.05, H 6.28, N 6.41.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-7-chloro-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine Oxide (4ja): A deep red oil (40.1 mg, 87% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.24 (t, *J* = 7.2 Hz, 3 H), 1.28 (t, *J* = 7.2 Hz, 3 H), 2.72–2.79 (m, 1 H), 3.06–3.16 (m, 1 H), 4.14 (q, *J* = 7.2 Hz, 2 H), 4.20 (q, *J* = 7.2 Hz, 2 H), 4.80–4.81 (m, 2 H), 5.15 (d, *J* = 16.4 Hz, 1 H), 5.20 (d, *J* = 10.8 Hz, 1 H), 5.92–6.02 (m, 2 H), 6.15 (d, *J* = 14.8 Hz, 1 H), 6.79–6.85 (m, 1 H), 7.01–7.11 (m, 3 H), 7.31 (d, *J* = 7.6 Hz, 1 H), 8.38 (d, *J* = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.7, 43.6, 60.4, 60.8, 68.9, 115.2, 116.8, 120.3, 123.5, 124.1, 125.3, 125.6, 132.4, 133.4, 134.1, 135.9, 141.1, 141.4, 160.4, 165.2, 165.6 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2983, 2934, 1717, 1699, 1659, 1600, 1557, 1472, 1445, 1369, 1337, 1275, 1165, 1094, 1039, 983, 787, 750, 731 cm^{-1}. MS (ESI): *m/z* = 483.0 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{23}H_{25}ClN_2O_6Na$ [M + Na]$^+$ 483.1293; found 483.1291.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-7-bromo-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine Oxide (4ka): A deep red oil (40.6 mg, 77% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.24 (t, *J* = 7.2 Hz, 3 H), 1.28 (t, *J* = 7.2 Hz, 3 H), 2.72–2.78 (m, 1 H), 3.06–3.13 (m, 1 H), 4.14 (q, *J* = 7.2 Hz, 2 H), 4.19 (q, *J* = 7.2 Hz, 2 H), 4.85–4.86 (m, 2 H), 5.13 (d, *J* = 16.8 Hz, 1 H), 5.21 (d, *J* = 10.4 Hz, 1 H), 5.93 (d, *J* = 15.6 Hz, 1 H), 5.97–6.03 (m, 1 H), 6.15 (d, *J* = 14.4 Hz, 1 H), 6.78–6.85 (m, 1 H), 6.97 (t, *J* = 8.0 Hz, 1 H), 7.01–7.10 (m, 2 H), 7.49 (d, *J* = 8.0 Hz, 1 H), 8.44 (d, *J* = 8.0 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.7, 43.1, 60.3, 60.8, 68.9, 102.1, 116.7, 120.6, 123.9, 124.4, 125.3, 125.6, 132.4, 133.2, 137.3, 137.5, 141.1, 141.4, 160.6, 165.1, 165.6 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2982, 2933, 1717, 1655, 1595, 1558, 1442, 1369, 1040, 964, 786, 730 cm^{-1}. MS (ESI): *m/z* = 507.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{23}H_{25}N_2O_6BrNa$ [M + Na]$^+$ 527.0788; found 527.0780.

(2*E*,6*E*,*NE*)-*N*-(1-Benzyl-5-methyl-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine Oxide (4na): A deep red oil (43.2 mg, 88% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.23 (t, *J* = 7.2 Hz, 3 H), 1.28 (t, *J* = 7.2 Hz, 3 H), 2.31 (s, 3 H), 2.74–2.81 (m, 1 H), 3.10–3.18 (m, 1 H), 4.12 (q, *J* = 7.2 Hz, 2 H), 4.19 (q, *J* = 7.2 Hz, 2 H), 4.90 (d, *J* = 15.6 Hz, 1 H), 4.98 (d, *J* = 15.6 Hz, 1 H), 5.97 (d, *J* = 16.0 Hz, 1 H), 6.18 (d, *J* = 14.4 Hz, 1

H), 6.62 (d, J = 8.0 Hz, 1 H), 6.83–6.91 (m, 1 H), 7.06–7.16 (m, 3 H), 7.27–7.35 (m, 5 H), 8.20 (s, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 20.9, 34.7, 43.7, 60.3, 60.7, 68.1, 108.6, 117.6, 125.2, 125.4, 125.7, 127.1, 127.7, 128.8, 132.4, 132.9, 134.4, 135.3, 138.1, 141.4, 141.8, 160.3, 165.2, 165.6 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2929, 1697, 1615, 1558, 1486, 1338, 1183, 1041, 978, 810, 698, 557 cm^{-1}. MS (ESI): m/z = 491.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{28}H_{31}N_2O_6$ [M + H]$^+$ 491.2177; found 491.2175.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-6-bromo-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine Oxide (4ia): A deep red oil (42.2 mg, 80% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.24 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 2.72–2.79 (m, 1 H), 3.07–3.15 (m, 1 H), 4.13 (q, J = 7.2 Hz, 2 H), 4.19 (q, J = 7.2 Hz, 2 H), 4.38–4.81 (m, 2 H), 5.25 (d, J = 17.2 Hz, 1 H), 5.29 (d, J = 10.8 Hz, 1 H), 5.80–5.89 (m, 1 H), 5.94 (d, J = 15.6 Hz, 1 H), 6.15 (d, J = 14.8 Hz, 1 H), 6.78–6.85 (m, 1 H), 6.97–7.07 (m, 3 H), 7.24 (d, J = 8.4 Hz, 1 H), 8.20 (d, J = 8.4 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.6, 42.4, 60.4, 60.8, 68.6, 112.2, 116.5, 118.3, 125.3, 125.6, 125.9, 126.1, 130.4, 133.6, 141.1, 141.2, 141.4, 159.7, 165.2, 165.6 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2984, 2932, 1716, 1558, 1478, 1462, 1244, 1039 cm^{-1}. MS (ESI): m/z = 507.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{23}H_{25}N_2O_6BrNa$ [M + Na]$^+$ 527.0788; found 527.0779.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-5-methyl-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine oxide (4ea): A deep red oil (41.2 mg, 89% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.24 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 2.34 (s, 3 H), 2.72–2.79 (m, 1 H), 3.09–3.16 (m, 1 H), 4.13 (q, J = 7.2 Hz, 2 H), 4.19 (q, J = 7.2 Hz, 2 H), 4.36–38 (m, 2 H), 5.23 (d, J = 16.8 Hz, 1 H), 5.24 (d, J = 10.8 Hz, 1 H), 5.80–5.88 (m, 1 H), 5.95 (d, J = 15.6 Hz, 1 H), 6.15 (d, J = 14.4 Hz, 1 H), 6.73 (d, J = 8.0 Hz, 1 H), 6.79–6.87 (m, 1 H), 7.03–7.08 (m, 2 H), 7.17 (d, J = 8.0 Hz, 1 H), 8.20 (s, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 21.0, 34.7, 42.4, 60.3, 60.8, 68.2, 108.5, 117.6, 117.8, 125.2, 125.4, 125.7, 131.0, 132.4, 132.9, 134.5, 138.2, 141.4, 141.8, 159.9, 165.3, 165.7 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2981, 2927, 2386, 1719, 1655, 1614, 1560, 1486, 1038, 776, 734 cm^{-1}. MS (ESI): m/z = 441.1 [M +-H]$^+$. HRMS (ESI): calcd. for $C_{24}H_{28}N_2O_6Na$ [M + Na]$^+$ 463.1840; found 463.1849.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-7-fluoro-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine oxide (4la): A deep red oil (42.0 mg, 90% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.24 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 2.72–2.79 (m, 1 H), 3.07–3.12 (m, 1 H), 4.13 (q, J = 7.2 Hz, 2 H), 4.20 (q, J = 7.2 Hz, 2 H), 4.53 (d, J = 5.6 Hz, 2 H), 5.21 (d, J = 9.2 Hz, 1 H), 5.25 (d, J = 18.8 Hz, 1 H), 5.89–5.96 (m, 2 H), 6.16 (d, J = 14.4 Hz, 1 H), 6.78–6.86 (m, 1 H), 7.02–7.15 (m, 4 H), 8.19 (d, J = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.7, 44.1 (d, $J_{C\text{-}F}$ = 4.9 Hz), 60.4, 60.8, 68.6, 117.5, 119.9 (d, $J_{C\text{-}F}$ = 19.7 Hz), 120.3 (d, $J_{C\text{-}F}$ = 4.1 Hz), 121.0 (d, $J_{C\text{-}F}$ = 3.0 Hz), 123.9 (d, $J_{C\text{-}F}$ = 6.0 Hz), 125.3, 125.6, 126.5 (d, J = 9.8 Hz), 131.6, 133.9, 141.1, 141.4, 146.7 (d, $J_{C\text{-}F}$ = 243.1 Hz), 159.6, 165.2, 165.6 ppm. ^{19}F NMR ($CDCl_3$, 400 MHz, $CFCl_3$): δ = –134.980 to –134.985 (m, 1 F) ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2982, 2934, 1719, 1655, 1628, 1560, 1491, 1458, 1155, 1037, 981, 788, 727, 595 cm^{-1}. MS (ESI): m/z = 467.0 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{23}H_{25}FN_2O_6Na$ [M + Na]$^+$ 467.1589; found 467.1583.

(2*E*,6*E*,NE)-*N*-[1-allyl-2-oxo-7-(trifluoromethyl)indolin-3-ylidene]-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine Oxide (4ma): A deep red oil (39.6 mg, 80% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.24 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 2.73–2.79 (m, 1 H), 3.07–3.14 (m, 1 H), 4.13 (q, J = 7.2 Hz, 2 H), 4.20 (q, J = 7.2 Hz, 2 H), 4.61–4.62 (m, 2 H), 5.10 (d, J = 17.2 Hz, 1 H), 5.17 (d, J = 10.4 Hz, 1 H), 5.82–5.90 (m, 1 H), 5.94 (d, J = 16.0 Hz, 1 H), 6.16 (d, J = 14.8 Hz, 1 H), 6.78–6.85 (m, 1 H), 7.01–7.12 (m, 2 H), 7.19 (t, J = 8.0 Hz, 1 H), 7.68 (d, J = 8.0 Hz, 1 H), 8.70 (d, J = 8.0 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.7, 44.6 (q, $J_{C\text{-}F}$ = 4.6 Hz), 60.4, 60.9, 69.2, 112.5 (q, $J_{C\text{-}F}$ = 33.0 Hz), 116.7, 120.1, 122.7, 123.1 (q, $J_{C\text{-}F}$ = 270.1 Hz), 125.4, 125.8, 128.1, 129.4 (q, $J_{C\text{-}F}$ = 6.1 Hz), 131.3, 132.6, 141.0, 141.3, 161.0, 165.2, 165.6 ppm. ^{19}F NMR (400 MHz, $CDCl_3$, TMS): δ = –55.432 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2983, 2928, 2855, 1731, 1660, 1592, 1557, 1451, 1429, 1327, 1176, 1124, 1080, 977, 804, 743, 704, 508 cm^{-1}. MS (ESI): m/z = 495.1 [M + H]$^+$. HRMS (ESI): calcd. for $C_{24}H_{26}N_2O_6F_3$ [M + H]$^+$ 495.1738; found 495.1742.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-5-chloro-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine oxide (4ga): A deep red oil (41.1 mg, 85% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.24 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 2.72–2.79 (m, 1 H), 3.08–3.15 (m, 1 H), 4.14 (q, J = 7.2 Hz, 2 H), 4.19 (q, J = 7.2 Hz, 2 H), 4.38–4.40 (m, 2 H), 5.23 (d, J = 16.8 Hz, 1 H), 5.27 (d, J = 9.6 Hz, 1 H), 5.80–5.87 (m, 1 H), 5.95 (d, J = 15.6 Hz, 1 H), 6.16 (d, J = 14.8 Hz, 1 H), 6.76–6.84 (m, 2 H), 7.02–7.06 (m, 2 H), 7.33 (dd, J = 8.0, 2.0 Hz, 1 H), 8.36 (d, J = 2.0 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.6, 42.5, 60.4, 60.8, 68.7, 109.7, 118.2, 118.7, 124.8, 125.4, 125.7, 128.6, 130.6, 131.4, 133.6, 138.6, 141.1, 141.3, 159.5, 165.1, 165.6 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2982, 2932, 1717, 1655, 1608, 1558, 1465, 1443, 1369, 1326, 1275, 1184, 1040, 980, 812, 749, 682 cm^{-1}. MS (ESI): m/z = 483.0 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{23}H_{25}ClN_2O_6Na$ [M + Na]$^+$ 483.1293; found 483.1286.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-6-methyl-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine oxide (4ea): A deep red oil (38.3 mg, 87% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.23 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 2.39 (s, 3 H), 2.72–2.79 (m, 1 H), 3.08–3.15 (m, 1 H), 4.13 (q, J = 7.2 Hz, 2 H), 4.19 (q, J = 7.2 Hz, 2 H), 4.37–4.38 (m, 2 H), 5.24 (d, J = 17.6 Hz, 1 H), 5.25 (d, J = 9.6 Hz, 1 H), 5.81–5.91 (m, 1 H), 5.94 (d, J = 15.6 Hz, 1 H), 6.15 (d, J = 14.8 Hz, 1 H), 6.65 (s, 1 H), 6.80–6.87 (m, 1 H), 6.91 (d, J = 8.0 Hz, 1 H), 7.00–7.10 (m, 2 H), 8.22 (d, J = 8.0 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 22.4, 34.6, 42.2, 60.3, 60.7, 67.9, 109.6, 115.2, 117.7, 123.8, 125.0, 125.1, 125.3, 130.9, 134.2, 140.6, 141.5, 141.9, 143.2, 160.2, 165.3, 165.7 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2983, 2930, 1717, 1616, 1558, 1457, 1376, 1276, 1040, 980, 817, 749, 707 cm^{-1}. MS (ESI): m/z = 441.1 [M + H]$^+$. HRMS (ESI): calcd. for $C_{24}H_{29}N_2O_6$ [M + H]$^+$ 441.2020; found 441.2030.

(2*E*,6*E*,*NE*)-*N*-(1-Allyl-5-bromo-2-oxoindolin-3-ylidene)-1,8-diethoxy-1,8-dioxoocta-2,6-dien-4-amine oxide (4fa): A deep red oil (41.8 mg, 83% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 1.24 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 2.73–2.78 (m, 1 H), 3.07–3.13 (m, 1 H), 4.14 (q, J = 7.2 Hz, 2 H), 4.20 (q, J = 7.2 Hz, 2 H), 4.38–4.39 (m, 2 H), 5.25–5.28 (m, 2 H), 5.81–5.88 (m, 1 H), 5.95 (d, J = 15.6 Hz, 1 H), 6.15 (d, J = 14.8 Hz, 1 H), 6.72 (d, J = 8.4 Hz, 1 H), 6.78–6.83 (m, 1 H), 7.01–7.07 (m, 2 H), 7.48 (dd, J = 8.4, 2.0 Hz, 1 H), 8.51 (d, J = 2.0 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.1, 34.7, 42.5, 60.4, 60.9, 68.8, 110.2, 115.9, 118.2, 119.2, 125.4, 125.7, 127.6, 130.6, 131.4, 134.4, 139.1, 141.1, 141.4, 159.5, 165.2, 165.7 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2984, 2931, 1716, 1655, 1608, 1558, 1462, 1443, 1369, 1326, 1244, 1184, 1040, 980, 812, 749 cm^{-1}. MS (ESI): m/z = 507.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{23}H_{25}N_2O_6BrNa$ [M + Na]$^+$ 527.0788; found 527.0789.

(*E*)-Ethyl 3-{[(*E*)-(1-Benzyl-2-oxoindolin-3-ylidene)amino]oxy}but-2-enoate [(3aa), the *E*-configuration was determined by its analogue

3ca]: A yellow oil (30.9 mg, 85% yield). ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ = 1.29 (t, J = 7.5 Hz, 3 H), 2.57 (s, 3 H), 4.18 (q, J = 7.2 Hz, 2 H), 4.95 (s, 2 H), 6.19 (s, 1 H), 6.75 (d, J = 7.8 Hz, 1 H), 7.07 (t, J = 7.8 Hz, 1 H), 7.27–7.37 (m, 6 H), 8.00 (d, J = 7.8 Hz, 1 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, TMS): δ = 14.3, 16.1, 43.8, 59.8, 96.9, 109.9, 115.1, 123.4, 127.3, 127.9, 128.9, 129.0, 134.0, 134.9, 144.7, 146.6, 162.9, 167.4, 169.2 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2981, 2902, 2884, 1713, 1625, 1511, 1451, 1378, 1258, 1104, 990, 821, 769 cm^{-1}. MS (ESI): m/z = 365.1 [M + H]$^+$. HRMS (ESI): calcd. for $C_{21}H_{20}N_2O_4Na$ [M + Na]$^+$ 387.1315; found 387.1327.

(*E*)-Ethyl 3-{[(*E*)-(1-Allyl-4-bromo-2-oxoindolin-3-ylidene)amino]-oxy}but-2-enoate [(3oa), the *E*-configuration was determined by its analogue 3ca]: A yellow oil (33.1 mg, 80% yield). ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ = 1.31 (t, J = 7.2 Hz, 3 H), 2.54 (s, 3 H), 4.20 (q, J = 7.2 Hz, 2 H), 4.36 (d, J = 5.2 Hz, 2 H), 5.257 (d, J = 16.4 Hz, 1 H), 5.264 (d, J = 11.2 Hz, 1 H), 5.77–5.86 (m, 1 H), 6.14 (s, 1 H), 6.80 (d, J = 7.6 Hz, 1 H), 7.25 (t, J = 7.6 Hz, 1 H), 7.29 (t, J = 7.6 Hz, 1 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, TMS): δ = 14.4, 16.1, 42.2, 59.7, 96.1, 108.3, 117.1, 118.4, 128.0, 130.3, 133.0, 144.7, 145.3, 155.7, 167.6, 170.0 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2928, 2902, 1718, 1643, 1595, 1449, 1332, 1270, 1248, 1170, 1126, 967, 697 cm^{-1}. MS (ESI): m/z = 393.0 [M + H]$^+$. HRMS (ESI): calcd. for $C_{17}H_{17}O_4N_2BrNa$ [M + Na]$^+$ 415.0264; found 415.0254.

(*E*)-Ethyl 3-[(*E*)-2-Oxo-1-tritylindolin-3-ylideneaminooxy]but-2-enoate (3ca): A yellow solid; m.p. 180–182 °C. ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ = 1.25 (t, J = 7.2 Hz, 3 H), 2.53 (s, 3 H), 4.14 (q, J = 7.2 Hz, 2 H), 6.13 (s, 1 H), 6.33 (d, J = 8.0 Hz, 1 H), 6.98 (t, J = 8.0 Hz, 1 H), 7.06 (t, J = 8.0 Hz, 1 H), 7.20–7.29 (m, 9 H), 7.44–7.46 (m, 6 H), 8.01 (d, J = 8.0 Hz, 1 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, TMS): δ = 14.3, 16.0, 59.7, 75.1, 96.7, 116.0, 116.5, 122.8, 127.1, 127.8, 128.3, 129.3, 132.4, 141.4, 145.7, 146.3, 163.6, 167.5, 169.3 ppm. IR (EtOH): $\tilde{\nu}$ = 2919, 2850, 2362, 1734, 1702, 1645, 1597, 1449, 1241, 1130, 1051, 958, 843, 784, 745 cm^{-1}. MS (ESI): m/z = 539.2 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{33}H_{28}O_4N_2Na$ [M + Na]$^+$ 539.1947; found 539.1944.

General Procedure for 3ac: Following the general procedure, the *E*/*Z* ratio (10:1) was determined by ^{1}H NMR spectroscopic analysis of the mixed product purified by column chromatography; a yellow oil (26.4 mg, 60% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS, for *E*-**3ac**): δ = 2.05 (d, J = 7.2 Hz, 3 H), 4.93 (s, 2 H), 5.23 (s, 2 H), 5.33 (s, 2 H), 6.69 (d, J = 7.2 Hz, 1 H), 6.94 (t, J = 7.2 Hz, 1 H), 7.18–7.42 (m, 12 H), 7.84 (d, J = 7.2 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS, for *E*-**3ac**): δ = 15.0, 43.6, 66.5, 70.2, 109.3, 115.8, 123.0, 127.3, 127.9, 128.0, 128.4, 128.8, 132.3, 135.3, 135.9, 143.5, 146.2, 163.5, 166.2 ppm. IR (CH_2Cl_2, for *E*-**3ac**): $\tilde{\nu}$ = 2955, 1713, 1651, 1604, 1464, 1454, 1346, 1242, 1138, 1092, 1028, 967, 843, 728, 694 cm^{-1}. MS (ESI, for *E*-**3ac**): m/z = 463.0 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{27}H_{24}O_4N_2Na$ [M + Na]$^+$ 463.1628; found 463.1618.

General Procedure for 5: Under an argon atmosphere, a solution of **4aa** (47.6 mg, 0.10 mol), $Yb(OTf)_3$ (20 mol-%), and 4 Å molecular sieves (100 mg) were added into a Schlenk tube, and then toluene (2.0 mL) was added. The mixture was stirred at 100 °C for 36 h, and the reaction was monitored by TLC. When **4aa** disappeared, the solvent was removed under reduced pressure, and the residue was purified by flash chromatography on silica gel (pentane/EtOAc, 5:1) to give **4aa** as yellow solid (30.9 mg, 65% yield).

(1*R*,2*R*,3*R*,4*S*,6*S*)-Ethyl 1′-Benzyl-6-[(*E*)-3-ethoxy-3-oxoprop-1-en-1-yl]-2′-oxo-7-oxa-1-azaspiro[bicyclo[2.2.1]heptane-2,3′-indoline]-3-carboxylate (5aa): A yellow solid (30.9 mg, 65% yield); m.p. 160–161 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 0.45 (t, J = 7.2 Hz, 3 H), 1.24 (t, J = 7.2 Hz, 3 H), 1.99–2.04 (m, 1 H), 2.34 (dd, J = 12.0, 8.0 Hz, 1 H), 3.32 (s, 1 H), 3.60 (q, J = 7.2 Hz, 2 H), 4.15 (q, J = 7.2 Hz, 2 H), 4.66 (d, J = 16.0 Hz, 1 H), 5.16 (dd, J = 12.0, 7.2 Hz, 1 H), 5.27 (d, J = 16.0 Hz, 1 H), 5.58 (d, J = 4.8 Hz, 1 H), 5.87 (d, J = 16.0 Hz, 1 H), 6.67 (d, J = 8.0 Hz, 1 H), 6.87 (dd, J = 16.0, 6.8 Hz, 1 H), 7.00 (t, J = 7.6 Hz, 1 H), 7.16 (d, J = 7.6 Hz, 1 H), 7.27–7.34 (m, 5 H), 7.47 (d, J = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.1, 14.2, 39.7, 44.2, 59.4, 60.3, 60.6, 60.7, 75.3, 82.4, 109.1, 121.4, 123.6, 125.8, 127.0, 127.8, 128.7, 129.2, 129.4, 134.9, 141.6, 147.6, 166.2, 168.6, 172.1 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2980, 2902, 1707, 1653, 1612, 1493, 1471, 1374, 1351, 1260, 1185, 1094, 1040, 973, 868, 795, 690 cm^{-1}. MS (ESI): m/z = 477.2 [M + H]$^+$. HRMS (ESI): calcd. for $C_{27}H_{29}O_6N_2$ [M + H]$^+$ 477.2026; found 477.2024.

(1*R*,2*R*,3*R*,4*S*,6*S*)-Ethyl 6-[(*E*)-3-Ethoxy-3-oxoprop-1-en-1-yl]-2′-oxo-1′-trityl-7-oxa-1-azaspiro[bicyclo[2.2.1]heptane-2,3′-indoline]-3-carboxylate (5ca): A white solid (37.7 mg, 65% yield); m.p. 160–162 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 0.28 (t, J = 7.2 Hz, 3 H), 1.27 (t, J = 7.2 Hz, 3 H), 1.90–1.95 (m, 1 H), 2.18–2.23 (m, 1 H), 3.21 (s, 1 H), 3.46–3.59 (m, 2 H), 4.15–4.26 (m, 2 H), 4.77–4.82 (m, 1 H), 5.51 (d, J = 5.2 Hz, 1 H), 5.93 (dd, J = 15.6, 1.2 Hz, 1 H), 6.25–6.27 (m, 1 H), 6.85–6.91 (m, 3 H), 7.20–7.28 (m, 10 H), 7.37–7.40 (m, 1 H), 7.45–7.47 (m, 6 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.0, 14.2, 39.7, 59.8, 59.9, 60.4, 60.5, 74.8, 76.2, 82.5, 115.5, 121.5, 123.0, 125.0, 127.0, 127.7, 127.9, 129.2, 129.4, 141.6, 142.2, 147.8, 166.2, 168.8, 172.5 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2980, 2902, 2884, 1714, 1659, 1626, 1476, 1372, 1262, 1171, 1108, 1041, 992, 804, 700 cm^{-1}. MS (ESI): m/z = 629.2 [M + H]$^+$. HRMS (ESI): calcd. for $C_{39}H_{36}O_6N_2Na$ [M + Na]$^+$ 651.2466; found 651.2475.

(1*R*,2*R*,3*R*,4*S*,6*S*)-Ethyl 1′-Allyl-6-[(*E*)-3-ethoxy-3-oxoprop-1-en-1-yl]-2′-oxo-7-oxa-1-azaspiro[bicyclo[2.2.1]heptane-2,3′-indoline]-3-carboxylate (5da): A yellow liquid (30.7 mg, 72% yield). ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 0.62 (t, J = 7.2 Hz, 3 H), 1.23 (t, J = 7.2 Hz, 3 H), 1.96–2.02 (m, 1 H), 2.31 (dd, J = 12.0, 8.4 Hz, 1 H), 3.25 (s, 1 H), 3.59–3.68 (m, 2 H), 4.14 (q, J = 7.2 Hz, 2 H), 4.19–4.25 (m, 1 H), 4.51–4.57 (m, 1 H), 5.10 (dd, J = 12.0, 7.6 Hz, 1 H), 5.23 (d, J = 9.6 Hz, 1 H), 5.26 (d, J = 16.4 Hz, 1 H), 5.56 (d, J = 5.2 Hz, 1 H), 5.81–5.88 (m, 1 H), 5.94 (d, J = 15.6 Hz, 1 H), 6.79 (d, J = 7.6 Hz, 1 H), 6.85 (dd, J = 15.6, 6.8 Hz, 1 H), 7.03 (t, J = 7.6 Hz, 1 H), 7.24–7.28 (m, 1 H), 7.47 (d, J = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.3, 14.2, 39.6, 42.7, 59.3, 60.3, 60.6, 60.7, 75.3, 82.4, 108.8, 117.5, 121.4, 123.5, 125.8, 129.2, 129.4, 130.4, 141.8, 147.7, 166.2, 168.6, 171.7 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2981, 2958, 1739, 1708, 1657, 1612, 1488, 1468, 1370, 1303, 1264, 1182, 1096, 926, 867, 754, 698 cm^{-1}. MS (ESI): m/z = 449.2 [M + Na]$^+$. HRMS (ESI): calcd. for $C_{23}H_{26}O_6N_2Na$ [M + Na]$^+$ 449.1689; found 449.1681.

(1*R*,2*R*,3*R*,4*S*,6*S*)-Ethyl 1′-Allyl-5′-chloro-6-[(*E*)-3-ethoxy-3-oxoprop-1-en-1-yl]-2′-oxo-7-oxa-1-azaspiro[bicyclo[2.2.1]heptane-2,3′-indoline]-3-carboxylate (5ga): A yellow solid (31.3 mg, 68% yield); m.p. 127–129 °C. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 0.72 (t, J = 7.2 Hz, 3 H), 1.24 (t, J = 7.2 Hz, 3 H), 1.98–2.03 (m, 1 H), 2.31 (dd, J = 11.6, 8.4 Hz, 1 H), 3.25 (s, 1 H), 3.70–3.77 (m, 2 H), 4.14 (q, J = 7.2 Hz, 2 H), 4.18–4.23 (m, 1 H), 4.51–4.56 (m, 1 H), 5.06 (dd, J = 11.6, 7.6 Hz, 1 H), 5.24 (d, J = 16.8 Hz, 1 H), 5.25 (d, J = 10.8 Hz, 1 H), 5.57 (d, J = 5.2 Hz, 1 H), 5.79–5.86 (m, 1 H), 5.95 (d, J = 15.6 Hz, 1 H), 6.73 (d, J = 8.4 Hz, 1 H), 6.84 (dd, J = 15.6, 6.8 Hz, 1 H), 7.24–7.26 (m, 1 H), 7.48 (d, J = 1.2 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.4, 14.2, 39.6, 42.8, 59.3, 60.3, 60.6, 61.0, 75.2, 82.5, 109.8, 117.7, 121.5, 126.2, 129.0, 129.3, 130.0, 130.7, 140.3, 147.2, 166.1, 168.2, 171.2 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2981, 2902, 1710, 1658, 1611, 1484, 1433, 1368,

1351, 1261, 1180, 1096, 1037, 983, 852, 812, 720 cm^{-1}. MS (ESI): m/z = 483.1 $[M + Na]^+$. HRMS (ESI): calcd. for $C_{23}H_{25}O_6ClN_2Na$ $[M + Na]^+$ 483.1299; found 483.1286.

(1*R*,2*R*,3*R*,4*S*,6*S*)-Ethyl 1′-Allyl-6-[(*E*)-3-ethoxy-3-oxoprop-1-en-1-yl]-6′-methyl-2′-oxo-7-oxa-1-azaspiro[bicyclo[2.2.1]heptane-2,3′-indoline]-3-carboxylate (5ha): A white solid (28.6 mg, 65% yield); m.p. 132–134 °C. ^1H NMR (400 MHz, $CDCl_3$, TMS): δ = 0.65 (t, J = 7.2 Hz, 3 H), 1.23 (t, J = 7.2 Hz, 3 H), 1.95–2.00 (m, 1 H), 2.29 (dd, J = 11.6, 8.4 Hz, 1 H), 2.32 (s, 3 H), 3.22 (s, 1 H), 3.63–3.70 (m, 2 H), 4.14 (q, J = 7.2 Hz, 2 H), 4.18–4.23 (m, 1 H), 4.49–4.54 (m, 1 H), 5.09 (dd, J = 11.6, 6.8 Hz, 1 H), 5.23 (d, J = 10.4 Hz, 1 H), 5.24 (d, J = 17.6 Hz, 1 H), 5.54 (d, J = 5.2 Hz, 1 H), 5.80–5.89 (m, 1 H), 5.94 (d, J = 15.6 Hz, 1 H), 6.61 (s, 1 H), 6.83–6.88 (m, 2 H), 7.33 (d, J = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.3, 14.1, 21.6, 39.6, 42.6, 59.3, 60.2, 60.4, 60.7, 75.2, 82.4, 109.6, 117.2, 121.2, 124.0, 125.5, 126.2, 130.4, 139.7, 141.8, 147.8, 166.3, 168.7, 171.9 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2981, 2902, 1708, 1657, 1620, 1503, 1449, 1378, 1345, 1266, 1183, 1117, 1038, 982, 867, 811, 701 cm^{-1}. MS (ESI): m/z = 463.2 $[M + Na]^+$. HRMS (ESI): calcd. for $C_{24}H_{28}O_6N_2Na$ $[M + Na]^+$ 463.1645; found 463.1641.

(1*R*,2*R*,3*R*,4*S*,6*S*)-Ethyl 1′-Benzyl-6-[(*E*)-3-ethoxy-3-oxoprop-1-en-1-yl]-5′-methyl-2′-oxo-7-oxa-1-azaspiro[bicyclo[2.2.1]heptane-2,3′-indoline]-3-carboxylate (5na): A yellow solid (34.3 mg, 70% yield); m.p. 150–151 °C. ^1H NMR (400 MHz, $CDCl_3$, TMS): δ = 0.47 (t, J = 7.2 Hz, 3 H), 1.24 (t, J = 7.2 Hz, 3 H), 1.20–2.04 (m, 1 H), 2.45 (s, 3 H), 2.33 (dd, J = 12.0, 8.4 Hz, 1 H), 3.31 (s, 1 H), 3.58–3.66 (m, 2 H), 4.15 (q, J = 7.2 Hz, 2 H), 4.65 (d, J = 16.0 Hz, 1 H), 5.16 (dd, J = 12.0, 7.6 Hz, 1 H), 5.58 (d, J = 5.2 Hz, 1 H), 5.96 (d, J = 16.0 Hz, 1 H), 6.55 (d, J = 7.6 Hz, 1 H), 6.88 (dd, J = 16.0, 7.2 Hz, 1 H), 6.95 (d, J = 7.6 Hz, 1 H), 7.26–7.33 (m, 6 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.1, 14.2, 21.0, 39.6, 44.2, 59.4, 60.3, 60.6, 60.7, 75.4, 82.4, 108.8, 121.4, 126.4, 127.0, 127.7, 128.7, 129.1, 129.6, 133.2, 135.0, 139.2, 147.7, 166.2, 168.6, 172.0 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2980, 2955, 1739, 1708, 1657, 1619, 1496, 1454, 1370, 1350, 1302, 1269, 1190, 809, 698 cm^{-1}. MS (ESI): m/z = 513.2 $[M + Na]^+$. HRMS (ESI): calcd. for $C_{28}H_{30}O_6N_2Na$ $[M + Na]^+$ 513.2002; found 513.2000.

One-Pot Procedure for 5ba: A solution of **1b** (88.0 mg, 0.50 mmol), ethyl 2,3-butadienoate (**2a**; 0.18 mL, 1.50 mmol), and $P(4\text{-}FC_6H_4)_3$ (30.1 mg, 20 mol-%) in toluene (10.0 mL) was stirred at 50 °C for 3 h. Without purification, $Yb(OTf)_3$ (20 mol-%) and 4 Å molecular sieves (300 mg) were added to the reaction mixture, and after heating the reaction temperate to 100 °C, the reaction mixture was stirred for another 36 h. Then the reaction mixture was cooled to room temperature and the solvent was quickly removed under reduced pressure. The residue was purified by flash chromatography on silica gel (pentane/EtOAc, 4:1) to give **5ba** as a yellow oil (114.0 mg, 57% yield).

(1*R*,2*R*,3*R*,4*S*,6*S*)-Ethyl 6-[(*E*)-3-Ethoxy-3-oxoprop-1-en-1-yl]-1′-methyl-2′-oxo-7-oxa-1-azaspiro[bicyclo[2.2.1]heptane-2,3′-indoline]-3-carboxylate (5ba): A yellow oil (114.0 mg, 57% yield). ^1H NMR (400 MHz, $CDCl_3$, TMS): δ = 0.62 (t, J = 7.2 Hz, 3 H), 1.23 (t, J = 7.2 Hz, 3 H), 1.96–2.01 (m, 1 H), 2.31 (dd, J = 12.0, 8.4 Hz, 1 H), 3.21 (s, 1 H), 3.27 (s, 3 H), 3.62 (dq, J = 7.2, 2.4 Hz, 2 H), 4.14 (q, J = 7.2 Hz, 2 H), 5.10 (dd, J = 12.0, 7.6 Hz, 1 H), 5.55 (d, J = 5.2 Hz, 1 H), 5.94 (d, J = 16.0 Hz, 1 H), 6.85 (dd, J = 16.0, 7.2 Hz, 2 H), 7.05 (t, J = 7.6 Hz, 1 H), 7.30 (t, J = 7.6 Hz, 1 H), 7.46 (d, J = 7.6 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.3, 14.2, 26.8, 39.6, 59.3, 60.3, 60.4, 60.6, 75.4, 82.3, 107.9, 121.3, 123.6, 125.7, 129.1, 129.6, 142.6, 147.6, 166.2, 168.6, 171.8 ppm. IR (CH_2Cl_2): $\tilde{\nu}$ = 2980, 2904, 1708, 1658, 1612, 1493, 1471, 1374, 1351, 1260, 1185, 1094, 1038, 981, 868, 795, 694 cm^{-1}. MS (ESI): m/z = 423.2 $[M + Na]^+$. HRMS (ESI): calcd. for $C_{21}H_{24}O_6N_2Na$ $[M + Na]^+$ 423.1532; found 423.1556.

Supporting Information (see footnote on the first page of this article): Spectroscopic data and NMR spectra; X-ray crystal data of **1a**, **3ca**, **4da**, and **5ca**; detailed experimental procedures.

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[12] CCDC-850473 (for **4da**) contains 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/data_request/cif.

[13] CCDC-860057 (for **5ca**) contains 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/data_request/cif.

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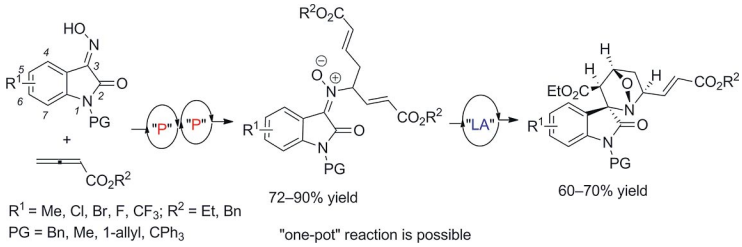
Tandem Reactions



Phosphorus containing Lewis base catalyzed cascade reactions of isatin-derived oximes with allenic esters afford the corresponding functionalized nitrones. Further Lewis acid catalyzed highly regioselective intramolecular [3+2] cyclizations give the corresponding bridged cycloadducts. A combined "one-pot" reaction is also feasible for the above two catalytic reactions.

Keywords: Lewis bases / Domino reactions / Heterocycles / Allenes / Cyclization

