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Visible-Light Driven Photocascade Catalysis: Union of *N,N*-Dimethylanilines and α-Azidochalcones in Flow Microreactors

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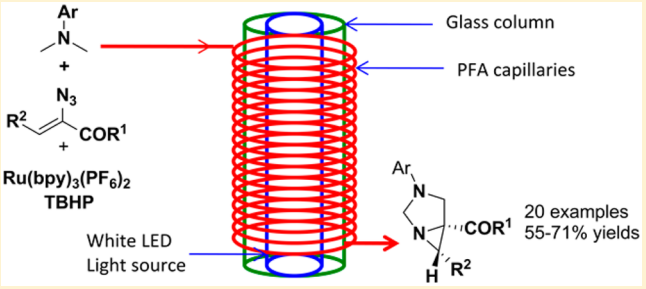
Supporting Information

ABSTRACT: *N,N*-Dimethylanilines were coupled with α-azidochalcones using visible-light driven $Ru(bpy)_3(PF_6)_2$ catalyzed photocascade continuous flow microfluidic approach that involves the creation of one C−C and two C−N new bonds. The reaction involves dual photocatalysis ensuing two sp^3 C−H bond functionalization of *N,N*-dimethylanilines. To explore the scope of the reaction, 20 different 1,3-diazabicyclo[3.1.0]hexanes were synthesized in good yields (55−71%).



Visible-light driven organic transformations have attracted considerable interest over the past decade and significant progress has been made in this area.[1] Most of the organic compounds do not absorb light in the visible region (390−700 nm) hence a photocatalyst is often required to promote the reactions. Such reactions either proceed through photosensitization (energy transfer) or photoredox catalysis (electron transfer) pathways and are well studied.[1,2] Recently, we and Xiao et al. independently investigated some organic transformations that involve both the photosensitization and photoredox catalysis.[3] This article deals with an efficient synthetic strategy that utilizes both the photosensitization and photoredox catalysis to generate reactive intermediates which subsequently combine to raise structurally novel aziridine containing heterocycles. Aziridines are largely utilized as versatile synthetic intermediates for the synthesis of numerous fine chemicals and pharmaceuticals via regio- and stereoselective ring opening reactions.[4] Moreover, the promising antitumor and antibiotic activities associated with aziridines have demanded newer possesses to generate such molecular libraries for biological evaluation.[4,5]

Visible-light mediated sp^3 C−H bond functionalization adjacent to a nitrogen atom has been extensively utilized to generate libraries of nitrogen containing compounds.[6] Both the radical **III** and iminium ion **IV** generated during visible-light photoredox catalyzed oxidation of *tert*-amines (Scheme 1, eq 1) have been fruitfully trapped to yield corresponding products. When the *tert*-amine contains acidic α-hydrogen (suitably substituted electron withdrawing group), the iminium ion **IV** has been reported to yield a stabilized azomethine ylide **V** (Scheme 1, eq 1) which has been widely exploited in [3+2] cycloaddition reactions.[3d,7] However, formation and employment of nonstabilized azomethine ylides have not been explored under visible-light photoredox conditions. As a part of our continuing interest over exploring the reactivity of vinyl azides, we attempted to functionalize *N,N*-dimethylanilines with α-azidochalcones (Scheme 1, eq 3). A careful survey of literature revealed that *N,N*-dimethylanilines react with a number of nucleophiles and alkenes under visible-light photoredox conditions through iminium ion or radical pathways and single sp^3 C−H bond functionalization is observed in the overall process (Scheme 1, eq 2).[8] However, it is worth to note that when we treated *N,N*-dimethylanilines with α-azidochalcones under similar conditions, we were delighted to have two sp^3 C−H bond functionalization and obtained a beautiful aziridine containing heterocyclic scaffold.

At the start, the coupling of *N,N*-dimethylaniline **1a** with α-azidochalcone **2a** was taken as a model reaction to study the various reaction parameters (Table 1). We did not observe any reaction between **1a** and **2a** in absence of light or photocatalyst (Table 1, entry 1−3). Product **3a** was obtained in 34% yield using $Ru(bpy)_3(PF_6)_2$ as a photocatalyst and molecular oxygen as an oxidant (Table 1, entry 4). An improved yield of **3a**

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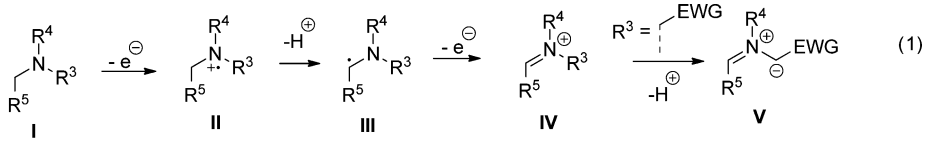
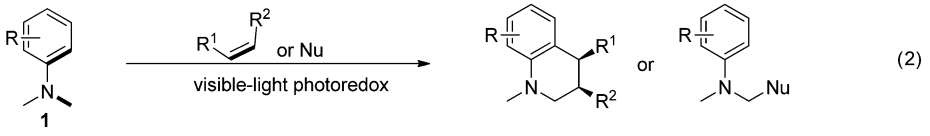
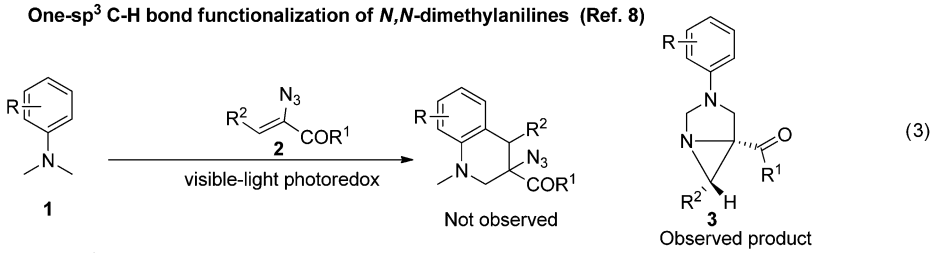
Scheme 1. Functionalization of *tert*-Amines under Visible-Light Photoredox Conditions



General pathways for the oxidation of *tert*-amines under visible-light photoredox conditions

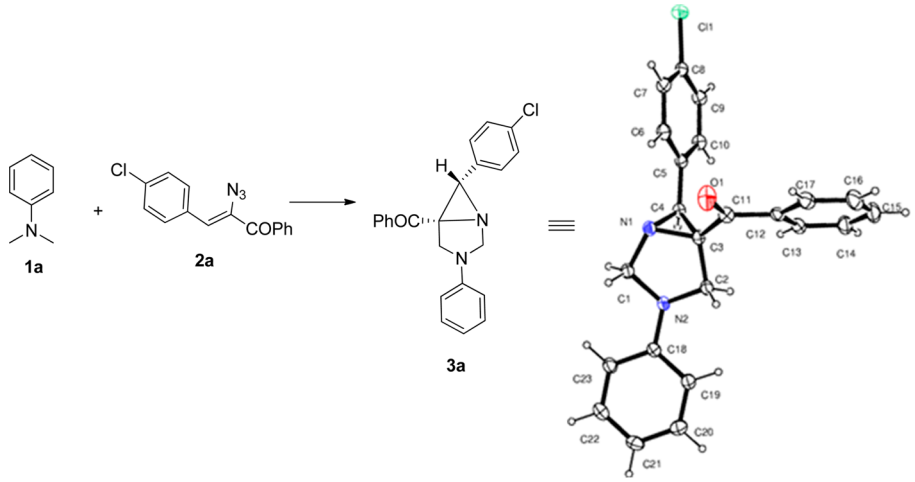


One-sp^3 C-H bond functionalization of *N,N*-dimethylanilines (Ref. 8)



Two-sp^3 C-H bond functionalization of *N,N*-dimethylanilines (This work)

Table 1. Coupling of *N,N*-Dimethylaniline 1a with α-Azidochalcone 2a[a]



entry	light[b]	catalyst	oxidant	solvent	yield of **3a**,[c] %
1	X		O_2 balloon	CH_3CN	ND
2	√		O_2 balloon	CH_3CN	ND
3	X	$Ru(bpy)_3(PF_6)_2$ (1 mol%)	O_2 balloon	CH_3CN	ND
4	√	$Ru(bpy)_3(PF_6)_2$ (1 mol%)	O_2 balloon	CH_3CN	34
5	√	$Ru(bpy)_3(PF_6)_2$ (1 mol%)	TBHP (5 equiv)	CH_3CN	51
6	√	$Ru(bpy)_3(PF_6)_2$ (1 mol%)	$PhNO_2$ (5 equiv)	CH_3CN	ND
7	√	$Ru(bpy)_3(PF_6)_2$ (2 mol%)	TBHP (5 equiv)	CH_3CN	52
8	√	$Ru(bpy)_3(PF_6)_2$ (0.5 mol%)	TBHP (5 equiv)	CH_3CN	44
9	√	$Ru(bpy)_3Cl_2·6H_2O$ (1 mol%)	TBHP (5 equiv)	CH_3CN	50
10	√	Rose Bengal (1 mol%)	TBHP (5 equiv)	CH_3CN	ND
11	√	Eosin Y (1 mol%)	TBHP (5 equiv)	CH_3CN	ND
12	√	$[Ir(dtbbpy)(ppy)_2]PF_6$ (1 mol%)	TBHP (5 equiv)	CH_3CN	ND
13	√	$Ru(bpy)_3(PF_6)_2$ (1 mol%)	TBHP (5 equiv)	THF	15
14	√	$Ru(bpy)_3(PF_6)_2$ (1 mol%)	TBHP (5 equiv)	$CHCl_3$	14
15	√	$Ru(bpy)_3(PF_6)_2$ (1 mol%)	TBHP (5 equiv)	DMF	17

[a]Reaction condition: **1a** (0.5 mmol), **2a** (0.5 mmol), oxidant, catalyst, solvent (15 mL), stir, 12 h. [b]17W white LED kept at a distance of 10 cm (approx) from the reaction flask. [c]Isolated yields. ND = Not determined.

(51%) was obtained using *tert*-butyl hydroperoxide (TBHP) as an oxidant (Table 1, entry 5). However, when nitrobenzene was used as an oxidant, no product corresponding to **3a** was observed on TLC (Table 1, entry 6). Yield of **3a** was not much improved by increasing the amount of catalyst from 1 mol% to 2 mol%, however it was decreased by lowering the catalyst

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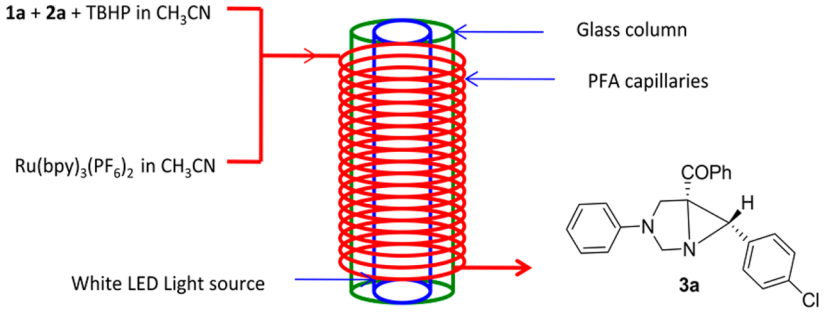

Figure 1. Coupling of *N*,*N*-dimethylaniline **1a** with *α*-azidochalcone **2a** in a flow microreactor.

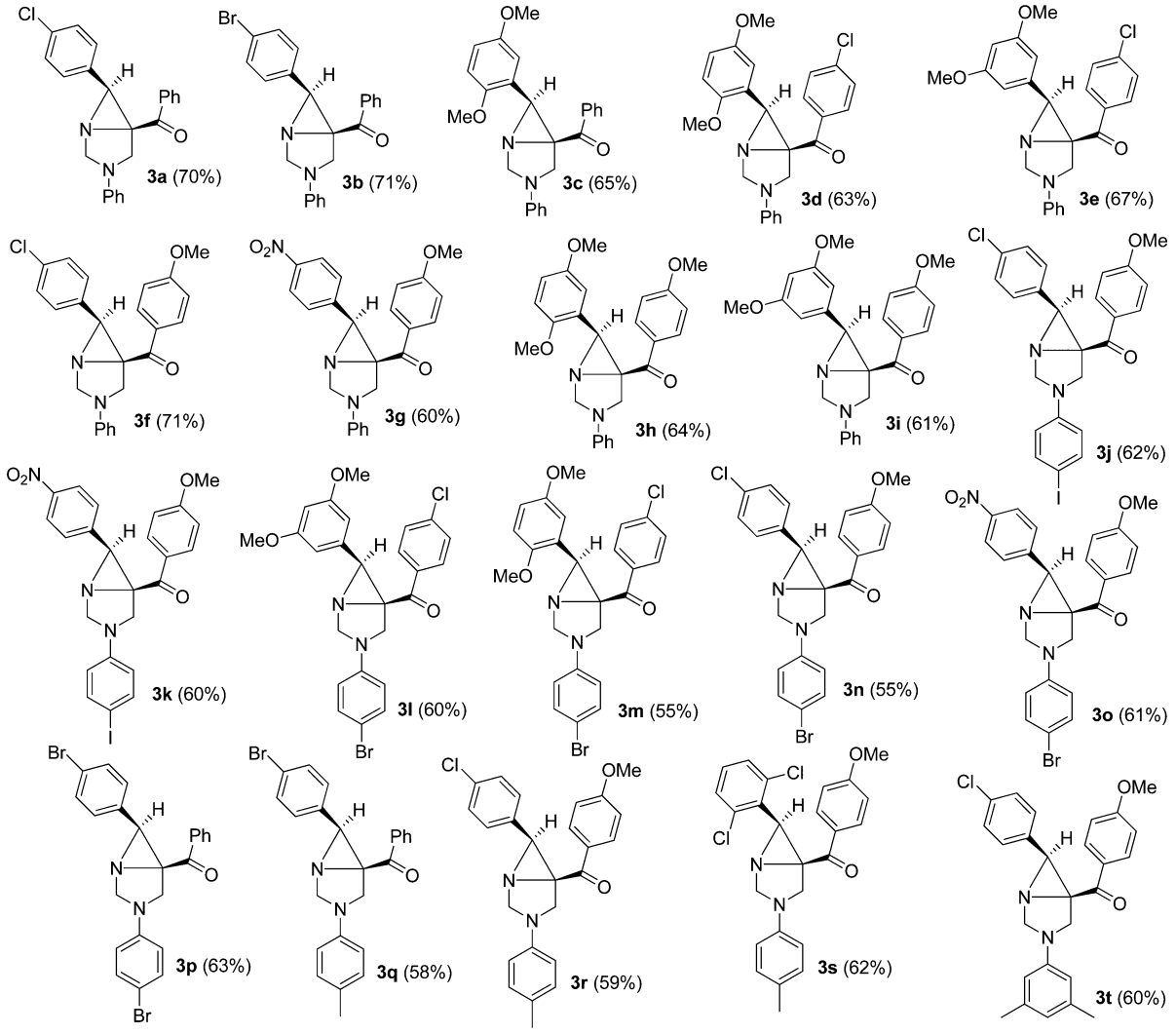

Figure 2. Scope of the visible-light driven coupling of *N*,*N*-dimethylanilines **1** and *α*-azidochalcones **2** to yield aziridine derivatives **3** in the flow microreactor.

loading (Table 1, entries 7−8). $Ru(bpy)_3Cl_2·6H_2O$ was also found a suitable photocatalyst for the reaction but other photocatalysts, such as $[Ir(dtbbpy)(ppy)_2]PF_6$, Rose Bengal, and Eosin Y, did not give the desired product **3a** (Table 1, entries 9−12). Among several solvents screened CH_3CN was found the best in terms of product yield (Table 1, entry 13−15). The structural assignment of **3a** was made by analyzing its MS/HRMS, ^1H and ^{13}C NMR spectra. The relative stereochemical assignments were made by analyzing a single crystal X-ray diffraction pattern of **3a** and **3j** (*vide infra*). For details of crystal information, please see the Supporting Information.

As a part of our continuing interest in flow microreactors,[9] we decided to translate the visible-light driven coupling of *N*,*N*-dimethylaniline **1a** and *α*-azidochalcone **2a** on a continuous flow microfluidic platform. Microreactors are greatly suited for photochemical reactions as they offer superior surface illumination area per unit volume and high illumination homogeneity which allows the formation of cleaner products in comparison to batch reactors.[3d,7f,10] Furthermore, since the

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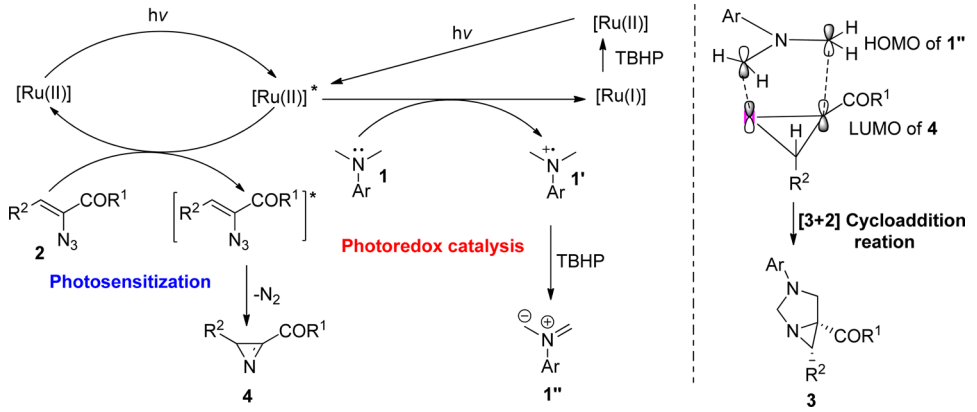
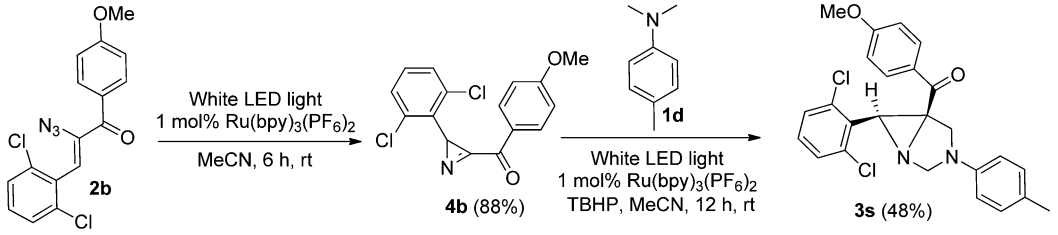
Scheme 2. Mechanistic Rationalization for the Formation of 1,3-Diazabicyclo[3.1.0]hexanes 3 via Visible-Light Driven Photocascade Catalysis



Scheme 3. Photosensitized Generation of 2*H*-Azirine 4b and Its Coupling with *N*,*N*,4-Trimethylaniline 1d in a Photoredox/[3+2] Cycloaddition Reaction Cascade



product once formed mechanically moves away from the reaction site, the chances of its degradation/overoxidation under visible-light photoredox conditions are minimized. Therefore, we setup a photochemical microfluidic platform for coupling of *N*,*N*-dimethylaniline **1a** and α-azidochalcone **2a** by wrapping a visible-light transparent PFA (perfluoroalkoxy) tubing (ID = 0.76 mm, length = 15 m, volume = 6.8 mL) over a glass column and connections were made as shown in Figure 1.

A solution of *N*,*N*-dimethylaniline **1a** and α-azidochalcone **2a** (0.1 M in acetonitrile containing 5 eq. TBHP) was kept in one syringe (20 mL) and the solution of photocatalyst Ru(bpy)$_3$(PF$_6$)$_2$ (0.001 M in acetonitrile) was kept in another syringe (20 mL). Both the solutions were pumped through a syringe pump, mixed on a T-junction and flown through the capillary microreactor wrapped over a visible light source (17W white LED). After initial optimization (for details, see Table S1 in the Supporting Information), full conversion (70% yield) of **3a** was achieved in a residence time of 56 min. Increased yields of **3a** (51% in batch vs 70% in flow) and shortened reaction time (12 h in batch vs 56 min in flow) can be accounted by considering increased illumination homogeneity and high photon flux in the microreactor.

Having been inspired by the significantly improved product yield and short reaction time in the microreactor, we planned to extend the scope of the reaction by synthesizing a library of 1,3-diazabicyclo[3.1.0]hexanes **3** in the same microfluidic setup. A number of *N*,*N*-dimethylanilines were coupled with α-azidochalcones in the flow microreactor to give the desired aziridine containing heterocycles (Figure 2). The reaction was successfully generalized using *N*,*N*-dimethylaniline **1a**, 4-iodo-*N*,*N*-dimethylaniline **1b**, 4-bromo-*N*,*N*-dimethylaniline **1c**, *N*,*N*,4-trimethylaniline **1d**, and *N*,*N*,3,5-tetramethylaniline **1e** giving high yields of 1,3-diazabicyclo[3.1.0]hexanes **3** (55–71%). The reaction was not successful with electron deficient anilines [4-(dimethylamino)benzonitrile and 4-(dimethylamino)benzaldehyde]. A number of α-azidochalcones containing halogen, electron withdrawing as well as electron releasing functional group in their aromatic rings worked well under the reaction conditions. However, the reaction did not work well with α-azidochalcones derived from heteroaromatic or aliphatic aldehydes. The reaction was also not successful with *N*,*N*-diethylaniline and *N*-alkyl 1,2,3,4-tetrahydroisoquinolines as they all gave complex reaction mixtures which could not be purified using column chromatography. All of the synthesized compounds **3a**–**t** were characterized by their MS/HRMS, ^{1}H, and ^{13}C NMR spectra.

Formation of 1,3-diazabicyclo[3.1.0]hexanes **3a**–**t** via visible light mediated coupling of *N*,*N*-dimethylanilines and α-azidochalcones can be explained by a plausible mechanism depicted in Scheme 2. In the presence of visible light and Ru(bpy)$_3$(PF$_6$)$_2$, α-azidochalcone **2** gets converted to 2*H*-azirine **4** via photosensitized decomposition.[3,11] Ru(bpy)$_3$(PF$_6$)$_2$ oxidizes amine **1** to a radical cation **1′** which further oxidizes to a nonstabilized azomethine ylide **1″**. The diastereoselective formation of **3** can be explained by HOMO (highest occupied molecular orbital)-LUMO (lowest unoccupied molecular orbital) controlled [3+2] cycloaddition reaction of **1″** and **4**. The azomethine ylide **1″** approaches 2*H*-azirine **4** from the top face maintaining least steric crowding to yield **3** (Scheme 2).

Though the diastereoselective formation of 1,3-diazabicyclo[3.1.0]hexanes **3** could be explained by [3+2] cycloaddition reaction between a nonstabilized azomethine ylide **1″**and 2*H*-azirine **4**, the possible alternative stepwise radical pathways cannot be discounted. The involvement of a dual photocatalysis was proven by performing a stepwise synthesis of **3s** (Scheme 3). Visible-light/Ru(bpy)$_3$(PF$_6$)$_2$ mediated photosensitized decomposition of 2-azido-3-(2,6-

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dichlorophenyl)-1-(4-methoxyphenyl)prop-2-en-1-one **2b** yielded 2*H*-azirine **4b** in 88% yield. When the decomposition of **2b** was complete, the same reaction vessel was charged with *N*,*N*,4-trimethylaniline **1d** and TBHP, and irradiated with visible-light for 12 h. After usual workup, the desired product **3s** was isolated in 48% yield.

In conclusion, we developed an efficient photocascade strategy to synthesize structurally diverse N-heterocycles that involves visible-light driven coupling of *N*,*N*-dimethylanilines and α-azidochalcones. The scope and limitations of the synthetic strategy were studied by synthesizing 20 different 1,3-diazabicyclo[3.1.0]hexanes in exclusive diastereoselectivity and high yields (55−71%) using a flow microreactor. The reaction involves dual photocatalysis (photoredox catalysis and photosensitization) wherein two sp^3 C−H bonds of *N*,*N*-dimethylanilines were functionalized, and one C−C and two C−N new bonds were formed in the overall process. The successful demonstration of the photocascade strategy opens the possibility of exploring unconventional reactivity of organic molecules to raise structurally novel molecular libraries for drug discovery programs.

EXPERIMENTAL SECTION

General Information. All the reagents and chemicals were obtained from commercial traders and used without any additional purification. Anhydrous solvents were prepared from industrial LR grade solvents using standard procedures. Flash column chromatography was performed using 200−300 mesh silica gel. The 17 W white light LED bulb commonly used for domestic lighting was used for our study. The syringe pumps, visible light transparent capillaries (PFA capillaries, id = 760 μm), and fittings were obtained from commercial suppliers. The reactions were monitored using thin layer chromatography (TLC) visualized under UV irradiation and iodine.

Safety warning: Organic azides must be handled carefully as they are shock sensitive and explosive reagents, and can decompose with slightest input of energy. Vinyl azides were prepared according to the literature procedures and stored in a refrigerator.[3b,d] While concentrating their solutions on rotary evaporator, the temperature of the water bath was kept below 35 °C.

*General Experimental Procedure for the Visible-Light Driven Coupling of N,N-Dimethylaniline **1a** and α-Azidochalcone **2a** under Batch Conditions.* To a 25 mL round-bottom flask, *N*,*N*-dimethylaniline **1a** (0.5 mmol), α-azidochalcone **2a** (0.5 mmol), $Ru(bpy)_3(PF_6)_2$ (4.3 mg, 1 mol%), TBHP (0.75 mL of 3.25 M solution in toluene), and MeCN (15 mL) were added. The reaction vessel was kept at a distance of 10 cm (approx.) from a visible light source (17W white LED bulb) and stirred until the reaction was complete (12 h). Compound **3a** was obtained by purifying the crude reaction product (obtained by evaporating the reaction solvent) by silica-gel column chromatography using ethyl acetate/hexane in increasing polarity.

*Experimental Procedure for the Visible-Light Sensitized Decomposition of 2-Azido-3-(2,6-dichlorophenyl)-1-(4-methoxyphenyl)-prop-2-en-1-one **2b** to 2H-Azirine **4b** and Its Coupling with N,N,4-Trimethylaniline **1d**.* To a 25 mL round-bottom flask, α-azidochalcone **2b** (0.5 mmol), $Ru(bpy)_3(PF_6)_2$ (4.3 mg, 1 mol%), and anhydrous MeCN (15 mL) were added. The reaction vessel was kept at a distance of 10 cm (approx.) from a visible light source (17W white LED bulb) and stirred in a nitrogen atmosphere until the decomposition of **2b** was complete (TLC). Next, *N*,*N*,4-trimethylaniline **1d** (0.5 mmol) and TBHP (0.75 mL of 3.25 M solution in toluene) were added to the reaction vessel and the reaction mixture was further exposed to the visible light for 12 h. Compound **3s** was obtained by purifying the crude reaction mixture (obtained by evaporating the reaction solvent) by silica-gel column chromatography using ethyl acetate/hexane in increasing polarity. Yield: 109 mg (48%).

Experimental Procedures for the Visible-Light Driven Coupling of N,N-Dimethylanilines and α-Azidochalcones in Flow Microreactors. A solution of *N*,*N*-dimethylanilines **1** and α-azidochalcones **2** (0.1 M in acetonitrile containing 5 eq. TBHP) was kept in one syringe (20 mL) and the solution of photocatalyst $Ru(bpy)_3(PF_6)_2$ (0.001 M in acetonitrile) was kept in another syringe (20 mL). Both the solutions were pumped through a syringe pump with the same flow rate, and flown through the capillary microreactor using a T-junction. Under stable conditions, the reaction mixture (30 mL) from the microreactor outlet was collected and concentrated to yield a crude product which was purified by silica-gel column chromatography to yield compound **3** in pure form.

Characterization Data for the Synthesized Compounds. *6-(4-Chlorophenyl)-3-phenyl-1,3-diazabicyclo[3.1.0]hexan-5-yl)-(phenyl)methanone (**3a**).* Yield, 394 mg (70%); white solid, mp 190−192 °C, R*f* = 0.83 (EtOAc/hexane = 1:3; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, *J* = 7.4 Hz, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.7 Hz, 2H), 7.28−7.22 (m, 4H), 7.15 (d, *J* = 8.4 Hz, 2H), 6.82 (t, *J* = 7.3 Hz, 1H), 6.61 (d, *J* = 8.1 Hz, 2H), 4.76 (d, *J* = 7.7 Hz, 1H), 4.51 (d, *J* = 7.6 Hz, 1H), 4.37 (d, *J* = 9.8 Hz, 1H), 3.53 (s, 1H), 3.41 (d, *J* = 9.8 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.0, 146.0, 136.1, 133.8, 133.4, 129.5, 128.9, 128.7, 128.5, 128.4, 118.5, 113.3, 70.9, 61.6, 50.5, 48.0. IR (KBr, cm^{-1}): 2915, 2836, 1676, 1598, 1499, 1362, 1231, 1176. HRMS (ESI, Orbitrap) calcd for $C_{23}H_{20}ClN_2O$ $[M+H]^+$ = 375.1264, found = 375.1264.

*6-(4-Bromophenyl)-3-phenyl-1,3-diazabicyclo[3.1.0]hexan-5-yl)-(phenyl)methanone (**3b**).* Yield, 446 mg (71%); white solid, R*f* = 0.82 (EtOAC/hexane = 1/3), mp. 188−189 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.92 (d, *J* = 7.1 Hz, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.8 Hz, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 7.28−7.24 (m, 2H), 7.17 (d, *J* = 8.5 Hz, 2H), 6.82 (t, *J* = 7.4 Hz, 1H), 6.61 (d, *J* = 7.8 Hz, 2H), 4.76 (d, *J* = 7.7 Hz, 1H), 4.51 (d, *J* = 7.6 Hz, 1H), 4.37 (d, *J* = 9.9 Hz, 1H), 3.51 (s, 1H), 3.41 (d, *J* = 9.8 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.0, 146.0, 136.1, 133.9, 133.8, 131.4, 129.5, 128.9, 128.9, 128.7, 121.6, 118.5, 113.3, 70.9, 61.6, 50.5, 48.0. **IR** (KBr, cm^{-1}): 3069, 2920, 2860, 1673, 1599, 1505, 1363, 1231. HRMS (ESI, Orbitrap) calcd for $C_{23}H_{20}BrN_2O$ $[M+H]^+$ = 419.0759, found = 419.0754.

*6-(2,5-Dimethoxyphenyl)-3-phenyl-1,3-diazabicyclo[3.1.0]hexan-5-yl)(phenyl)methanone (**3c**).* Yield, 390 mg (65)%; white solid, mp 179−181 °C, R*f* = 0.66 (EtOAc/hexane = 1:3; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, *J* = 7.6 Hz, 2H), 7.51 (t, *J* = 7.1 Hz, 1H), 7.39 (t, *J* = 7.3 Hz, 2H), 7.26 (s, 2H), 6.92 (s, 1H), 6.80 (t, *J* = 7.2 Hz, 1H), 6.66−6.59 (m, 4H), 4.70 (d, *J* = 7.4 Hz, 1H), 4.50 (d, *J* = 7.3 Hz, 1H), 4.41 (d, *J* = 9.5 Hz, 1H), 3.86 (s, 1H), 3.80 (s, 3H), 3.65 (s, 3H), 3.40 (d, *J* = 9.6 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.4, 153.4, 151.9, 146.1, 136.6, 133.4, 129.5, 128.9, 128.4, 123.7, 118.1, 114.3, 113.1, 112.8, 111.0, 70.8, 61.5, 55.8, 55.7, 50.3, 45.2. IR (KBr, cm^{-1}): 3063, 29526, 2847, 1681, 1600, 1498, 1364, 1225. HRMS (ESI, Orbitrap) calcd for $C_{25}H_{25}N_2O_3$ $[M+H]^+$ = 401.1865, found = 401.1865.

*(4-Chlorophenyl)-6-(2,5-dimethoxyphenyl)-3-phenyl-1,3-diazabicyclo[3.1.0]hexan-5-yl)methanone (**3d**).* Yield, 411 mg (63%); white solid, mp 158−160 °C, R*f* = 0.73 (EtOAc/hexane = 1:3; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 8.5 Hz, 2H), 7.35 (d, *J* = 8.5 Hz, 2H), 7.31−7.18 (m, 2H), 6.89 (d, *J* = 2.5 Hz, 1H), 6.81 (t, *J* = 7.3 Hz, 1H), 6.66−6.60 (m, 4H), 4.69 (d, *J* = 7.5 Hz, 1H), 4.48 (d, *J* = 7.4 Hz, 1H), 4.38 (d, *J* = 9.7 Hz, 1H), 3.83 (s, 1H), 3.79 (s, 3H), 3.65 (s, 3H), 3.39 (d, *J* = 9.6 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.4, 153.4, 151.9, 146.0, 139.8, 134.9, 130.3, 129.5, 128.7, 123.5, 118.3, 114.2, 113.1, 113.0, 111.0, 70.8, 61.2, 55.8, 55.7, 50.1, 45.1. IR (KBr, cm^{-1}): 2925, 2839, 1683, 1594, 1496, 1361, 1279, 1224, 1179. HRMS (ESI, Orbitrap) calcd for $C_{25}H_{24}ClN_2O_3$ $[M+H]^+$ = 435.1476, found = 435.1476.

*(4-Chlorophenyl)-6-(3,5-dimethoxyphenyl)-3-phenyl-1,3-diazabicyclo[3.1.0]hexan-5-yl)methanone (**3e**).* Yield, 437 mg (67%); white solid, R*f* = 0.75 (EtOAC/hexane = 1/3), mp. 137−138 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.93 (d, *J* = 7.1 Hz, 2H), 7.41 (d, *J* = 7.7 Hz, 2H), 7.29 (s, 2H), 6.85 (t, *J* = 6.7 Hz, 1H), 6.64 (d, *J* = 6.9 Hz, 2H), 6.43 (s, 2H), 6.25 (s, 1H), 4.78 (d, *J* = 7.3 Hz, 1H), 4.53 (d, *J* = 7.5 Hz, 1H), 4.37 (d, *J* = 9.3 Hz, 1H), 3.67 (s, 6H), 3.51 (s, 1H), 3.41 (d, *J* = 9.3 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.6, 160.6, 145.9, 140.1, 136.9, 134.7, 130.4, 129.5, 128.9, 118.5, 113.2, 104.9, 100.2, 70.9, 61.3, 55.3, 50.4, 48.8. IR (KBr, cm^{-1}): 2922, 2849,

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1680, 1594, 1501, 1465, 1363, 1281, 1205, 1151. HRMS (ESI, Orbitrap) calcd for $C_{25}H_{24}ClN_2O_3$ $[M+H]^+$ = 435.1476, found = 435.1473.

*6-(4-Chlorophenyl)-3-phenyl-1,3-diazabicyclo[3.1.0]hexan-5-yl)(4-methoxyphenyl)methanone (**3f**).* Yield, 431 mg (71%); white solid, mp 188−190 °C, R*f* = 0.72 (EtOAc/hexane = 3:7; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.8 Hz, 2H), 7.35−7.24 (m, 2H), 7.21 (d, *J* = 8.4 Hz, 2H), 7.15 (d, *J* = 8.5 Hz, 2H), 6.89 (d, *J* = 8.8 Hz, 2H), 6.82 (t, *J* = 7.3 Hz, 1H), 6.61 (d, *J* = 8.1 Hz, 2H), 4.76 (d, *J* = 7.7 Hz, 1H), 4.51 (d, *J* = 7.6 Hz, 1H), 4.35 (d, *J* = 9.8 Hz, 1H), 3.86 (s, 3H), 3.47 (s, 1H), 3.40 (d, *J* = 9.8 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 192.2, 164.1, 146.0, 133.7, 133.3, 131.4, 129.5, 129.0, 128.4, 118.5, 113.9, 113.2, 70.9, 61.5, 55.6, 50.8, 47.7. IR (KBr, cm^{-1}): 2972, 2839, 1669, 1599, 1574, 1506, 1366, 1258. HRMS (ESI, Orbitrap) calcd for $C_{24}H_{21}ClN_2O_2$ Na$[M+Na]^+$ = 427.1189, found = 427.1180.

*(4-Methoxyphenyl)-6-(4-nitrophenyl)-3-phenyl-1,3-diazabicyclo-[3.1.0]hexan-5-yl)methanone (**3g**).* Yield, 374 mg (60%); light yellow solid, R*f* = 0.49 (EtOAC/hexane = 1/3), mp. 196−197 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.97 (d, *J* = 8.3 Hz, 2H), 7.88 (d, *J* = 8.5 Hz, 2H), 7.38 (d, *J* = 8.5 Hz, 2H), 7.29−7.12 (m, 2H), 6.82 (d, *J* = 8.5 Hz, 2H), 6.77 (t, *J* = 7.3 Hz, 1H), 6.56 (d, *J* = 7.8 Hz, 2H), 4.73 (d, *J* = 7.6 Hz, 1H), 4.47 (d, *J* = 7.4 Hz, 1H), 4.32 (d, *J* = 10.1 Hz, 1H), 3.79 (s, 3H), 3.52 (s, 1H), 3.38 (d, *J* = 10.0 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 190.3, 164.3, 145.9, 142.9, 131.4, 129.6, 128.6, 128.0, 124.3, 123.5, 118.7, 114.1, 113.3, 70.8, 62.0, 55.6, 50.8, 47.2. IR (KBr, cm^{-1}): 3067, 2926, 2840, 1667, 1598, 1511, 1344, 1255, 1160. HRMS (ESI, Orbitrap) calcd for $C_{24}H_{22}N_3O_4$ $[M+H]^+$ = 416.1610, found = 416.1592.

*6-(2,5-Dimethoxyphenyl)-3-phenyl-1,3-diazabicyclo[3.1.0]hexan-5-yl)(4-methoxyphenyl)methanone (**3h**).* Yield, 413 mg (64%); white solid, mp 170−172 °C, R*f* = 0.56 (EtOAc/hexane = 3:7; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8.8 Hz, 2H), 7.37−7.21 (m, 2H), 6.91 (d, *J* = 2.8 Hz, 1H), 6.86 (d, *J* = 8.8 Hz, 2H), 6.80 (t, *J* = 7.3 Hz, 1H), 6.66−6.59 (m, 4H), 4.69 (d, *J* = 7.5 Hz, 1H), 4.49 (d, *J* = 7.4 Hz, 1H), 4.39 (d, *J* = 9.7 Hz, 1H), 3.84 (s, 3H), 3.83 (s, 1H), 3.80 (s, 3H), 3.65 (s, 3H), 3.39 (d, *J* = 9.6 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.5, 163.8, 153.4, 151.9, 146.2, 131.4, 129.5, 124.0, 118.1, 114.2, 113.6, 113.1, 112.6, 111.1, 70.9, 61.4, 55.8, 55.7, 55.5, 50.5, 44.7. IR (KBr, cm^{-1}): 2926, 2842, 1672, 1598, 1499, 1461, 1272, 1164. HRMS (ESI, Orbitrap) calcd for $C_{26}H_{27}N_2O_4$ $[M+H]^+$ = 431.1971, found = 431.1966.

*6-(3,5-Dimethoxyphenyl)-3-phenyl-1,3-diazabicyclo[3.1.0]hexan-5-yl)(4-methoxyphenyl)methanone (**3i**).* Yield, 393 mg (61%); white solid, mp 166−168 °C, R*f* = 0.58 (EtOAc/hexane = 3:7; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 8.3 Hz, 2H), 7.26 (s, 2H), 6.89 (d, *J* = 8.4 Hz, 2H), 6.81 (t, *J* = 7.1 Hz, 1H), 6.61 (d, *J* = 7.7 Hz, 2H), 6.43 (s, 2H), 6.22 (s, 1H), 4.76 (d, *J* = 7.3 Hz, 1H), 4.51 (d, *J* = 7.5 Hz, 1H), 4.34 (d, *J* = 9.7 Hz, 1H), 3.85 (s, 3H), 3.65 (s, 6H), 3.44 (s, 1H), 3.38 (d, *J* = 9.7 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.5, 164.0, 160.6, 146.1, 137.5, 131.5, 129.5, 125.0, 118.3, 113.8, 113.2, 104.9, 100.3, 71.0, 61.4, 55.5, 55.3, 50.8, 48.7. IR (KBr, cm^{-1}): 2923, 2853, 1633, 1544, 1507, 1458, 1260, 1162. HRMS (ESI, Orbitrap) calcd for $C_{26}H_{27}N_2O_4$ $[M+H]^+$ = 431.1971, found = 431.1971.

*6-(4-Chlorophenyl)-3-(4-iodophenyl)-1,3-diazabicyclo[3.1.0]-hexan-5-yl)(4-methoxyphenyl)methanone (**3j**).* Yield, 494 mg (62%); light blue solid, R*f* = 0.62 (EtOAC/hexane = 1/3), mp. 213-214 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.8 Hz, 2H), 7.50 (d, *J* = 8.6 Hz, 2H), 7.21 (d, *J* = 8.4 Hz, 2H), 7.14 (d, *J* = 8.4 Hz, 2H), 6.88 (d, *J* = 8.8 Hz, 2H), 6.37 (d, *J* = 8.7 Hz, 2H), 4.70 (d, *J* = 7.6 Hz, 1H), 4.48 (d, *J* = 7.6 Hz, 1H), 4.30 (d, *J* = 9.8 Hz, 1H), 3.85 (s, 3H), 3.42 (s, 1H), 3.37 (d, *J* = 9.8 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 191.9, 164.2, 145.5, 138.1, 133.4, 131.4, 128.9, 128.5, 128.4, 115.4, 114.0, 79.7, 70.8, 61.4, 55.6, 50.7, 47.9. IR (KBr, cm^{-1}):3074, 3009, 2920, 2855, 1665, 1599, 1579, 1495, 1374, 1260. HRMS (ESI, Orbitrap) calcd for $C_{24}H_{21}ClIN_2O_2$ $[M+H]^+$ = 531.0336, found = 531.0322.

*3-(4-Iodophenyl)-6-(4-nitrophenyl)-1,3-diazabicyclo[3.1.0]hexan-5-yl)(4-methoxyphenyl)methanone (**3k**).* Yield, 487 mg (60%); light yellow solid, R*f* = 0.54 (EtOAC/hexane = 1/3), Mp. 170−171 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 (d, *J* = 8.7 Hz, 2H), 7.93 (d, *J* = 8.8 Hz, 2H), 7.52 (d, *J* = 8.7 Hz, 2H), 7.44 (d, *J* = 8.6 Hz, 2H), 6.88 (d, *J* = 8.8 Hz, 2H), 6.39 (d, *J* = 8.7 Hz, 2H), 4.75 (d, *J* = 7.8 Hz, 1H), 4.52 (d, *J* = 7.7 Hz, 1H), 4.35 (d, *J* = 10.0 Hz, 1H), 3.85 (s, 3H), 3.55 (s, 1H), 3.42 (d, *J* = 9.9 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.2, 164.4, 147.3, 142.6, 138.1, 131.4, 128.5, 128.0, 123.5, 115.5, 114.1, 77.0, 70.8, 61.9, 55.6, 50.7, 47.4. IR (KBr, cm^{-1}): 3072, 2922, 2845, 1662, 1596,, 1507, 1344, 1252. HRMS (ESI, Orbitrap) calcd for $C_{24}H_{21}IN_3O_4$ $[M+H]^+$ = 542.0577, found = 542.0577.

*3-(4-Bromophenyl)-6-(3,5-dimethoxyphenyl)-1,3-diazabicyclo-[3.1.0]hexan-5-yl)(4-chlorophenyl)methanone (**3l**).* Yield, 463 mg (60%); white solid, R*f* = 0.68 (EtOAC/hexane = 1/3), Mp. 157−158 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 (d, *J* = 8.4 Hz, 2H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.34 (d, *J* = 8.6 Hz, 2H), 6.47 (d, *J* = 8.6 Hz, 2H), 6.39 (d, *J* = 1.9 Hz, 2H), 6.22 (s, 1H), 4.70 (d, *J* = 7.6 Hz, 1H), 4.48 (d, *J* = 7.6 Hz, 1H), 4.30 (d, *J* = 9.8 Hz, 1H), 3.65 (s, 3H), 3.45 (s, 1H), 3.36 (d, *J* = 9.7 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.3, 160.7, 144.9, 140.2, 136.7, 134.6, 132.2, 130.4, 128.9, 114.8, 110.6, 104.9, 100.3, 71.0, 61.2, 55.3, 50.4, 49.0. IR (KBr, cm^{-1}): 2920, 2843, 1678, 1594, 1497, 1362, 1205. HRMS (ESI, Orbitrap) calcd for $C_{25}H_{23}BrClN_2O_3$ $[M+H]^+$ = 515.0560, found = 515.0556.

*3-(4-Bromophenyl)-6-(2,5-dimethoxyphenyl)-1,3-diazabicyclo-[3.1.0]hexan-5-yl)(4-chlorophenyl)methanone (**3m**).* Yield, 424 mg (55%); white solid, R*f* = 0.64 (EtOAC/hexane = 1/3), mp. 166−167 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (d, *J* = 8.3 Hz, 2H), 7.47−7.30 (m, 4H), 6.88 (s, 1H), 6.64 (s, 2H), 6.47 (d, *J* = 8.6 Hz, 2H), 4.64 (d, *J* = 7.3 Hz, 1H), 4.46 (d, *J* = 7.4 Hz, 1H), 4.34 (d, *J* = 9.8 Hz, 1H), 3.80 (s, 4H), 3.65 (s, 3H), 3.37 (d, *J* = 9.7 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.2, 153.4, 151.8, 145.0, 139.9, 134.8, 132.2, 130.3, 128.7, 123.2, 114.7, 114.2, 113.1, 111.0, 110.3, 70.9, 61.2, 55.8, 55.7, 50.2, 45.4. IR (KBr, cm^{-1}): 2932, 2860, 1660, 1595, 1498, 1368, 1215. HRMS (ESI, Orbitrap) calcd for $C_{25}H_{23}BrClN_2O_3$ $[M+H]^+$ = 515.0560, found = 515.0554.

*3-(4-Bromophenyl)-6-(4-chlorophenyl)-1,3-diazabicyclo[3.1.0]-hexan-5-yl)(4-methoxyphenyl)methanone (**3n**).* Yield, 399 mg (55%); white solid, R*f* = 0.64 (EtOAC/hexane = 1/3), mp. 210−211 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.6 Hz, 2H), 7.33 (d, *J* = 8.4 Hz, 2H), 7.21 (d, *J* = 8.2 Hz, 2H), 7.15 (d, *J* = 8.1 Hz, 2H), 6.88 (d, *J* = 8.6 Hz, 2H), 6.47 (d, *J* = 8.5 Hz, 2H), 4.70 (d, *J* = 7.5 Hz, 1H), 4.48 (d, *J* = 7.6 Hz, 1H), 4.31 (d, *J* = 9.6 Hz, 1H), 3.85 (s, 3H), 3.44 (s, 1H), 3.37 (d, *J* = 9.7 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 191.9, 164.2, 145.0, 133.5, 133.4, 132.2, 131.4, 128.9, 128.5, 128.4, 114.8, 114.0, 110.5, 71.0, 61.5, 55.6, 50.9, 47.9. IR (KBr, cm^{-1}): 3075, 2916, 2835, 1666, 1599, 1575, 1497, 1371, 1261. HRMS (ESI, Orbitrap) calcd for $C_{24}H_{21}BrClN_2O_2$ $[M+H]^+$ = 483.0475, found = 483.0470.

*3-(4-Bromophenyl)-6-(4-nitrophenyl)-1,3-diazabicyclo[3.1.0]-hexan-5-yl)(4-methoxyphenyl)methanone (**3o**).* Yield, 452 mg (61%); light yellow solid, R*f* = 0.54 (EtOAC/hexane = 1/3), mp. 210−211 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (d, *J* = 8.4 Hz, 2H), 7.94 (d, *J* = 8.5 Hz, 2H), 7.45 (d, *J* = 8.5 Hz, 2H), 7.35 (d, *J* = 8.5 Hz, 2H), 6.89 (d, *J* = 8.4 Hz, 2H), 6.49 (d, *J* = 8.5 Hz, 2H), 4.75 (d, *J* = 7.6 Hz, 1H), 4.52 (d, *J* = 7.5 Hz, 1H), 4.35 (d, *J* = 10.0 Hz, 1H), 3.86 (s, 3H), 3.56 (s, 1H), 3.42 (d, *J* = 10.0 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 191.2, 164.4, 147.3, 144.8, 142.6, 132.3, 131.4, 128.6, 128.0, 123.5, 114.9, 114.1, 110.8, 70.9, 61.9, 55.6, 50.8, 47.4. IR (KBr, cm^{-1}): 3077, 2928, 2842, 1665, 1599, 1575, 1514, 1347, 1262. HRMS (ESI, Orbitrap) calcd for $C_{24}H_{21}BrN_3O_4$ $[M+H]^+$ = 494.0715, found = 494.0693.

*3,6-Bis(4-bromophenyl)-1,3-diazabicyclo[3.1.0]hexan-5-yl)-(phenyl)methanone (**3p**).* Yield, 470 mg (63%); white solid, R*f* = 0.85 (EtOAC/hexane = 1/3), mp. 189−190 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 (d, *J* = 7.5 Hz, 2H), 7.55 (t, *J* = 7.3 Hz, 1H), 7.49 (t, *J* = 7.9 Hz, 1H), 7.42 (dd, *J* = 15.3, 7.8 Hz, 2H), 7.34−7.29 (m, 3H), 7.16 (d, *J* = 8.3 Hz, 2H), 6.47 (d, *J* = 8.7 Hz, 2H), 4.71 (d, *J* = 7.6 Hz, 1H), 4.48 (d, *J* = 7.5 Hz, 1H), 4.32 (d, *J* = 9.8 Hz, 1H), 3.48 (s, 1H), 3.38 (d, *J* = 9.8 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.7, 144.9, 136.1, 133.9, 132.2, 131.4, 130.8, 128.9, 128.8, 128.7, 121.7, 114.8, 110.6, 70.9, 61.6, 50.6, 48.2. IR (KBr, cm^{-1}): 3059, 2919, 2861, 1673, 1595, 1498, 1377, 1178. HRMS (ESI, Orbitrap) calcd for $C_{23}H_{19}Br_2N_2O$ $[M+H]^+$ = 496.9864, found = 496.9835.

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*6-(4-Bromophenyl)-3-(p-tolyl)-1,3-diazabicyclo[3.1.0]hexan-5-yl)-(phenyl)methanone (**3q**).* Yield, 377 mg (58%); white solid, R*f* = 0.76 (EtOAC/hexane = 1/3), mp. 175−176 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.4 Hz, 2H), 7.48 (t, *J* = 6.9 Hz, 1H), 7.34 (t, *J* = 7.4 Hz, 2H), 7.20 (d, *J* = 11.8 Hz, 2H), 7.09 (d, *J* = 8.1 Hz, 2H), 6.99 (d, *J* = 7.8 Hz, 2H), 6.46 (d, *J* = 8.0 Hz, 2H), 4.67 (d, *J* = 7.5 Hz, 1H), 4.38 (d, *J* = 7.5 Hz, 1H), 4.27 (d, *J* = 9.7 Hz, 1H), 3.48 (s, 1H), 3.28 (d, *J* = 9.7 Hz, 1H), 2.19 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.0, 143.8, 136.1, 134.0, 133.8, 131.4, 130.0, 128.9, 128.9, 128.7, 127.8, 121.5, 113.3, 71.1, 61.6, 50.8, 47.8, 20.4. IR (KBr, cm^{-1}): 2919, 2857, 1672, 1621, 1523, 1374, 1230. HRMS (ESI, Orbitrap) calcd for $C_{24}H_{22}BrN_2O$ $[M+H]^+$ = 433.0916, found = 433.0915.

*6-(4-Chlorophenyl)-3-(p-tolyl)-1,3-diazabicyclo[3.1.0]hexan-5-yl)(4-methoxyphenyl)methanone (**3r**).* Yield, 371 mg (59%); white solid, R*f* = 0.84 (EtOAC/hexane = 1/3), mp. 187−188 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.8 Hz, 2H), 7.14 (d, *J* = 8.5 Hz, 2H), 7.07 (d, *J* = 8.5 Hz, 2H), 6.99 (d, *J* = 8.2 Hz, 2H), 6.81 (d, *J* = 8.8 Hz, 2H), 6.45 (d, *J* = 8.4 Hz, 2H), 4.66 (d, *J* = 7.6 Hz, 1H), 4.37 (d, *J* = 7.5 Hz, 1H), 4.25 (d, *J* = 9.8 Hz, 1H), 3.78 (s, 3H), 3.43 (s, 1H), 3.28 (d, *J* = 9.8 Hz, 1H), 2.19 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 192.2, 164.1, 143.9, 133.8, 133.3, 131.4, 130.0, 129.0, 128.44, 128.41, 127.7, 113.9, 113.3, 71.1, 61.5, 55.5, 51.0, 47.4, 20.4. IR (KBr, cm^{-1}): 3072, 2914, 2851, 1665, 1601, 1521, 1368, 1258, 1167. HRMS (ESI, Orbitrap) calcd for $C_{25}H_{24}ClN_2O_2$ $[M+ H]^+$ = 419.1526, found = 419.1512.

*6-(2,6-Dichlorophenyl)-3-(p-tolyl)-1,3-diazabicyclo[3.1.0]hexan-5-yl)(4-methoxyphenyl)methanone (**3s**).* Yield, 421 mg (62%); white solid, R*f* = 0.40 (EtOAC/hexane = 1/3), mp. 196−197 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.5 Hz, 2H), 7.09 (d, *J* = 7.5 Hz, 2H), 7.02 (d, *J* = 7.9 Hz, 2H), 6.89 (t, *J* = 7.7 Hz, 1H), 6.70−6.55 (m, 4H), 4.88 (d, *J* = 7.3 Hz, 1H), 4.41 (d, *J* = 10.2 Hz, 1H), 4.38 (d, *J* = 7.6 Hz, 1H), 3.75 (s, 3H), 3.71 (d, *J* = 10.2 Hz, 1H), 3.51 (s, 1H), 2.27 (s, 3H). IR (KBr, cm^{-1}): 2917, 2854, 1655, 1598, 1518, 1431, 1358, 1257, 1165. ^{13}C NMR (126 MHz, $CDCl_3$) δ 195.3, 162.8, 144.1, 136.5, 131.6, 130.9, 129.9, 128.8, 128.0, 127.4, 113.3, 112.6, 70.7, 60.5, 55.3, 49.9, 47.7, 20.4. HRMS (ESI, Orbitrap) calcd for $C_{25}H_{23}Cl_2N_2O_2$ $[M+H]^+$ = 453.1137, found = 453.1133.

*6-(4-Chlorophenyl)-3-(3,5-dimethylphenyl)-1,3-diazabicyclo-[3.1.0]hexan-5-yl)(4-methoxyphenyl)methanone (**3t**).* Yield, 390 mg (60%); white solid, R*f* = 0.66 (EtOAC/hexane = 1/3), mp. 180−181 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.8 Hz, 2H), 7.14 (d, *J* = 8.4 Hz, 2H), 7.07 (d, *J* = 8.4 Hz, 2H), 6.81 (d, *J* = 8.7 Hz, 2H), 6.41 (s, 1H), 6.17 (s, 2H), 4.66 (d, *J* = 7.6 Hz, 1H), 4.40 (d, *J* = 7.6 Hz, 1H), 4.26 (d, *J* = 9.8 Hz, 1H), 3.78 (s, 3H), 3.38 (s, 1H), 3.30 (d, *J* = 9.8 Hz, 1H), 2.20 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.2, 164.1, 146.1, 139.2, 133.8, 133.3, 131.4, 129.0, 128.4, 120.5, 113.9, 111.2, 70.9, 61.4, 55.5, 50.8, 47.6, 21.6. IR (KBr, cm^{-1}): 2917, 2850, 1679, 1600, 1574, 1490, 1359, 1256, 1164. HRMS (ESI, Orbitrap) calcd for $C_{26}H_{26}ClN_2O_2$ $[M+H]^+$ = 433.1683, found = 433.1682.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.6b02932.

^{1}H and ^{13}C NMR spectra of all the products and crystal data information for compounds **3a** and **3j** (PDF)

Crystal data information for compounds **3a** (CIF)

Crystal data information for compounds **3a** (CIF)

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Notes

The authors declare no competing financial interest.

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