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Benzyl C-O and C-N Bond Construction via C-C Bond Dissociation of Oxime Ester under Visible Light Irradiation

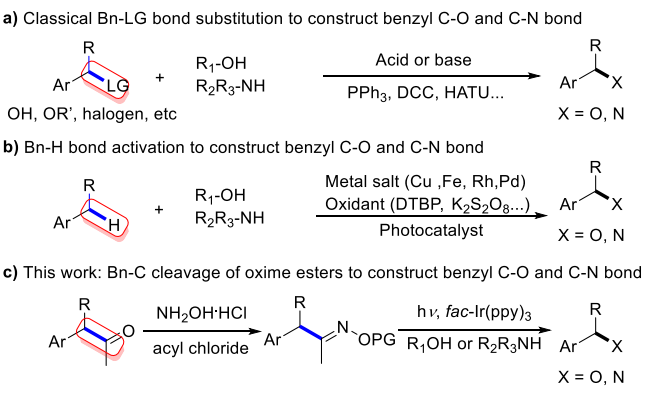
Xiuwei Fan,[a, b] Tao Lei,[a, b] Zan Liu,[a, b] Xiu-Long Yang,[a, b] Yuan-Yuan Cheng,[a, b] Ge Liang,[a, b] Bin Chen,[a, b] Chen-Ho Tung[a, b] and Li-Zhu Wu*[a, b]

Abstract: A photoredox benzyl activation was developed via formidable C(sp^3)-C(sp^3) bond dissociation of 1-aryl acetone oxime esters, which were easily perapared from benzyl ketones. Further coupling with *O*- and *N*- nucleophiles successfully forged important benzyl ether and amines derivatives in one pot. In this process, different substitutions on oxime esters were found compatible and various primary, secondary alcohols and amines as well as amides showed good performance as nucleophiles. Mechanistic studies via control experiments, electrochemical measurements and *in-situ* NMR spectra proposed a N-O bond interruption /C-C bond fragmentation /oxidation sequence to provide the key cation intermediate for the next electrophilic S_N process. The features of mild condition, short reaction time and broad substrate scope made this new strategy much promising in the transformation of benzyl compounds, which might be valuable in last-stage functionlizations.

Introduction

The construction of benzyl carbon-heteroatom (Bn-Het) bonds, especially Bn-O and Bn-N bonds, are always an attractive and significant research topic in modern organic chemistry.[1] Due to the wide existence of benzyl ethers and amines derivatives in natural products and medical compounds,[2] numerous synthetic strategies have been developed.[3-8] Among them, one straightforward access is to couple *O*-, *N*-nucleophiles with benzyl carbon atom generated from available precursors. In this context, active benzyl species with good leaving groups (Bn-X) such as alcohol derivatives (X = OH, OAc, OPT *etc.*)[3-4] and halides (X = Cl, Br, I)[5] have been well exploited via SN_2 substitution mechanism, which had established efficient way for benzyl C-O and C-N bond formation. Recently, more stable Bn-H bond as an available alternative has received increasing attentions. With the assistance of thermochemical oxidation [7] or visible light catalysis,[8] the formation of benzyl C-Het bond via C-H bond activation has been achieved. Contrast to above mentioned Bn-X and Bn-H precursors, however, direct Bn-C bond dissociation to provide benzyl ether and amine derivatives always needs much higher active energy and is a hitherto formidable challenge.

Here, we report that 1-aryl acetone oxime ester is able to efficiently construct benzyl C-O and C-N bonds via C-C bond dissociation (Scheme 1c). In contrast to the previous reports on oxime esters with photocatalytic radical addition process,[9-10] 1-aryl acetone oxime esters were found to experience sequential N-O bond interruption/*β*-fragmentation of C(sp^3)-C(sp^3) bond/oxidation to provide benzyl cation, which further rapidly reacted with nucleophilic *O*- and *N*-atoms to construct benzyl C−Het bond efficiently. Although many elegant works based on fragmentation of iminyl radicals have been established to realize the bond cleavage from cyclic iminyl radicals and then to react with radical acceptors, only two examples by Zhou[10a] and Shi[10e] realized the benzyl C-C bond dissociation via ring opening of cyclic reactant to provide the benzyl C-O bond with remote CN substitution. Especially, Shi and co-workers[10e] found the intramolecular fragmentation-rearrangement sequence of cycloketoxime esters, leading to the carbon ring opening and the carboxylic group migration. Jiang and co-workers[10h] reported the benzyl C-C single bond cleavage using CuI and O_2 at heating condition to yield aryl nitriles and ketones. Our work, however, is to develop a general activation strategy of common benzyl carbonyl compound via the C-C bond dissociation and intermolecular nucleophilic addition with various exotic nucleophiles including primary, secondary alcohols and amines even H_2O is established to construct benzyl ethers and benzyl amines. Through our method, various 1-aryl acetone oxime esters have been established as potential precursors to react with different alcohols and amines. Electron and steric properties on both oxime esters and nucleophiles showed great compatible for the construction of benzyl C-O and C-N bonds in an effective manner, which represented a general method to construct significant benzyl ether especially amine via the activation of benzyl substrate C-C bond.



Scheme 1. Visible-light-promoted benzyl C-O and C-N bond construction.

[a] X.-W. Fan, Dr. T. Lei , Z. Liu, Dr X.-L. Yang, Y.-Y. Cheng, G. Liang, Dr. B. Chen, Prof. Dr. C.-H. Tung, Prof. Dr. L.-Z. Wu
Key Laboratory of Photochemical Conversion and optoelectronic Materials, Technical Institute of Physics and Chemistry, The Chinese Academy of Sciences
Beijing, 100190, PR China
E-mail: lzwu@mail.ipc.ac.cn
Homepage: http://lsp.ipc.ac.cn/
[b] X.-W. Fan, Dr. T. Lei , Z. Liu, Dr X.-L. Yang, Y.-Y. Cheng, G. Liang, Dr. B. Chen, Prof. Dr. C.-H. Tung, Prof. Dr. L.-Z. Wu
School of Future Technology, University of Chinese Academy of Sciences
Beijing, 100049, PR China

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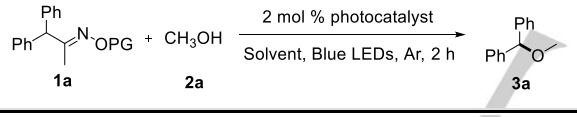
Results and Discussion

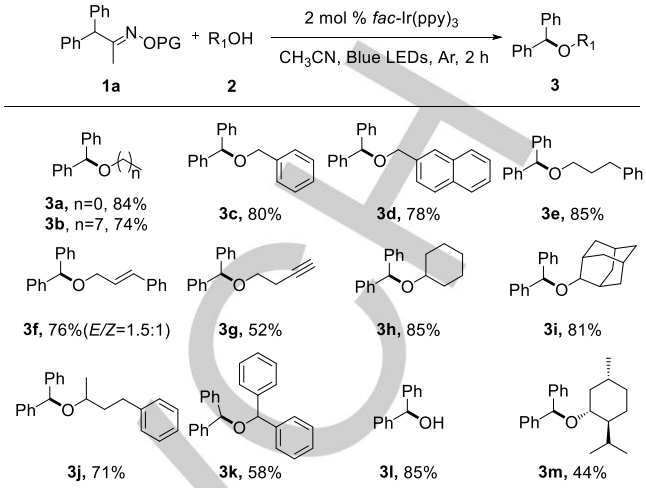
Initially, oxime ester **1a** and methanol **2a** were selected as model substrates to explore the feasibility of this transformation. To our delight, after irradiation of CH_3CN solution of **1a** (0.1 mmol), **2a** (0.1 mmol), and *fac*-Ir(ppy)$_3$ (2 mol %) for 2 h, the desired (methoxymethylene)dibenzene **3a** was obtained in 73% yield (Table 1, entry 1). This good result stimulated us to further optimize the reaction conditions. Firstly, a brief evaluation on the dosage of **2a** demonstrated that 2 equiv. of **2a** was appropriate to give the desired product in 92% yield (Table 1, entries 2−3). Contrast to the good performance of CH_3CN, CH_2Cl_2 led to a moderate yield and only 6% yield was obtained in THF (Table 1, entries 4−5). With respect to photocatalyst, other photocatalysts like Ru(bpy)$_3$Cl$_2$·6H$_2$O, Acr$^+$-Mes ClO$_4^-$ and eosin Y exhibited no catalytic activities at all on this reaction (Table 1, entries 6-8). Control experiments showed that omitting any component including photocatalyst and visible light resulted in no reaction. When this reaction was carried out in air, almost quantitative benzophenone was detected. Thus, the optimized reaction condition was achieved, 0.1 mmol of **1a**, 0.2 mmol of **2a**, 2 mol % *fac*-Ir(ppy)$_3$ in 2 mL of CH_3CN with irradiation of blue LEDs under Ar atmosphere for 2 h.

Table 1. Optimization of Reaction Condition.[a]



Entry	Photocatalyst	Solvent	n_{2a} (eq.)	Yield (%)[b]
1	*fac*-Ir(ppy)$_3$	CH_3CN	1.0	73
2	*fac*-Ir(ppy)$_3$	CH_3CN	2.0	92 (84)[c]
3	*fac*-Ir(ppy)$_3$	CH_3CN	2.5	93
4	*fac*-Ir(ppy)$_3$	CH_2Cl_2	2.0	57
5	*fac*-Ir(ppy)$_3$	THF	2.0	6
6	Ru(bpy)$_3$Cl$_2$·6H$_2$O	CH_3CN	2.0	---
7	Acr$^+$–Mes ClO$_4^-$	CH_3CN	2.0	---
8	Eosin Y	CH_3CN	2.0	---
9	---	CH_3CN	2.0	---
10[d]	*fac*-Ir(ppy)$_3$	CH_3CN	2.0	---
11[e]	*fac*-Ir(ppy)$_3$	CH_3CN	2.0	---

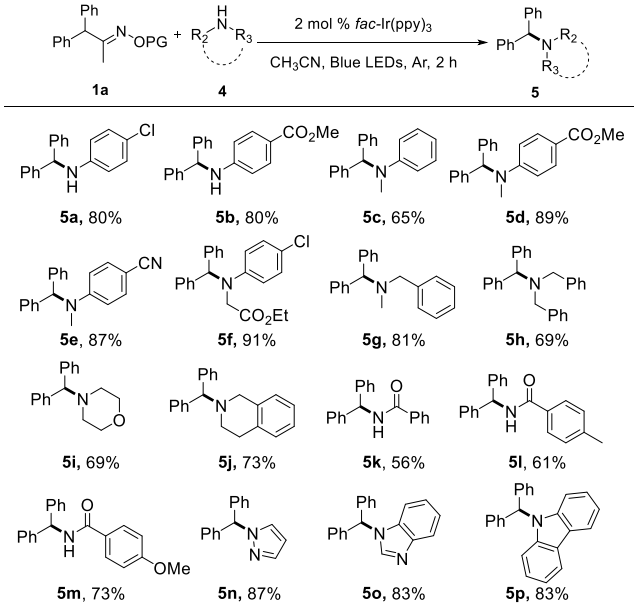
[a] Reaction conditions: **1a** (0.1 mmol), **2a** (0.2 mmol), photocatalyst (2 mol %), solvent (2 mL), 3 W blue LEDs, argon atmosphere, rt. PG = 4-(trifluoromethyl)benzoyl. [b] Yields were determined by ^{1}H NMR using diphenylacetonitrile as the internal standard. [c] Isolated yield in parentheses. [d] In dark. [e] In air atmosphere.



Scheme 2. Scope of alcohols. Standard conditions: **1a** (0.1 mmol), **2** (0.2 mmol), *fac*-Ir(ppy)$_3$ (2 mol %), CH_3CN (2 mL), 3 W blue LEDs, argon atmosphere, rt. PG = 4-(trifluoromethyl)benzoyl.

With the optimum condition in hand, we explored alcohol scope with oxime **1a** as reaction partner. The results were summarized in Scheme 2 and several conclusions were obtained as follow: a) Various primary and sencondary alcohols showed good activity to react with oxime **1a** and to construct benzyl C-O bond smoothly (**3a**-**3l**). b) The length of carbon chain and the steric hinderance of alcohols had little influence on reaction conversion. For example, octan-1-ol with eight carbon atom was well tolerant to provide 74% yield of product (**3b**) and adamantan-2-ol enabled to produce bulky ether in 81% yield (**3j**). c) Different substitutions on the terminus of alchols including phenyl group (**3c**, **3e**, **3j**), naphthalene (**3d**) and acyclic ring were all compatible. The corresponding products were isolated with good to excellent yields. Notably, cinnamyl alcohol and 3-butyn-1-ol were both smoothly converted into desired products with the unsaturated bond intact respectively (**3f**-**3g**). Even enantioenriched alpha-substituted alcohol like L-menthol was compatiable to give target product **3m** in 44% yield. d) Through this method, we could construct tetrabenzyl substituted ether with moderate yield (**3k**). e) Besides alcohol, water was also competent to deliever diphenylmethanol in 85% yield (**3l**).

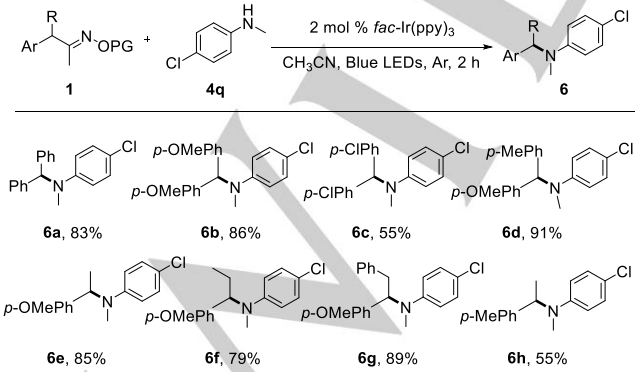
Having confirmed the generality of benzyl C-O bond formation, more effort was trend to investigate the scope of important benzyl C-N bond construction. To our delight, both aryl and alkyl amines were well capable to provide diverse benzyl aza-compounds in good to excellent yields. As shown in Scheme 3, primary and secondary aryl amines with electron-withdrawing groups afforded corresponding products with ≥ 80% yields (**5a**-**5b**, **5d**-**5f**). *N*-methyl aniline without substitution only gave 65% yield (**5c**), suggesting a negative electron effect for aryl *N*-atom nucleophiles. Besides aniline, alkyl amine like *N*-methyl-1-phenylmethanamine, dibenzylamine, morpholine and 1,2,3,4-tetrahydroisoquinoline all worked well to achieve relative products with 69%-81% yields (**5g**-**5j**). As less active nucleophile, benzamides were also found to work smoothly (**5k**-**5m**). Moreover, heteroarene as nucleophile was well tolerated. 1-



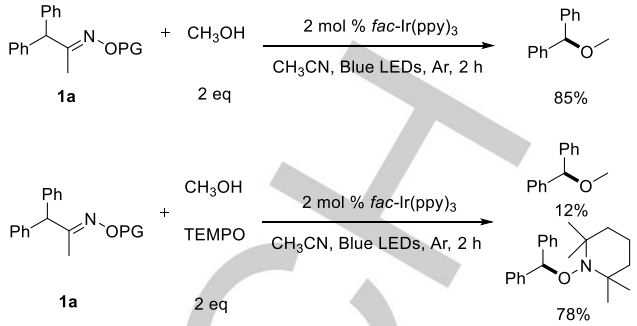
Scheme 3. Scope of amines. Standard conditions: **1a** (0.1 mmol), **4** (0.2 mmol), *fac*-Ir(ppy)$_3$ (2 mol %), CH_3CN (2 mL), 3 W blue LEDs, argon atmosphere, rt. PG = 4-(trifluoromethyl)benzoyl.

Benzhydryl substituted pyrazole, benzimidazole and carbazole were successfully synthesized in yields of 83-87% (**5n**-**5p**).

Then different variations on benzyl reactants were tested via reaction with *N*-methyl-*p*-chloroaniline, to examine the generality of *O*-acyl oximes esters (Scheme 4). It was found that 1-aryl and 1-alkyl substitutions on benzyl position were both capable. Specifically, 1,1-diaryl substrates with electron-donating group showed a higher reactivity than electron-withdrawing ones (**6a-6d**). Replacing the methoxy group (**1b**) by halide (**1c**) decreased the yield from 86% (**6b**) to 55% (**6c**). As for alkyl substituents (**R** in Scheme 4), expected products **6e-6h** in moderate yields were obtained for tested methyl (**6e, 6h**), ethyl (**6f**) and phenylmethyl (**6g**) oxime esters. It should be noted that, 1,1-dialkyl substituted substrate were unsuitable in this reaction, suggesting the



Scheme 4. Scope of *O*-acyl oximes. Standard conditions: **1** (0.1 mmol), **4q** (0.2 mmol), *fac*-Ir(ppy)$_3$ (2 mol %), CH_3CN (2 mL), 3 W blue LEDs, argon atmosphere, rt. PG = 4-(trifluoromethyl)benzoyl.

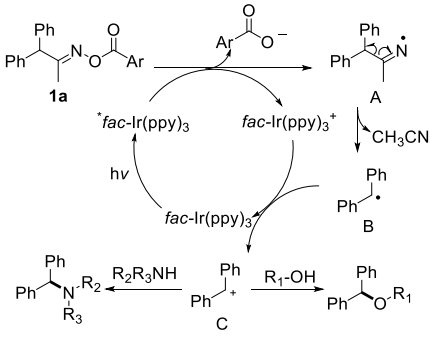


Scheme 5. Radical trapping Experiments.

importance of benzyl moiety.

In order to get more details about the mechanism, several control experiments were carried out. Under optimal condition, 84% yield of benzyl ether **3a** was obtained for the template reaction. However, when 2 equiv 2,2,6,6-tetramethyl piperidin-1-oxyl (TEMPO) was added as a radical capture, the yield was sharply decreased into 12% (Scheme 5), accompanying with an addition product of benzhydryl radical and TEMPO in 78% yield. This result demonstrated a possible radical procedure in this reaction. Furthermore, electrochemical data showed that excited **fac*-Ir(ppy)$_3$ ($E_{1/2}^{V/*III}$ = -1.84V vs. SCE, $E_{1/2}^{*III/II}$ = 0.31V vs. SCE)[10a] enabled to transfer one electron to oxime **1a** (E_{red} = −1.69 V vs SCE, E_{ox} > +2.00 V vs SCE), revealing an oxidative quenching pathway. As for other three photocatalysts, $Ru(bpy)_3Cl_2{\cdot}6H_2O$ ($E_{1/2}^{IV/*III}$ = -0.81 V vs. SCE),[11a] Acr^+–Mes ClO_4^- ($E_{1/2}^{M+/*M}$ = -0.51 V vs. SCE)[11b] and eosin Y ($E_{1/2}^{EY\bullet+/EY*}$ = -1.11 V vs. SCE)[11c], they had much lower reductive abilities and could not initiate this electron transfer process, and thus resulting in no products at all (Table 1, entries 6-8). Besides, in-situ ^{1}H NMR and GC-HRMS spectra were selected to confirm the release of CH_3CN molecule in the step of C-C bond interruption. Through comparing the spectra before and after irradiation, a clear signal of CH_3CN was detected, which directly proved the *β*-fragmentation process to eliminate a CH_3CN molecule (for more details, see Supporting Information).

Based on the above results, a proposed mechanism was



Scheme 6. Proposed reaction pathway.

depicted shown in Scheme 6. Under the visible light irradiation, *fac*-Ir(ppy)$_3$ was excited to its triplet state **fac*-Ir(ppy)$_3$. A single electron transfer from **fac*-Ir(ppy)$_3$ to oxime ester **1a** generated iminyl radical **A** along with oxidative *fac*-Ir(ppy)$_3^+$. Sequential *β*-fragmentation with CH_3CN elimination provided benzyl radical **B** via C-C bond dissociation. Further oxidation of **B** by *fac*-Ir(ppy)$_3^+$ produced benzyl cation **C** with the concomitant regeneration of photocatalyst. Finally, the intermediate **C** coupled with *O*- and *N*-nucleophiles to yield the desired products.

Conclusions

In summary, we have disclosed 1-aryl acetone oxime esters as readily accessible and highly efficient precursors for the construction of benzyl C-O and C-N bonds. Under visible light catalysis, substrates showed good activity to realize the Bn-C bond dissociation and to couple with diverse primary and secondary alcohols, amines and amides in one pot. We believe that this C-C bond activation strategy will provide a general and novel method for the Bn-O and Bn-N compounds constructions and might be of great potential in last-stage functionalization of benzyl ketones.

Experimental Section

General Information ^{1}H and ^{13}C NMR spectra were recorded with 400 and 100 MHz NMR instruments. Chemical shifts (δ, parts per million) are given with tetramethylsilane (TMS) as an internal standard. The following abbreviations are used to describe peak patterns where appropriate: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet or unresolved and brs = broad signal. All coupling constants (*J*) are given in Hz and chemical shifts in ppm. ^{13}C NMR spectra were referenced to $CDCl_3$ at 77.16 ppm. ^{9}F NMR were recorded at 282 MHz using $CDCl_3$ as solvent. Flash column chromatography was performed over silica gel 200−300 mesh, and the eluent was a mixture of ethyl acetate (EA) and petroleum ether (PE). Analytical TLC was performed on silica gel plates, and the spots were visualized under UV light (λ = 254 nm). High-resolution mass spectra (HRMS) were recorded on a Q-TOF mass spectrometer. All commercially available reagents and solvents were used without further purification.

General procedure for the Synthesis of 1,1-Disubstituted Ketones: Method A: To a solution of 10 mmol aryl bromide in 10 mL THF/toluene (1:1) was added 1 mol % $Pd(dba)_2$ (57.5 mg), 1 mol % P^tBu_3, 1 eq. Cs_2CO_3 (3.25 g) and 1.1 eq. α-aryl ketone. The reaction mixture was stirred at 80-85 °C for 12 h. After the reaction was finished, the reaction mixture was diluted with EtOAc (100 mL). The mixture was washed with a saturated aqueous solution of NH_4Cl (25 mL x 3), water (50 mL) and brine (50 mL). The organic layer was dried over Na_2SO_4 and concentrated in vacuum. The crude product was purified by flash column chromatography.[12] **Method B**: To a solution of 10 mmol α-aryl ketone and 3.5 mol % benzyltrimethylammonium chloride in 5 mL 50 wt % aqueous solution of NaOH was slowly added a solution of 1.5 eq. alkyl iodide in 2 mL DCM at 0 °C. After 1 h, 40 mL of H_2O and 60 mL of ethyl acetate were added to the reaction mixture. The organic layer was separated, and was washed with H_2O until its pH became neutral. The resulting organic phase was washed with 30 mL of brine. The organic layer was separated and dried over Na_2SO_4, filtrated, and the filtrate was concentrated in vacuum. The crude product was purified by flash column chromatography.[13]

General Procedure for the Synthesis of Oxime Esters: To a solution of 10 mmol ketone in 30 mL MeOH was added 1.2 eq. hydroxylamine hydrochloride (0.863 g) and 1.2 eq. pyridine (1.2 mL). The reaction mixture was heated at reflux for 5 h. After removal of solvent in vacuum, 20 mL DCM and 15 mmol triethylamine (2.08 mL) were added at 0 °C. To this cooled solution was slowly added a solution of 12 mmol 4-(trifluoromethyl) benzoyl chloride (1.78 mL) in dry DCM (5 mL). The mixture was stirred at r.t. for 2 h. After completion, the reaction was quenched with 50 mL $NaHCO_3$ saturated solution and extracted with 50 mL DCE for three times. The extract was washed with brine and dried over Na_2SO_4 and concentrated in vacuum. The crude product was purified by flash column chromatography.[14]

(*E*)-1,1-diphenylpropan-2-one O-(4-(trifluoromethyl)benzoyl) oxime (1a): The product **1a** (white solid, mp: 96–98 °C) was synthesized by the procedure of oxime esters; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 8.2 Hz, 2H), 7.73 (d, *J* = 8.2 Hz, 2H), 7.39 – 7.34 (m, 4H), 7.33-7.27 (m, 6H), 5.38 (s, 1H), 2.12 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.99, 162.75, 138.94, 134.87 (q, *J* = 32.3 Hz), 132.68, 130.13, 129.22, 128.86, 127.52, 126.42 (q, *J* = 273.7 Hz) 125.73 (q, *J* = 3.7 Hz), 56.72, 15.44; HRMS (ESI): $[M+Na]^+$ calcd for $C_{23}H_{18}NaF_3NO_2^+$, 420.1182, found, 420.1171.

(*E*)-1,1-bis(4-methoxyphenyl)propan-2-one O-(4-(trifluoromethyl)benzoyl) oxime (1b): The reaction was run following the procedure **A** for the synthesis of the corresponding 1,1-diketone. Then the product **1b** (viscous oil) was synthesized by the procedure of oxime esters; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.2 Hz, 2H), 7.73 (d, *J* = 8.3 Hz, 2H), 7.21 (d, *J* = 8.7 Hz, 4H), 6.89 (d, *J* = 8.7 Hz, 4H), 5.26 (s, 1H), 3.81 (s, 6H), 2.09 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.46, 162.83, 158.93, 134.84 (q, *J* = 33.3 Hz), 132.72, 131.15, 130.18, 130.11, 125.71 (q, *J* = 4.0 Hz), 123.70 (q, *J* = 273.7 Hz), 114.22, 55.40, 55.19, 15.27; HRMS (ESI): $[M+H]^+$ calcd for $C_{25}H_{23}F_3NO_4^+$, 480.1393, found, 480.1374.

(*E*)-1,1-bis(4-chlorophenyl)propan-2-one O-(4-(trifluoromethyl)benzoyl) oxime (1c): The reaction was run following the Procedure **A** for the synthesis of the corresponding 1,1-diketone. Then the product **1c** (viscous oil) was synthesized by the procedure of oxime esters; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.1 Hz, 2H), 7.74 (d, *J* = 8.2 Hz, 2H), 7.34 (d, *J* = 8.3 Hz, 4H), 7.21 (d, *J* = 8.3 Hz, 4H), 5.27 (s, 1H), 2.10 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.14, 162.65, 136.98, 135.04 (q, *J* = 32.3 Hz), 133.80, 132.42, 130.46, 130.15, 129.20, 125.80 (q, *J* = 4.0 Hz), 123.66 (q, *J* = 272.7 Hz), 55.80, 15.59; HRMS (ESI): $[M+Na]^+$ calcd for $C_{23}H_{16}Cl_2F_3NNaO_2^+$, 488.0402, found, 488.0385.

(*E*)-1-(4-methoxyphenyl)-1-(p-tolyl)propan-2-one O-(4-(trifluoromethyl)benzoyl) oxime (1d): The reaction was run following the Procedure **A** for the synthesis of the corresponding 1,1-diketone. Then the product **1d** (viscous oil) was synthesized by the procedure of oxime esters; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 8.1 Hz, 2H), 7.73 (d, *J* = 8.2 Hz, 2H), 7.24 – 7.14 (m, 6H), 6.89 (d, *J* = 8.5 Hz, 2H), 5.28 (s, 1H), 3.81 (s, 3H), 2.35 (s, 3H), 2.10 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.37, 162.80, 158.93, 137.09, 136.14, 134.82 (q, *J* = 33.3 Hz), 132.72, 131.03, 130.26, 130.10, 129.50, 128.97, 125.70 (q, *J* = 4.0 Hz), 123.69 (q, *J* = 272.7 Hz), 114.21, 55.58, 55.39, 21.16, 15.31; HRMS (ESI): $[M+Na]^+$ calcd for $C_{25}H_{22}F_3NNaO_3^+$, 464.1444, found, 464.1426.

(*E*)-3-(4-methoxyphenyl)butan-2-one O-(4-(trifluoromethyl)benzoyl) oxime (1e): The reaction was run following the procedure **B** for the synthesis of the corresponding 1,1-diketone. Then the product **1e** (white solid, mp: 61–65 °C) was synthesized by the procedure of oxime esters;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 8.1 Hz, 2H), 7.73 (d, *J* = 8.1 Hz, 2H), 7.26 (d, *J* = 8.4 Hz, 2H), 6.90 (d, *J* = 8.5 Hz, 2H), 3.96 (q, *J* = 7.1 Hz, 1H), 3.80 (s, 3H), 1.92 (s, 3H), 1.57 (d, *J* = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.39, 162.93, 158.94, 134.72 (q, *J* = 32.3 Hz), 132.80, 132.45, 130.03, 128.72, 125.64 (q, *J* = 4.0 Hz), 123.67 (q, *J* = 273.7 Hz), 114.27, 55.34, 44.51, 17.34, 13.64; HRMS (ESI): $[M+Na]^+$ calcd for $C_{19}H_{18}F_3NNaO_3^+$, 388.1131, found, 388.1125.

(*E*)-3-(4-methoxyphenyl)pentan-2-one O-(4-(trifluoromethyl)benzoyl) oxime (1f): The reaction was run following the procedure **B** for the synthesis of the corresponding 1,1-diketone. Then the product **1f** (white solid, mp: 71–75 °C) was synthesized by the procedure of oxime esters. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.0 Hz, 2H), 7.72 (d, *J* = 8.1 Hz, 2H), 7.26 (d, *J* = 7.8 Hz, 2H), 6.89 (d, *J* = 8.4 Hz, 2H), 3.80 (s, 3H), 3.67 (t, *J* = 7.7 Hz, 1H), 2.12 - 1.95 (m, 2H), 1.91 (s, 3H), 0.97 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.55, 162.81, 158.86, 134.60 (q, *J* = 32.3 Hz), 132.74, 131.11, 129.93, 129.15, 125.53 (q, *J* = 4.0 Hz), 123.58 (q, *J* = 273.7 Hz), 114.14, 55.24, 52.08, 24.22, 13.58, 12.04; HRMS (ESI): $[M+Na]^+$ calcd for $C_{20}H_{20}F_3NNaO_3^+$, 402.1287, found, 402.1282.

(*E*)-3-(4-methoxyphenyl)-4-phenylbutan-2-one O-(4-(trifluoromethyl)-benzoyl) oxime (1g): The reaction was run following the procedure **B** for the synthesis of the corresponding 1,1-diketone. Then the product **1g** (viscous oil) was synthesized by the procedure of oxime esters; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (d, *J* = 8.1 Hz, 2H), 7.72 (d, *J* = 8.2 Hz, 2H), 7.24-7.10 (m, 7H), 6.84 (d, *J* = 8.4 Hz, 2H), 3.97 (t, *J* = 7.7 Hz, 1H), 3.77 (s, 3H), 3.47 (dd, *J* = 13.9, 7.0 Hz, 1H), 3.18 (dd, *J* = 13.9, 8.5 Hz, 1H), 1.96 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.60, 162.68, 158.94, 139.23, 135.64 (q, *J* = 33.33 Hz), 132.72, 130.76, 129.96, 129.40, 129.23, 128.24, 126.21, 125.56 (q, *J* = 4.0 Hz), 123.59 (q, *J* = 273.3 Hz), 114.15, 55.23, 53.06, 38.19, 15.15; HRMS (ESI): $[M+Na]^+$ calcd for $C_{25}H_{22}F_3NNaO_3^+$, 464.1444, found, 464.1425.

(*E*)-3-(p-tolyl)butan-2-one O-(4-(trifluoromethyl)benzoyl) oxime (1h): The reaction was run following the procedure **B** for the synthesis of the corresponding 1,1-diketone. Then the product **1h**(white solid, mp: 62–67 °C) was synthesized by the procedure of oxime esters; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.2 Hz, 2H), 7.73 (d, *J* = 8.3 Hz, 2H), 7.23 (d, *J* = 8.1 Hz, 2H), 7.17 (d, *J* = 7.1 Hz, 2H), 3.97 (q, *J* = 7.1 Hz, 1H), 2.34 (s, 3H), 1.91 (s, 3H), 1.57 (d, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.33, 162.94, 137.52, 137.08, 134.78 (q, *J* = 32.3 Hz), 132.86, 130.07, 129.61, 127.63, 125.68 (q, *J* = 3.7 Hz), 123.71 (q, *J* = 273.3 Hz), 45.02, 21.14, 17.35, 13.82; HRMS (ESI): $[M+Na]^+$ calcd for $C_{19}H_{18}NaF_3NO_2^+$, 372.1182, found, 372.1176.

(*E*)-3-methylbutan-2-one O-(4-(trifluoromethyl)benzoyl) oxime (1i): The product **1i** (oil) was synthesized by the procedure of oxime esters; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.1 Hz, 2H), 7.74 (d, *J* = 8.2 Hz, 2H), 2.92 – 2.80 (m, 1H), 2.07 (s, 3H), 1.21 (d, *J* = 6.9 Hz, 6H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.22, 162.95, 134.75 (q, *J*=33.3Hz), 132.90, 130.04, 125.66 (q *J* = 4.0 Hz), 123.70 (q, *J*=273.7Hz), 34.6, 19.69, 12.46; HRMS (ESI): $[M+Na]^+$ calcd for $C_{13}H_{14}F_3NNaO_2^+$, 296.0869, found, 296.0862.

General procedure for the construction of benzyl C-O and C-N bonds: *O*-acyl oxime esters (0.1 mmol, 1 eq.), nucleophilic reagent (0.2 mmol, 2 eq.), and *fac*-Ir(ppy)$_3$ (2 μmol, 0.02 eq.) were dissolved in CH_3CN (2 mL) in a 10 mL Pyrex tube equipped with a magnetic stir bar and a rubber septum, then the argon-purged solution was irradiated with blue LEDs (λ_{max} = 450 nm) at room temperature for 4 h. The solvent was removed under reduced pressure. The crude product was purified by flash column chromatography.

(methoxymethylene)dibenzene (3a): Colorless oil, 16.6 mg (84%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.29 (m, 8H), 7.24 (t, *J* = 6.8 Hz, 2H), 5.24 (s, 1H), 3.38 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.23, 128.53, 127.59, 127.06, 85.58, 57.15; MS-EI$^+$: $[M]^+$ calcd for $C_{14}H_{14}O^+$, 198.1040, found, 198.1046.

((octyloxy)methylene)dibenzene (3b): Colorless oil, 21.9 mg (74%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.27 (m, 8H), 7.25 – 7.19 (m, 2H), 5.32 (s, 1H), 3.44 (t, *J* = 6.6 Hz, 2H), 1.67 – 1.59 (m, 2H), 1.42-1.32 (m, 2H), 1.31 – 1.22 (m, 8H), 0.87 (t, *J* = 6.9 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.84, 128.45, 127.42, 127.11, 83.74, 69.41, 32.00, 30.04, 29.59, 29.41, 26.41, 22.81, 14.24; MS-EI$^+$: $[M]^+$ calcd for $C_{14}H_{14}O^+$, 296.2135, found, 296.2138.

((benzyloxy)methylene)dibenzene (3c): Colorless oil, 21.9 mg (80%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.22 (m, 15H), 5.44 (s, 1H), 4.54 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.30, 138.55, 128.54, 128.50, 127.84, 127.67, 127.60, 127.28, 82.64, 70.64; HRMS (ESI): $[M+Na]^+$ calcd for $C_{20}H_{18}ONa^+$, 297.1250, found. 297.1241.

2-((benzhydryloxy)methyl)naphthalene (3d): Colorless oil, 25.3 mg (78%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 – 7.76 (m, 4H), 7.52-7.44 (m, 3H), 7.42 – 7.37 (m, 4H), 7.33 (t, *J* = 7.5 Hz, 4H), 7.28 – 7.21 (m, 2H), 5.48 (s, 1H), 4.70 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.26, 135.98, 133.43, 133.11, 128.55, 128.25, 128.01, 127.82, 127.62, 127.29, 126.55, 126.17, 125.98, 125.93, 82.60, 70.75; MS-EI$^+$: $[M]^+$ calcd for $C_{24}H_{20}O^+$, 324.1509, found, 324.1505.

((3-phenylpropoxy)methylene)dibenzene (3e): Colorless oil, 25.7 mg (85%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.27 (m, 8H), 7.27 – 7.20 (m, 4H), 7.19 – 7.13 (m, 3H), 5.32 (s, 1H), 3.47 (t, *J* = 6.3 Hz, 2H), 2.74 (t, *J* = 6.3 Hz, 2H), 2.00-1.91 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.71, 142.22, 128.61, 128.47, 128.42, 127.48, 127.12, 125.85, 83.78, 68.42, 32.64, 31.66; MS-EI$^+$: $[M]^+$ calcd for $C_{22}H_{22}O^+$, 302.1666, found, 302.1669.

(E)-((cinnamyloxy)methylene)dibenzene (3f): Colorless oil, 22.8 mg (76%, E/Z=1.5:1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.19 (m, 14H), 7.14 (d, *J* = 7.4 Hz, 1H), 6.60 (d, *J* = 12.5 Hz, 1H), 6.33/5.95 (m, 1H), 6.00 – 5.89 (m, 1H), 5.48/5.40 (s, 1H), 4.28/4.17 (d, *J* = 4.0 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.32, 142.22, 136.93, 136.77, 132.42, 131.89, 129.07, 128.85, 128.66, 128.55, 128.47, 128.29, 127.75, 127.59, 127.56, 127.24, 127.20, 126.62, 126.34, 83.24, 82.80, 69.51, 65.84; HRMS (ESI): $[M+Na]^+$ calcd for $C_{22}H_{20}ONa^+$, 323.1406, found. 323.1395.

((but-3-yn-1-yloxy)methylene)dibenzene (3g): Colorless oil, 12.3 mg (52%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42-7.30 (m, 8H), 7.29-7.24 (m, 2H), 5.43 (s, 1H), 3.62 (t, *J* = 7.1 Hz, 2H), 2.56 (td, *J* = 7.0, 2.5 Hz, 2H), 1.99 (t, *J* = 2.5 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.23, 128.53, 127.65, 127.19, 83.99, 83.97, 81.52, 69.41, 69.39, 67.32; HRMS (ESI): $[M+Na]^+$ calcd for $C_{17}H_{16}ONa^+$, 259.1093, found. 259.1085.

((cyclohexyloxy)methylene)dibenzene (3h): Colorless oil, 22.6 mg (85%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.26 (m, 8H), 7.25-7.18 (m, 2H), 5.54 (s, 1H), 3.39 – 3.31 (m, 1H), 1.91 (dd, *J* = 9.2, 3.3 Hz, 2H), 1.74 (dd, *J* = 9.4, 4.5 Hz, 2H), 1.51 – 1.38 (m, 3H), 1.26 – 1.17 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.32, 128.39, 127.31, 127.71, 80.12, 75.18, 32.52, 26.01, 24.24; MS-EI$^+$: $[M]^+$ calcd for $C_{19}H_{22}O^+$, 266.1666, found, 266.1671.

(1r,3r,5r,7r)-2-(benzhydryloxy)adamantine (3i): White solid, mp: 71–74 °C, 25.8 mg (81%); 1H NMR (400 MHz, $CDCl_3$) δ 7.29 (d, *J* = 7.4 Hz, 4H), 7.22 (t, *J* = 7.5 Hz, 4H), 7.18 – 7.11 (m, 2H), 5.45 (s, 1H), 3.44 (s,

1H), 2.15 (d, *J* = 12.1 Hz, 2H), 1.97 (s, 2H), 1.72 (d, *J* = 13.3 Hz, 4H), 1.63 (s, 2H), 1.45 (dd, *J* = 20.4, 12.0 Hz, 4H); ^{13}C NMR (101 MHz, CDCl3) δ 143.48, 128.21, 127.13, 127.09, 79.44, 79.03, 37.70, 36.58, 32.05, 31.89, 27.61, 27.52; MS-EI$^+$: [M]$^+$ calcd for $C_{23}H_{26}O^+$, 318.1979, found, 318.1984.

(((4-phenylbutan-2-yl)oxy)methylene)dibenzene (3j): Colorless oil, 24.1 mg (71%);^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 7.2 Hz, 4H), 7.30 (dd, *J* = 13.0, 7.2 Hz, 4H), 7.26 – 7.19 (m, 4H), 7.14 (t, *J* = 7.2 Hz, 1H), 7.09 (d, *J* = 7.5 Hz, 2H), 5.47 (s, 1H), 3.63 – 3.50 (m, 1H), 2.79 – 2.68 (m, 1H), 2.63 – 2.53 (m, 1H), 2.02-1.89 (m, 1H), 1.83-1.72 (m, 1H), 1.21 (d, *J* = 6.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.43, 142.88, 142.62, 128.47, 128.41, 128.37, 127.59, 127.52, 127.28, 127.06, 125.76, 80.79, 72.45, 38.73, 31.93, 19.92; HRMS (ESI): [M+Na]$^+$ calcd for $C_{23}H_{24}ONa^+$, 339.1719, found, 339.1712.

(oxybis(methanetriyl))tetrabenzene (3k): Colorless oil, 20.3 mg (58%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 – 7.27 (m, 8H), 7.24 (t, *J* = 7.3 Hz, 8H), 7.20 – 7.17 (m, 4H), 5.32 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.36, 128.52, 127.56, 127.41, 80.15; HRMS (ESI): [M+Na]$^+$ calcd for $C_{26}H_{22}ONa^+$, 373.1563, found, 373.1552.

diphenylmethanol (3l): White solid, mp: 65–68 °C, 15.6 mg (85%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53-7.43 (m, 8H), 7.43-7.37 (m, 2H), 5.95 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.94, 128.63, 127.70, 126.68, 76.40; MS-EI$^+$: [M$^+$] calcd for $C_{13}H_{12}O^+$, 184.0883, found, 184.0879.

((((1R,2S,5R)-2-isopropyl-5-methylcyclohexyl)oxy)methylene)dibenzene (3m): Colorless solid, , mp: 58–62 °C, 13.6 mg (44%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.13 (m, 10H), 5.52 (s, 1H), 3.14 (td, *J* = 10.4, 4.1 Hz, 1H), 2.43 – 2.30 (m, 1H), 2.24 – 2.09 (m, 1H), 1.66 – 1.53 (m, 2H), 1.41 – 1.30 (m, 1H), 1.28 – 1.18 (m, 1H), 0.98 – 0.82 (m, 9H), 0.44 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.89, 142.61, 128.25, 128.12, 127.98, 127.44, 126.92, 126.74, 79.96, 75.94, 48.78, 40.46, 34.59, 31.52, 25.10, 22.93, 22.44, 21.36, 15.68; HRMS (ESI): [M+Na]$^+$ calcd for $C_{23}H_{30}ONaO^+$, 345.2189, found. 345.2178.

N-benzhydryl-4-chloroaniline (5a): Colorless oil, 23.4 mg (80%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.21 (m, 10H), 7.04 (d, *J* = 8.8 Hz, 2H), 6.45 (d, *J* = 8.8 Hz, 2H), 5.44 (s, 1H), 4.27 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.91, 142.57, 129.09, 128.96, 127.66, 127.54, 122.53, 114.78, 63.28; HRMS (ESI): [M+H]$^+$ calcd for $C_{19}H_{17}ClN^+$, 294.1044, found, 294.1035.

methyl 4-(benzhydrylamino)benzoate (5b): White solid, mp: 66–71 °C, 27.2 mg (80%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, *J* = 8.7 Hz, 2H), 7.37 – 7.24 (m, 10H), 6.50 (d, *J* = 8.7 Hz, 2H), 5.58 (s, 1H), 4.67 (brs, 1H), 3.80 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.33, 150.95, 142.04, 131.51, 129.00, 127.78, 127.54, 119.06, 112.57, 62.53, 51.64; HRMS (ESI): [M+Na]$^+$ calcd for $C_{21}H_{19}NNaO_2^+$, 340.1308, found, 340.1303.

N-benzhydryl-N-methylaniline (5c): Colorless oil, 17.7 mg (65%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.16 (m, 12H), 6.79 (d, *J* = 7.9 Hz, 2H), 6.72 (t, *J* = 7.2 Hz, 1H), 6.18 (s, 1H), 2.73 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 150.26, 140.79, 129.23, 128.86, 128.49, 127.30, 116.93, 113.11, 67.18, 34.63; HRMS (ESI): [M+H]$^+$ calcd for $C_{20}H_{20}N^+$, 274.1590, found, 274.1576.

methyl 4-(benzhydryl(methyl)amino)benzoate (5d): White solid, mp: 102–105 °C, 29.5 mg (89%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (d, *J* = 9.0 Hz, 2H), 7.36 – 7.27 (m, 6H), 7.19 – 7.12 (m, 4H), 6.76 (d, *J* = 9.0 Hz, 2H), 6.27 (s, 1H), 3.83 (s, 3H), 2.80 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.44, 139.90, 131.45, 128.79, 128.71, 127.68, 117.96, 111.65, 66.72, 51.62, 34.79; HRMS (ESI): [M+Na]$^+$ calcd for $C_{22}H_{21}NNaO_2^+$, 354.1465, found, 354.1462.

4-(benzhydryl(methyl)amino)benzonitrile(5e): White solid, mp: 62–66 °C, 25.3 mg (85%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.0 Hz, 2H), 7.41 – 7.27 (m, 6H), 7.14 (d, *J* = 7.2 Hz, 4H), 6.75 (d, *J* = 8.1 Hz, 2H), 6.21 (s, 1H), 2.80 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 152.48, 139.39, 133.52, 128.73, 128.62, 127.78, 120.50, 112.27, 98.36, 66.59, 34.71; HRMS (ESI): [M+Na]$^+$ calcd for $C_{21}H_{18}N_2Na^+$, 321.1362, found, 321.1354.

ethyl 2-(benzhydryl(4-chlorophenyl)amino)acetate (5f): Colorless oil, 34.5 mg (91%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 – 7.21 (m, 10H), 7.10 (d, *J* = 9.1 Hz, 2H), 6.63 (d, *J* = 9.1 Hz, 2H), 6.12 (s, 1H), 4.01-3.94 (m, 4H), 1.11 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.92, 147.46, 140.29, 129.16, 128.91, 128.68, 127.69, 123.19, 115.74, 67.69, 60.90, 50.73, 14.23; HRMS (ESI): [M+Na]$^+$ calcd for $C_{23}H_{22}ClNNaO_2^+$, 402.1231, found, 402.1230.

N-benzyl-N-methyl-1,1-diphenylmethanamine (5g): Colorless oil, 23.2 mg (81%);^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, *J* = 7.4 Hz, 4H), 7.44 (d, *J* = 7.3 Hz, 2H), 7.39 – 7.30 (m, 6H), 7.28 (d, *J* = 7.9 Hz, 1H), 7.22 (t, *J* = 7.3 Hz, 2H), 4.51 (s, 1H), 3.54 (s, 2H), 2.11 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.16, 140.06, 128.73, 128.58, 128.34, 128.19, 127.04, 126.99, 75.61, 59.88, 40.42; HRMS (ESI): [M+H]$^+$ calcd for $C_{21}H_{22}N^+$, 288.1747, found, 288.1744.

N,N-dibenzyl-1,1-diphenylmethanamine (5h): Colorless oil, 25.0 mg (69%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (t, *J* = 8.5 Hz, 8H), 7.52 – 7.33 (m, 12H), 5.14 (s, 1H), 3.74 (s, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.51, 139.69, 129.40, 128.79, 128.45, 128.25, 127.11, 126.97, 67.28, 53.81; HRMS (ESI): [M+H]$^+$ calcd for $C_{27}H_{26}N^+$, 364.2060, found, 364.2058.

4-benzhydrylmorpholine (5i): Colorless oil, 17.5 mg (69%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (d, *J* = 7.3 Hz, 4H), 7.26 (t, *J* = 7.6 Hz, 4H), 7.17 (t, *J* = 7.3 Hz, 2H), 4.19 (s, 1H), 3.73 – 3.66 (m, 4H), 2.42 – 2.33 (m, 4H);^{13}C NMR (101 MHz, $CDCl_3$) δ 142.45, 128.64, 128.06, 127.14, 79.62, 67.32, 52.79; HRMS (ESI): [M+H]$^+$ calcd for $C_{17}H_{20}NO^+$, 254.1539, found, 254.1536.

2-benzhydryl-1,2,3,4-tetrahydroisoquinoline (5j): White solid, mp: 80–84 °C, 21.8 mg (73%); 1H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 7.5 Hz, 4H), 7.45 (t, *J* = 7.5 Hz, 4H), 7.35 (t, *J* = 7.4 Hz, 2H), 7.31 – 7.19 (m, 3H), 7.04 (d, *J* = 7.4 Hz, 1H), 4.58 (s, 1H), 3.74 (s, 2H), 3.05 (t, *J* = 5.7 Hz, 2H), 2.89 (t, *J* = 5.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.40, 134.78, 134.18, 128.02, 127.96, 127.34, 126.42, 126.18, 125.46, 124.94, 75.32, 54.55, 48.63, 28.75; HRMS (ESI): [M+H]$^+$ calcd for $C_{22}H_{22}N^+$, 300.1747, found, 300.1744.

N-benzhydrylbenzamide (5k): White solid, mp: 158–163 °C, 16.1 mg (56%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (d, *J* = 7.4 Hz, 2H), 7.50 (t, *J* = 7.3 Hz, 1H), 7.43 (t, *J* = 7.5 Hz, 2H), 7.38 – 7.24 (m, 10H), 6.69 (d, *J* = 7.2 Hz, 1H), 6.45 (d, *J* = 7.8 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.48, 141.48, 134.28, 131.69, 128.76, 128.64, 127.58, 127.51, 127.05, 57.47; HRMS (ESI): [M+Na]$^+$ calcd for $C_{20}H_{17}NaNO^+$, 310.1202, found, 310.1188.

N-benzhydryl-4-methylbenzamide (5l): White solid, mp: 137–141 °C, 18.4 mg (61%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 8.0 Hz, 2H), 7.39 – 7.18 (m, 12H), 6.66 (d, *J* = 7.4 Hz, 1H), 6.44 (d, *J* = 7.8 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.41, 142.14, 141.59, 131.41, 129.27, 128.73, 127.52, 127.06, 57.39, 21.46; HRMS (ESI): [M+Na]$^+$ calcd for $C_{21}H_{19}NNaO^+$, 324.1359, found, 324.1345.

N-benzhydryl-4-methoxybenzamide (5m): White solid, mp: 192–197 °C, 23.1 mg (73%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (d, *J* = 8.5 Hz, 2H), 7.37 – 7.25 (m, 10H), 6.92 (d, *J* = 8.6 Hz, 2H), 6.59 (d, *J* = 7.3 Hz, 1H), 6.44 (d, *J* = 7.6 Hz, 1H), 3.84 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.12, 162.51, 141.79, 129.01, 128.86, 127.65, 126.65, 113.96, 57.54, 55.57; HRMS (ESI): $[M+H]^+$ calcd for $C_{21}H_{20}NO_2^+$, 318.1489, found, 318.1474.

1-benzhydryl-1H-pyrazole (5n): White solid, mp: 65–69 °C, 20.4 mg (87%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (s, 1H), 7.35 – 7.25 (m, 7H), 7.09 (d, *J* = 6.7 Hz, 4H), 6.79 (s, 1H), 6.27 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.86, 139.71, 129.53, 128.75, 128.35, 128.13, 105.53, 69.56; HRMS (ESI): $[M+H]^+$ calcd for $C_{16}H_{15}N_2^+$, 235.1230, found, 235.1228.

1-benzhydryl-1H-benzo[d]imidazole (5o): Brown solid, mp: 106–111 °C, 23.6 mg (83%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (d, *J* = 8.0 Hz, 1H), 7.71 (s, 1H), 7.39 – 7.33 (m, 6H), 7.26 – 7.09 (m, 7H), 6.75 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.90, 137.95, 134.08, 129.19, 128.74, 128.31, 123.38, 122.90, 120.30, 111.06, 63.96; HRMS (ESI): $[M+H]^+$ calcd for $C_{20}H_{17}N_2^+$, 285.1386, found, 285.1382.

9-benzhydryl-9H-carbazole (5p): White solid, mp: 165–170 °C, 27.6 mg (83%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.4 Hz, 2H), 7.30 – 7.27 (m, 6H), 7.24 – 7.16 (m, 8H), 7.07 (s, 1H), 7.05 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.82, 139.03, 128.77, 128.52, 127.98, 125.67, 123.64, 120.26, 119.32, 110.82, 62.45; HRMS (ESI): $[M+Na]^+$ calcd for $C_{25}H_{19}NNa^+$, 356.1410, found, 356.1398.

N-benzhydryl-4-chloro-N-methylaniline (6a): Colorless oil, 25.5 mg (83%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 – 7.26 (m, 5H), 7.19-7.11 (m, 5H), 6.69 (d, *J* = 8.9 Hz, 2H), 6.10 (s, 1H), 2.71 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 148.88, 140.42, 129.03, 128.81, 128.61, 127.50, 121.84, 114.33, 67.50, 34.88; MS-EI$^+$: $[M^+]$ calcd for $C_{20}H_{18}ClN^+$, 307.1122, found, 307.1129.

N-(bis(4-methoxyphenyl)methyl)-4-chloro-N-methylaniline (6b): Colorless oil, 31.6 mg (86%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12 (d, *J* = 8.6 Hz, 2H), 7.07 (d, *J* = 8.3 Hz, 4H), 6.85 (d, *J* = 8.3 Hz, 4H), 6.67 (d, *J* = 8.7 Hz, 2H), 5.99 (s, 1H), 3.79 (s, 6H), 2.68 (s, 3H); HRMS (ESI): $[M+Na]^+$ calcd for $C_{22}H_{22}ClNNaO_2^+$, 390.1231, found, 390.1222.

N-(bis(4-chlorophenyl)methyl)-4-chloro-N-methylaniline (6c): Colorless oil, 20.6 mg (55%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (d, *J* = 8.4 Hz, 4H), 7.06 (d, *J* = 8.9 Hz, 2H), 7.00 (d, *J* = 8.3 Hz, 4H), 6.58 (d, *J* = 8.9 Hz, 2H), 5.92 (s, 1H), 2.58 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 148.58, 138.42, 133.58, 130.02, 129.15, 128.93, 122.64, 114.79, 66.70, 34.81; HRMS (ESI): $[M+Na]^+$ calcd for $C_{20}H_{16}Cl_3NNa^+$, 398.0241, found, 398.0229.

4-chloro-N-((4-methoxyphenyl)(phenyl)methyl)-N-methylaniline (6d): Colorless oil, 31.9 mg (91%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12 (d, *J* = 8.7 Hz, 4H), 7.05 (t, *J* = 8.0 Hz, 4H), 6.84 (d, *J* = 8.6 Hz, 2H), 6.67 (d, *J* = 8.9 Hz, 2H), 6.01 (s, 1H), 3.79 (s, 3H), 2.69 (s, 3H), 2.34 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.92, 148.90, 137.69, 137.03, 132.68, 129.95, 129.27, 128.97, 128.59, 121.55, 114.19, 113.91, 66.58, 55.38, 34.61, 21.21; HRMS (ESI): $[M+Na]^+$ calcd for $C_{22}H_{22}ClNNaO^+$, 374.1282, found, 374.1271.

4-chloro-N-(1-(4-methoxyphenyl)ethyl)-N-methylaniline (6e): Colorless oil, 23.4 mg (85%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 – 7.13 (m, 4H), 6.85 (d, *J* = 8.7 Hz, 2H), 6.73 (d, *J* = 8.9 Hz, 2H), 5.01 (q, *J* = 6.8 Hz, 1H), 3.79 (s, 3H), 2.62 (s, 3H), 1.50 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.86, 149.05, 134.49, 129.09, 128.12, 121.65, 114.60, 114.01, 56.66, 55.42, 32.07, 16.52; HRMS (ESI): $[M+H]^+$ calcd for $C_{14}H_{18}NO_2^+$, 232.1332, found, 232.1322.

4-chloro-N-(1-(4-methoxyphenyl)propyl)-N-methylaniline (6f): Colorless oil, 22.8 mg (79%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.14 (dd, *J* = 8.0, 5.1 Hz, 4H), 6.83 (d, *J* = 8.3 Hz, 2H), 6.72 (d, *J* = 8.7 Hz, 2H), 4.73 (dd, *J* = 9.0, 6.1 Hz, 1H), 3.77 (s, 3H), 2.63 (s, 3H), 2.08 – 1.86 (m, 2H), 0.95 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.71, 149.69, 133.32, 129.02, 128.33, 121.16, 114.19, 113.86, 62.97, 55.34, 31.70, 24.99, 11.77; MS-EI$^+$: $[M]^+$ calcd for $C_{17}H_{20}ClNO^+$, 289.1228, found, 289.1233.

4-chloro-N-(1-(4-methoxyphenyl)-2-phenylethyl)-N-methylaniline (6g): Colorless oil, 29.1 mg (83%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24 – 7.13 (m, 7H), 7.05 (d, *J* = 8.6 Hz, 2H), 6.83 (d, *J* = 8.3 Hz, 2H), 6.52 (d, *J* = 8.6 Hz, 2H), 5.16 – 5.08 (m, 1H), 3.77 (s, 3H), 3.33 – 3.18 (m, 2H), 2.65 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.84, 149.18, 139.16, 132.75, 129.07, 128.85, 128.48, 128.42, 126.41, 121.60, 114.70, 113.91, 63.59, 55.36, 37.84, 32.56; HRMS (ESI): $[M+Na]^+$ calcd for $C_{22}H_{22}ClNNaO^+$, 374.1282, found, 374.1270.

4-chloro-N-methyl-N-(1-(p-tolyl)ethyl)aniline (6h): Colorless oil, 14.2 mg (55%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21-7.10 (m, 6H), 6.72 (d, *J* = 8.7 Hz, 2H), 5.01 (q, *J* = 6.7 Hz, 1H), 2.64 (s, 3H), 2.33 (s, 3H), 1.51 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 148.98, 139.42, 136.71, 129.27, 129.05, 126.87, 121.43, 114.35, 56.77, 32.13, 21.15, 16.63; HRMS (ESI): $[M+Na]^+$ calcd for $C_{16}H_{18}ClNNa^+$, 282.1020, found, 282.1011.

(((2,2,6,6-tetramethylcyclohexyl)oxy)methylene)dibenzene: Colorless oil,; ^{1}H NMR (400 MHz, Chloroform-d) δ 7.49 (d, J = 7.5 Hz, 4H), 7.38 (t, J = 7.5 Hz, 4H), 7.27 (t, J = 7.3 Hz, 2H), 5.76 (s, 1H), 1.78 – 1.61 (m, 2H), 1.54 (d, J = 5.0 Hz, 4H), 1.27 (s, 7H), 0.86 (s, 7H); ^{13}C NMR (101 MHz, Chloroform-d) δ 144.85, 128.13, 126.70, 126.54, 90.75, 59.88, 40.42, 33.92, 20.42, 17.15. HRMS (ESI): $[M+H]^+$ calcd for $C_{22}H_{30}NO^+$, 324.2322, found, 324.2315.

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[1] a) F. Collet, R. H. Dodd, P. Dauban, *Chem. Commun.* **2009**, 5061-5074; b) D. N. Zalatan, J. D. Bois, *Top. Curr. Chem.* **2009**, *292*, 347-378.

[2] a) M. Arend, B. Westermann, N. Risch, *Angew. Chem. Int. Ed.*, **1998,** *37*, 1044-1070; b) K. C. Nicolaou, M. O. Frederick, R. J. Aversa, *Angew. Chem. Int. Ed.*, **2008**, *47*, 7182-7225.

[3] a) O. Mitsunobu, M. Yamada, *Bull. Chem. Soc. Jpn.* **1967**, *40*, 2380-2382; b) Y. Nishibayashi, M. D. Milton, Y. Inada, M. Yoshikawa, I. Wakiji, M. Hidai, S. Uemura, *Chem. Eur. J.* **2005**, *11*, 1433-1451; c) A. Prades, R. Corberan, M. Poyatos, E. Peris, *Chem. Eur. J.* **2008**, *14*,

11474-11479; d) T. Müller, L. Levi, S. Scheuren, *Synthesis* **2014**, *46*, 3059-3066; e) H. Huang, J. Y. Kang, *J. Org. Chem.* **2017**, *82*, 6604-6614; f) O. S. Nayal, M. S. Thakur, M. Kumar, N. Kumar, S. K. Maurya, *Adv. Synth. Catal.* **2018**, *360*, 730-737.

[4] For selected recent examples of benzylic alcohol derivatives see e.g.: a) P. A. Albiniak, S. M. Amisial, G. B. Dudley, J. P. Hernandez, S. E. House, M. E. Matthews, E. O. Nwoye, M. K. Reilly, S. F. Tlais, *Synth. Commun.* **2008**, *38*, 656-665; b) G. Hattori, H. Matsuzawa, Y. Miyake, Y. Nishibayashi, *Angew. Chem. Int. Ed.* **2008**, *47*, 3781-3783; c) G. Hattori, K. Sakata, H. Matsuzawa, Y. Tanabe, Y. Miyake, Y. Nishibayashi, *J. Am. Chem. Soc.* **2010**, 10592-10608; d) R. J. Detz, Z. Abiri, R. le Griel, H. Hiemstra, J. H. van Maarseveen, *Chem. Eur. J.* **2011**, *17*, 5921-5930; e) D. R. Wallach, P. C. Stege, J. P. Shah, J. D. Chisholm, *J. Org. Chem.* **2015**, *80*, 1993-2000.

[5] For selected examples of benzylic halides, see: a) S S. Paul, M. Gupta, *Tetrahedron Lett.* **2004**, *45*, 8825-8829; b) J. L. Romera, J. M. Cid, A. A. Trabanco, *Tetrahedron Lett.* **2004**, *45*, 8797-8800; c) T. M. Shaikh, A. Sudalai, *Tetrahedron Lett.* **2005**, *46*, 5589-5592; d) G. Joshi, S. Adimurthy, *Synth. Commun.* **2011**, *41*, 720-728; e) A. Dhakshinamoorthy, P. Visuvamithiran, V. Tharmaraj, K. Pitchumani, *Catal. Commun.* **2011**, *16*, 15-19.

[6] For selected examples of other leaving group, see: a) M. Zhang, D. L. Flynn, P. R. Hanson, *J. Org. Chem.* **2007**, *72*, 3194-3198; b) H. Danafar, B. Yadollahi, *Catal. Commun.* **2009**, *10*, 842-847; c) E. Tayama, M. Ishikawa, H. Iwamoto, E. Hasegawa, *Tetrahedron Lett.* **2012**, *53*, 5159-5161; d) S. Sueki, Y. Kuninobu, *Org. Lett.* **2013**, *7*, 1544-1547; e) E. Barragan, A. Bugarin, *J. Org. Chem.* **2017**, *82*, 1499-1506.

[7] a) Q. Xia, W. Chen, H. Qiu, *J. Org. Chem.* **2011**, *76*, 7577-7582; b) H. J. Kim, J. Kim, S. H. Cho, S. Chang, *J. Am. Chem. Soc.* **2011**, *133*, 16382-16385; c) A. Iglesias, R. Alvarez, A. R. de Lera, K. Muniz, *Angew. Chem. Int. Ed.* **2012**, *51*, 2225-2228; d) Q. Xue, J. Xie, H. Li, Y. Cheng, C. Zhu, *Chem. Comm.* **2013**, *49*, 3700-3702.

[8] a) G. Pandey, S. Pal, R. Laha, *Angew. Chem. Int. Ed.* **2013**, *52*, 5146-5149; b) G. Pandey, R. Laha, *Angew. Chem. Int. Ed.* **2015**, *54*, 14875-14879; c) G. Pandey, R. Laha, D. Singh, *J. Org. Chem.* **2016**, *81*, 7161-7171; d) H. Im, D. Kang, S. Choi, S. Shin, S. Hong, *Org. Lett.*, **2018**, *20*, 7437-7441.

[9] For selected examples of the generation of iminyl radical from oxime via visible light catalysis, see:: a) H. Jiang, X. An, K. Tong, T. Zheng, Y. Zhang, S. Yu, *Angew. Chem. Int. Ed.* **2015**, *54*, 4055-4059; b) J. Davies, S. G. Booth, S. Essafi, R. A. W. Dryfe, D. Leonori, *Angew. Chem. Int. Ed.* **2015**, *54*, 14017-14021; c) W. Shu, C. Nevado, *Angew. Chem. Int. Ed.* **2017**, *56*, 1881-1884.

[10] For selected examples of the generation of C-centered radical from oxime via visible light catalysis, see: a) L. Li, H. Chen, M. Mei, L. Zhou, *Chem. Comm.* **2017**, *53*, 11544-11547; b) X.-Y. Yu, J.-R. Chen, P.-Z. Wang, M.-N. Yang, D. Liang, W.-J. Xiao, *Angew. Chem. Int. Ed.* **2018**, *57*, 738-743; c) X. Shen, J. J. Zhao, S. Yu, *Org. Lett.* **2018**, *20*, 5523-5527; d) E. M. Dauncey, S. P. Morcillo, J. J. Douglas, N. S. Sheikh, D. Leonori, *Angew. Chem. Int. Ed.* **2018**, *57*, 744-748; e) B. Zhao, C. Chen, J. Lv, Z. Li, Y. Yuan, Z. Shi, *Org. Chem. Front.* **2018**, *5*, 2719-2722; f) W. Ai, Y. Liu, Q. Wang, Z. Lu, Q. Liu, *Org. Lett.* **2018**, *20*, 409-412; g) P. Wang, B. Zhao, Y. Yuan, Z. Shi, *Chem. Commun.* **2019**, *55*, 1971-1974; (h) C. Zhu, F. Chen, C. Liu, H. Zeng, Z. Yang, W. Wu, H. Jiang, *J. Org. Chem.*, 2018, **83**, 14713-14722.

[11] a) C. K. Prier, D. A. Rankic, D. W. MacMillan, *Chem. Rev.* **2013**, *113*, 5322-5363; b) D. P. Hari, B. König, *Chem. Commun.* **2014**, *50*, 6688-6699; c) N. A. Romero, D. A. Nicewicz, *Chem. Rev.* **2016**, *116*, 10075-10166.

[12] Y.-C. Tan, J. F. Hartwig, *J. Am. Chem. Soc.*, **2010**, *132*, 3676-3677.

[13] C. Kong, N. Jana, C. Jones, T. G. Driver, *J. Am. Chem. Soc.*, **2016**, *138*, 13271-13280.

[14] H. Jiang, X. An, K. Tong, T. Zheng, Y. Zhang, S.-Y. Yu, *Angew. Chem. Int. Ed.*, **2015**, *54*, 4055-4059.

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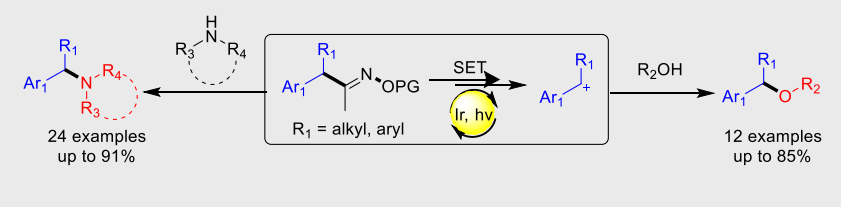

A photoredox benzyl activation was developed via formidable C(sp^3)-C(sp^3) bond dissociation of 1-aryl acetone oxime esters, easily perapared from benzyl ketones. The generated benzyl cation coupling with diverse *O*- and *N*- nucleophiles successfully forged important benzyl ether and amines derivatives that are valuable in last-stage functionlizations.

C-C bond dissociation*

*X. Fan, T. Lei, Z. Liu, X.-L. Yang, Y.-Y. Cheng, G. Liang, B. Chen, C.-H. Tung and L.-Z. Wu**

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Benzyl C-O and C-N Bond Construction via C-C Bond Dissociation of Oxime Ester under Visible Light Irradiation