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Diiodomethane-Mediated Generation of *N*-Aryliminium Ions and Subsequent [4+2] Cycloadditions with Olefins

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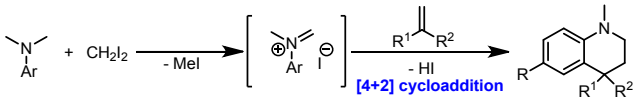


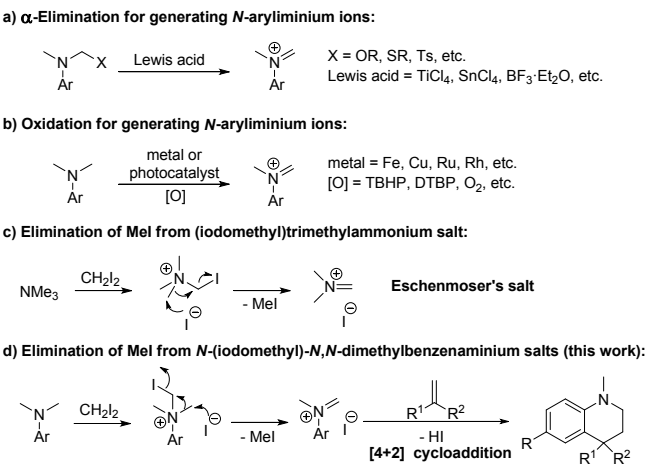
ABSTRACT: Herein we report a method for in situ generation of *N*-aryliminium ions via reactions of *N,N*-dimethylanilines with diiodomethane. We used the method to prepare tetrahydroquinolines via one-pot three-component reactions between *N,N*-dimethylanilines, diiodomethane, and olefins. This transformation involves initial reaction of the aniline with diiodomethane to form an iodomethylammonium salt, which undergoes fragmentation accompanied by elimination of methyl iodide to give an *N*-aryliminium ion, which is trapped by the olefin via a [4+2] cycloaddition to give the final product. This method for generating *N*-aryliminium ions requires neither a catalyst nor a strong oxidant, suggesting that it can be expected to find broad utility, especially for substrates that are sensitive to Lewis acids, transition metals, or strong oxidants.

INTRODUCTION

N-Aryliminium ions are useful building blocks in organic syntheses.[1] Because these electrophiles are highly reactive, they are commonly prepared in situ by methods such as α-elimination reactions of *N,N*-dialkylanilines bearing a leaving group attached to the α-carbon of one of the alkyl substituents (Scheme 1a)[2] and direct oxidation of *N,N*-dialkylanilines via transition metal catalysis[3] or oxidative photoredox catalysis[4] (Scheme 1b).[5,6] Although many interesting and useful transformations have been accomplished with these methods, they have some disadvantages. The α-elimination method usually requires more than one equivalent of a Lewis acid to facilitate elimination of the leaving group, and attaching the leaving group to the substrate in the first place requires additional synthetic steps. As for the oxidation method, strong oxidants such as *tert*-butyl hydroperoxide and di-*tert*-butyl peroxide are often used, which limits the compatible substrates to those that are not sensitive to strong oxidants.

Therefore, it would be useful to develop an alternative approach for generating *N*-aryliminium ions without the need for Lewis acids, transition metals, or strong oxidants. Our work in this area was inspired by the chemistry of Eschenmoser's salt,[7] a powerful dimethylaminomethylating reagent, which is frequently used in the total synthesis of natural products.[8] This salt is generated via a two-step process (Scheme 1c): first, trimethylamine reacts with diiodomethane (CH_2I_2) to give (iodomethyl)trimethylammonium iodide; and second, elimination of methyl iodide via thermal fragmentation produces the desired iminium ion. We speculated that *N*-aryliminium ions could be prepared in a similar fashion via reactions between *N,N*-dialkylanilines and CH_2I_2. Although various trialkylamines have been shown to react with CH_2I_2 to give the corresponding iminium ions,[9] *N,N*-dialkylanilines have never been used as amine precursors for such reactions, probably because of the challenges presented by the substantially weaker nucleophilicity and basicity of *N,N*-dialkylanilines relative to trialkylamines, which inhibit both the amine quaternization reaction with CH_2I_2 and elimination of the alkyl halide. Indeed, there are no reports describing the quaternization of an *N,N*-dialkylaniline with CH_2I_2. In 1985, Isaacs et al. reported that heating *N,N*-dimethylaniline and CH_2Br_2 for over five days gave a mixture of quaternary ammonium salt [$PhMe_2N(CH_2Br)$]Br (44% yield) and bisammonium salt [$(PhMe_2N)_2CH_2$]Br_2 (56% yield),[10] but subsequent transformations of these ammonium bromides were not explored. Herein, we report our discovery that reactions of anilines with CH_2I_2 generate N-aryliminium ions, which can undergo [4+2] cycloaddition reactions with olefins to provide tetrahydroquinolines (Scheme 1d).

Scheme 1. Methods for Generation of Iminium Ions

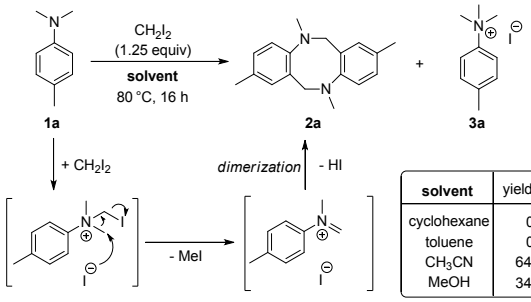


RESULTS AND DISCUSSION

We began by studying the reaction of *p*-methyl-*N,N*-dimethylaniline (**1a**) with CH_2I_2 at 80 °C (Scheme 2). When cyclohexane or toluene was used as the solvent, no reaction was observed, and **1a** could be recovered unchanged. However, when more polar solvents, i.e., acetonitrile and methanol, were tested,

two compounds derived from **1a** were observed. One of the compounds, **2a**, was determined to be the product of dimerization of the desired *N*-aryliminium ion, and the other product, **3a**, was formed by quaternization of **1a** with methyl iodide, which is a byproduct of *N*-aryliminium ion formation. The dimerization reaction is very similar to the chemistry in the preparation of Tröger's base[11] via electrophilic aromatic substitution of *N*-aryliminium ions. The formation of **2a** and **3a** demonstrated that our proposed reaction pathway for formation of *N*-aryliminium ions was feasible, at least in polar media. In addition, the 64% yield of **2a** in acetonitrile suggested that the iminium formation was quite effective in this solvent.

Scheme 2. Reaction of Aniline 1a with CH_2I_2

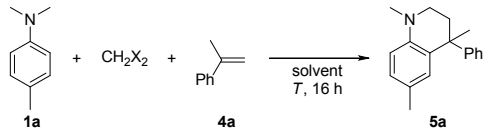


solvent	yield (**2a**)	yield (**3a**)
cyclohexane	0	0
toluene	0	0
CH_3CN	64%	34%
MeOH	34%	30%

To demonstrate the utility of the reaction, we sought to develop a method for trapping the *N*-aryliminium ion in situ. We speculated that a concerted or stepwise [4+2] cycloaddition reaction with an olefin (the Povarov reaction[12,13]) would be ideal because it would involve both the iminium ion and the aromatic ring in a process that is unique to *N*-aryliminium ions. In addition, *N*-aryliminium ions are more reactive than the *N*-arylimines that are commonly used in Povarov reactions, because the lower electron density of the former decreases the energy of the lowest unoccupied molecular orbital of the diene in this inverse-electron-demand aza-Diels–Alder reaction. However, iminium ions are not commonly used for Povarov reactions, and most of the reported reactions use a Lewis or Brønsted acid to activate the *N*-arylimine so that its reactivity is adequate.[12,13] The poor accessibility of *N*-aryliminium ions or the incompatibility of the reaction conditions for generating these reactive species with the subsequent cycloaddition may be the main reason that *N*-aryliminium ions are rarely used in Povarov reactions.

To explore this possibility, we investigated the three-component reaction of **1a** (4 equiv), CH_2I_2 (5 equiv), and α-methylstyrene (**4a**, 1 equiv) (Table 1). We chose α-methylstyrene as the starting material because the resulting tetrahydroquinoline would contain a quaternary carbon center; such compounds are difficult to access via other synthetic methods (e.g., hydrogenations of quinolines). When the reaction was run in acetonitrile at 80 °C for 16 h, the desired cycloaddition occurred regioselectively to give tetrahydroquinoline **5a** in 92% yield (entry 1). Consistent with the results shown in Scheme 2, the yield was higher in polar solvents than in less polar ones (entries 2–5). Decreasing the reaction temperature to 60 °C or raising it to 100 °C decreased the yield (entries 6 and 7). CH_2Br_2 could be used in place of CH_2I_2, but the yield dropped to 40% (entry 8). However, switching to CH_2Cl_2 resulted in only a trace of the desired product (entry 9).

Table 1. Optimization of Conditions for the Three-component Reaction[a]



entry	CH_2X_2	solvent	*T* (°C)	yield (%)[b]
1	CH_2I_2	CH_3CN	80	92 (87[c])
2	CH_2I_2	MeOH	80	73
3	CH_2I_2	DMF	80	61
4	CH_2I_2	$CHCl_3$	80	33
5	CH_2I_2	toluene	80	trace
6	CH_2I_2	CH_3CN	60	57
7	CH_2I_2	CH_3CN	100	64
8	CH_2Br_2	CH_3CN	80	40[d]
9	CH_2Cl_2	CH_3CN	80	trace

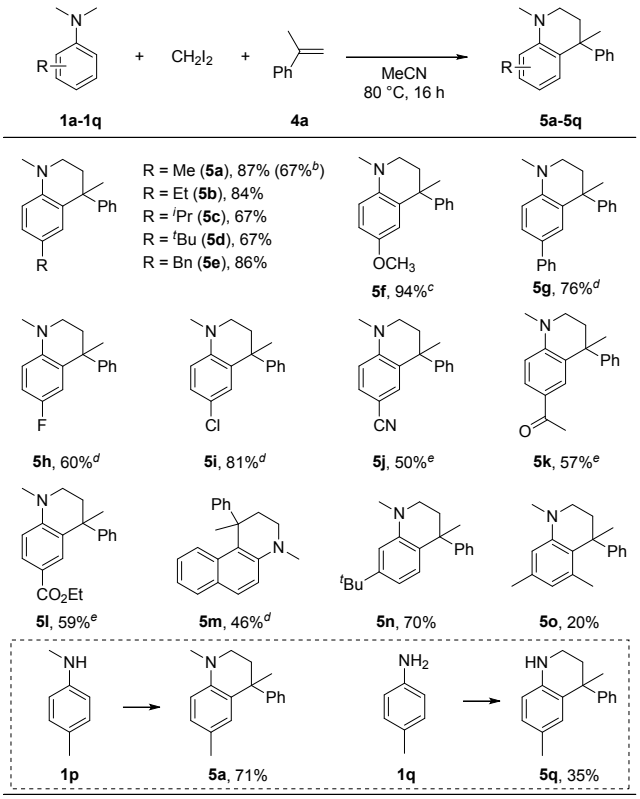
[a] Unless otherwise specified, all reactions were performed with **1a** (0.4 mmol), CH_2X_2 (0.5 mmol), and **4a** (0.1 mmol) in 0.5 mL of solvent under N_2. [b] Yields were determined by ^1H NMR with CH_2Br_2 as the internal standard. [c] Isolated yield. [d] NMR yield with PhOMe as the internal standard.

With the optimal conditions in hand, we explored the scope of this three-component reaction by testing various anilines in reactions with **4a** (Table 2). *para*-Alkyl-*N*,*N*-dimethylanilines produced the corresponding tetrahydroquinolines (**5a**–**5e**) in good yields. When the aniline was substituted with an electron-donating methoxy group (**1f**), the reaction temperature could be lowered to 60 °C, and **5f** was obtained in 94% yield. For anilines with weakly electron-withdrawing groups (phenyl, F, and Cl), the best yields of the corresponding products (**5g**–**5i**) were obtained at 100 °C; whereas anilines with strongly electron-withdrawing groups (nitrile, acetyl, and ethoxylcarbonyl) required a much higher temperature (140 °C) for the formation of **5j**–**5l**. Theoretically, the [4+2] cycloaddition of electron-deficient aryls should be favorable because electron-deficient aryls decrease the energy of the lowest unoccupied molecular orbital of the aza-diene moiety (for the concerted mechanism) or make the iminium more electrophilic (for the stepwise mechanism). However, the relationship between the optimal reaction temperatures for the substrates with electron-donating and electron-withdrawing groups was the opposite of what would be expected on the basis of this reasoning. We reasoned that the decrease in the electron density on the aryl ring was accompanied by a decrease in the nucleophilicity of the amine, making it less reactive toward diiodomethane in the amine quaternization step, which should be the rate-determining step of the overall process.

The cycloaddition reaction of *N*,*N*-dimethyl-2-naphthalenamine with **4a** occurred at the α position of the naphthyl ring to give cycloaddition product **5m** in 46% yield. With a *meta*-*t*-butyl-substituted aniline, the reaction occurred at the less hindered of the two *ortho* positions to give **5n**, and the yield of the reaction with a 3,5-dimethyl-substituted aniline was low (**5o**, 20%), indicating that steric hindrance inhibited the reaction. Under the same conditions, reactions of a 4-methylaniline with only one *N*-methyl group (**1p**) and a 4-methylaniline with no *N*-alkyl groups at all (**1q**) generated corresponding tetrahydroquinolines **5a** and **5q** in 71% and 35% yields, respectively. In both reactions, HI instead of methyl iodide was eliminated during iminium formation. We found that the reaction was limited to aniline substrates with a *para* substituent or

a bulky *meta* substituent because other anilines, including unsubstituted and *ortho*-substituted anilines, tended to undergo electrophilic substitution reactions with diiodomethane at the *para* position to give products such as $(p\text{-}Me_2NC_6H_4)_2CH_2$. We also tested 4-methylphenol for the reaction, but obtained a complex mixture from decompositions.

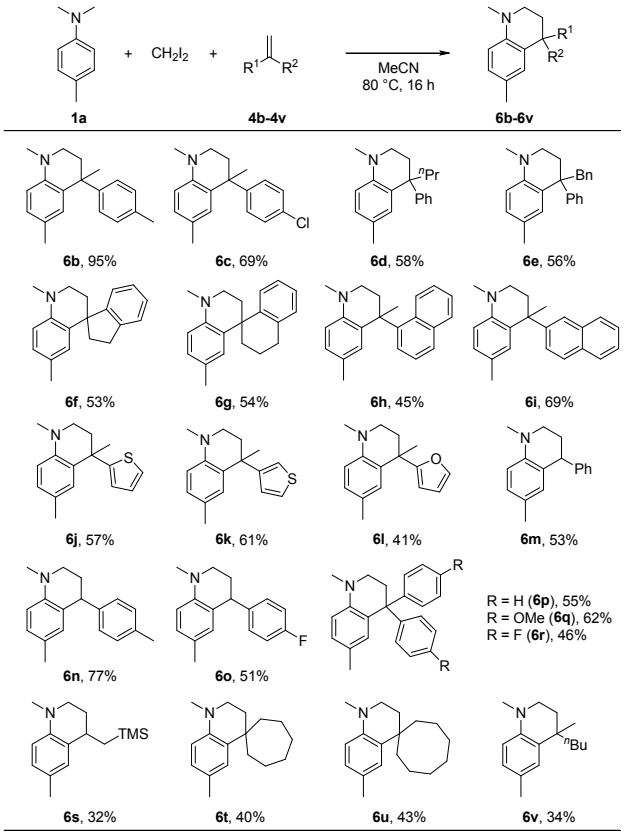
Table 2. Scope of the Three-component Reaction with Respect to the Aniline[a]



[a] Reaction conditions, unless otherwise noted: **1a**–**1q** (0.4 mmol), CH_2I_2 (0.5 mmol), and **4a** (0.1 mmol) in 0.5 mL of MeCN at 80 °C for 16 h under N_2; isolated yields are reported. [b] Yield of the gram-scale reaction. [c] Reaction temperature: 60 °C. [d] Reaction temperature: 100 °C. [e] Reaction temperature: 140 °C.

We next investigated the scope of the three-component reaction with respect to the olefin (Table 3). α-Alkylstyrenes were reactive, and the corresponding products (**6b**–**6e**) were obtained in moderate to high yields. Two substrates with terminal olefins attached to a benzene-fused cycloalkane were also suitable and generated tetrahydroquinolines with spiro bicyclic structures (**6f** and **6g**). The reaction was compatible with other aromatic rings: 1-naphthyl (**6h**), 2-naphthyl (**6i**), 2-thienyl (**6j**), 3-thienyl- (**6k**), and 2-furyl (**6l**). Monoaryl-substituted olefins (**6m**–**6o**), 1,1-diaryl-substituted olefins (**6p**–**6r**),[14] a monoalkyl-substituted olefin (**6s**), and dialkyl-substituted olefins (**6t**–**6v**) were also reactive.

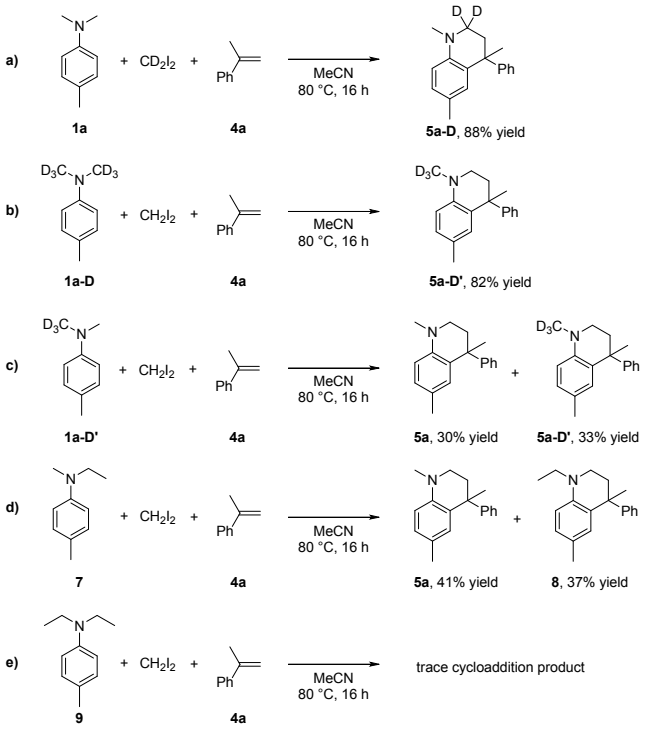
Table 3. Scope of the Three-component Reaction with Respect to the Olefin[a]



[a] Reaction conditions: **1a** (0.4 mmol), CH_2I_2 (0.5 mmol), and **4b**–**4v** (0.1 mmol) in 0.5 mL of MeCN at 80 °C for 16 h under N_2; isolated yields are reported.

We performed a series of control experiments to elucidate the mechanism of the reaction and to test its limits (Scheme 3). When CD_2I_2 was used instead of CH_2I_2 under the standard conditions, deuterium was incorporated exclusively on the methylene carbon connected to the nitrogen atom in the cycloaddition product (**5a-D**); and when an aniline with two fully deuterated *N*-methyl groups (**1a-D**) was subjected to the standard conditions, the resulting product contained only a single deuterated *N*-methyl group (**5a-D'**). These results are consistent with the proposed mechanism (Schemes 1 and 2). Furthermore, when an aniline with both deuterated and non-deuterated *N*-methyl groups (**1a-D'**) was tested, **5a** and **5a-D'** were obtained in similar yields, suggesting that the elimination step does not distinguish the two methyl groups. *N*-ethyl-*N*,4-dimethylaniline (**7**) gave *N*-methyl- and *N*-ethyl-substituted products (**5a** and **8**) in 41% and 37% yields, respectively. This result indicates that the elimination of methyl iodide and ethyl iodide occurred at similar rates. However, when we used *N*,*N*-diethyl-4-methylaniline (**9**) as a substrate, no cycloaddition occurred, and the starting material could be recovered. This result again suggests that amine quaternization with diiodomethane was the rate-limiting step and that the steric bulk of the two *N*-ethyl groups effectively shut down the reaction.

Scheme 3. Control Experiments



CONCLUSIONS

In summary, we have developed a new method for generation of *N*-aryliminium ions that does not require the use of Lewis acids, transition metals, or strong oxidants. We used this method to synthesize a number of tetrahydroquinolines bearing quaternary carbon centers via one-pot three-component reactions of olefins, diiodomethane, and *N*,*N*-dimethylanilines. Such tetrahydroquinolines are difficult to synthesize via conventional methods, and most of the tetrahydroquinolines were synthesized here for the first time. Work on the development of new transformations that involve trapping the *N*-aryliminium ions is underway in our laboratory.

EXPERIMENTAL SECTION

General Information : Unless otherwise noted, all materials were used as received from commercial sources without further purification. Solvents were freshly distilled from drying reagents. Analytical thin layer chromatography (TLC) was performed on Huanghai precoated (0.25 mm thickness) silica gel plates with F254 indicator. Visualization was accomplished with UV light (254 nm) or the potassium permanganate stain solution. Flash chromatography was performed with silica gel (32–63 μm) supplied by Shanghai Titan Scientific. ^{1}H NMR spectra were recorded on a Bruker DRX-400 (400 MHz) spectrometer and chemical shifts were reported in ppm. The peak information was described as: br = broad, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet; coupling constants in Hz. ^{13}C NMR spectra were recorded on a Bruker DRX-400 (101 MHz) spectrometer with complete proton decoupling. Chemical shifts of the NMR spectra were calibrated by the literature values of the solvent residual peaks. High-resolution mass spectra (HRMS) were obtained on a Thermo Scientific LTQ Orbitrap XL mass spectrometer. *N*,*N*-Dimethylanilines **1b**[15], **1c**[15], **1d**[15], **1e**[16], **1f**[15], **1g**[17], **1h**[15], **1i**[15], **1j**[15], **1n**[18] and olefins **4d**[19], **4e**[20], **4f**[21], **4g**[21], **4h**[22], **4i**[22], **4j**[22], **4k**[23], **4l**[24], **4q**[21], **4r**[21], **4t**[25], **4u**[26] were prepared according to previously reported procedures.

The Reaction of 1a with CH_2I_2: In a glovebox, *p*-methyl-*N*,*N*-dimethylaniline **1a** (54.1 mg, 0.4 mmol) and diiodomethane (133.9 mg, 0.5 mmol) were dissolved in a solvent (0.5 mL) in a 10 ml vial. The vial was capped and closed tightly. The solution was stirred at 80 °C (heating block) for 16 h. After being allowed to cool to room temperature, the reaction mixture was concentrated under reduced pressure. The obtained residue was purified by preparative HPLC (C18 column with water/acetonitrile as the eluent) to afford compounds **2a** and **3a**.

2,5,8,11-Tetramethyl-5,6,11,12-tetrahydrodibenzo[b,f][1,5]diazocine (2a).[27] A white solid. 34.0 mg, 64 % yield (MeCN as solvent). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.01 (d, *J* = 8.0 Hz, 2H), 6.93 (s, 2H), 6.79 (d, *J* = 8.0 Hz, 2H), 4.23 (s, 4H), 2.81 (s, 6H), 2.28 (s, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 147.5, 130.9, 130.4, 127.4, 126.1, 114.5, 57.7, 38.3, 19.3. HRMS (ESI) calcd. for $C_{18}H_{23}N_2^+$ $(M+H)^+$: 267.1856, found: 267.1859.

N,N,N,4-Tetramethylbenzenaminium iodide (3a).[28] A white solid. 37.7 mg, 34% yield (MeCN as solvent). 33.2 mg, 30% yield (MeOH as solvent). ^{1}H NMR (400 MHz, CD_3OD) δ 7.87 (d, *J* = 8.8 Hz, 2H), 7.49 (d, *J* = 8.8 Hz, 2H), 3.73 (s, 9H), 2.45 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, CD_3OD) δ 146.3, 142.3, 132.1, 121.0, 58.1, 20.9.

General Procedure of the Three-Component Synthesis of Tetrahydroquinolines: In a glovebox, aniline (0.4 mmol, 4.0 equiv), diiodomethane (0.5 mmol, 5.0 equiv) and alkene (0.1 mmol, 1.0 equiv) were dissolved in 0.5 mL MeCN in a 10 ml vial. The vial was capped and closed tightly. The solution was stirred at 80 °C (heating block) for 16 h. After being allowed to cool to room temperature, the reaction mixture was concentrated under reduced pressure. Purification by column chromatography over silica gel using ethyl acetate/petroleum ether (1/10) as eluent afforded the product.

1,4,6-Trimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5a). A colorless oil, 21.8 mg, 87% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28-7.21 (m, 2H), 7.19-7.10 (m, 3H), 6.95 (d, *J* = 8.2 Hz, 1H), 6.76 (s, 1H), 6.60 (d, *J* = 8.2 Hz, 1H), 3.12-3.05 (m, 1H), 2.98-2.90 (m, 1H), 2.86 (s, 3H), 2.23-2.14 (m, 4H), 2.06-1.97 (m, 1H), 1.72 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.8, 144.4, 129.7, 129.2, 128.0, 127.9, 127.4, 125.6, 125.2, 111.4, 47.9, 41.1, 39.7, 39.3, 29.9, 20.5. HRMS (ESI): calcd. for $C_{18}H_{22}N^+$ $(M+H)^+$: 252.1747, found: 252.1750.

6-Ethyl-1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5b). A colorless oil, 22.3 mg, 84% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28-7.21 (m, 2H), 7.19-7.10 (m, 3H), 6.99 (dd, *J* = 8.3, 2.0 Hz, 1H), 6.80 (d, *J* = 2.0 Hz, 1H), 6.84 (d, *J* = 8.3 Hz, 1H), 3.14-3.06 (m, 1H), 2.99-2.91 (m, 1H), 2.86 (s, 3H), 2.48 (q, *J* = 7.6 Hz, 2H), 2.24-2.16 (m, 1H), 2.07-1.98 (m, 1H), 1.72 (s, 3H), 1.13 (t, *J* = 7.6 Hz, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.7, 144.5, 131.9, 129.6, 128.1, 127.9, 127.4, 126.5, 125.6, 111.2, 47.8, 41.1, 39.6, 39.2, 29.9, 28.0, 16.0. HRMS (ESI): calcd. for $C_{19}H_{24}N^+$ $(M+H)^+$: 266.1903, found: 266.1907.

6-Isopropyl-1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5c). A colorless oil, 18.7 mg, 67% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28-7.20 (m, 2H), 7.19-7.09 (m, 3H), 7.02 (d, *J* = 8.4 Hz, 1H), 6.83 (s, 1H), 6.63 (d, *J* = 8.4 Hz, 1H), 3.14-3.05 (m, 1H), 2.98-2.89 (m, 1H), 2.86 (s, 3H), 2.80-2.68 (m. 1H), 2.24-2.15 (m, 1H), 2.08-1.98 (m, 1H), 1.73 (s, 3H), 1.15 (dd, *J* = 6.9, 1.8 Hz, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.8, 144.6, 136.5, 129.4, 127.9, 127.4, 126.9, 125.6, 124.9, 111.1, 47.8,

41.2, 39.6, 39.2, 33.2, 29.9, 24.3. HRMS (ESI): calcd. for $C_{20}H_{26}N^+$ $(M+H)^+$: 280.2060, found: 280.2060.

6-(Tert-butyl)-1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5d). A white solid, 19.6 mg, 67% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.27-7.20 (m, 2H), 7.19-7.10 (m, 4H), 7.00 (d, *J* = 2.4 Hz, 1H), 6.61 (d, *J* = 8.6 Hz, 1H), 3.13-3.04 (m, 1H), 2.97-2.88 (m, 1H), 2.86 (s, 3H), 2.25-2.16 (m, 1H), 2.08-1.98 (m, 1H), 1.73 (s, 3H), 1.22 (s, 9H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 150.7, 144.2, 138.6, 129.0, 127.9, 127.3, 125.7, 125.6, 123.9, 110.6, 47.8, 41.4, 39.4, 39.2, 33.9, 31.5, 29.9. HRMS (ESI): calcd. for $C_{21}H_{28}N^+$ $(M+H)^+$: 294.2216, found: 294.2219.

6-Benzyl-1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5e). A colorless oil, 28.1 mg, 86% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.28-7.19 (m, 4H), 7.18-7.08 (m, 6H), 6.91 (d, *J* = 8.3 Hz, 1H), 6.83 (s, 1H), 6.58 (d, *J* = 8.3 Hz, 1H), 3.81 (s, 2H), 3.14-3.04 (m, 1H), 2.98-2.89 (m, 1H), 2.83 (s, 3H), 2.24-2.14 (m, 1H), 2.07-1.96 (m, 1H), 1.69 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 150.6, 144.7, 142.3, 129.5, 129.3, 128.7, 128.4, 128.3, 127.9, 127.8, 127.3, 125.7, 125.6, 111.3, 47.7, 41.1, 39.5, 39.0, 29.8. HRMS (ESI): calcd. for $C_{24}H_{26}N^+$ $(M+H)^+$: 328.2060, found: 328.2061.

6-Methoxy-1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5f). A colorless oil, 24.6 mg, 92% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.25-7.18 (m, 2H), 7.16-7.08 (m, 3H), 6.72 (dd, *J* = 8.9, 2.9 Hz, 1H), 6.63 (d, *J* = 8.4 Hz, 1H), 6.54 (d, *J* = 2.9 Hz, 1H), 3.68 (s, 3H), 3.09-3.00 (m, 1H), 2.94-2.85 (m, 1H), 2.86 (s, 3H), 2.23-2.15 (m, 1H), 2.04-1.95 (m, 1H), 1.72 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 151.1, 150.5, 141.3, 131.4, 127.9, 127.3, 125.7, 115.2, 112.5, 112.3, 55.8, 48.0, 41.5, 40.1, 39.3, 30.0. HRMS (ESI): calcd. for $C_{18}H_{22}NO^+$ $(M+H)^+$: 268.1696, found: 268.1697.

1,4-Dimethyl-4,6-diphenyl-1,2,3,4-tetrahydroquinoline (5g). A colorless oil, 23.8 mg, 76% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.7 Hz, 2H), 7.41 (dd, *J* = 8.5, 2.1 Hz, 1H), 7.33 (t, *J* = 7.6 Hz, 2H), 7.29-7.13 (m, 7H), 6.73 (d, *J* = 8.5 Hz, 1H), 3.20-3.12 (m, 1H), 3.05-2.97 (m, 1H), 2.93 (s, 3H), 2.28-2.20 (m, 1H), 2.10-2.01 (m, 1H), 1.78 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 150.1, 145.6, 141.5, 129.6, 128.5, 128.0, 127.3, 127.1, 126.2, 126.0, 125.8, 125.7, 111.3, 47.6, 41.2, 39.3, 38.6, 29.8. HRMS (ESI): calcd. for $C_{23}H_{24}N^+$ $(M+H)^+$: 314.1903, found: 314.1902.

6-Fluoro-1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5h). A colorless oil, 15.3 mg, 60% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.38-7.31 (m, 2H), 7.29-7.18 (m, 3H), 6.97-6.89 (m, 1H), 6.78 (dd, *J* = 10.1, 3.0 Hz, 1H), 6.66 (dd, *J* = 9.0, 4.8 Hz, 1H), 3.23-3.15 (m, 1H), 3.08-3.00 (m, 1H), 2.86 (s, 3H), 2.35-2.27 (m, 1H), 2.14-2.04 (m, 1H), 1.70 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 155.1 (d, *J* = 245.4 Hz), 149.9, 142.9, 131.1 (d, *J* = 6.1 Hz), 128.1, 127.2, 125.9, 115.1 (d, *J* = 22.2 Hz), 113.6 (d, *J* = 22.2 Hz), 111.7 (d, *J* = 8.1 Hz), 47.7, 41.4, 39.8, 38.8, 29.7. HRMS (ESI): calcd. for $C_{17}H_{19}FN^+$ $(M+H)^+$: 256.1496, found: 256.1498.

6-Chloro-1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5i). A colorless oil, 22.0 mg, 81% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.27-7.21 (m, 2H), 7.19-7.12 (m, 1H), 7.11-7.02 (m, 3H), 6.90 (d, *J* = 2.4 Hz, 1H), 6.53 (d, *J* = 8.8 Hz, 1H), 3.14-3.06 (m, 1H), 2.99-2.90 (m, 1H), 2.84 (s, 3H), 2.22-2.14 (m, 1H), 2.01-1.92 (m, 1H), 1.68 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 149.5, 144.8, 131.0, 128.1, 128.0, 127.2, 127.1, 125.9, 120.7, 112.0, 47.5, 41.2, 39.3, 38.3, 29.6. HRMS (ESI): calcd. for $C_{17}H_{19}ClN^+$ $(M+H)^+$: 272.1201, found: 272.1204.

1,4-Dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline-6-carbonitrile (5j). A colorless oil, 13.1 mg, 50% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.39 (dd, *J* = 8.6, 2.0 Hz, 1H), 7.31-7.16 (m, 4H), 7.08-7.01 (m, 2H), 6.56 (d, *J* = 8.7 Hz, 1H), 3.28-3.19 (m, 1H), 3.11-3.02 (m, 1H), 2.95 (s, 3H), 2.27-2.19 (m, 1H), 2.00-1.91 (m, 1H), 1.70 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 148.8, 148.2, 132.0, 131.8, 129.2, 128.4, 126.9, 126.3, 121.1, 110.2, 96.8, 47.4, 40.8, 38.8, 37.0, 29.1. HRMS (ESI): calcd. for $C_{18}H_{19}N_2^+$ $(M+H)^+$: 263.1543, found: 263.1545.

1-(1,4-Dimethyl-4-phenyl-1,2,3,4-tetrahydroquinolin-6-yl)ethanone (5k). A colorless oil, 15.9 mg, 57% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.71 (dd, *J* = 8.7, 2.2 Hz, 1H), 7.63 (d, *J* = 2.2 Hz, 1H), 7.19-7.12 (m, 2H), 7.11-7.04 (m, 1H), 6.99-6.93 (m, 2H), 6.50 (d, *J* = 8.7 Hz, 1H), 3.14-3.07 (m, 1H), 3.00-2.90 (m, 1H), 2.87 (s, 3H), 2.37 (s, 3H), 2.18-2.09 (m, 1H), 1.97-1.86 (m, 1H), 1.67 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 196.4, 149.7, 148.8, 129.4, 128.7, 128.2, 127.8, 127.0, 126.0, 125.0, 109.3, 47.5, 40.8, 38.9, 37.3, 29.4, 25.9. HRMS (ESI): calcd. for $C_{19}H_{22}NO^+$ $(M+H)^+$: 280.1696, found: 280.1696.

Ethyl 1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline-6-carboxylate (5l). A colorless oil, 18.2 mg, 59% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.85 (dd, *J* = 8.7, 1.9 Hz, 1H), 7.77 (d, *J* = 1.9 Hz, 1H), 7.28-7.20 (m, 2H), 7.19-7.12 (m, 1H), 7.08-7.00 (m, 2H), 6.58 (d, *J* = 8.7 Hz, 1H), 4.28 (q, *J* = 7.1 Hz, 2H), 3.19-3.11 (m, 1H), 3.05-2.97 (m, 1H), 2.93 (s, 3H), 2.24-2.16 (m, 1H), 2.05-1.96 (m, 1H), 1.75 (s, 3H), 1.33 (t, *J* = 7.1 Hz, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 167.2, 149.4, 149.0, 129.8, 129.6, 128.2, 127.7, 127.0, 125.9, 116.9, 109.5, 60.0, 47.5, 40.8, 38.9, 37.5, 29.5, 14.5. HRMS (ESI): calcd. for $C_{20}H_{24}NO_2^+$ $(M+H)^+$: 310.1802, found: 310.1805.

1,4-Dimethyl-1-phenyl-1,2,3,4-tetrahydrobenzo[f]quinoline (5m). A white solid, 13.2 mg, 46% yield. ^1H NMR (400 MHz, C_6D_6) δ 7.64-7.56 (m, 2H), 7.50 (d, *J* = 8.5 Hz, 1H), 7.33-7.21 (m, 2H), 7.11-6.91 (m, 6H), 2.88-2.80 (m, 1H), 2.79-2.72 (m, 1H), 2.62 (s, 3H), 2.10-2.00 (m, 1H), 1.91-1.82 (m, 4H). $^{13}C\{^1H\}$ NMR (101 MHz, DMSO-d_6) δ 151.8, 145.4, 131.7, 128.4, 128.2, 128.2, 127.8, 126.1, 125.4, 125.2, 124.5, 120.4, 119.4, 115.8, 46.8, 43.9, 40.8, 40.4, 27.8. HRMS (ESI): calcd. for $C_{21}H_{22}N^+$ $(M+H)^+$: 288.1747, found: 288.1749.

7-(tert-Butyl)-1,4-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5n). A colorless oil, 20.5 mg, 70% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.28-7.21 (m, 2H), 7.18-7.10 (m, 3H), 6.88 (d, *J* = 7.7 Hz, 1H), 6.67-6.63 (m, 2H), 3.16-3.07 (m, 1H), 3.01-2.92 (m, 1H), 2.91 (s, 3H), 2.24-2.15 (m, 1H), 2.08-1.96 (m, 1H), 1.71 (s, 3H), 1.33 (s, 9H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 150.7, 150.1, 145.8, 128.0, 127.9, 127.4, 126.6, 125.6, 113.5, 108.3, 48.0, 40.8, 39.5, 39.0, 34.6, 31.5, 29.8. HRMS (ESI): calcd. for $C_{21}H_{28}N^+$ $(M+H)^+$: 294.2216, found: 294.2218.

1,4,5,7-Tetramethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5o). A white solid, 5.3 mg, 20% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.21-7.13 (m, 4H), 7.11-7.04 (m, 1H), 6.36 (s, 1H), 6.21 (s, 1H), 3.19-3.09 (m, 1H), 2.99-2.91 (m, 1H), 2.87 (s, 3H), 2.19 (s, 3H), 2.11-2.00 (m, 1H), 1.88-1.78 (m, 1H), 1.70 (s, 3H), 1.60 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 152.0, 147.7, 137.6, 136.3, 128.1, 126.3, 125.8, 125.2, 122.2, 110.9, 47.8, 44.0, 41.2, 40.9, 27.0, 22.3, 21.3. HRMS (ESI): calcd. for $C_{19}H_{24}N^+$ $(M+H)^+$: 266.1903, found: 266.1910.

4,6-Dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (5q). A pale yellow oil, 8.3 mg, 35% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.33-7.24 (m, 2H), 7.23-7.13 (m, 3H), 6.87 (d, *J* = 8.0 Hz, 1H), 6.81 (s, 1H), 6.49 (d, *J* = 8.0 Hz, 1H), 3.75 (s, 1H), 3.27-3.15 (m, 1H), 3.10-2.95 (m, 1H), 2.28-2.11 (m, 4H), 2.08-1.95 (m, 1H), 1.77 (s, 3H); $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 150.6, 142.0, 129.2, 128.1, 127.9, 127.8, 127.3, 126.0, 125.6, 114.4, 40.6, 39.3, 38.5, 29.4, 20.6. HRMS (ESI): calcd. for $C_{17}H_{20}N^+$ $(M+H)^+$: 238.1590, found: 238.1596.

1,4,6-Trimethyl-4-(p-tolyl)-1,2,3,4-tetrahydroquinoline (6b). A colorless oil, 25.2 mg, 95% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.11-7.02 (m, 4H), 6.96 (dd, *J* = 8.3, 1.6 Hz, 1H), 6.79 (d, *J* = 1.6 Hz, 1H), 6.61 (d, *J* = 8.3 Hz, 1H), 3.13-3.06 (m, 1H), 3.00-2.93 (m, 1H), 2.85 (s, 3H), 2.30 (s, 3H), 2.22-2.14 (m, 4H), 2.06-1.97 (m, 1H), 1.70 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 147.8, 144.3, 135.0, 129.9, 129.1, 128.6, 127.8, 127.2, 125.2, 111.3, 47.8, 40.7, 39.6, 39.3, 29.9, 20.9, 20.4. HRMS (ESI): calcd. for $C_{19}H_{24}N^+$ $(M+H)^+$: 266.1903, found: 266.1907.

4-(4-Chlorophenyl)-1,4,6-trimethyl-1,2,3,4-tetrahydroquinoline (6c). A colorless oil, 19.7 mg, 69% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25-7.19 (m, 2H), 7.11-7.06 (m, 2H), 6.97 (dd, *J* = 8.3, 1.8 Hz, 1H), 6.74 (d, *J* = 1.8 Hz, 1H), 6.61 (d, *J* = 8.3 Hz, 1H), 3.15-3.07 (m, 1H), 2.99-2.90 (m, 1H), 2.85 (s, 3H), 2.20-2.12 (m, 4H), 2.06-1.97 (m, 1H), 1.69 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 149.2, 144.2, 131.4, 129.1, 128.9, 128.8, 128.1, 128.0, 125.3, 111.4, 47.7, 40.8, 39.5, 39.1, 29.8, 20.4. HRMS (ESI): calcd. for $C_{18}H_{21}ClN^+$ $(M+H)^+$: 286.1357, found: 286.1359.

1,6-Dimethyl-4-phenyl-4-propyl-1,2,3,4-tetrahydroquinoline (6d). A colorless oil, 16.2 mg, 58% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30-7.22 (m, 2H), 7.20-7.10 (m, 3H), 6.97 (d, *J* = 8.2 Hz, 1H), 6.80 (s, 1H), 6.61 (d, *J* = 8.2 Hz, 1H), 3.10-3.02 (m, 1H), 2.99-2.90 (m, 1H), 2.84 (s, 3H), 2.29-2.19 (m, 4H), 2.15-2.03 (m, 3H), 1.40-1.25 (m, 2H), 0.94 (t, *J* = 7.3 Hz, 3H); ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.6, 145.1, 129.4, 127.9, 127.7, 127.6, 127.0, 125.5, 124.8, 111.5, 47.6, 44.8, 43.5, 39.6, 34.8, 20.6, 17.9, 14.8. HRMS (ESI): calcd. for $C_{20}H_{26}N^+$ $(M+H)^+$: 280.2060, found: 280.2059.

4-Benzyl-1,6-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (6e). A colorless oil, 18.3 mg, 56% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.18-7.02 (m, 7H), 7.01-6.95 (m, 2H), 6.94-6.87 (m, 1H), 6.81-6.71 (m, 2H), 6.45 (d, *J* = 8.3 Hz, 1H), 3.39-3.27 (m, 2H), 2.85-2.73 (m, 2H), 2.60 (s, 3H), 2.22 (s, 3H), 2.19-2.11 (m, 1H), 2.07-1.95 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 148.0, 144.8, 138.3, 131.2, 129.3, 128.0, 127.8, 127.5, 127.3, 126.1, 125.8, 124.4, 119.1, 111.6, 47.9, 47.5, 45.2, 39.3, 33.4, 20.7. HRMS (ESI): calcd. for $C_{24}H_{26}N^+$ $(M+H)^+$: 328.2060, found: 328.2062.

1',6'-Dimethyl-2,2',3,3'-tetrahydro-1'H-spiro[indene-1,4'-quinoline] (6f). A colorless oil, 13.9 mg, 53% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32-7.12 (m, 3H), 6.97 (d, *J* = 7.2 Hz, 1H), 6.90 (d, *J* = 7.9 Hz, 1H), 6.60 (d, *J* = 8.3 Hz, 1H), 6.49 (s, 1H), 3.34-3.17 (m, 2H), 2.98 (t, *J* = 7.2 Hz, 2H), 2.93 (s, 3H), 2.31-2.17 (m, 2H), 2.14-2.04 (m, 4H), 1.93-1.86 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.7, 143.4, 142.7, 128.9, 128.1, 126.8, 125.7, 125.6, 124.6, 123.3, 110.3, 49.6, 47.8, 42.7, 38.8, 33.9, 28.7, 19.3. HRMS (ESI): calcd. for $C_{19}H_{22}N^+$ $(M+H)^+$: 264.1747, found: 264.1749.

1',6'-Dimethyl-2',3,3',4-tetrahydro-1'H,2H-spiro[naphthalene-1,4'-quinoline] (6g). A colorless oil, 15.0 mg, 54% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16-7.00 (m, 3H), 7.68-7.64 (m, 2H), 6.59 (d, *J* = 8.3 Hz, 1H), 6.45 (s, 1H), 3.38-3.26 (m, 1H), 3.18-3.09 (m, 1H), 3.02-2.78 (m, 5H), 2.33-2.20 (m, 1H), 2.14-1.94 (m, 6H), 1.92-1.76 (m, 2H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 145.6, 144.6, 137.5, 132.6, 130.6, 130.0, 128.6, 127.5, 125.9, 125.5, 125.3, 111.2, 47.8, 41.0, 39.7, 39.1, 37.6, 30.4, 20.4, 18.9. HRMS (ESI): calcd. for $C_{20}H_{24}N^+$ $(M+H)^+$: 278.1903, found: 278.1906.

1,4,6-Trimethyl-4-(naphthalen-1-yl)-1,2,3,4-tetrahydroquinoline (6h). A white solid, 13.5 mg, 45% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84-7.68 (m, 4H), 7.47 (t, *J* = 7.8 Hz, 1H), 7.37-7.29 (m, 1H), 7.24-7.17 (m, 1H), 6.85 (dd, *J* = 8.2, 1.8 Hz, 1H), 6.67 (d, *J* = 8.2 Hz, 1H), 6.36 (s, 1H), 3.54-3.42 (m, 1H), 3.25-3.15 (m, 1H), 3.08-2.96 (m, 4H), 1.93 (s, 3H), 1.83 (s, 3H), 1.74-1.65 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 145.2, 143.0, 134.8, 132.2, 130.5, 128.7, 128.6, 127.6, 127.0, 126.0, 124.6, 124.5, 124.4, 124.3, 111.3, 48.59, 40.8, 39.9, 36.5, 33.2, 20.0. HRMS (ESI): calcd. for $C_{22}H_{24}N^+$ $(M+H)^+$: 302.1903, found: 302.1906.

1,4,6-Trimethyl-4-(naphthalen-2-yl)-1,2,3,4-tetrahydroquinoline (6i). A colorless oil, 20.8 mg, 69% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81-7.66 (m, 3H), 7.57 (s, 1H), 7.47-7.35 (m, 2H), 7.33-7.25 (m, 1H), 7.00-6.90 (m, 1H), 6.71 (s, 1H), 6.65-6.56 (m, 1H), 3.21-3.09 (m, 1H), 3.04-2.94 (m, 1H), 2.87 (s, 3H), 2.40-2.27 (m, 1H), 2.14 (s, 3H), 2.05-1.94 (m, 1H), 1.80 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 148.2, 144.4, 133.1, 131.8, 129.9, 129.5, 128.0, 127.9, 127.6, 127.4, 126.4, 125.8, 125.7, 125.5, 125.4, 111.5, 48.0, 41.3, 39.7, 39.1, 30.0, 20.5. HRMS (ESI): calcd. for $C_{22}H_{24}N^+$ $(M+H)^+$: 302.1903, found: 302.1902.

1,4,6-Trimethyl-4-(thiophen-2-yl)-1,2,3,4-tetrahydroquinoline (6j). A colorless oil, 14.6 mg, 57% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22-7.12 (m, 1H), 7.04-6.96 (m, 2H), 6.94-6.87 (m, 1H), 6.68-6.58 (m, 2H), 3.21-3.07 (m, 2H), 2.91 (s, 3H), 2.31-2.09 (m, 5H), 1.82 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 156.8, 143.6, 128.7, 128.6, 128.3, 126.2, 125.1, 124.5, 123.3, 111.4, 47.7, 39.9, 39.6, 39.5, 31.3, 20.4. HRMS (ESI): calcd. for $C_{16}H_{20}NS^+$ $(M+H)^+$: 258.1311, found: 258.1313.

1,4,6-Trimethyl-4-(thiophen-3-yl)-1,2,3,4-tetrahydroquinoline (6k). A colorless oil, 15.7 mg, 61% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (dd, *J* = 5.0, 3.0 Hz, 1H), 6.94 (dd, *J* = 8.3, 1.6 Hz, 1H), 6.89 (dd, *J* = 5.0, 1.3 Hz, 1H), 6.80 (d, *J* = 1.6 Hz, 1H), 6.75 (dd, *J* = 3.0, 1.3 Hz, 1H), 6.59 (d, *J* = 8.3 Hz, 1H), 3.19-3.10 (m, 1H), 3.06-2.97 (m, 1H), 2.88 (s, 3H), 3.25-2.13 (m, 4H), 2.05-1.95 (m, 1H), 1.70 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.4, 143.8, 129.5, 128.7, 128.0, 126.9, 125.2, 121.1, 111.4, 47.9, 39.7, 39.1, 38.4, 30.0, 20.5. HRMS (ESI): calcd. for $C_{16}H_{20}NS^+$ $(M+H)^+$: 258.1311, found: 258.1314.

4-(Furan-2-yl)-1,4,6-trimethyl-1,2,3,4-tetrahydroquinoline (6l). A colorless oil, 9.9 mg, 41% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (s, 1H), 6.94 (d, *J* = 8.2 Hz, 1H), 6.82 (s, 1H), 6.59 (d, *J* = 8.3 Hz, 1H), 6.27 (dd, *J* = 2.8, 1.8 Hz, 1H), 5.90 (d, *J* = 2.9 Hz, 1H), 3.24-3.04 (m, 2H), 2.89 (s, 3H), 2.48-2.37 (m, 1H), 2.20 (s, 3H), 1.99-1.87 (m, 1H), 1.66 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 162.1, 143.9, 141.1, 128.4, 128.2, 127.3, 125.2, 111.6, 109.6, 106.2, 47.8, 39.7, 38.1, 35.4, 28.1, 20.4. HRMS (ESI): calcd. for $C_{16}H_{20}NO^+$ $(M+H)^+$: 242.1539, found: 242.1543.

1,6-Dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (6m). A colorless oil, 12.6 mg, 53% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33-7.27 (m, 2H), 7.25-7.18 (m, 1H), 7.16-7.08 (m, 2H), 6.94 (dd, *J* = 8.3, 2.1 Hz, 1H), 6.63 (d, *J* = 8.3 Hz, 1H), 6.58 (d, *J* = 1.6 Hz, 1H), 4.12 (t, *J* = 6.2 Hz, 1H), 3.20-3.08 (m, 2H), 2.92 (s, 3H), 2.32-2.22 (m, 1H), 2.16-2.03 (m, 4H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 146.9, 144.9, 130.6, 128.7, 128.3, 128.1, 126.1, 125.5, 124.9, 111.5, 48.6, 43.4, 39.6, 31.5, 20.3. HRMS (ESI): calcd. for $C_{17}H_{20}N^+$ $(M+H)^+$: 238.1590, found: 238.1595.

1,6-Dimethyl-4-(p-tolyl)-1,2,3,4-tetrahydroquinoline (6n). A colorless oil, 19.3 mg, 77% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.15-7.08 (m, 2H), 7.04-6.99 (m, 2H), 6.96-6.91 (m, 1H), 6.66-6.57 (m, 2H), 4.08 (t, *J* = 6.2 Hz, 1H), 3.20-3.07 (m, 2H), 2.92 (s, 3H), 2.34 (s, 3H), 2.30-2.20 (m, 1H), 2.13 (s, 3H), 2.10-2.01 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 144.9, 144.0, 135.6, 130.6, 129.0, 128.6, 128.0, 125.5, 125.1, 111.4, 48.6, 43.0, 39.6, 31.6, 21.0, 20.3. HRMS (ESI): calcd. for $C_{18}H_{22}N^+$ $(M+H)^+$: 252.1747, found: 252.1749.

4-(4-Fluorophenyl)-1,6-dimethyl-1,2,3,4-tetrahydroquinoline (6o). A colorless oil, 13.0 mg, 51% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12-7.03 (m, 2H), 7.02-6.91 (m, 3H), 6.62 (d, *J* = 8.3 Hz, 1H), 6.55 (s, 1H), 4.10 (t, *J* = 6.2 Hz, 1H), 3.21-3.05 (m, 2H), 2.91 (s, 3H), 2.31-2.19 (m, 1H), 2.14 (s, 3H), 2.08-1.98 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 161.3 (d, *J* = 245.4 Hz), 144.8, 142.5 (d, *J* = 3.0 Hz), 130.5, 130.0 (d, *J* = 8.1 Hz), 128.2, 125.5, 124.7, 115.0 (d, *J* = 21.2 Hz), 111.5, 48.5, 42.7, 39.5, 31.5, 20.2. HRMS (ESI): calcd. for $C_{17}H_{19}FN^+$ $(M+H)^+$: 256.1496, found: 256.1495.

1,6-Dimethyl-4,4-diphenyl-1,2,3,4-tetrahydroquinoline (6p). A white solid, 17.2 mg, 55% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31-7.17 (m, 6H), 7.11-7.01 (m, 4H), 6.94 (dd, *J* = 8.2, 1.6 Hz, 1H), 6.55 (d, *J* = 8.2 Hz, 1H), 6.26 (d, *J* = 1.6 Hz, 1H), 3.05-2.95 (m, 2H), 2.81 (s, 3H), 2.72-2.66 (m, 2H), 2.07 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 147.7, 144.0, 131.3, 129.4, 128.3, 128.2, 127.9, 126.1, 124.1, 110.8, 51.7, 47.7, 39.0, 36.0, 20.5. HRMS (ESI): calcd. for $C_{23}H_{24}N^+$ $(M+H)^+$: 314.1903, found: 314.1906.

4,4-Bis(4-methoxyphenyl)-1,6-dimethyl-1,2,3,4-tetrahydroquinoline (6q). A white solid, 23.1 mg, 62% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.00-6.91 (m, 5H), 6.84-6.77 (m, 4H), 6.55 (d, *J* = 8.2 Hz, 1H), 6.28 (d, *J* = 1.8 Hz, 1H), 3.81 (s, 6H), 3.05-2.97 (m, 2H), 2.82 (s, 3H), 2.66-2.59 (m, 2H), 2.09 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 157.7, 143.9, 140.1, 131.1, 130.3, 128.8, 128.1, 124.0, 113.1, 110.7, 55.2, 47.7, 39.0, 36.1, 20.5. HRMS (ESI): calcd. for $C_{25}H_{28}NO_2^+$ $(M+H)^+$: 374.2115, found: 374.2119.

4,4-Bis(4-fluorophenyl)-1,6-dimethyl-1,2,3,4-tetrahydroquinoline (6r). A white solid, 16.1 mg, 46% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.07-6.91 (m, 9H), 6.56 (d, *J* = 8.3 Hz, 1H), 6.22 (d, *J* = 1.6 Hz, 1H), 3.04-2.96 (m, 2H), 2.82 (s, 3H), 2.67-2.60 (m, 2H), 2.09 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 161.3 (d, *J* = 246.4 Hz), 143.8, 143.1 (d, *J* = 3.0 Hz), 130.8, 130.8 (d, *J* = 8.1 Hz), 128.5, 127.9, 124.2, 114.7 (d, *J* = 21.2 Hz), 110.9, 50.7, 47.5, 38.9, 36.2, 20.5. HRMS (ESI): calcd. for $C_{23}H_{22}F_2N^+$ $(M+H)^+$: 350.1715, found: 350.1716.

1,6-Dimethyl-4-((trimethylsilyl)methyl)-1,2,3,4-tetrahydroquinoline (6s). A colorless oil, 7.9 mg, 32% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.90-6.81 (m, 2H), 6.53 (d, *J* = 8.2 Hz, 1H), 3.28-3.19 (m, 1H), 3.14-3.06 (m, 1H), 2.95-2.84 (m, 4H), 2.24 (s, 3H), 2.09-1.97 (m, 1H), 1.76-1.67 (m, 1H), 1.05-0.97 (m, 1H), 0.92-0.81(m, 1H), 0.08 (s, 9H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.7, 130.1, 128.7, 127.2, 125.3, 111.2, 47.9, 39.3, 32.5, 29.5, 25.7, 20.3, -0.6. HRMS (ESI): calcd. for $C_{15}H_{26}NSi^+$ $(M+H)^+$: 248.1829, found: 248.1833.

1',6'-Dimethyl-2',3'-dihydro-1'H-spiro[cycloheptane-1,4'-quinoline] (6t). A colorless oil, 9.7 mg, 40% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.09 (s, 1H), 6.88 (d, *J* = 8.0 Hz, 1H), 6.50 (d, *J* = 8.2 Hz, 1H), 3.16 (t, *J* = 5.9 Hz, 2H), 2.86 (s, 3H), 2.24 (s, 3H), 1.98-1.89 (m, 2H), 1.82 (t, *J* = 5.9 Hz, 2H), 1.71-1.49 (m, 10H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.0, 133.8, 127.0, 126.5, 124.9, 111.1, 47.5, 41.3, 39.5, 37.9, 34.1, 30.2, 23.4, 20.6. HRMS (ESI): calcd. for $C_{17}H_{26}N^+$ $(M+H)^+$: 244.2060, found: 244.2059.

1',6'-Dimethyl-2',3'-dihydro-1'H-spiro[cyclooctane-1,4'-quinoline] (6u). A colorless oil, 11.0 mg, 43% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.04 (s, 1H), 6.89 (d, *J* = 8.3 Hz, 1H), 6.50 (d, *J* = 8.3 Hz, 1H), 3.22 (t, *J* = 6.2 Hz, 2H), 2.88 (s, 3H), 2.25 (s, 3H), 2.12-2.00 (m, 2H), 1.78 (t, *J* = 6.4 Hz, 2H), 1.73-1.46 (m, 12H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 141.3, 130.9, 125.6, 125.0, 122.8, 109.3, 45.9, 37.7, 35.8, 33.9, 32.7, 27.5, 24.1, 21.5, 19.2. HRMS (ESI): calcd. for $C_{18}H_{26}N^+$ $(M-H)^+$: 256.2060, found: 256.2060.

4-Butyl-1,4,6-trimethyl-1,2,3,4-tetrahydroquinoline (6v). A colorless oil, 7.9 mg, 34% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.94 (s, 1H), 6.91-6.86 (m, 1H), 6.54 (d, *J* = 8.2 Hz, 1H), 3.22-3.08 (m, 2H), 2.86 (s, 3H), 2.25 (s, 3H), 1.98-1.88 (m, 1H), 1.71-1.48 (m, 3H), 1.32-1.15 (m, 7H), 0.92-0.85 (m, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.9, 131.4, 127.1, 127.0, 125.2, 111.4, 47.9, 42.3, 39.7, 34.9, 34.2, 29.4, 26.1, 23.5, 20.6, 14.1. HRMS (ESI): calcd. for $C_{16}H_{26}N^+$ $(M+H)^+$: 232.2060, found: 232.2064.

Gram-Scale Synthesis of 5a

In a glovebox, aniline **1a** (5.41 g, 40 mmol), diiodomethane (13.39 g, 50 mmol) and alkene **4a** (1.18 g, 10 mmol) were dissolved in 50 mL MeCN in a 150 mL heavy-wall glass tube. The tube was sealed. The solution was stirred at 80 °C (oil bath) for 16 h. After being allowed to cool to room temperature, the reaction mixture was concentrated under reduced pressure. Purification by column chromatography over silica gel using ethyl acetate/petroleum ether (1/10) as eluent afforded product **5a** as a colorless oil (1.68 g, 67% yield).

Control Experiments

Scheme 3a: 1a (54.1 mg, 0.4 mmol), CD_2I_2 (134.9 mg, 0.5 mmol) and **4a** (11.8 mg, 0.1 mmol) in 0.5 mL MeCN were stirred at 80 °C (heating block) for 16 h. After being allowed to cool to the room temperature, the reaction mixture was concentrated under reduced pressure. Purification by column chromatography over silica gel afforded compound **5a-D** as a colorless oil (22.3 mg, 88% yield).

5a-D: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20-7.12 (m, 2H), 7.10-7.02 (m, 3H), 6.86 (dd, *J* = 8.2, 1.8 Hz, 1H), 6.69 (d, *J* = 1.8 Hz, 1H), 6.51 (d, *J* = 8.2 Hz, 1H), 2.77 (s, 3H), 2.14-2.04 (m, 4H), 1.91 (d, *J* = 13.2 Hz, 1H), 1.63 (s, 3H).

Scheme 3b: 1a-D (56.5 mg, 0.4 mmol), CH_2I_2 (133.9 mg, 0.5 mmol) and **4a** (11.8 mg, 0.1 mmol) in 0.5 mL MeCN were stirred at 80 °C (heating block) for 16 h. After being allowed to cool to the room temperature, the reaction mixture was concentrated under reduced pressure. Purification by column chromatography over silica gel afforded compound **5a-D′** as a colorless oil (20.9 mg, 82% yield).

5a-D′: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33-7.26 (m, 2H), 7.24-7.14 (m, 3H), 6.99 (dd, *J* = 8.3, 1.6 Hz, 1H), 6.80 (d, *J* = 1.6 Hz, 1H), 6.63 (d, *J* = 8.3 Hz, 1H), 3.18-3.07 (m, 1H), 3.03-2.93 (m, 1H), 2.29-2.17 (m, 4H), 2.10-2.00 (m, 1H), 1.76 (s, 3H).

Scheme 3c: **1a-D'** (55.3 mg, 0.4 mmol), CH_2I_2 (133.9 mg, 0.5 mmol) and **4a** (11.8 mg, 0.1 mmol) in 0.5 mL MeCN were stirred at 80 °C (heating block) for 16 h. After being allowed to cool to the room temperature, the reaction mixture was concentrated under reduced pressure. Purification by column chromatography over silica gel afforded the mixture of compounds **5a** (7.5 mg, 30% yield) and **5a-D′** (8.4 mg, 33% yield) as a colorless oil.

Scheme 3d: Aniline **7** (59.6 mg, 0.4 mmol), CH_2I_2 (133.9 mg, 0.5 mmol) and **4a** (11.8 mg, 0.1 mmol) in 0.5 mL MeCN was stirred at 80 °C (heating block) for 16 h. After being allowed to cool to the room temperature, the reaction mixture was concentrated under reduced pressure. Purification by column chromatography over silica gel afforded products **5a** (10.3 mg, 41% yield) and **8** (9.8 mg, 37% yield) as colorless oils.

1-Ethyl-4,6-dimethyl-4-phenyl-1,2,3,4-tetrahydroquinoline (8). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.21 (m, 2H), 7.19-7.08 (m, 3H), 6.93 (d, *J* = 8.3 Hz, 1H), 6.80 (d, *J* = 1.5 Hz, 1H), 6.61 (d, *J* = 8.2 Hz, 1H), 3.43-3.21 (m, 2H), 3.14-3.04 (m, 1H), 2.97-2.85 (m, 1H), 2.21-2.10 (m, 4H), 2.05-1.95 (m, 1H), 1.71 (s, 3H), 1.08 (t, *J* = 7.0 Hz, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 149.5, 141.4, 128.1, 126.8, 126.3, 124.5, 123.3, 110.1, 44.5, 43.5, 39.9, 37.8, 28.6,

19.4, 9.4. HRMS (ESI): calcd. for $C_{19}H_{24}N^+$ $(M+H)^+$: 266.1903, found: 266.1906.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website.

Reaction optimization, crystallography methods and NMR spectra (PDF) and X-ray crystallography data (CIF).

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REFERENCES

(1) For recent reviews, see: (a) Girard, S. A.; Knauber, T.; Li, C.-J. The Cross-Dehydrogenative Coupling of C_{sp^3}–H Bonds: A Versatile Strategy for C–C Bond Formations. *Angew. Chem., Int. Ed.* **2014**, *53,* 74–100. (b) Nakamura, H. C(sp3)–H versus C(sp3)–C(sp) in Activation of Propargylic Amines under Transition-Metal Catalysis. *Synlett*. **2015**, *26*, 1649–1664. (c) Beatty, J. W.; Stephenson, C. R. Amine Functionalization via Oxidative Photoredox Catalysis: Methodology Development and Complex Molecule Synthesis. *Acc. Chem. Res*. **2015**, *48*, 1474–1484. (d) Xie, J.; Jin, H.; Hashmi, A. S. K. The recent achievements of redox-neutral radical C–C cross-coupling enabled by visible-light. *Chem. Soc. Rev.* **2017**, *46*, 5193–5203.

(2) For selected reports, see: (a) Shono, T.; Matsumura, Y.; Inoue, K.; Ohmizu, H.; Kashimura, S. Electroorganic chemistry. 62. Reaction of iminium ion with nucleophile: a versatile synthesis of tetrahydroquinolines and julolidines. *J. Am. Chem. Soc.* **1982**, *104*, 5753−5757. (b) Beifuss, U.; Ledderhose, S. Intermolecular polar [4π+ 2π] cycloadditions of cationic 2-azabutadienes from thiomethylamines: a new and efficient method for the regio- and diastereo-selective synthesis of 1,2,3,4-tetrahydroquinolines. *J. Am. Soc. Chem. Commun.* **1995**, 2137−2138. (c) Beifuss, U.; Ledderhose, S.; Taraschewski, M.; Tonko, C. Cationic 2-Azabutadienes from α-Arylaminosulfones and α-Arylaminonitriles: Intermolecular Polar [4π+2π]-Cycloadditions for the Regio- and Diastereoselective Synthesis of 1,2,3,4-Tetrahydroquinolines. *Synlett*. **1996**, 34−36. (d) Ha, H.-J.; Choi, C,-J.; Ahn, Y.-G.; Yun, H.; Dong, Y.; Lee, W. K. Cycloaddition of Lewis Acid-Induced N-Methyleneanilines as Azadienes to 1,2-Bistrimethylsilyloxycyclobutene and Oxidative Ring Expansion to 1,2,4,5-Tetrahydro-1-benzazocine-3,6-diones. *J. Org. Chem.* **2000**, *65*, 8384−8386. (e) Garve, L. K. B.; Jones, P. G.; Werz, D. B. Ring-Opening 1-Amino-3-aminomethylation of Donor-Acceptor Cyclopropanes via 1,3-Diazepanes. *Angew. Chem., Int. Ed.* **2017**, *56*, 9226−9230. (f) Zhu, C.; Xu, G.; Sun, J. Gold-Catalyzed Formal [4+1]/[4+3] Cycloadditions of Diazo Esters with Triazines. *Angew. Chem., Int. Ed.* **2016**, *55*, 11867−11871.

(3) For selected reports, see: (a) Li, Z.; Li C.-J. CuBr-Catalyzed Efficient Alkynylation of sp^3 C−H Bonds Adjacent to a Nitrogen Atom. *J. Am. Chem. Soc.* **2004**, *126,* 11810−11811. (b) Murahashi, S.; Nakae, T.; Terai, H.; Komiya, N. Ruthenium-Catalyzed Oxidative Cyanation of Tertiary Amines with Molecular Oxygen or Hydrogen Peroxide and Sodium Cyanide: sp^3 C−H Bond Activation and Carbon−Carbon Bond Formation. *J. Am. Chem. Soc.* **2008**, *130,* 11005−11012. (c) Boess, E.; Schmitz, C.; Klussmann, M. A Comparative Mechanistic Study of Cu-Catalyzed Oxidative Coupling Reactions with *N*-Phenyltetrahydroisoquinoline. *J. Am. Chem. Soc.* **2012**, *134,* 5317−5325. (d) Ratnikov, M. O.; Doyle, M. P. Mechanistic Investigation of Oxidative Mannich Reaction with tert-Butyl Hydroperoxide. The Role of Transition Metal Salt. *J. Am. Chem. Soc.* **2013**, *135,* 1549−1557.

(4) For selected reports, see: (a) Fava, E.; Millet, A.; Nakajima, M.; Loescher, S.; Rueping, M. Reductive Umpolung of Carbonyl Derivatives with Visible - Light Photoredox Catalysis: Direct Access to Vicinal Diamines and Amino Alcohols via α-Amino Radicals and Ketyl Radicals. *Angew. Chem., Int. Ed.* **2016**, *55*, 6776–6779. (b) Zhu, S.; Das, A.; Bui, L.; Zhou, H.; Curran, D. P.; Rueping, M. Oxygen Switch in Visible-Light Photoredox Catalysis: Radical Additions and Cyclizations and Unexpected C–C-Bond Cleavage Reactions. *J. Am. Chem. Soc.* **2013**, *135*, 1823−1829. (c) Rueping, M.; Vila, C. Visible Light Photoredox-Catalyzed Multicomponent Reactions. *Org. Lett.* **2013**, *15*, 2092−2095. (d) Murphy, J. J.; Bastida, D.; Paria, S.; Fagnoni, M.; Melchiorre, P. Asymmetric catalytic formation of quaternary carbons by iminium ion trapping of radicals. *Nature* **2016**, *532*, 218−222. (e) Condie, A. G.; González-Gómez, J. C.; Stephenson, C. R. Visible-Light Photoredox Catalysis: Aza-Henry Reactions via C−H Functionalization. *J. Am. Chem. Soc.* **2010**, *132*, 1464−1465. (f) Tucker, J. W.; Zhang, Y.; Jamison, T. F.; Stephenson, C. R. J. Visible-Light Photoredox Catalysis in Flow. *Angew. Chem., Int. Ed.* **2012**, *51*, 4144−4147.

(5) For oxidations without a catalyst, see: (a) Magnus, P.; Lacour, J.; Weber, W. Direct *N*-alkyl azidonation of *N,N*-dialkylarylamines with the iodosylbenzene/trimethylsilyl azide reagent combination. *J. Am. Chem. Soc.* **1993**, *115*, 9347−9348. (b) Bosmani, A.; Pujari, S. A.; Besnard, C.; Guénée, L.; Poblador-Bahamonde, A. I.; Lacour, J. Stereoselective and Enantiospecific Mono- and Bis-C−H Azidation of Tröger Bases: Insight on Bridgehead Iminium Intermediates and Application to Anion-Binding Catalysis. *Chem. Eur. J.* **2017**, *23*, 8678−8684.

(6) Recently, an alternative method using $B(C_6F_5)_3$ as the catalyst for hydride abstraction has emerged. For relevant studies, see: (a) Maier, A. F. G.; Tussing, S.; Schneider, T.; Flörke U.; Qu, Z.-W.; Grimme, S. Paradies, J. Frustrated Lewis Pair Catalyzed Dehydrogenative Oxidation of Indolines and Other Heterocycles. *Angew. Chem., Int. Ed.* **2016**, *55*, 12219−12223. (b) Maier, A. F. G.; Tussing, S.; Zhu, H.; Wicker, G.; Tzvetkova, P.; Flörke U.; Daniliuc, C. G.; Grimme, S.; Paradies, J. Borane-Catalyzed Synthesis of Quinolines Bearing Tetrasubstituted Stereocenters by Hydride Abstraction-Induced Electrocyclization. *Chem. Eur. J.* **2018**, *24*, 16287−16291. (c) Kojima, C.; Kanai, M. Tris(pentafluorophenyl)borane-Catalyzed Acceptorless Dehydrogenation of N-Heterocycles. *Angew. Chem., Int. Ed.* **2016**, *55*, 12224−12227. (d) Tian, J.-J.; Zeng N.-N.; Liu, N.; Tu, X.-S.; Wang, X.-C. Intramolecular Cyclizations of Vinyl-Substituted *N,N*-Dialkyl Arylamines Enabled by Borane-Assisted Hydride Transfer. *ACS Catal.* **2019**, *9*, 295−300. (e) Shang, M.; Chan J. Z.; Cao, M.; Chang, Y.; Wang, Q.; Cook, B.; Torker, S.; Wasa, M. C–H Functionalization of Amines via Alkene-Derived Nucleophiles through Cooperative Action of Chiral and Achiral Lewis Acid Catalysts: Applications in Enantioselective Synthesis. *J. Am. Chem. Soc.* **2018**, *140*, 10593−10601. (f) Chan, J. Z.; Chang, Y.; Wasa, M. $B(C_6F_5)_3$-Catalyzed C–H Alkylation of *N*-Alkylamines Using Silicon Enolates without External Oxidant. *Org. Lett.* **2019**, *21*, 984−988.

(7) Schreiber, J.; Maag, H.; Hashimoto, N.; Eschenmoser, A. Dimethyl(methylene)ammonium Iodide. *Angew. Chem., Int. Ed.* **1971**, *10*, 330−331.

(8) For selected recent examples for applications of Eschenmoser's salt in total syntheses of natural products, see: (a) Kumar, N. N. B.; Mukhina, O. A.; Kutateladze, A. G. Photoassisted Synthesis of Enantiopure Alkaloid Mimics Possessing Unprecedented Polyheterocyclic Cores. *J. Am. Chem. Soc.* **2013**, *135*, 9608−9611. (b) Xiong, X.; Li, Y.; Wan, M.; Deng, J.; Wu, S.; Shao, H.; Li, A. Synthesis of the 6,6,5,7-tetracyclic core of daphnilongeranin B. *Chem. Commun.* **2014**, *50*, 5294−5297. (c) Wojtas, K. P.; Riedrich, M.; Lu, J.-Y.; Winter, P.; Winlker, T.; Walter, S.; Arndt, H.-D. Total Synthesis of Nosiheptide. *Angew. Chem., Int. Ed.* **2016**, *55*, 9772−9776. (d) Firth, J. D.; Canipa, S. J.; Ferris, l.; O'Brien, P. Gram-Scale Synthesis of the (−)-Sparteine Surrogate and (−)-Sparteine. *Angew. Chem., Int. Ed.* **2018**, *57*, 223−226. (e) Ma, K.; Yin, X.; Dai, M. Total Syntheses of Bisdehydroneostemoninine and Bisdehydrostemoninine by Catalytic Carbonylative Spirolactonization. *Angew. Chem., Int. Ed.* **2018**, *57*, 15209−15212.

(9) For selected reports on trialkylamine-derived analogs of Eschenmoser' salt and their reactions, see: (a) Fletcher, M. O.; Zhang, L.;

Vu, Q.; Dolbier, W. R. Kinetic evidence for a novel, Grob-like substitution/fragmentation mechanism for the reaction of nucleophiles with trialkylammoniomethyl halides. *J. Chem. Soc., Perkin Trans. 2,* **1999**, 1187–1192. (b) Chen, X.; Chen. T.; Zhou, Y.; Au, C.-T.; Han, L.-B.; Yin, S.-F. Efficient synthesis of propargylamines from terminal alkynes, dichloromethane and tertiary amines over silver catalysts. *Org. Biomol. Chem.* **2014**, *12*, 247–250. (c) Zhao, Y.; Chen, X.; Chen, T.; Zhou, Y.; Yin, S.-F.; Han, L.-B. Catalyst-Free and Selective C–N Bond Functionalization: Stereospecific Three-Component Coupling of Amines, Dichloromethane, and >P(O)H Species Affording α-Aminophosphorus Compounds. *J. Org. Chem.* **2015**, *80*, 62−69.

(10) Almarzoqi, B.; George, A. V.; Isaacs, N. S. The Quarternisation of Tertiary Amines with Dihalomethane. *Tetrahedron* **1986**, *42*, 601−607.

(11) (a) Tröger, J. Ueber einige mittelst nascirenden Formaldehydes entstehende Basen. *J. Prakt. Chem.* **1887**, *36*, 225−245. (b) Rúnarsson, O. V.; Artacho, J.; Wärnmark, K. The 125th Anniversary of the Tröger's Base Molecule: Synthesis and Applications of Tröger's Base Analogues. *Eur. J. Org. Chem.* **2012**, 7015−7041. (c) Bosmani, A.; Guarnieri-Ibáñez, A.; Lacour, J. Configurational Lability of Imino-Substituted Ethano Tröger Bases. Insight on the Racemization Mechanism. *Helv. Chim. Acta* **2019**, *102*, e1900021.

(12) For selected reviews of Povarov reactions, see: (a) Kouznetsov, V. V. Recent synthetic developments in a powerful imino Diels–Alder reaction (Povarov reaction): application to the synthesis of N-polyheterocycles and related alkaloids. *Tetrahedron* **2009**, *65*, 2721−2750. (b) Jiang, X.; Wang, R. Recent Developments in Catalytic Asymmetric Inverse-Electron-Demand Diels–Alder Reaction. *Chem. Rev.* **2013**, *113*, 5515−5546.

(13) For selected recent reports on Povarov reactions, see: (a) Roy, S.; Reiser, O. A Catalytic Multicomponent Approach for the Stereoselective Synthesis of cis-4,5-Disubstituted Pyrrolidinones and Tetrahydro-3H-pyrrolo[3,2-c]quinolines. *Angew. Chem., Int. Ed.* **2012**, *51*, 4722–4725. (b) Bunescu, A.; Wang, Q.; Zhu, J. Three-Component Povarov Reaction–Heteroannulation with Arynes: Synthesis of 5,6-Dihydroindolo[1,2-a]quinolines. *Org. Lett.* **2014**, *16*, 1756−1759. (c) Xie, M.; Chen, X.; Zhu, Y.; Gao, B.; Lin, L.; Feng, X. Asymmetric Three-Component Inverse Electron-Demand Aza-Diels-Alder Reaction: Efficient Synthesis of Ring-Fused Tetrahydroquinolines. *Angew. Chem., Int. Ed.* **2010**, *49*, 3799–3802. (d) Luo, C.; Huang, Y. A Highly Diastereo- and Enantioselective Synthesis of Tetrahydroquinolines: Quaternary Stereogenic Center Inversion and Functionalization.*J. Am. Chem. Soc.* **2013**, *135*, 8193–8196. (e) Yu, J.; Jiang, H.-J.; Zhou, Y.; Luo, S.-W.; Gong, L.-Z. *Angew. Chem., Int. Ed.* **2015**, *54*, 11209–11213. (f) Min, C.; Lin, C.-T.; Seidel, D. Catalytic Enantioselective Intramolecular Aza-Diels-Alder Reactions. *Angew. Chem., Int. Ed.* **2015**, *54*, 6608–6612. (g) Jarrige, L.; Blanchard, F.; Masson, G. Enantioselective Organocatalytic Intramolecular Aza-Diels-Alder Reaction. *Angew. Chem., Int. Ed.* **2017**, *56*, 10573–10576. (h) Bush, T. S.; Yap, G. P. A.; Chain, W. J. Transformation of *N*,*N*−Dimethylaniline *N*−Oxides into Diverse Tetrahydroquinoline Scaffolds via Formal Povarov Reactions. *Org. Lett.* **2018**, *20*, 5406−5409.

(14) CCDC 1953403 (crystal structure of **6r**) contain the supplementary crystallographic data for this paper. These data are provided free of charge by The Cambridge Crystallographic Data Centre.

(15) Chandrasekharam, M.; Chiranjeevi, B.; Gupta, K. S. V.; Sridhar, B. Iron-Catalyzed Regioselective Direct Oxidative Aryl–Aryl Cross-Coupling. *J. Org. Chem*. **2011**, *76*, 10229–10235.

(16) Ueda, M.; Nakakoji, D.; Kuwahara, Y.; Nishimura, K.; Ryu, I. Transition-metal-free Cross-coupling Reaction of Benzylic Halides with Arylboronic Acids Leading to Diarylmethanes**.** *Tetrahedron Lett.* **2016**, *57*, 4142–4144.

(17) Döben, N.; Yan, H.; Kischkewitz, M.; Mao, J.; Studer, A. Intermolecular Acetoxyaminoalkylation of α-Diazo Amides with (Diacetoxyiodo)benzene and Amines. *Org. Lett.* **2018**, *20*, 7933–7936.

(18) Hartsel, J. A.; Craft, D. T.; Chen, Q.-H.; Ma, M.; Carlier, P. R. Access to "Friedel–Crafts-Restricted" *tert*-Alkyl Aromatics by Activation/Methylation of Tertiary Benzylic Alcohols. *J. Org. Chem*. **2012**, *77*, 3127–3133.

(19) Molloy, J. J.; Metternich, J. B.; Daniliuc, C. G.; Watson, A. J. B.; Gilmour, R. Contra-Thermodynamic, Photocatalytic *E*→*Z* Isomerization of Styrenyl Boron Species: Vectors to Facilitate Exploration of Two-Dimensional Chemical Space. *Angew. Chem., Int. Ed.* **2018**, *57*, 3168–3172.

(20) Cussó, O.; Ribas, X.; Lloret-Fillol, J.; Costas, M. Synergistic Interplay of a Non-Heme Iron Catalyst and Amino Acid Coligands in H_2O_2 Activation for Asymmetric Epoxidation of α-Alkyl-Substituted Styrenes. *Angew. Chem., Int. Ed.* **2015**, *54*, 2729–2733.

(21) Liwosz, T. W.; Chemler, S. R. Copper-Catalyzed Oxidative Amination and Allylic Amination of Alkenes. *Chem. Eur. J.* **2013**, *19*, 12771–12777.

(22) Sun, X.; Li, X.; Song, S.; Zhu, Y.; Liang, Y.-F.; Jiao, N. Mn-Catalyzed Highly Efficient Aerobic Oxidative Hydroxyazidation of Olefins: A Direct Approach to β-Azido Alcohols. *J. Am. Chem. Soc.* **2015**, *137*, 6059–6066.

(23) Wang, Z.; Kanai, M.; Kuninobu, Y. Iron-Catalyzed Acyloxyalkylation of Styrenes Using Hypervalent Iodine Reagents. *Org. Lett.* **2017**, *19*, 2398–2401.

(24) Phan, D. H. T.; Kou, K. G. M.; Dong, V. M. Enantioselective Desymmetrization of Cyclopropenes by Hydroacylation. *J. Am. Chem. Soc.* **2010**, *132*, 16354–16355.

(25) Poplata, S.; Bach, T. Enantioselective Intermolecular [2+2] Photocycloaddition Reaction of Cyclic Enones and Its Application in a Synthesis of (−)-Grandisol. *J. Am. Chem. Soc.* **2018**, *140*, 3228–3231.

(26) den Hartog, T.; Toro, J. M. S.; Chen, P. A Palladium-Catalyzed Methylenation of Olefins Using Halomethylboronate Reagents. *Org. Lett.* **2014**, *16*, 1100–1103.

(27) López-Cortés, J. G.; Penieres-Carrillo, G.; Ortega-Alfaro, M. C.; Gutiérrez-Pérez, R.; Toscano, R. A.; Alvarez-Toledano, C. Oxidative Coupling-type Mechanism of *N,N*-dialkylanilines in Solvent-free Conditions Forming Crystal Violet Derivatives. A clay-mediated and Microwave-promoted Approach. *Can. J. Chem.* **2000**, *78*, 1299–1304.

(28) Adams, D. J.; Johns, B.; Vedernikov, A. N. Methyl Transfer Reactivity of Pentachloromethylplatinate(IV) Anion with a series of *N*-Nucleophiles. *J. Organomet. Chem.* **2019**, *880*, 22–28.