Supporting Information

For

Ni-Catalyzed Deaminative Hydroalkylation of Internal Alkynes

Ze-Fan Zhu, Jia-Lin Tu and Feng Liu*

Jiangsu Key Laboratory of Neuropsychiatric Diseases and Department of Medicinal Chemistry, College of Pharmaceutical Sciences, Soochow University, 199 Ren-Ai Road, Suzhou, Jiangsu 215123, People’s Republic of China
E-mail: fliu2@suda.edu.cn
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1. General remarks

$^1$H NMR spectra were recorded on 400 or 600 MHz (100 or 150 MHz for $^{13}$C NMR, 376 or 564 MHz for $^{19}$F NMR) agilent NMR spectrometer with CDCl$_3$ as the solvent and tetramethylsilane (TMS) as the internal standard. Chemical shifts were reported in parts per million (ppm, $\delta$ scale) downfield from TMS at 0.00 ppm and referenced to the CDCl$_3$ at 7.26 ppm (for $^1$H NMR) or 77.16 ppm (for $^{13}$C NMR). $^{19}$F NMR chemical shifts were determined relative to CFCl$_3$ at $\delta$ 0.00 ppm. Mass spectroscopy data of the products were collected on a GCT PremierTM (CI) and Agilent Technologies 1290 Infinity (ESI). Mass Spectrometer Infrared (FT-IR) spectra were recorded on a Varian 1000FT-IR, $\nu_{\text{max}}$ in cm$^{-1}$. Melting points were measured using SGW, X-4B and values are uncorrected. All commercially available reagents and solvents were used as received unless otherwise specified.

2. Synthesis of alkynes

Procedure A:

\[
\text{Ar-X} + \text{Pd(PPh}_3)^2\text{Cl}_2 (2.5 \text{~mol\%}) \xrightarrow{\text{DIPEA}} \xrightarrow{\text{DMF}} \xrightarrow{1.2 \text{~equiv}} \text{Ar} \quad \text{(1.0 equiv)}
\]

To a 25 mL two-neck bottle, Ar-X (5 mmol, 1.0 equiv), PdCl$_2$(PPh$_3$)$_2$ (87.7 mg, 0.125 mmol, 2.5mol%), CuI (47.5 mg, 0.25 mmol, 5 mol%), NEt$_3$ (1.5 mL), and DMF (2.5 mL) were added. The tube was degassed under reduced pressure and refilled with Ar for three times. The mixture was stirred at 80 °C for 5 minutes. Then 1-Hexyne (0.69 mL, 6 mmol, 1.2 equiv) was added into the mixture to stir for 12h. After cooling to room temperature, saturated NH$_4$Cl solution was poured into the reaction mixture and extracted with CH$_2$Cl$_2$. The organic layer was washed with water, dried over Na$_2$SO$_4$, and filtered. The filtrate was concentrated in vacuo. The residue was purified by silica gel column chromatography to afford alkyne. (Angew. Chem. Int. Ed. 2015, 54, 12923–12927.)

Procedure B:

\[
\text{Ar-X} + \text{Pd}(\text{pph}_3)^2\text{Cl}_2 (10 \text{~mol\%}) \xrightarrow{\text{dppb (20 mol\%)}} \xrightarrow{\text{DBU (3 equiv) /TBAF (2 equiv)}} \xrightarrow{\text{DMSO}} \text{Ar} \quad \text{(1.0 equiv)}
\]

To a 50 mL two-neck bottle, PdCl$_2$(PPh$_3$)$_2$ (35 mg, 0.05mmol, 1 mol%), 1,4-bis(diphenylphosphino)butane (dppb) (42 mg, 0.10 mmol, 2 mol%), 2-butylnoic acid (0.50 g, 6.0 mmol, 1.2 equiv), ArX (5.0 mmol, 1.0 equiv), DMSO (15 mL), and
DBU (2.2 mL, 15 mmol, 3.0 equiv) or TBAF (1 M in THF, 10 mL, 10 mmol) were added. The tube was degassed under reduced pressure and refilled with Ar for three times. The solution was stirred at 110 °C for 12 h. After cooling to room temperature, sat. NH₄Cl aq. was poured into the reaction mixture and extracted with CH₂Cl₂. The organic layer was washed with water, dried over Na₂SO₄, and filtered. The filtrate was concentrated in vacuo. The residue was purified by silica gel column chromatography to afford alkyne. (Angew. Chem. Int. Ed. 2015, 54, 12923–12927.)

Procedure C:

To a dried 50 mL two-neck bottle, 4-bromophenylacetylene (900 mg, 5.0 mmol) and anhydrous THF (25 mL) were added. The bottle was allowed to be cooled around -78 °C; n-BuLi (2.5 M in THF, 1.8 mL, 4.5 mmol) was added dropwise and the reaction mixture was stirred for 1 h. To the reaction mixture, MeI (0.62 mL, 10 mmol) was added dropwise, and the reaction mixture was stirred at room temperature for 2 h. After quenching with sat. NH₄Cl aq., the mixture was extracted with CH₂Cl₂. The organic layer was dried over Na₂SO₄, and filtered. The filtrate was concentrated in vacuo. The residue was purified by silica gel column chromatography and further purification by silica gel chromatography provided pure product 1ad (72%) as a pale yellow oil. (Angew. Chem. Int. Ed. 2015, 54, 12923–12927.)

Procedure D:

To a 100 ml oven-dried round-bottomed flask equipped with magnetic stir bar added indomethacin (1.0 g, 3.0 mmol), (4-(prop-1-yn-1-yl)phenyl)methanol (1ag) (481.8 mg, 3.3 mmol), DMAP (36.6 mg, 0.3 mmol) and DCM (50 ml). Then DCC (681 mg, 3.3 mmol) dissolved in DCM (10 ml) was added dropwise. The mixture was stirred at room temperature for overnight. The mixture was quenched by sat. NH₄Cl aq, extracted by EtOAc, washed by sat NaHCO₃, sat NaCl. The organic layer was dried over Na₂SO₄, and filtered. The filtrate was concentrated in vacuo. The residue was purified by silica gel column chromatography (DCM : EtOAc = 10:1 to DCM : EtOAc = 2:1) and further purification by silica gel chromatography provided pure
product as yellow solid.

Procedure E:

\[
\begin{align*}
\text{CHO} & \quad \text{CBr}_4 (2.0 \text{ equiv}) \\
& \quad \text{PPPh}_3 (4.0 \text{ equiv}) \\
& \quad \text{DCM}
\end{align*}
\]

\[
\begin{align*}
\text{Br} & \quad \text{Br} \\
& \quad 1) \text{n-BuLi} (2.0 \text{ equiv}) \\
& \quad \text{THF} \\
& \quad 2) \text{Mel} (3.0 \text{ equiv})
\end{align*}
\]

Step 1: To a solution of carbon tetrabromide (3.31 g, 10.0 mmol) and tri-phenylphosphine (5.24 g, 20.0 mmol) in dichloromethane (CH$_2$Cl$_2$ 20 ml) was added dropwise a solution of tert-butyl 4-formylpiperidine-1-carboxylate (1.0 g, 5 mmol) in CH$_2$Cl$_2$ (30 ml) at 0 °C, and the mixture was stirred at 0 °C for 1 h. This solution was diluted with diethyl ether (Et$_2$O, 50 ml), and the precipitate was filtered off. The filtrate was concentrated in vacuo. The residue was chromatographed on silica gel (10% EtOAc–hexane) to give 1.4755 g (80%) of tert-butyl 4-(2,2-dibromovinyl)piperidine-1-carboxylate as a white solid.

Step 2: To a solution of tert-butyl 4-(2,2-dibromovinyl)piperidine-1-carboxylate (738 mg, 2.0 mmol) in tetrahydrofuran (THF, 4.0 ml) was added n-butyllithium (n-BuLi, 2.5 M solution in hexane, 1.6 ml, 4.0 mmol) at -78 °C under a nitrogen atmosphere, and the mixture was stirred at -78 °C for 1 h and at 0 °C for 1 h. Ethyl chloroformate (0.4 ml, 6.0 mmol) was added at -78 °C, and the reaction mixture was allowed to warm to rt to stir for overnight. The resulting mixture was poured into water, and extracted with EtOAc. The extract was washed with brine, dried and evaporated. The residue was chromatographed on silica gel (10% EtOAc–hexane) to give 413 mg (93%) of 1bi as a colorless oil. (Chem. Pharm. Bull. 2004, 52, 6, 675–687.)

3. Synthesis of pyridinium salts

Procedure F:

\[
\begin{align*}
\text{CHO} & \quad \text{BF}_3/\text{Et}_2\text{O} \\
& \quad \text{Ph} \\
& \quad \text{Ph} \\
& \quad \text{Ph} \\
& \quad \text{EtOH/4h}
\end{align*}
\]

Synthesis of triphenylpyrylium tetrafluoroborate: Benzaldehyde (1 equiv) and acetophenone (2 equiv) were placed in a closed two-necked flask equipped with a magnetic stirrer, then boron trifluoride etherate (2.5 equiv) was added dropwise under argon treatment. The mixture was reacted at 100 °C for two hours and cooled to ambient temperature. Methyl tert-butyl ether was added to the reaction mixture and the resulting suspension stirred at ambient temperature. The solid was collected by filtration and washed with methyl tert-butyl ether. Recrystallization by acetone and
methyl tert-butyl ether to get pure light yellow solid.

A closed flask equipped with a magnetic stir bar was charged with triphenylpyrylium tetrafluoroborate (1.0 equiv) and the corresponding primary amine (1.2 equiv). Ethanol (1.0 M) was added to the reaction vessel and the tube sealed. No precautions to protect the reaction mixture from air and moisture were taken. The reaction mixture was heated to 90 °C for 4 h and then cooled to ambient temperature. Methyl tert-butyl ether was added to the reaction mixture and the resulting suspension stirred at room temperature. The solid was collected by filtration and washed with methyl tert-butyl ether. After the operations required the solids were dried under reduced pressure to obtain the analytically pure pyridinium salts.

Amine hydrochlorides as starting materials: In case amine hydrochlorides were used as feedstocks for the pyridinium salts, the amine hydrochloride (1.2 equiv) was added to a clean and closed flask. Ethanol (1.0 M) and triethyl amine (1.2 equiv) were added. The resulting suspension was stirred for 30 min at ambient temperature. Triphenylpyrylium tetrafluoroborate (1.0 equiv) was added, the tube sealed and stirred for 4 h at 90 °C. Methyl tert-butyl ether was added to the reaction mixture and the resulting suspension stirred at room temperature for at least 1 h to complete the precipitation process. The solid was collected by filtration and washed with methyl tert-butyl ether. After the operations required the solids were dried under reduced pressure to obtain the analytically pure pyridinium salts. To remove water-soluble impurities, the collected solids were washed with water before washing with methyl tert-butyl ether. (Org. Biomol. Chem., 2019, 17, 1531–1534.)

**Procedure G:**

This reaction was set-up under air. The alkyl amine (1.1 equiv) was added to a suspension of 2,4,6-triphenylpyrylium tetrafluoroborate (1.0 equiv) and CH₂Cl₂ (0.5 M) in a round-bottomed flask equipped with a stir bar. The mixture was stirred as Et₃N (1.0 equiv for free base amines; 2.0 equiv for amine hydrochloride salts) was added by syringe. And the mixture was stirred at rt for 30 min. Then acetic acid (2.0 equiv) was added to the mixture by needle and the mixture was stirred at rt overnight. The filtrate was then washed successively with aq. HCl (1.0 M), aq. NaHCO₃ (sat.), and sat. NaCl, dried with Na₂SO₄, filtered, and purified by silica gel chromatography with acetone/CH₂Cl₂ as the eluent. (J. Am. Chem. Soc. 2019, 141, 6, 2257–2262.)
4. Optimization of the Reaction Conditions$^a,b$

![Chemical diagram](image)

$L1$: $R_1 = H, R_2 = H$
$L2$: $R_1 = t$-Bu, $R_2 = H$
$L3$: $R_1 = H, R_2 = Me$

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$^a$ Reaction conditions: A mixture of 1a (0.2 mmol), 2a (0.3 mmol), NiBr$_2$•DME (nickel(II) bromide dimethoxyethane, 10 mol%), ligand (12 mol%), “Si-H” (0.6 mmol) and base (0.5 mmol) in solvent (0.6 mL, used without dehydration) was stirred at rt for 6 h. $^b$ Isolated yields. $^c$ PMHS =
polymethylhydrosiloxane. NiCl$_2$ or Ni(acac)$_2$ as catalyst. No Ni catalysis.

Our investigation commenced with 1-Phenylpropyne 1aa and Katritzky salt 2a as the model substrates to screen the reaction conditions (Table 1). An initial evaluation of the parameters revealed very good regio- and stereo-selectivity to afford the desired product 3a with various commercially available bi-/tri-dentate nitrogen ligands (entries 2, 3, 5 and 6). Next, we briefly screened a series of “Si-H” species, inorganic bases, solvents (used without dehydration), and nickel catalysts (entries 7–19). In the presence of catalyst NiBr$_2$·DME, the combination of ligand L2, (Me$_2$HSi)$_2$O, K$_2$CO$_3$, and DMA was determined to be the optimal reaction conditions (entry 9), offering the desired product 3a in 73% yield with excellent regiocontrol (> 20:1 r.r.) and stereoselectivity (> 20:1 E:Z). Without nickel catalysis, most of the starting material was recovered and no desired product was detected (entry 20).

5. General experimental procedure

To a 10 mL Schlenk tube equipped with a magnetic stir bar was added NiBr$_2$·DME (6.3 mg, 0.02 mmol, 10 mol%), 4,4′-Di-tert-butyl-2,2′-dipyridyl (6.6 mg, 0.024 mmol, 12 mol%), K$_2$CO$_3$ (69.1 mg, 0.5 mmol, 2.5 equiv) and the Katritzky salt (0.3 mmol, 1.5 equiv). The resulting mixture was sealed and degassed via vacuum evacuation and subsequent backfill with nitrogen for three times. Then the alkyne (0.2 mmol, 1.0 equiv) and silane (80 mg, 0.6 mmol, 3.0 equiv) was added. At last, degassed DMA (0.6 mL) was added. The mixture was stirred at room temperature for 4-24 hours. The solvent was removed on a rotary evaporator under reduced pressure and the residue was subjected to column chromatography isolation on silica gel by elution with hexane / ethyl acetate to give the corresponding product.
Procedure for low-boiling point alkynes: To a 10 mL Schlenk tube equipped with a magnetic stir bar was added NiBr$_2$·DME (6.3 mg, 0.02 mmol, 10 mol%), 4,4′-Di-tert-butyl-2,2′-dipyridyl (6.6 mg, 0.024 mmol, 12 mol%), K$_2$CO$_3$ (69.1 mg, 0.5 mmol, 2.5 equiv) and the Katritzky salt (0.2 mmol, 1.0 equiv). The resulting mixture was sealed and degassed via vacuum evacuation and subsequent backfill with nitrogen for three times. Then the alkyne (0.6 mmol, 3.0 equiv) and silane (80 mg, 0.6 mmol, 3.0 equiv) was added. At last, degassed DMA (0.6 mL) was added. The mixture was stirred at room temperature for 6-8 hours. The solvent was removed on a rotary evaporator under reduced pressure and the residue was subjected to column chromatography isolation on silica gel by elution with hexane/ethyl acetate to give the corresponding product.

6. Gram-scale reaction

To a 100 mL Schlenk tube equipped with a magnetic stir bar was added NiBr$_2$·DME (154 mg, 0.5 mmol, 10 mol%), 4,4′-Di-tert-butyl-2,2′-dipyridyl (161 mg, 0.6 mmol, 12 mol%), K$_2$CO$_3$ (1.7 g, 0.5 mmol, 2.5 equiv) and the Katritzky salts (4.3 g, 7.5 mmol, 1.5 equiv). The resulting mixture was sealed and degassed via vacuum evacuation and subsequent backfill with nitrogen for three times. Then the alkyne (0.625 mL, 5.0 mmol, 1.0 equiv) and silane (2.4 mL, 15.0 mmol, 3.0 equiv) was added. At last, degassed DMA (15.0 mL) was added. The mixture was stirred at room temperature for about 8 hours. The solvent was removed on a rotary evaporator under reduced pressure and the residue was subjected to column chromatography isolation on silica gel by elution with hexane / ethyl acetate (100:1) to hexane / ethyl acetate (20:1) to give the corresponding product 3a (1.05 g, 70%).
7. Mechanistic studies

a) Radical trapping experiment

When 2.0 equiv of TEMPO was added to the reaction of 1aa with 2g under the standard conditions, no desired product (3g) was detected by TLC. A TEMPO-trapped product was determined by HRMS and NMR.

![Figure S1. HRMS trace of the TEMPO trapping experiment.](image)

b) Isotopic labelling experiment

To a 10 mL Schlenk tube equipped with a magnetic stir bar was added NiBr₂·DME
(6.3 mg, 0.02 mmol, 10 mol%), 4,4′-Di-tert-butyl-2,2′-dipyridyl (6.6 mg, 0.024 mmol, 12 mol%), K$_2$CO$_3$ (69.1 mg, 0.5 mmol, 2.5 equiv) and Katritzky salt 2a (0.3 mmol, 1.5 equiv). The resulting mixture was sealed and degassed via vacuum evacuation and subsequent backfill with nitrogen for three times. Then the alkyne 1aa (0.2 mmol, 1.0 equiv) and silane (80 mg, 0.6 mmol, 3.0 equiv) was added. At last, degassed dry DMA (0.6 mL) and D$_2$O (40 μL, 2 mmol) was added. The resulting mixture was stirred at r.t for 6 hours. After the reaction was finished, the solvent was removed on a rotary evaporator under reduced pressure and the residue was subjected to column chromatography isolation on silica gel by elution with hexane/ethyl acetate to give the corresponding product 3a as white solid (29.6 mg, 49% yield).

8. Characterization of the substrates and products

1-(1-(tert-Butoxycarbonyl)piperidin-4-yl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2a): Prepared via general procedure F; white solid; $^1$H NMR (600 MHz, CDCl$_3$) δ 7.80 – 7.65 (m, 8H), 7.63 – 7.53 (m, 6H), 7.53 – 7.48 (m, 1H), 7.47 – 7.39 (m, 2H), 4.76 (t, $J$ = 12.0 Hz, 1H), 4.02 – 3.79 (m, 2H), 2.27 – 2.00 (m, 4H), 1.72 – 1.55 (m, 2H), 1.30 (s, 9H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 157.2, 155.5, 154.3, 134.1, 133.9, 132.1, 131.2, 129.7, 129.4, 129.1, 128.4, 80.2, 70.0, 44.7, 43.8, 32.8, 28.4; $^{19}$F NMR (564 MHz, CDCl$_3$) δ -152.96 (s), -153.01 (s).

2,4,6-Triphenyl-1-(1-tosylpiperidin-4-yl)pyridin-1-ium tetrafluoroborate (2b): Prepared via general procedure F; white solid; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.73 (s,
2H), 7.71 – 7.64 (m, 6H), 7.61 – 7.48 (m, 7H), 7.45 – 7.36 (m, 4H), 7.22 (d, J = 8.0 Hz, 2H), 4.58 – 4.47 (m, 1H), 3.63 – 3.54 (m, 2H), 2.40 (s, 3H), 2.25 – 2.16 (m, 2H), 1.85 – 1.70 (m, 4H); 13C NMR (150 MHz, CDCl3) δ 157.3, 155.5, 143.9, 133.9, 133.7, 133.2, 132.2, 131.2, 129.8, 129.7, 129.3, 129.2, 128.4, 128.3, 127.5, 69.1, 46.4, 32.3, 21.7; 19F NMR (564 MHz, CDCl3) δ -152.88 (s), -152.93 (s).

2,4,6-Triphenyl-1-(tetrahydro-2H-pyran-4-yl)pyridin-1-ium tetrafluoroborate (2c): Prepared via general procedure F; yellowish solid; 1H NMR (400 MHz, CDCl3) δ 7.79 – 7.70 (m, 6H), 7.69 – 7.64 (m, 2H), 7.63 – 7.53 (m, 6H), 7.50 (t, J = 7.4 Hz, 1H), 7.41 (t, J = 7.5 Hz, 2H), 4.94 – 4.80 (m, 1H), 3.76 – 3.65 (m, 2H), 2.78 (t, J = 11.2 Hz, 2H), 2.05 (d, J = 11.9 Hz, 2H), 1.92 – 1.78 (m, 2H); 13C NMR (600 MHz, CDCl3) δ 157.3, 155.3, 134.1, 133.9, 132.1, 131.2, 129.7, 129.4, 129.1, 128.4, 128.3, 69.2, 67.9, 33.9; 19F NMR (376 MHz, CDCl3) δ -152.86 (s), -152.92 (s);

1-Cyclohexyl-2,4,6-triphenylypyridin-1-ium tetrafluoroborate (2d): Prepared via general procedure F; white solid; 1H NMR (600 MHz, CDCl3) δ 7.76 (s, 2H), 7.71 (t, J = 6.8 Hz, 6H), 7.63 – 7.52 (m, 6H), 7.49 (t, J = 7.4 Hz, 1H), 7.43 (t, J = 7.6 Hz, 2H), 4.64 – 4.55 (m, 1H), 2.15 – 2.05 (m, 2H), 1.61 – 1.52 (m, 2H), 1.52 – 1.40 (m, 2H), 1.37 – 1.30 (m, 1H), 0.78 – 0.67 (m, 2H), 0.65 – 0.54 (m, 1H); 13C NMR (150 MHz, CDCl3) δ 157.2, 155.1, 134.12, 134.09, 131.9, 130.9, 129.6, 129.4, 128.9, 128.4, 128.2, 72.0, 33.7, 26.6, 24.7; 19F NMR (564 MHz, CDCl3) δ -153.30 (s), -153.36 (s).
1-Cyclopentyl-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2e): Prepared via general procedure F; white solid; $^1$H NMR (600 MHz, CDCl$_3$) δ 7.78 – 7.74 (m, 6H), 7.69 (d, $J$ = 7.4 Hz, 2H), 7.60 – 7.53 (m, 6H), 7.49 (t, $J$ = 7.4 Hz, 1H), 7.43 (t, $J$ = 7.6 Hz, 2H), 5.02 (p, $J$ = 9.0 Hz, 1H), 2.25 – 2.16 (m, 2H), 2.03 – 1.96 (m, 2H), 1.18 – 1.10 (m, 2H), 0.96 – 0.87 (m, 2H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 157.8, 154.9, 134.2, 134.1, 132.0, 130.9, 129.7, 129.6, 129.0, 128.3, 128.2, 70.8, 33.8, 24.7; $^{19}$F NMR (564 MHz, CDCl$_3$) δ -153.38 (s), -153.43 (s).

1-(1-Hydroxy-3-phenylpropan-2-yl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2f): Prepared via general procedure F; white solid; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.85 – 7.71 (m, 7H), 7.68 – 7.29 (m, 10H), 7.19 – 7.13 (m, 1H), 7.12 – 7.07 (m, 2H), 6.60 – 6.55 (m, 2H), 5.45 – 5.32 (m, 1H), 3.79 – 3.69 (m, 1H), 3.54 (dd, $J$ = 11.9, 5.6 Hz, 1H), 3.26 – 3.17 (m, 1H), 2.53 (dd, $J$ = 14.1, 7.9 Hz, 1H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 155.1, 135.8, 133.7, 133.5, 132.3, 131.1, 130.2, 129.8, 129.1, 129.0, 128.6, 128.3, 127.5, 73.3, 62.4, 38.5; $^{19}$F NMR (564 MHz, CDCl$_3$) δ -152.59 (s), -152.64 (s).

(1-Methoxy-1-oxo-3-phenylpropan-2-yl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2g): Prepared via general procedure F; white solid; $^1$H NMR (600 MHz, CDCl$_3$) δ 7.93 (s, 2H), 7.86 – 7.69 (m, 4H), 7.60 (t, $J$ = 7.2 Hz, 2H), 7.57 – 7.40 (m, 9H), 7.14 – 7.05 (m, 3H), 6.77 (d, $J$ = 7.3 Hz, 2H), 5.64 (dd, $J$ = 7.5, 3.7 Hz, 1H), 3.69 (s, 3H), 3.49 – 3.42 (m, 1H), 2.93 (dd, $J$ = 14.4, 8.0 Hz, 1H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 168.0, 157.1, 157.0, 136.4, 133.8, 132.5, 132.4, 131.7, 129.8, 129.6, 129.2, 129.1, 128.72, 128.66, 128.0, 127.3, 70.3, 53.9, 37.8; $^{19}$F NMR (564 MHz, CDCl$_3$) δ -152.80 (d, $J$ = 4.5 Hz), -152.86 (d, $J$ = 3.5 Hz).
1-(3-(4-Hydroxyphenyl)-1-methoxy-1-oxopropan-2-yl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2h): Prepared via general procedure F; yellowish solid; $^1$H NMR (600 MHz, CDCl$_3$) δ 7.92 (s, 2H), 7.86 – 7.83 (m, 2H), 7.79 – 7.46 (m, 13H), 6.62 (d, $J = 8.5$ Hz, 2H), 6.44 (d, $J = 8.4$ Hz, 2H), 5.60 (t, $J = 6.7$ Hz, 1H), 3.70 (s, 3H), 3.15 (dd, $J = 14.8$, 7.1 Hz, 1H), 2.89 (dd, $J = 14.8$, 6.4 Hz, 1H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 168.2, 157.1, 156.3, 133.4, 132.9, 132.2, 131.9, 130.0, 129.8, 129.4, 128.7, 127.8, 116.3, 70.9, 53.9, 36.7; $^{19}$F NMR (564 MHz, CDCl$_3$) δ -151.85 (s), -151.90 (s); HRMS (ESI) calcd C$_{33}$H$_{28}$NO$_3$[M-BF$_4$]$^+$: 486.2064, found: 486.2062.

(1-Methoxy-4-(methylthio)-1-oxobutan-2-yl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2i): Prepared via general procedure F; white solid; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.87 (s, 2H), 7.81 – 7.64 (m, 5H), 7.63 – 7.50 (m, 8H), 7.46 (t, $J = 7.3$ Hz, 2H), 5.92 (d, $J = 7.7$ Hz, 1H), 3.73 (s, 3H), 2.37 – 2.16 (m, 3H), 1.95 – 1.85 (m, 1H), 1.84 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 168.4, 156.9, 133.8, 132.5, 132.2, 131.5, 129.6, 129.2, 129.1, 128.5, 127.9, 66.7, 53.9, 31.4, 30.8, 14.7; $^{19}$F NMR (564 MHz, CDCl$_3$) δ -152.74 (s), -152.79 (s).

1-(1-(Diacetylamino)-1-oxo-3-phenylpropan-2-yl)-2,4,6-triphenylpyridin-1-ium-te
trafluoroborate (2j): Prepared via general procedure F; Green solid; $^1$H NMR (600 MHz, CDCl$_3$) δ 8.04 (br, 2H), 7.85 (s, 2H), 7.76 (d, $J = 7.7$ Hz, 2H), 7.74 – 7.49 (m, 9H), 7.46 (t, $J = 7.6$ Hz, 2H), 7.16 – 7.07 (m, 3H), 6.87 (d, $J = 7.5$ Hz, 2H), 5.96 (dd,
\[ J = 9.5, 3.4 \text{ Hz}, 1H \], 3.53 (dd, \( J = 14.3, 3.2 \text{ Hz}, 1H \)), 3.23 – 3.04 (m, 2H), 2.96 – 2.85 (m, 1H), 2.26 – 2.10 (m, 2H), 0.98 (t, \( J = 6.2 \text{ Hz}, 3H \)), 0.37 (t, \( J = 6.3 \text{ Hz}, 3H \)); \( ^{13}C \) NMR (150 MHz, CDCl\(_3\)) \( \delta \) 165.2, 157.7, 155.8, 145.8, 135.8, 133.9, 133.6, 132.4, 131.2, 129.9, 129.7, 129.0, 128.93, 128.87, 128.5, 128.4, 127.4, 126.8, 70.9, 41.3, 40.6, 39.1, 12.8, 12.2; \( ^{19}F \) NMR (564 MHz, CDCl\(_3\)) \( \delta \) -152.75 (s), -152.80 (s); HRMS (ESI) calcd C\(_{36}\)H\(_{35}\)N\(_2\)O [M-BF\(_4\)]\(^+\): 511.2744, found: 511.2743.

1-(4-Chlorobenzyl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2k): Prepared via general procedure F; white solid; \( ^1H \) NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.89 (s, 2H), 7.75 (d, \( J = 7.4 \text{ Hz}, 2H \)), 7.65 (d, \( J = 6.9 \text{ Hz}, 4H \)), 7.59 – 7.41 (m, 9H), 7.05 (d, \( J = 8.1 \text{ Hz}, 2H \)), 6.41 (d, \( J = 8.1 \text{ Hz}, 2H \)), 5.73 (s, 2H); \( ^{13}C \) NMR (150 MHz, CDCl\(_3\)) \( \delta \) 157.5, 156.6, 134.4, 133.8, 132.8, 132.5, 131.2, 129.9, 129.4, 129.2, 129.1, 128.3, 127.9, 126.8, 57.7; \( ^{19}F \) NMR (564 MHz, CDCl\(_3\)) \( \delta \) -152.64 (s), -152.69 (s).

1-(4-Methylbenzyl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2l): Prepared via general procedure F; white solid; \( ^1H \) NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.89 (s, 2H), 7.77 (d, \( J = 7.2 \text{ Hz}, 2H \)), 7.64 (d, \( J = 6.6 \text{ Hz}, 4H \)), 7.59 – 7.38 (m, 9H), 6.88 (d, \( J = 7.7 \text{ Hz}, 2H \)), 6.32 (d, \( J = 7.7 \text{ Hz}, 2H \)), 5.71 (s, 2H), 2.22 (s, 3H); \( ^{13}C \) NMR (150 MHz, CDCl\(_3\)) \( \delta \) 157.6, 156.3, 138.3, 133.9, 132.9, 132.4, 131.1, 131.0, 129.9, 129.5, 129.2, 128.3, 126.6, 126.2, 58.2, 21.1; \( ^{19}F \) NMR (564 MHz, CDCl\(_3\)) \( \delta \) -153.00 (s), -153.05 (s).
2,4,6-Triphenyl-1-(4-(trifluoromethyl)benzyl)pyridin-1-ium tetrafluoroborate (2m): Prepared via general procedure F; yellow solid; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.99 (s, 2H), 7.83 (d, $J = 7.3$ Hz, 2H), 7.65 (d, $J = 6.7$ Hz, 4H), 7.59 – 7.45 (m, 9H), 7.37 (d, $J = 7.9$ Hz, 2H), 6.63 (d, $J = 7.7$ Hz, 2H), 5.86 (s, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 157.5, 156.7, 138.0, 133.7, 132.7, 132.6, 131.2, 130.4 (q, $J = 32.7$ Hz), 129.9, 129.4, 129.2, 128.3, 126.9, 126.8, 125.8 (q, $J = 3.6$ Hz), 123.6 (q, $J = 272.2$ Hz), 58.0; $^{19}$F NMR (377 MHz, CDCl$_3$) $\delta$ -62.77 (s), -152.48 (s), -152.53 (d, $J = 2.0$ Hz).

\[
\begin{align*}
\text{Ph} & \quad \text{N} & \quad \text{Ph} \\
\text{Ph} & \quad \text{BF}_4^- & \quad \text{Ph}
\end{align*}
\]

2,4,6-Triphenyl-1-(pyridin-3-ylmethyl)pyridin-1-ium tetrafluoroborate (2n): Prepared via general procedure F; white solid; $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 8.38 (dd, $J = 4.8$, 1.2 Hz, 1H), 7.96 (s, 2H), 7.82 – 7.78 (m, 2H), 7.71 (d, $J = 1.9$ Hz, 1H), 7.68 (d, $J = 7.2$ Hz, 4H), 7.59 (t, $J = 7.4$ Hz, 1H), 7.54 (t, $J = 7.4$ Hz, 4H), 7.50 (t, $J = 7.3$ Hz, 4H), 7.04 (dd, $J = 7.9$, 4.8 Hz, 1H), 6.86 (d, $J = 8.0$ Hz, 1H), 5.83 (s, 2H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 157.6, 157.0, 149.7, 147.5, 134.6, 133.8, 132.70, 132.66, 131.5, 130.1, 130.0, 129.6, 129.2, 128.3, 126.9, 123.8, 56.1; $^{19}$F NMR (564 MHz, CDCl$_3$) $\delta$ -152.76 (s), -152.81 (s).

\[
\begin{align*}
\text{Ph} & \quad \text{N} & \quad \text{Ph} \\
\text{Ph} & \quad \text{BF}_4^- & \quad \text{COOEt}
\end{align*}
\]

1-(2-Ethoxy-2-oxoethyl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2o): Prepared via general procedure F; white solid; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.97 (s, 2H), 7.95 – 7.67 (m, 5H), 7.68 – 7.47 (m, 10H), 5.12 (s, 2H), 4.00 (q, $J = 7.0$ Hz, 2H), 1.04 (t, $J = 7.0$ Hz, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 167.2, 157.5, 157.1, 134.0, 132.6, 132.3, 131.4, 129.9, 129.2, 128.4, 126.3, 62.9, 56.7, 14.0; $^{19}$F NMR (564 MHz, CDCl$_3$) $\delta$ -153.40 (s), -153.46 (d, $J = 0.9$ Hz).
1-Benzyl-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2p): Prepared via general procedure F; white solid; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.94 (s, 2H), 7.81 (d, $J$ = 7.0 Hz, 2H), 7.71 – 7.43 (m, 13H), 7.22 – 7.06 (m, 3H), 6.46 (d, $J$ = 7.1 Hz, 2H), 5.77 (s, 2H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 157.7, 156.4, 134.3, 133.9, 132.9, 132.5, 131.1, 129.9, 129.3, 129.2, 128.9, 128.4, 128.3, 126.7, 126.4, 58.4; $^{19}$F NMR (564 MHz, CDCl$_3$) δ -153.13 (s), -153.19 (s).

1-(2-Methylbenzyl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2q): Prepared via general procedure F; yellowish solid; $^1$H NMR (600 MHz, CDCl$_3$) δ 7.96 (s, 2H), 7.83 (d, $J$ = 7.3 Hz, 2H), 7.69 – 7.51 (m, 7H), 7.51 – 7.45 (m, 2H), 7.45 – 7.37 (m, 4H), 7.14 – 7.08 (m, 2H), 6.93 – 6.87 (m, 1H), 6.47 – 6.40 (m, 1H), 5.66 (s, 2H), 1.63 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 157.8, 156.4, 135.5, 134.0, 133.2, 132.6, 132.5, 131.1, 130.7, 129.9, 129.1, 129.0, 128.3, 128.2, 126.8, 126.4, 124.9, 56.1, 18.7; $^{19}$F NMR (564 MHz, CDCl$_3$) δ -153.17 (s), -153.23 (s); FT-IR (thin film, KBr): ν (cm$^{-1}$) 1619, 1559, 1051, 767, 704; HRMS (ESI) calcd C$_{33}$H$_{26}$N [M-BF$_4$]$^+$: 412.2060, found: 412.2065.

1-(2,6-Dimethylbenzyl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2r): Prepared via general procedure G; yellow solid; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.89 (s, 2H), 7.80 (d, $J$ = 7.1 Hz, 2H), 7.73 – 7.65 (m, 4H), 7.62 – 7.51 (m, 3H), 7.51 – 7.40 (m, 6H), 6.86 (t, $J$ = 7.3 Hz, 1H), 6.63 (d, $J$ = 7.3 Hz, 2H), 5.95 (s, 2H), 1.72 (s, 6H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 158.8, 155.7, 136.4, 133.5, 132.6, 131.5, 131.1, 130.0,
129.4, 129.1, 129.0, 128.9, 128.6, 128.2, 127.3, 126.6, 57.3, 20.3; $^{19}$F NMR (564 MHz, CDCl$_3$) $\delta$ -152.78 (s), -152.84 (s); FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2921, 2851, 1616, 1055, 701; HRMS (ESI) calcd C$_{32}$H$_{28}$N [M -BF$_4$]$^+$: 426.2216, found: 426.2218.

(R)-1-(Nonan-2-yl)-2,4,6-triphenylpyridin-1-ium tetrafluoroborate (2s): Prepared via general procedure F; green solid; $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.87 – 7.65 (m, 7H), 7.64 – 7.55 (m, 6H), 7.54 – 7.44 (m, 4H), 4.92 – 4.87 (m, 1H), 1.81 – 1.73 (m, 1H), 1.42 (d, $J$ = 5.7 Hz, 3H), 1.27 – 1.24 (m, 2H), 1.24 – 1.20 (m, 2H), 1.15 – 1.07 (m, 4H), 1.05 – 0.95 (m, 3H), 0.84 (t, $J$ = 7.3 Hz, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 157.3, 155.3, 134.1, 134.0, 132.1, 131.0, 129.7, 129.5, 128.9, 128.5, 67.2, 37.0, 31.7, 29.0, 28.8, 26.8, 22.6, 21.9, 14.1; $^{19}$F NMR (564 MHz, CDCl$_3$) $\delta$ -153.30 (s), -153.35 (s).

1-Chloro-4-(prop-1-yn-1-yl)benzene (1ac): Prepared via general procedure B; colorless oil; 68%; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.33 (d, $J$ = 7.8 Hz, 2H), 7.27 (d, $J$ = 8.0 Hz, 2H), 2.06 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 133.5, 132.8, 128.6, 122.7, 87.0, 78.8, 4.4.
1-Bromo-4-(prop-1-yn-1-yl)benzene (1ad):
Prepared via general procedure C; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.41 (d, $J = 7.9$ Hz, 2H), 7.25 (d, $J = 8.1$ Hz, 2H), 2.04 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 133.1, 131.5, 123.1, 121.7, 87.3, 78.9, 4.5.

1-Methoxy-4-(prop-1-yn-1-yl)benzene (1ae): Prepared via general procedure B; white solid; 85%; $^1$H NMR (600 MHz, CDCl$_3$) δ 7.34 (d, $J = 8.6$ Hz, 2H), 6.82 (d, $J = 8.7$ Hz, 2H), 3.78 (s, 3H), 2.03 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 159.1, 132.9, 116.3, 113.9, 84.2, 79.5, 55.2, 4.3.

Methyl(4-(prop-1-yn-1-yl)phenyl)sulfane (1af): Prepared via general procedure B; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.30 (d, $J = 8.1$ Hz, 2H), 7.15 (d, $J = 8.2$ Hz, 2H), 2.46 (s, 3H), 2.04 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 138.3, 131.9, 126.1, 120.6, 85.9, 79.5, 15.6, 4.5.

(4-(Prop-1-yn-1-yl)phenyl)methanol (1ag): Prepared via general procedure B; white solid; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.36 (d, $J = 8.1$ Hz, 2H), 7.22 (d, $J = 8.0$ Hz, 2H), 4.59 (s, 2H), 2.40 (br, 1H), 2.04 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 140.3, 131.7, 126.8, 123.2, 86.0, 79.7, 64.8, 4.4.
N,N-Diethyl-4-(prop-1-yn-1-yl)benzamide (1ah): Prepared via general procedure B; 
$^1$H NMR (400 MHz, CDCl$_3$) δ 7.36 (d, $J = 7.9$ Hz, 2H), 7.25 (d, $J = 7.8$ Hz, 2H), 3.60 – 3.41 (m, 2H), 3.31 – 3.12 (m, 2H), 2.02 (s, 3H), 1.27 – 1.14 (m, 3H), 1.12 – 0.97 (m, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 170.9, 136.3, 131.6, 126.4, 125.1, 87.3, 79.3, 43.4, 39.4, 14.3, 13.0, 4.4.

Methyl 3-methyl-4-(prop-1-yn-1-yl)benzoate (1ai): Prepared via general procedure B; yellow oil; 65%; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.84 (s, 1H), 7.76 (d, $J = 8.0$ Hz, 1H), 7.39 (d, $J = 8.0$ Hz, 1H), 3.89 (s, 3H), 2.43 (s, 3H), 2.11 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 167.0, 140.2, 131.9, 130.4, 128.8, 128.7, 126.7, 93.2, 78.3, 52.2, 20.7, 4.7.

2-(Prop-1-yn-1-yl)-1,1'-biphenyl (1aj): Prepared via general procedure B; yellow oil; 65%; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.58 (d, $J = 7.4$ Hz, 2H), 7.49 (d, $J = 7.5$ Hz, 1H), 7.40 (t, $J = 7.3$ Hz, 2H), 7.37 – 7.29 (m, 3H), 7.26 – 7.21 (m, 1H), 1.91 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 143.7, 140.9, 133.3, 129.6, 129.4, 128.0, 127.9, 127.3, 127.1, 122.4, 89.0, 79.3, 4.6.

2-(Prop-1-yn-1-yl)pyridine (1ak): Prepared via general procedure B; yellow oil; 49%; $^1$H NMR (400 MHz, CDCl$_3$) δ 8.52 (d, $J = 3.8$ Hz, 1H), 7.59 (t, $J = 7.4$ Hz, 1H), 7.34 (d, $J = 7.8$ Hz, 1H), 7.19 – 7.13 (m, 1H), 2.06 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 149.9, 144.0, 136.1, 126.7, 122.4, 86.7, 79.7, 4.4.
1-(Hex-1-yn-1-yl)-4-(trifluoromethyl)benzene (1al): Prepared via general procedure A; Yellow oil; 97%; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.53 (d, $J = 8.4$ Hz, 2H), 7.48 (d, $J = 8.3$ Hz, 2H), 2.43 (t, $J = 7.0$ Hz, 2H), 1.66 – 1.56 (m, 2H), 1.53 – 1.43 (m, 2H), 0.96 (t, $J = 7.3$ Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 131.9, 129.2 (q, $J_{C-F} = 32.5$ Hz), 128.1 (q, $J_{C-F} = 1.0$ Hz), 125.2 (q, $J_{C-F} = 3.8$ Hz), 124.2 (q, $J = 272.1$ Hz), 93.5, 79.6, 30.8, 22.2, 19.3, 13.8.

![Methyl 4-(hex-1-yn-1-yl)benzoate (1am)](image)

Methyl 4-(hex-1-yn-1-yl)benzoate (1am): Prepared via general procedure A; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.95 (d, $J = 8.0$ Hz, 2H), 7.44 (d, $J = 8.0$ Hz, 2H), 3.90 (s, 3H), 2.43 (t, $J = 6.9$ Hz, 2H), 1.62 – 1.55 (m, 2H), 1.55 – 1.41 (m, 2H), 0.95 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 166.8, 131.6, 129.5, 129.1, 128.9, 94.1, 80.2, 52.3, 30.8, 22.2, 19.3, 13.7.

![1-(Hex-1-yn-1-yl)naphthalene (1an)](image)

1-(Hex-1-yn-1-yl)naphthalene (1an): Prepared via general procedure A; yellow oil; ~100%; $^1$H NMR (600 MHz, CDCl$_3$) δ 8.35 (d, $J = 8.3$ Hz, 1H), 7.84 (d, $J = 8.0$ Hz, 1H), 7.78 (d, $J = 8.3$ Hz, 1H), 7.63 (d, $J = 7.1$ Hz, 1H), 7.58 – 7.54 (m, 1H), 7.52 – 7.49 (m, 1H), 7.41 – 7.39 (m, 1H), 2.59 (t, $J = 7.1$ Hz, 2H), 1.75 – 1.68 (m, 2H), 1.61 – 1.53 (m, 2H), 1.01 (t, $J = 7.4$ Hz, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 133.7, 133.3, 130.1, 128.3, 128.0, 126.6, 126.4, 126.3, 125.4, 122.0, 95.7, 78.7, 31.2, 22.3, 19.6, 13.8.

![3-(Prop-1-yn-1-yl)quinoline (1ao)](image)

3-(Prop-1-yn-1-yl)quinoline (1ao): Prepared via general procedure B; $^1$H NMR (400 MHz, CDCl$_3$) δ 8.85 (d, $J = 1.9$ Hz, 1H), 8.08 (d, $J = 1.2$ Hz, 1H), 8.03 (d, $J = 8.5$ Hz, 1H), 7.70 – 7.58 (m, 2H), 7.46 (t, $J = 7.5$ Hz, 1H), 2.07 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 152.5, 146.6, 137.9, 129.6, 129.3, 127.4, 127.3, 127.1, 118.2, 89.5, 77.2, 4.5.
1,2-Di-p-tolylethyne (1ap): Prepared via general procedure A; white solid; 93%; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.43 (d, $J$ = 7.8 Hz, 4H), 7.16 (d, $J$ = 7.7 Hz, 4H), 2.37 (s, 6H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 138.3, 131.6, 129.2, 120.5, 89.0, 21.6.

1-Methyl-4-(phenylethynyl)benzene (1aq): Prepared via general procedure A; yellowish solid; 57%; $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.54 – 7.52 (m, 2H), 7.43 (d, $J$ = 8.0 Hz, 2H), 7.37 – 7.31 (m, 3H), 7.18 – 7.15 (m, 2H), 2.38 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 138.5, 131.7, 131.6, 129.3, 128.5, 128.2, 123.6, 120.3, 89.7, 88.9, 21.7.

Methyl 4-(phenylethynyl)benzoate (1ar): Prepared via general procedure A; yellow solid; 84%; $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 8.02 (d, $J$ = 8.2 Hz, 2H), 7.59 (d, $J$ = 8.2 Hz, 2H), 7.58 – 7.53 (m, 2H), 7.38 – 7.35 (m, 3H), 3.92 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 166.6, 131.8, 131.6, 129.6, 129.5, 128.8, 128.5, 128.1, 122.8, 92.5, 88.7, 52.3.

4-(Prop-1-yn-1-yl)benzyl
2-(1-(4-chlorobenzoyl)-5-methoxy-2-methyl-1H-indol-3-yl)acetate (1as): Prepared
via general procedure D; yellow solid; m.p. 113-116 °C; \(^1^H\) NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.63 (d, \(J = 8.1\) Hz, 2H), 7.46 (d, \(J = 8.1\) Hz, 2H), 7.34 (d, \(J = 7.8\) Hz, 2H), 7.20 (d, \(J = 7.8\) Hz, 2H), 6.94 – 6.86 (m, 2H), 6.67 (d, \(J = 7.8\) Hz, 1H), 5.10 (s, 2H), 3.77 (s, 3H), 3.71 (s, 2H), 2.35 (s, 3H), 2.05 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 170.7, 168.4, 156.2, 139.4, 136.1, 135.1, 134.0, 131.8, 131.3, 130.9, 130.7, 129.3, 128.2, 124.3, 115.1, 112.5, 112.0, 101.3, 86.7, 79.4, 66.5, 55.8, 30.6, 13.5, 4.5; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2931, 1729, 1645, 1362, 1148; HRMS (ESI) calcd C\(_{29}\)H\(_{25}\)ClNO\(_4\) [M + H]\(^+\): 486.1472, found: 486.1470.

**tert-Butyl 4-(prop-1-yn-1-yl)piperidine-1-carboxylate (1bi):** Prepared via general procedure E; colorless oil; 93%; \(^1^H\) NMR (400 MHz, CDCl\(_3\)) \(\delta\) 3.74 – 3.61 (m, 2H), 3.17 – 3.05 (m, 2H), 2.53 – 2.43 (m, 1H), 1.78 (d, \(J = 2.3\) Hz, 3H), 1.75 – 1.66 (m, 2H), 1.54 – 1.48 (m, 2H), 1.44 (s, 9H); \(^{13}\)C NMR (150 MHz, CDCl\(_3\)) \(\delta\) 154.9, 81.4, 79.5, 42.8, 42.0, 31.9, 28.6, 27.2, 3.6; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2921, 1689, 1425, 1228, 1168;

**tert-Butyl (E)-4-(1-phenylprop-1-en-2-yl)piperidine-1-carboxylate (3a):**

44 mg (73%, major : minor >20:1 r.r.); white solid; m.p. 63-65 °C; \(^1^H\) NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.32 (t, \(J = 7.4\) Hz, 2H), 7.27 – 7.16 (m, 3H), 6.30 (s, 1H), 4.32 – 4.13 (m, 2H), 2.82 – 2.67 (m, 2H), 2.16 (t, \(J = 11.8\) Hz, 1H), 1.84 (s, 3H), 1.80 – 1.69 (m, 2H), 1.56 – 1.45 (m, 11H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 154.9, 142.0, 138.4, 129.0, 128.1, 126.1, 124.1, 79.4, 46.3, 44.3, 30.8, 28.6, 16.1; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2944, 1686, 1425, 1228, 1161; HRMS (ESI) calcd C\(_{19}\)H\(_{28}\)NO\(_2\) [M + H]\(^+\): 302.2120, found: 302.2123.

**(E)-4-(1-Phenylprop-1-en-2-yl)-1-tosylpiperidine (3b):**

31 mg (44%, major : minor >20:1 r.r.); colorless oil; \(^1^H\) NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.69 – 7.65 (m, 2H), 7.36 – 7.28 (m, 4H), 7.21 – 7.17 (m, 3H), 6.24 (s, 1H), 3.93 – 3.87 (m, 2H), 2.44 (s, 3H), 2.28 (td, \(J = 11.8, 2.7\) Hz, 2H), 1.98 – 1.88 (m, 1H), 1.83 –
1.77 (m, 5H), 1.73 (td, \( J = 12.1, 3.8 \) Hz, 2H); \(^{13}\)C NMR (150 MHz, CDCl\(_3\)) \( \delta \) 143.6, 141.3, 138.2, 133.4, 129.7, 129.0, 128.2, 127.9, 126.3, 124.6, 46.8, 45.5, 30.3, 21.7, 16.0; FT-IR (thin film, KBr): \( \nu \) (cm\(^{-1}\)) 2925, 1726, 1338, 1165, 721; HRMS (ESI) calcd C\(_{21}\)H\(_{26}\)NO\(_2\)S [M + H]\(^+\): 356.1684, found: 356.1678.

(E)-4-(1-Phenylprop-1-en-2-yl)tetrahydro-2H-pyran (3c):
26.5 mg (66%, major : minor >20:1 r.r.); yellowish oil; \(^1\)H NMR (600 MHz, CDCl\(_3\)) \( \delta \) 7.32 (t, \( J = 7.6 \) Hz, 2H), 7.24 (d, \( J = 7.4 \) Hz, 2H), 7.19 (t, \( J = 7.3 \) Hz, 1H), 6.30 (s, 1H), 4.07 (t, \( J = 3.0 \) Hz, 1H), 4.06 – 4.04 (m, 1H), 3.52 – 3.43 (m, 2H), 2.29 – 2.23 (m, 1H), 1.85 (d, \( J = 0.9 \) Hz, 3H), 1.72 – 1.67 (m, 4H); \(^{13}\)C NMR (150 MHz, CDCl\(_3\)) \( \delta \) 142.1, 138.6, 129.1, 128.1, 126.1, 124.0, 68.4, 45.2, 31.7, 16.2; FT-IR (thin film, KBr): \( \nu \) (cm\(^{-1}\)) 2934, 2838, 1439, 1128, 701; HRMS (CI) calcd C\(_{14}\)H\(_{19}\)O [M + H]\(^+\): 203.1436, found: 203.1433.

(E)-(2-Cyclohexylprop-1-en-1-yl)benzene (3d):
35 mg (88%, major : minor >20:1 r.r.); yellowish oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.33 – 7.28 (m, 2H), 7.25 – 7.22 (m, 2H), 7.20 – 7.14 (m, 1H), 6.27 (s, 1H), 2.05 – 1.98 (m, 1H), 1.83 (d, \( J = 1.3 \) Hz, 3H), 1.82 – 1.76 (m, 4H), 1.76 – 1.68 (m, 1H), 1.37 – 1.24 (m, 5H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 144.5, 139.1, 129.1, 128.1, 125.8, 123.1, 48.4, 32.1, 26.9, 26.5, 16.3; FT-IR (thin film, KBr): \( \nu \) (cm\(^{-1}\)) 2921, 2848, 1642, 1442, 694; HRMS (CI) calcd C\(_{15}\)H\(_{21}\) [M + H]\(^+\): 201.1643, found: 201.1644.

(E)-(2-Cyclopentylprop-1-en-1-yl)benzene (3e):
23 mg (62%, major : minor >20:1 r.r.); yellowish oil; \(^1\)H NMR (600 MHz, CDCl\(_3\)) \( \delta \) 7.33 – 7.29 (m, 2H), 7.26 – 7.23 (m, 2H), 7.19 – 7.16 (m, 1H), 6.32 (s, 1H), 2.61 – 2.53 (m, 1H), 1.87 – 1.81 (m, 5H), 1.75 – 1.68 (m, 2H), 1.66 – 1.58 (m, 2H), 1.53 – 1.46 (m, 2H); \(^{13}\)C NMR (150 MHz, CDCl\(_3\)) \( \delta \) 142.2, 139.0, 129.1, 128.1, 125.8, 123.3, 50.0, 31.3, 25.6, 16.2; FT-IR (thin film, KBr): \( \nu \) (cm\(^{-1}\)) 2948, 1692, 1422, 1171, 701; HRMS (ESI) calcd C\(_{14}\)H\(_{19}\) [M + H]\(^+\): 187.1487, found: 187.1484.
(E)-2-Benzyl-3-methyl-4-phenylbut-3-en-1-ol (3f):
23 mg (47%, major : minor >20:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) δ
7.34 – 7.26 (m, 4H), 7.23 – 7.16 (m, 6H), 6.31 (s, 1H), 3.70 – 3.66 (m, 2H), 2.86 – 2.77 (m, 2H), 2.76 – 2.66 (m, 1H), 1.85 (d, $J$ = 1.3 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ
140.1, 137.9, 137.6, 129.1, 129.0, 128.8, 128.6, 128.5, 128.4, 128.2, 126.4, 126.2, 63.8, 53.8, 36.5, 15.2; FT-IR (thin film, KBr): ν (cm$^{-1}$) 3349, 2921, 1492, 1028, 701; HRMS (ESI) calcd C$_{18}$H$_{20}$ONa [M + Na]$^+$: 275.1412, found: 275.1423.

Methyl (E)-2-benzyl-3-methyl-4-phenylbut-3-en-1-0ate (3g) (major product):
30 mg (53%, major : minor = 7:1 r.r.); colorless oil; $^1$H NMR (400 MHz, CDCl$_3$) δ
7.35 – 7.25 (m, 4H), 7.23 – 7.14 (m, 6H), 6.34 (s, 1H), 3.67 (s, 3H), 3.44 (t, $J$ = 7.6 Hz, 1H), 3.26 (dd, $J$ = 13.6, 8.0 Hz, 1H), 2.95 (dd, $J$ = 13.7, 7.3 Hz, 1H), 1.89 (s, 3H);
$^{13}$C NMR (100 MHz, CDCl$_3$) δ 173.8, 139.4, 137.7, 135.0, 129.1, 129.0, 128.5, 128.2, 126.6, 126.5, 57.1, 52.1, 36.9, 16.0; FT-IR (thin film, KBr): ν (cm$^{-1}$) 2948, 1732, 1439, 1151, 697; HRMS (ESI) calcd C$_{19}$H$_{20}$O$_2$Na [M + Na]$^+$: 303.1361, found: 303.1361.

Methyl (E)-2-(4-hydroxybenzyl)-3-methyl-4-phenylbut-3-en-1-0ate (3h) (major product):
69 mg (93%, major : minor = 16:1 r.r.); yellow oil; $^1$H NMR (400 MHz, CDCl$_3$) δ
7.31 (t, $J$ = 7.4 Hz, 2H), 7.24 – 7.15 (m, 3H), 7.06 (d, $J$ = 8.0 Hz, 2H), 6.74 (d, $J$ = 8.0 Hz, 2H), 6.37 (s, 1H), 5.51 (s, 1H), 3.68 (s, 3H), 3.41 (t, $J$ = 7.6 Hz, 1H), 3.19 (dd, $J$ = 13.7, 8.3 Hz, 1H), 2.89 (dd, $J$ = 13.2, 7.1 Hz, 1H), 1.89 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 174.2, 154.3, 137.6, 135.0, 131.3, 130.2, 129.5, 129.0, 128.2, 126.6, 115.4, 57.4, 52.1, 36.0, 16.0; FT-IR (thin film, KBr): ν (cm$^{-1}$) 3392, 2955, 1709, 1215, 697; HRMS (CI) calcd C$_{19}$H$_{20}$O$_3$ [M]$^+$: 296.1412, found: 296.1412.
Methyl (E)-3-methyl-2-(2-(methylthio)ethyl)-4-phenylbut-3-enolate (3i) (major product):
30 mg (58%, major : minor = 6:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.36 – 7.30 (m, 3H), 7.27 – 7.20 (m, 2H), 6.46 (s, 1H), 3.71 (s, 3H), 3.36 (t, $J$ = 7.5 Hz, 1H), 2.55 – 2.45 (m, 2H), 2.26 – 2.15 (m, 1H), 2.11 (s, 3H), 2.00 – 1.91 (m, 1H), 1.86 (d, $J$ = 1.3 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 173.9, 137.6, 134.8, 129.3, 129.1, 128.2, 126.7, 53.8, 52.1, 32.0, 29.3, 15.5; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2911, 1729, 1435, 1141, 697; HRMS (ESI) calcd C$_{15}$H$_{21}$O$_2$S [M + H]$^+$: 265.1262, found: 265.1258.

(E)-2-Benzyl-N,N-diethyl-3-methyl-4-phenylbut-3-enamide (3j) (major product):
52 mg (81%, major : minor = 9:1 r.r.); yellow oil; $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.29 (t, $J$ = 7.6 Hz, 2H), 7.25 – 7.22 (m, 2H), 7.21 – 7.17 (m, 3H), 7.17 – 7.12 (m, 3H), 6.22 (s, 1H), 3.49 – 3.42 (m, 2H), 3.40 – 3.31 (m, 2H), 3.27 – 3.20 (m, 1H), 3.19 – 3.12 (m, 1H), 2.90 (dd, $J$ = 13.4, 6.6 Hz, 1H), 1.88 (d, $J$ = 1.0 Hz, 3H), 1.08 (t, $J$ = 7.1 Hz, 3H), 1.01 (t, $J$ = 7.1 Hz, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 171.2, 140.6, 137.8, 136.5, 129.4, 128.9, 128.4, 128.2, 128.1, 126.4, 126.1, 55.0, 41.8, 40.6, 38.0, 15.7, 14.5, 13.0; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2971, 1629, 1425, 1131, 701; HRMS (ESI) calcd C$_{22}$H$_{28}$NO [M + H]$^+$: 322.2171, found: 322.2165.

(E)-1-Chloro-4-(2-methyl-3-phenylallyl)benzene (3k) (major product):
41 mg (84%, major : minor = 8:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.35 – 7.28 (m, 3H), 7.27 – 7.21 (m, 4H), 7.21 – 7.15 (m, 2H), 6.35 (s, 1H), 3.44 (s, 2H), 1.78 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 138.4, 138.2, 137.7, 132.1, 130.5, 129.0, 128.6, 128.2, 127.2, 126.4, 46.5, 17.8; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2918, 1489, 1088, 1015, 694; HRMS (CI) calcd C$_{16}$H$_{16}^{35}$Cl [M + H]$^+$: 243.0941, found: 243.0937.
(E)-1-Methyl-4-(2-methyl-3-phenylallyl)benzene (3l) (major product):
41 mg (93%, major : minor = 6:1 r.r.); colorless oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.35 – 7.29 (m, 2H), 7.28 – 7.24 (m, 3H), 7.22 – 7.17 (m, 1H), 7.15 – 7.12 (m, 3H), 6.37 (s, 1H), 3.44 (s, 2H), 2.34 (s, 3H), 1.80 (s, 3H); \(^1\)C NMR (150 MHz, CDCl\(_3\)) \(\delta\) 145.8, 138.5, 138.4, 136.9, 135.8, 129.2, 129.0, 128.2, 126.7, 126.1, 46.8, 21.2, 17.8; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2918, 1515, 1018, 801, 694; HRMS (ESI) calcd C\(_{17}\)H\(_{19}\) [M + H]\(^+\): 223.1487, found: 223.1494.

(E)-1-(2-Methyl-3-phenylallyl)-4-(trifluoromethyl)benzene (3m) (major product):
43.5 mg (79%, major : minor = 7:1 r.r.); yellowish oil; \(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.56 (d, \(J = 7.9\) Hz, 2H), 7.36 (d, \(J = 7.8\) Hz, 2H), 7.32 (t, \(J = 7.5\) Hz, 2H), 7.25 (d, \(J = 7.4\) Hz, 2H), 7.21 (t, \(J = 7.3\) Hz, 1H), 6.38 (s, 1H), 3.53 (s, 2H), 1.79 (s, 3H); \(^1\)C NMR (150 MHz, CDCl\(_3\)) \(\delta\) 144.1, 138.1, 137.1, 129.4, 129.0, 128.7 (q, \(J_{C-F} = 32.3\) Hz), 128.3, 127.7, 126.5, 125.4 (q, \(J_{C,F} = 7.2, 3.5\) Hz), 122.7 (q, \(J_{C,F} = 272.0\) Hz), 47.0, 17.8; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2908, 1616, 1318, 1065, 694; HRMS (ESI) calcd C\(_{17}\)H\(_{16}\)F\(_3\) [M + H]\(^+\): 277.1204, found: 277.1216.

(E)-3-(2-Methyl-3-phenylallyl)pyridine (3n) (major product):
40.5 mg (97%, major : minor = 5:1 r.r.); yellowish oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.55 (s, 1H), 8.51 (s, 1H), 7.60 (d, \(J = 7.1\) Hz, 1H), 7.37 – 7.30 (m, 3H), 7.29 – 7.16 (m, 4H), 6.38 (s, 1H), 3.48 (s, 2H), 1.81 (s, 3H); \(^1\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 150.4, 147.8, 138.0, 136.9, 136.7, 135.5, 129.0, 128.3, 127.7, 126.5, 123.6, 44.2, 17.8; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2918, 1572, 1422, 1024, 697; HRMS (ESI) calcd C\(_{15}\)H\(_{16}\)N [M + H]\(^+\): 210.1283, found: 210.1286.

tert-Butyl (Z)-4-(1,2-diphenylvinyl)piperidine-1-carboxylate (3o):
53 mg (73%); yellowish solid; m.p. 99-103 \(^\circ\)C; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.37 – 7.27 (m, 3H), 7.11 (d, \(J = 7.1\) Hz, 2H), 7.08 – 6.99 (m, 3H), 6.86 (d, \(J = 6.4\) Hz, 2H),

S25
6.40 (s, 1H), 4.32 – 4.09 (m, 2H), 2.79 – 2.63 (m, 2H), 2.46 (t, J = 11.8 Hz, 1H), 1.86 – 1.73 (m, 2H), 1.53 – 1.36 (m, 1H); 13C NMR (150 MHz, CDCl3) δ 154.9, 146.8, 140.9, 137.3, 129.2, 129.0, 128.7, 127.9, 127.1, 126.4, 125.5, 79.5, 45.8, 44.3, 31.3, 28.6; FT-IR (thin film, KBr): ν (cm⁻¹) 2921, 1666, 1425, 1121, 694; HRMS (ESI) calcd C24H29N2O2 [M + Na]⁺: 386.2096, found: 386.2093.

Methyl (Z)-2-benzyl-3,4-diphenylbut-3-enoate (3p):
40 mg (58%); yellowish oil; 1H NMR (400 MHz, CDCl3) δ 7.31 – 7.27 (m, 3H), 7.26 – 7.22 (m, 2H), 7.22 – 7.16 (m, 3H), 7.11 – 7.05 (m, 5H), 6.92 – 6.87 (m, 2H), 6.65 (s, 1H), 3.74 (dd, J = 9.0, 6.2 Hz, 1H), 3.64 (s, 3H), 3.24 (dd, J = 13.8, 9.1 Hz, 1H), 3.00 (dd, J = 13.9, 6.2 Hz, 1H); 13C NMR (100 MHz, CDCl3) δ 173.6, 140.2, 139.7, 139.4, 136.6, 129.4, 129.3, 129.2, 129.0, 128.8, 128.5, 128.0, 127.5, 126.9, 126.5, 56.5, 52.1, 37.7; FT-IR (thin film, KBr): ν (cm⁻¹) 3028, 1732, 1492, 1155, 694; HRMS (ESI) calcd C24H23O2 [M + H]⁺: 343.1698, found: 343.1701.

(E)-ethyl 4-(4-(hydroxymethyl)phenyl)-3-methylbut-3-enoate and (Z)-ethyl 3-(4-(hydroxymethyl)phenyl)pent-3-enoate (3q):
18.5 mg (40%, major : minor = 5:1 r.r.); colorless oil; 1H NMR (400 MHz, CDCl3) δ 7.35 – 7.31 (m, 2H), 7.28 – 7.24 (m, 2H), 6.38 (s, 1H)/5.72 (q, J = 6.9 Hz, 0.2H), 4.68 (d, J = 5.2 Hz, 2H), 4.22 – 4.14 (m, 2H)/4.05 (q, J = 7.1 Hz, 0.4H), 3.34 – 3.33 (m, 0.4H)/3.17 (d, J = 1.0 Hz, 2H), 1.94 (d, J = 1.3 Hz, 3H)/1.63 (dt, J = 6.9, 1.0 Hz, 0.6H), 1.67 (t, J = 5.5 Hz, 1H), 1.28 (t, J = 7.1 Hz, 3H)/1.15 (t, J = 7.1 Hz, 0.6H); 13C NMR (150 MHz, CDCl3) δ 171.7, 139.8, 139.5, 139.1, 137.3, 132.0, 129.2, 128.9, 128.8, 127.0, 126.5, 65.3, 60.8, 60.7, 46.1, 18.2, 14.4, 14.3; FT-IR (thin film, KBr): ν (cm⁻¹) 3406, 2925, 1732, 1155, 1038; HRMS (ESI) calcd C14H18O3Na [M + Na]⁺: 257.1154, found: 257.1149.

(E)-3-(2-(Tetrahydro-2H-pyran-4-yl)prop-1-en-1-yl)quinoline (3r):
37 mg (73%, major : minor >20:1 r.r.); yellowish oil; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 8.80 (s, 1H), 8.07 (d, \(J = 8.4\) Hz, 1H), 7.98 (s, 1H), 7.79 (d, \(J = 8.0\) Hz, 1H), 7.67 (t, \(J = 7.5\) Hz, 1H), 7.53 (t, \(J = 7.4\) Hz, 1H), 6.41 (s, 1H), 4.13 – 4.05 (m, 2H), 3.55 – 3.45 (m, 2H), 2.44 – 2.30 (m, 1H), 1.94 (s, 3H), 1.80 – 1.68 (m, 4H); \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 152.2, 146.6, 145.5, 134.6, 131.6, 129.3, 129.1, 128.0, 127.8, 126.8, 120.6, 128.0, 119.9, 79.5, 46.4, 44.2, 30.8, 28.6, 16.2; FT-IR (thin film, KBr): \(\nu\) (cm\textsuperscript{-1}) 2945, 1489, 1235, 1128, 751; HRMS (ESI) calcd C\textsubscript{17}H\textsubscript{20}NO \([\text{M + H}]^+\): 254.1545, found: 254.1543.

**tert-Butyl ((E)-4-(1-(4-chlorophenyl)prop-1-en-2-yl)piperidine-1-carboxylate (4a):**
36 mg (53%, major : minor >20:1 r.r.); white solid; m.p. 53-56 \(^\circ\)C; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 7.27 (d, \(J = 8.1\) Hz, 2H), 7.14 (d, \(J = 8.2\) Hz, 2H), 6.22 (s, 1H), 4.32 – 4.10 (m, 2H), 2.81 – 2.63 (m, 2H), 2.22 – 2.07 (m, 1H), 1.80 (s, 3H), 1.77 – 1.68 (m, 2H), 1.50 – 1.44 (m, 1H); \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 155.0, 143.0, 136.9, 131.8, 130.3, 128.3, 123.1, 79.5, 46.3, 44.3, 30.8, 28.6, 16.2; FT-IR (thin film, KBr): \(\nu\) (cm\textsuperscript{-1}) 2928, 1679, 1422, 1161, 1068; HRMS (ESI) calcd C\textsubscript{19}H\textsubscript{27}ClNO\textsubscript{2} \([\text{M + H}]^+\): 336.1730, found: 336.1731.

**tert-Butyl ((E)-4-(1-(4-bromophenyl)prop-1-en-2-yl)piperidine-1-carboxylate (4b):**
51 mg (67%, major : minor >20:1 r.r.); yellow oil; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 7.42 (d, \(J = 8.4\) Hz, 2H), 7.08 (d, \(J = 8.4\) Hz, 2H), 6.20 (s, 1H), 4.28 – 4.15 (m, 2H), 2.79 – 2.66 (m, 2H), 2.17 – 2.10 (m, 1H), 1.80 (d, \(J = 1.1\) Hz, 3H), 1.76 – 1.69 (m, 2H), 1.50 – 1.45 (m, 1H); \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 155.0, 143.1, 137.4, 131.2, 130.7, 123.1, 119.9, 79.5, 46.4, 44.2, 30.8, 28.6, 16.2; FT-IR (thin film, KBr): \(\nu\) (cm\textsuperscript{-1}) 2931, 1686, 1422, 1161, 761; HRMS (ESI) calcd C\textsubscript{19}H\textsubscript{27}BrNO\textsubscript{2}Na \([\text{M + Na}]^+\): 402.1045, found: 402.1040.

**tert-Butyl ((E)-4-(1-(4-methoxyphenyl)prop-1-en-2-yl)piperidine-1-carboxylate (4c):**
52 mg (79%, major : minor >20:1 r.r.); yellowish oil; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\)
7.16 (d, $J = 8.6$ Hz, 2H), 6.86 (d, $J = 8.7$ Hz, 2H), 6.23 (s, 1H), 4.28 – 4.12 (m, 2H), 3.81 (s, 3H), 2.80 – 2.67 (m, 2H), 2.17 – 2.09 (m, 1H), 1.82 (d, $J = 1.0$ Hz, 3H), 1.77 – 1.68 (m, 2H), 1.52 – 1.45 (m, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 157.9, 155.0, 140.7, 131.1, 130.2, 123.6, 113.6, 79.5, 55.4, 46.4, 44.2, 30.9, 28.6, 16.2; FT-IR (thin film, KBr): ν (cm$^{-1}$) 2938, 1689, 1422, 1248, 1168; HRMS (ESI) calcd C$_{20}$H$_{30}$NO$_3$ [M + H]: 332.2226, found: 332.2227.

**tert-Butyl**

**(E)-4-(1-(4-(methylthio)phenyl)prop-1-en-2-yl)piperidine-1-carboxylate (4d):**

43 mg (63%, major : minor >20:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.21 (d, $J = 7.8$ Hz, 2H), 7.15 (d, $J = 7.7$ Hz, 2H), 6.23 (s, 1H), 4.29 – 4.11 (m, 2H), 2.78 – 2.66 (m, 2H), 2.48 (s, 3H), 2.20 – 2.06 (m, 1H), 1.82 (s, 3H), 1.77 – 1.67 (m, 2H), 1.52 – 1.42 (m, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 155.0, 142.1, 135.9, 135.5, 129.5, 126.6, 123.6, 79.5, 46.4, 44.3, 30.9, 28.6, 16.3, 16.2; FT-IR (thin film, KBr): ν (cm$^{-1}$) 2935, 1689, 1419, 1228, 1168; HRMS (ESI) calcd C$_{20}$H$_{29}$NO$_3$Na [M + Na]: 370.1817, found: 370.1813.

**tert-Butyl**

**E**-

(E)-4-(1-(4-(hydroxymethyl)phenyl)prop-1-en-2-yl)piperidine-1-carboxylate (4e):

24 mg (43%, major : minor >20:1 r.r.); yellowish solid; m.p. 72-76 °C; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.31 (d, $J = 7.8$ Hz, 2H), 7.21 (d, $J = 7.7$ Hz, 2H), 6.27 (s, 1H), 4.67 (s, 2H), 4.25 – 4.16 (m, 2H), 2.78 – 2.67 (m, 2H), 2.16 – 2.09 (m, 1H), 1.82 (s, 3H), 1.76 – 1.69 (m, 2H), 1.50 – 1.44 (m, 1H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 155.0, 142.3, 138.8, 137.9, 129.2, 126.9, 123.8, 79.5, 65.3, 46.4, 44.2, 30.9, 28.6, 16.2; FT-IR (thin film, KBr): ν (cm$^{-1}$) 3429, 2921, 1662, 1431, 1168; HRMS (ESI) calcd C$_{20}$H$_{29}$NO$_3$Na [M + Na]: 354.2045, found: 354.2048.
tert-Butyl 

\( (E) \)-4-(1-(4-(diethylcarbamoyl)phenyl)prop-1-en-2-yl)piperidine-1-car-boxylate (4f):

54 mg (68%, major : minor >20:1 r.r.); yellowish oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.31 (d, \( J = 7.5 \) Hz, 2H), 7.23 (d, \( J = 7.6 \) Hz, 2H), 6.27 (s, 1H), 4.29 – 4.12 (m, 2H), 3.60 – 2.81 (m, 2H), 2.20 – 2.08 (m, 1H), 1.83 (s, 3H), 1.77 – 1.70 (m, 2H), 1.53 – 1.43 (m, 11H), 1.32 – 1.17 (m, 3H), 1.17 – 1.04 (m, 3H); \(^{13}\)C NMR (150 MHz, CDCl\(_3\)) \( \delta \) 171.4, 154.9, 143.2, 139.4, 134.9, 128.9, 126.3, 123.6, 79.5, 46.4, 44.1, 43.4, 39.4, 30.8, 28.6, 16.3, 14.4, 13.1; FT-IR (thin film, KBr): \( \nu \) (cm\(^{-1}\)) 2925, 1689, 1482, 1245, 697; HRMS (ESI) calcd C\(_{24}\)H\(_{37}\)N\(_2\)O\(_3\) [M + H]\(^+\): 401.2804, found: 401.2802.

MeOOC

tert-Butyl 

\( (E) \)-4-(1-(4-(methoxycarbonyl)-2-methylphenyl)prop-1-en-2-yl)piperidine-1-carboxylate (4g):

62 mg (78%, major : minor >20:1 r.r.); white solid; m.p. 64-66 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.84 (s, 1H), 7.80 (d, \( J = 8.0 \) Hz, 1H), 7.16 (d, \( J = 7.9 \) Hz, 1H), 6.24 (s, 1H), 4.30 – 4.16 (m, 2H), 3.89 (s, 3H), 2.80 – 2.69 (m, 2H), 2.24 (s, 3H), 2.22 – 2.14 (m, 1H), 1.80 – 1.73 (m, 2H), 1.66 (d, \( J = 0.8 \) Hz, 3H), 1.57 – 1.48 (m, 2H), 1.47 (s, 9H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 167.4, 154.9, 143.6, 142.7, 136.7, 130.9, 129.5, 128.1, 126.7, 122.5, 79.5, 52.1, 45.7, 44.4, 31.0, 28.6, 19.9, 16.1; FT-IR (thin film, KBr): \( \nu \) (cm\(^{-1}\)) 2938, 1719, 1686, 1158, 764; HRMS (ESI) calcd C\(_{24}\)H\(_{31}\)NO\(_4\)Na [M + Na]\(^+\): 396.2151, found: 396.2156.

tert-Butyl  \( (E) \)-4-(1-([1,1'-biphenyl]-2-yl)prop-1-en-2-yl)piperidine-1-carboxylate
(4h): 48 mg (64%, major : minor >20:1 r.r.); yellow oil; $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.36 – 7.24 (m, 9H), 6.08 (s, 1H), 4.22 – 4.03 (m, 2H), 2.71 – 2.60 (m, 2H), 2.09 – 2.02 (m, 1H), 1.66 (s, 3H), 1.62 – 1.58 (m, 2H), 1.45 (s, 9H), 1.41 – 1.31 (m, 2H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 155.0, 141.6, 141.3, 141.1, 136.6, 130.2, 129.8, 127.9, 126.91, 126.87, 126.7, 124.4, 79.4, 45.7, 44.3, 30.6, 28.6, 16.1; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2935, 1689, 1425, 1168, 740; HRMS (ESI) calcd C$_{25}$H$_{31}$NO$_2$ [M$^+$]: 377.2355, found: 377.2347.

**tert-Butyl (E)-4-(1-(pyridin-2-yl)prop-1-en-2-yl)piperidine-1-carboxylate (4i):**
33 mg (55%, major : minor >20:1 r.r.); yellow solid; m.p. 42-45 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.56 (d, $J = 3.2$ Hz, 1H), 7.60 (t, $J = 7.5$ Hz, 1H), 7.18 (d, $J = 7.8$ Hz, 1H), 7.09 – 7.02 (m, 1H), 6.34 (s, 1H), 4.31 – 4.08 (m, 2H), 2.80 – 2.65 (m, 2H), 2.24 – 2.10 (m, 1H), 2.02 (s, 3H), 1.80 – 1.69 (m, 2H), 1.52 – 1.41 (m, 1H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 157.4, 154.9, 149.1, 146.8, 136.0, 124.1, 124.0, 120.8, 79.5, 46.7, 44.3, 30.7, 28.6, 16.5; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2934, 1682, 1419, 1161, 767; HRMS (CI) calcd C$_{18}$H$_{27}$N$_2$O$_2$ [M + H$^+$]: 303.2073, found: 303.2081.

**tert-Butyl (E)-4-(1-(4-(trifluoromethyl)phenyl)hex-1-en-2-yl)piperidine-1-carboxylate (4j):**
47 mg (58%, major : minor >20:1 r.r.); yellow oil; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.55 (d, $J = 8.2$ Hz, 2H), 7.28 (d, $J = 8.2$ Hz, 2H), 6.25 (s, 1H), 4.31 – 4.15 (m, 2H), 2.80 – 2.66 (m, 2H), 2.24 – 2.18 (m, 2H), 2.18 – 2.09 (m, 1H), 1.81 – 1.74 (m, 2H), 1.48 (s, 9H), 1.45 – 1.38 (m, 3H), 1.35 – 1.24 (m, 3H), 0.88 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 155.0, 149.4, 142.4, 128.9, 128.2 (q, $J_{C-F} = 32.3$ Hz), 125.1 (q, $J_{C,F} = 3.6$ Hz), 124.5 (q, $J_{C,F} = 271.7$ Hz), 123.0, 79.6, 44.5, 43.2, 31.9, 31.2, 30.5, 28.6, 23.1, 14.0; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2931, 1692, 1325, 1121, 804; HRMS (CI) calcd C$_{23}$H$_{32}$NO$_2$F$_3$ [M$^+$]: 411.2385, found: 411.2386.
**tert-Butyl (E)-4-(1-(methoxycarbonyl)phenyl)hex-1-en-2-yl)piperidine-1-carboxylate (4k):**

42 mg (53%, major : minor >20:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.97 (d, $J = 8.0$ Hz, 2H), 7.75 (d, $J = 8.3$ Hz, 2H), 6.26 (s, 1H), 4.31 – 4.15 (m, 2H), 3.91 (s, 3H), 2.79 – 2.65 (m, 2H), 2.26 – 2.21 (m, 2H), 2.21 – 2.10 (m, 1H), 1.82 – 1.71 (m, 2H), 1.52 – 1.45 (m, 11H), 1.33 – 1.27 (m, 4H), 0.87 (t, $J = 7.0$ Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 167.2, 155.0, 149.5, 143.6, 129.6, 128.7, 127.8, 123.4, 79.6, 52.2, 44.5, 43.4, 31.9, 31.2, 30.7, 28.6, 23.1, 14.0; FT-IR (thin film, KBr): ν (cm$^{-1}$) 2935, 1719, 1682, 1278, 1171; HRMS (ESI) calcd C$_{24}$H$_{35}$NO$_4$Na [M + Na]$^+$: 424.2464, found: 424.2460.

**tert-Butyl (E)-4-(1-(naphthalen-1-yl)hex-1-en-2-yl)piperidine-1-carboxylate (4l):**

52 mg (67%, major : minor =11:1 r.r.); yellowish oil; $^1$H NMR (600 MHz, CDCl$_3$) δ 7.91 – 7.89 (m, 1H), 7.85 – 7.82 (m, 1H), 7.73 (d, $J = 8.2$ Hz, 1H), 7.48 – 7.44 (m, 2H), 7.43 – 7.40 (m, 1H), 7.27 – 7.24 (m, 1H), 6.60 (s, 1H), 4.38 – 4.17 (m, 2H), 2.86 – 2.73 (m, 2H), 2.29 – 2.22 (m, 1H), 2.11 – 2.04 (m, 2H), 1.96 – 1.88 (m, 2H), 1.62 – 1.55 (m, 2H), 1.49 (s, 9H), 1.35 – 1.28 (m, 2H), 1.16 – 1.09 (m, 2H), 0.71 (t, $J = 7.3$ Hz, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 155.0, 148.4, 136.1, 133.6, 132.3, 128.4, 126.9, 126.3, 125.8, 125.4, 125.3, 122.0, 79.5, 44.5, 42.2, 32.2, 31.2, 30.7, 28.7, 22.9, 13.9; FT-IR (thin film, KBr): ν (cm$^{-1}$) 2935, 1692, 1422, 1225, 1165; HRMS (CI) calcd C$_{26}$H$_{35}$NO$_2$ [M$^+$]: 393.2668, found: 393.2677.

**tert-Butyl (E)-4-(4-methoxy-4-oxobut-2-en-2-yl)piperidine-1-carboxylate (4m):**

S31
39 mg (69%, major: minor > 20:1 r.r.); white solid; m.p. 59-62 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 5.66 (s, 1H), 4.26 – 4.11 (m, 2H), 3.67 (s, 3H), 2.76 – 2.62 (m, 2H), 2.19 – 2.05 (m, 4H), 1.74 – 1.60 (m, 2H), 1.50 – 1.36 (m, 11H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 167.5, 162.6, 154.8, 114.6, 79.7, 51.0, 46.8, 44.1, 30.3, 28.6, 17.3; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2925, 1716, 1682, 1228, 1161; HRMS (ESI) calcd C\(_{15}\)H\(_{25}\)NO\(_4\)Na [M + Na]\(^+\): 306.1681, found: 306.1680.

**tert-Butyl (E)-4-(hex-2-en-2-yl)piperidine-1-carboxylate (4n):**
32 mg (60%, major: minor = 1.5:1 r.r.); yellowish oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 5.21 (q, \(J = 13.0, 6.4\) Hz, 0.4H)/ 5.14 (t, \(J = 6.6\) Hz, 0.6H), 4.24 – 4.03 (m, 2H), 2.75 – 2.57 (m, 2H), 2.04 – 1.87 (m, 3H), 1.66 – 1.54 (m, 5H), 1.45 (s, 9H), 1.38 – 1.21 (m, 4H), 0.94 – 0.81 (m, 3H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 155.0, 143.9, 138.5, 123.8, 117.9, 79.4, 45.5, 44.6, 43.3, 31.7, 31.0, 30.0, 28.6, 23.1, 22.3, 14.5, 13.9, 13.4; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2925, 1692, 1489, 1242, 697; HRMS (ESI) calcd C\(_{16}\)H\(_{29}\)NO\(_2\)Na [M + Na]\(^+\): 290.2096, found: 290.2092.

**tert-Butyl (E)-4-(4-methylpent-2-en-2-yl)piperidine-1-carboxylate (4o):**
25 mg (47%, major: minor = 2.6:1 r.r.); yellowish oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 5.16 (q, \(J = 6.7\) Hz, 0.27H)/ 4.96 (d, \(J = 8.8\) Hz, 0.68H), 4.24 – 4.03 (m, 2H), 2.88 – 2.78 (m, 0.27H)/ 2.56 – 2.43 (m, 0.67H), 2.74 – 2.59 (m, 2H), 2.01 – 1.85 (m, 1H), 1.63 – 1.49 (m, 5H), 1.45 (s, 9H), 1.40 – 1.27 (m, 2H), 0.98 (d, \(J = 7.0\) Hz, 1.67H)/ 0.91 (d, \(J = 6.6\) Hz, 4.55H); \(^1^3\)C NMR (150 MHz, CDCl\(_3\)) \(\delta\) 155.0, 149.2, 136.0, 131.7, 116.9, 79.3, 45.4, 44.6, 37.9, 33.9, 31.0, 29.0, 28.6, 27.0, 23.3, 21.0, 14.4, 13.0; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2931, 1692, 1419, 1228, 1175; HRMS (ESI) calcd C\(_{16}\)H\(_{29}\)NO\(_2\) [M]\(^+\): 267.2198, found: 267.2204.
**tert-Butyl (E)-4-(4-hydroxybut-2-en-2-yl)piperidine-1-carboxylate (4p):**
21.4 mg (47%, major : minor = 1:1 r.r.); yellowish oil; $^1$H NMR (600 MHz, CDCl$_3$) δ 5.41 (t, $J$ = 6.7 Hz, 1H), 4.23 – 4.08 (m, 4H), 2.73 – 2.63 (m, 2H), 2.02 – 1.97 (m, 1H), 1.67 – 1.62 (m, 5H), 1.46 (s, 9H), 1.42 – 1.33 (m, 2H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 155.0, 142.7, 122.8, 79.5, 59.5, 45.3, 44.4, 30.7, 28.6, 14.8; FT-IR (thin film, KBr): ν (cm$^{-1}$) 3406, 2935, 1696, 1425, 1166; HRMS (CI) calcd C$_{14}$H$_{23}$NO$_3$ [M]$^+$: 255.1834, found: 255.1843.

**tert-Butyl (Z)-4-(1-hydroxybut-2-en-2-yl)piperidine-1-carboxylate (4p’):**
Yellowish oil; $^1$H NMR (600 MHz, CDCl$_3$) δ 5.42 (q, $J$ = 6.8 Hz, 1H), 4.26 – 4.08 (m, 4H), 2.75 – 2.61 (m, 2H), 2.24 – 2.13 (m, 1H), 1.70 (d, $J$ = 6.6 Hz, 3H), 1.68 – 1.53 (m, 5H), 1.45 (s, 9H), 1.39 – 1.30 (m, 2H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 155.0, 142.9, 122.5, 79.4, 59.4, 44.5, 41.4, 31.6, 28.6, 13.4; FT-IR (thin film, KBr): ν (cm$^{-1}$) 3402, 2928, 1672, 1429, 1171; HRMS (Cl) calcd C$_{14}$H$_{25}$NO$_3$ [M]$^+$: 255.1834, found: 255.1843.

**tert-Butyl (E)-4-(5-hydroxypent-2-en-2-yl)piperidine-1-carboxylate (4q) (major product):**
21 mg (41%, major : minor = 2:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) δ 5.17 (t, $J$ = 6.6 Hz, 1H), 4.24 – 4.06 (m, 2H), 3.68 – 3.55 (m, 2H), 2.74 – 2.58 (m, 2H), 2.34 – 2.22 (m, 2H), 1.99 (t, $J$ = 11.4 Hz, 1H), 1.67 – 1.53 (m, 5H), 1.45 (s, 9H), 1.41 – 1.31 (m, 2H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 155.0, 142.2, 119.1, 79.5, 62.6, 45.6, 44.6, 31.5, 31.0, 28.6, 14.7; FT-IR (thin film, KBr): ν (cm$^{-1}$) 2928, 1696, 1425, 1235, 1168; HRMS (ESI) calcd C$_{15}$H$_{27}$NO$_3$Na [M + Na]$^+$: 292.1889, found: 292.1885.
**tert-Butyl (E)-4-(1-(trimethylsilyl)prop-1-en-2-yl)piperidine-1-carboxylate (4r):**
26 mg (44%), major : minor = 1:1 r.r.; yellowish oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 6.03 (q, J = 6.9 \text{ Hz}, 0.5H)/5.19 (s, 0.5H), 4.24 – 4.04 (m, 2H), 2.73 – 2.59 (m, 2H), 2.09 – 1.93 (m, 1H), 1.75 (s, 1.5)/1.74 (d, \(J = 5.5 \text{ Hz}, 1.5H\)), 1.69 – 1.61 (m, 1H)/1.58 – 1.50 (m, 1H), 1.45 (s, 9H), 1.39 – 1.28 (m, 2H), 0.15 (s, 4.5H)/0.08 (s, 4.5H); \(^13\)C NMR (150 MHz, CDCl\(_3\)) \(\delta 158.0, 155.0, 154.9, 144.8, 134.2, 121.9, 79.4, 79.3, 47.7, 44.7, 41.8, 32.9, 31.0, 28.6, 20.2, 18.0, 0.6, 0.2\); FT-IR (thin film, KBr): \(\nu (\text{cm}^{-1})\) 2934, 1692, 1235, 1168, 837; HRMS (CI) calcd C\(_{16}\)H\(_{31}\)NO\(_2\)Si [M]\(^+\): 297.2124, found: 297.2128.

**tert-Butyl (E)-4-(hex-3-en-3-yl)piperidine-1-carboxylate (4s):**
29 mg (54%); yellowish oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 5.07 (t, J = 6.9 \text{ Hz}, 1H), 4.22 – 4.05 (m, 2H), 2.72 – 2.61 (m, 2H), 2.07 – 1.97 (m, 4H), 1.96 – 1.90 (m, 1H), 1.69 – 1.59 (m, 2H), 1.46 (s, 9H), 1.40 – 1.22 (m, 2H), 0.99 – 0.91 (m, 6H); \(^13\)C NMR (150 MHz, CDCl\(_3\)) \(\delta 155.0, 144.1, 125.5, 79.3, 44.6, 43.2, 31.8, 28.6, 22.6, 21.0, 14.8, 14.3\); FT-IR (thin film, KBr): \(\nu (\text{cm}^{-1})\) 2961, 1689, 1419, 1225, 1168; HRMS (CI) calcd C\(_{16}\)H\(_{30}\)NO\(_2\) [M]\(^+\): 268.2277, found: 268.2272.

**tert-Butyl (E)-4-(oct-4-en-4-yl)piperidine-1-carboxylate (4t):**
25 mg (42%); yellowish oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 5.10 (t, J = 6.9 \text{ Hz}, 1H), 4.25 – 4.03 (m, 2H), 2.75 – 2.57 (m, 2H), 2.02 – 1.93 (m, 4H), 1.93 – 1.86 (m, 1H), 1.70 – 1.57 (m, 2H), 1.45 (s, 9H), 1.39 – 1.22 (m, 6H), 0.95 – 0.82 (m, 6H); \(^13\)C NMR (150 MHz, CDCl\(_3\)) \(\delta 155.0, 143.0, 124.2, 79.3, 44.6, 43.2, 32.1, 31.9, 29.9, 28.6, 23.3, 22.7, 14.5, 14.0\); FT-IR (thin film, KBr): \(\nu (\text{cm}^{-1})\) 2925, 1489, 1248, 1041, 697; HRMS (ESI) calcd C\(_{18}\)H\(_{33}\)NO\(_2\)Na [M + Na]\(^+\): 318.2409, found: 318.2406.
tert-Butyl (Z)-4-(1,2-di-p-tolylvinyl)piperidine-1-carboxylate (4u):  
41 mg (53%); yellowish solid; m.p. 94-97 °C; ¹H NMR (600 MHz, CDCl₃) δ 7.13 (d, J = 7.8 Hz, 2H), 6.99 (d, J = 7.9 Hz, 2H), 6.89 (d, J = 8.0 Hz, 2H), 6.77 (d, J = 8.1 Hz, 2H), 6.34 (s, 1H), 4.26 – 4.07 (m, 2H), 2.75 – 2.65 (m, 2H), 2.45 – 2.38 (m, 1H), 2.36 (s, 3H), 2.23 (s, 3H), 1.80 – 1.73 (m, 2H), 1.47 – 1.43 (m, 11H); ¹³C NMR (150 MHz, CDCl₃) δ 154.9, 145.8, 138.1, 136.6, 136.0, 134.5, 129.4, 129.0, 128.8, 128.7, 125.1, 79.4, 45.9, 44.5, 31.3, 28.6, 21.4, 21.2; FT-IR (thin film, KBr): ν (cm⁻¹) 2921, 1686, 1425, 1161, 731; HRMS (ESI) calcd C₂₆H₃₃NO₂Na [M + Na]⁺: 414.2409, found: 414.2414.

and

tert-Butyl (Z)-4-(1-phenyl-2-(p-tolyl)vinyl)piperidine-1-carboxylate (4v):  
39 mg (52%), major : minor = 1:1 r.r.; yellowish oil; ¹H NMR (400 MHz, CDCl₃) δ 7.38 – 7.27 (m, 2H), 7.15 – 7.01 (m, 3H), 6.99 (d, J = 8.0 Hz, 1H), 6.90 – 6.85 (m, 2H), 6.74 (d, J = 8.2 Hz, 1H), 6.37 (s, 0.5H)/6.36 (s, 0.5H), 4.26 – 4.11 (m, 2H), 2.77 – 2.65 (m, 2H), 2.48 – 2.40 (m, 1H), 2.36 (s, 1.5H)/2.22 (s, 1.5H), 1.84 – 1.74 (m, 2H), 1.50 – 1.42 (m, 11H); ¹³C NMR (150 MHz, CDCl₃) δ 154.9, 146.8, 145.8, 141.2, 137.9, 137.4, 136.7, 136.1, 134.4, 129.4, 129.2, 129.1, 129.0, 128.8, 128.7, 127.9, 127.0, 126.3, 125.31, 125.26, 79.5, 45.9, 45.8, 44.4, 31.3, 28.6, 21.4, 21.2; FT-IR (thin film, KBr): ν (cm⁻¹) 2931, 1692, 1422, 1161, 701; HRMS (ESI) calcd C₂₅H₃₂NO₂ [M + H]⁺: 378.2433, found: 378.2425.

and
**tert-Butyl**

**(Z)-4-(2-(4-(methoxycarbonyl)phenyl)-1-phenylvinyl)piperidine-1-carboxylate (4w):**

40 mg (48%, major : minor = 2.3:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.00 – 7.97 (m, 0.6H)/7.74 – 7.71 (m, 1.5H), 7.32 – 7.28 (m, 2H), 7.20 – 7.17 (m, 0.6H)/6.92 – 6.87 (m, 1.5H), 7.09 – 7.05 (m, 2.3H)/6.86 – 6.82 (m, 0.7H), 6.45 (s, 0.3H)/6.42 (s, 0.7H), 4.27 – 4.12 (m, 2H), 3.92 (s, 1H)/ 3.84 (s, 2H), 2.77 – 2.64 (m, 2H), 2.51 – 2.42 (m, 1H), 1.84 – 1.74 (m, 2H), 1.49 – 1.41 (m, 11H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 167.1, 167.0, 154.9, 149.5, 146.2, 145.8, 142.2, 140.4, 136.8, 130.0, 129.24, 129.19, 128.82, 128.76, 128.1, 127.8, 127.5, 126.7, 126.2, 124.7, 79.57, 79.55, 52.2, 52.1, 45.9, 45.5, 44.3, 31.3, 31.2, 28.6; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2945, 1719, 1689, 1275, 1168; HRMS (ESI) calcld C$_{26}$H$_{31}$NO$_4$Na [M + Na]$^+$: 444.2151, found: 444.2149.

\[ \text{\includegraphics[width=0.5\textwidth]{tert-butyl.png}} \]

**tert-Butyl**

**(E)-4-((1-(4-(2-(1-(4-chlorobenzoyl)-5-methoxy-2-methyl-1H-indol-3-yl)acetoxy)methyl)phenyl)prop-1-en-2-yl)piperidine-1-carboxylate (4x):**

107 mg (80%, major : minor >20:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.66 (d, $J$ = 8.0 Hz, 2H), 7.47 (d, $J$ = 8.0 Hz, 2H), 7.27 (d, $J$ = 8.0 Hz, 2H), 7.21 (d, $J$ = 7.5 Hz, 2H), 6.96 – 6.87 (m, 2H), 6.68 (d, $J$ = 8.8 Hz, 1H), 6.29 (s, 1H), 5.14 (s, 2H), 4.32 – 4.17 (m, 2H), 3.78 (s, 3H), 3.73 (s, 2H), 2.81 – 2.69 (m, 2H), 2.38 (s, 3H), 2.23 – 2.13 (m, 1H), 1.84 (s, 3H), 1.81 – 1.72 (m, 2H), 1.54 – 1.46 (m, 11H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 170.8, 168.4, 156.2, 155.0, 142.8, 139.4, 138.7, 136.0, 134.0, 133.5, 131.3, 130.9, 130.7, 129.24, 129.20, 128.2, 123.6, 115.1, 112.7, 112.0, 101.3, 79.5, 66.9, 55.8, 46.4, 44.4, 30.9, 30.6, 28.6, 16.3, 13.5; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 2925, 1689, 1362, 1161, 701; HRMS (ESI) calcld C$_{39}$H$_{43}$ClN$_2$O$_6$Na [M + Na]$^+$: 693.2707, found: 693.2702.

\[ \text{\includegraphics[width=0.5\textwidth]{tert-butyl.png}} \]

**Methyl 3-phenyl-2-((2,2,6,6-tetramethylpiperidin-1-yl)oxy)propanoate (5):**

colorless oil; 45%; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.32 (t, $J$ = 7.0 Hz, 2H), 7.27 (d, $J$ = 6.8 Hz, 1H), 7.25 – 7.19 (m, 2H), 4.52 (dd, $J$ = 10.0, 5.4 Hz, 1H), 3.57 (s, 3H), 3.32 (dd, $J$ = 13.1, 5.2 Hz, 1H), 3.11 – 3.01 (m, 1H), 1.57 – 1.45 (m, 4H), 1.42 – 1.32 (m,
2H), 1.30 (s, 3H), 1.19 (s, 6H), 1.09 (s, 3H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 172.9, 135.8, 129.2, 128.2, 126.5, 86.4, 60.4, 59.3, 50.9, 40.1, 40.0, 38.4, 33.4, 32.7, 20.1, 19.9, 16.9; HRMS (CI) calcd C$_{19}$H$_{30}$NO$_3$ [M + H]$^+$: 320.2226, found: 320.2234.

1,4-Bis(2-(benzo[d][1,3]dioxol-5-yl)ethyl)-2,4,6-triphenyl-1,4-dihydropyridine (6):
71 mg (78%); yellow oil; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.58 – 7.50 (m, 6H), 7.44 – 7.33 (m, 8H), 7.18 (t, $J$ = 7.3 Hz, 1H), 6.67 (d, $J$ = 7.9 Hz, 1H), 6.64 (d, $J$ = 1.5 Hz, 1H), 6.58 (dd, $J$ = 7.9, 1.6 Hz, 1H), 6.42 (d, $J$ = 7.8 Hz, 1H), 5.92 (dd, $J$ = 7.9, 1.6 Hz, 1H), 5.90 (d, $J$ = 1.4 Hz, 1H), 5.87 (s, 2H), 5.77 (s, 2H), 5.12 (s, 2H), 3.21 – 3.14 (m, 2H), 2.62 – 2.54 (m, 2H), 2.24 – 2.18 (m, 2H), 2.13 – 2.05 (m, 2H); $^{13}$C NMR (150 MHz, CDCl$_3$) δ 151.5, 147.6, 147.3, 145.6, 145.5, 143.2, 138.1, 137.0, 133.0, 128.5, 128.2, 128.1, 126.5, 125.7, 121.3, 121.1, 113.3, 109.1, 108.9, 108.2, 108.0, 100.8, 100.7, 50.3, 47.1, 43.9, 34.6, 32.5; FT-IR (thin film, KBr): ν (cm$^{-1}$) 2921, 1489, 1038, 701; HRMS (ESI) calcd C$_{41}$H$_{36}$NO$_4$ [M + H]$^+$: 606.2644, found: 606.2640.

(4-(2,3-Dimethyldec-1-en-1-yl)phenyl)methanol (7):
27 mg (52%, major : minor >20:1 r.r.); colorless oil; $^1$H NMR (400 MHz, CDCl$_3$) δ 7.31 (d, $J$ = 8.2 Hz, 2H), 7.24 (d, $J$ = 8.1 Hz, 2H), 6.26 (s, 1H), 4.67 (s, 2H), 2.32 – 2.20 (m, 1H), 1.76 (d, $J$ = 1.3 Hz, 3H), 1.72 – 1.63 (m, 1H), 1.50 – 1.39 (m, 1H), 1.38 – 1.18 (m, 10H), 1.07 (d, $J$ = 6.9 Hz, 3H), 0.88 (t, $J$ = 6.9 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 143.8, 138.5, 138.3, 129.3, 126.9, 124.0, 65.5, 43.8, 35.3, 32.1, 29.9, 29.5, 27.8, 22.8, 19.9, 14.3, 14.2; FT-IR (thin film, KBr): ν (cm$^{-1}$) 3332, 2921, 1489, 1424, 1038, 701; HRMS (ESI) calcd C$_{19}$H$_{36}$O [M]$^+$: 274.2297, found: 274.2291.
(E)-4-Methyl-5-phenylpent-3-en-1-ol (8a):
24 mg (68% yield, major : minor = 1.3:1 r.r.); yellowish oil; $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.31 – 7.27 (m, 2H), 7.22 – 7.16 (m, 3H), 5.50 (q, $J$ = 6.8 Hz, 0.43H)/ 5.27 (t, $J$ = 7.3 Hz, 0.55H), 3.66 (t, $J$ = 6.6 Hz, 1.1H)/ 3.60 (t, $J$ = 6.8 Hz, 0.9H), 3.34 (s, 0.9H)/ 3.33 (s, 1.1H), 2.34 (q, $J$ = 6.8 Hz, 1.1H)/ 2.30 (t, $J$ = 6.8 Hz, 0.9H), 1.69 (d, $J$ = 6.8 Hz, 1.4H)/ 1.60 (s, 1.6H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 140.20, 140.15, 138.2, 135.6, 129.0, 128.9, 128.44, 128.39, 126.23, 126.15, 124.3, 122.0, 62.6, 60.9, 46.4, 44.0, 32.9, 31.7, 16.2, 13.7; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 3342, 2908, 1492, 1041, 694; HRMS (Cl) calcd C$_{12}$H$_{16}$O [M]$^+$: 176.1201, found: 176.1204.

(E)-4-Methyl-5-(p-toly)pent-3-en-1-ol (8b):
19 mg (51% yield, major : minor = 1.5:1 r.r.); yellowish oil; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.17 – 7.08 (m, 4H), 5.24 (q, $J$ = 6.6 Hz, 0.4H)/ 5.06 (t, $J$ = 6.8 Hz, 0.6H), 3.70 – 3.58 (m, 2H), 3.32 (s, 2H), 2.40 – 2.29 (m, 2H), 2.26 (d, $J$ = 3.5 Hz, 3H), 1.65 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 138.0, 137.2, 136.96, 136.93, 134.5, 130.34, 130.28, 130.0, 129.8, 126.43, 126.35, 125.99, 125.95, 123.7, 121.6, 62.6, 61.1, 43.4, 41.0, 33.7, 31.7, 19.57, 19.55, 16.8, 13.7; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 3335, 2921, 1462, 1048, 734; HRMS (Cl) calcd C$_{13}$H$_{18}$O [M]$^+$: 190.1358, found: 190.1363.

(E)-5-(2,6-Dimethylphenyl)-4-methylpent-3-en-1-ol (8c):
18 mg (45% yield, major : minor = 3.5:1 r.r.); yellowish oil; $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.07 – 6.99 (m, 3H), 4.82 (q, $J$ = 13.6, 6.7 Hz, 0.25H)/ 4.67 (t, $J$ = 7.5 Hz, 0.75H), 3.80 – 3.76 (m, 0.5H)/ 3.52 (t, $J$ = 6.6 Hz, 1.5H), 3.31 (s, 2H), 2.48 – 2.43 (m, 1H), 2.29 – 2.21 (m, 7H), 1.75 (s, 2.25H)/ 1.57 (d, $J$ = 6.8 Hz, 0.75H); $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 137.3, 136.4, 136.1, 128.0, 126.1, 120.9, 119.1, 62.5, 61.3, 38.8, 36.6, 35.0, 31.6, 20.04, 19.96, 19.6, 17.6; FT-IR (thin film, KBr): $\nu$ (cm$^{-1}$) 3352, 2918, 1469, 1041, 767; HRMS (Cl) calcd C$_{14}$H$_{20}$O [M]$^+$: 204.1514, found: 204.1517.
**tert-Butyl (E)-4-(2-methyl-3-phenylprop-1-en-1-yl)piperidine-1-carboxylate (9a):**

49 mg (78% yield, major : minor = 1.5:1 r.r.); yellowish oil; ¹H NMR (400 MHz, CDCl₃) δ 7.35 – 7.29 (m, 2H), 7.27 – 7.19 (m, 3H), 5.18 – 5.11 (m, 1H), 4.24 – 4.05 (m, 2H), 3.32 (s, 1.2H), 2.87 – 2.76 (m, 1H), 2.74 – 2.63 (m, 1H), 2.44 – 2.33 (m, 0.6H)/1.82–1.75 (m, 0.4H), 1.75-1.62 (m, 4H), 1.75–1.26 (m, 4H), 1.72–1.68 (m, 1.2H)/1.52 (s, 5.4H)/1.50 (s, 3.6H); ¹³C NMR (150 MHz, CDCl₃) δ 155.02, 155.00, 142.1, 140.8, 140.3, 134.2, 131.0, 129.3, 128.9, 128.34, 128.26, 126.1, 125.9, 122.1, 79.40, 79.35, 46.3, 44.2, 39.9, 38.3, 35.4, 32.2, 30.2, 28.61, 28.59, 16.1, 13.1; FT-IR (thin film, KBr): ν (cm⁻¹) 2931, 1696, 1425, 1158, 694; HRMS (ESI) calcd C₂₀H₂₉NO₂Na [M + Na]⁺: 338.2096, found: 338.2092.

**tert-Butyl (E)-4-(2-methyl-3-(o-tolyl)prop-1-en-1-yl)piperidine-1-carboxylate (9b):**

32 mg (67% yield, major : minor = 1.7:1 r.r.); yellowish oil; ¹H NMR (600 MHz, CDCl₃) δ 7.14 – 7.10 (m, 3H), 7.10 – 7.04 (m, 1H), 4.92 – 4.89 (m, 0.63H)/4.70 – 4.66 (m, 0.37H), 4.28 – 4.15 (m, 0.74H)/4.10 – 3.95 (m, 1.26H), 3.27 (s, 1.31H)/3.20 (s, 0.73H), 2.82 – 2.66 (m, 2H), 2.40 – 2.31 (m, 1H), 2.25 (s, 1.9H)/2.19 (s, 1.1H), 1.76 – 1.17 (m, 4H), 1.61 (d, J = 0.7 Hz, 1.9H)/1.59 – 1.56 (m, 1.1H), 1.48 (s, 3.3H)/1.45 (s, 5.7H); ¹³C NMR (150 MHz, CDCl₃) δ 155.02, 154.99, 141.0, 138.4, 138.1, 137.0, 136.9, 133.1, 130.7, 130.6, 130.24, 130.21, 129.7, 126.28, 126.27, 125.9, 120.0, 79.5, 79.4, 44.2, 43.4, 38.3, 36.3, 35.3, 32.2, 30.0, 28.6, 19.6, 19.4, 16.6, 13.0; FT-IR (thin film, KBr): ν (cm⁻¹) 2925, 1692, 1425, 1235, 1161; HRMS (ESI) calcd C₂₁H₃₁NO₂Na [M + Na]⁺: 352.2252, found: 352.2250.

**tert-Butyl (E)-4-(2,6-dimethylphenyl)-2-methylprop-1-en-1-yl)piperidine-1-**
carboxylate (9c):  
49 mg (71% yield, major : minor = 2.4:1 r.r.); yellowish oil; \(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.05 – 6.97 (m, 3H), 4.54 – 4.51 (m, 0.78H)/4.50 – 4.47 (m, 0.3H), 4.31 – 4.18 (m, 0.6H)/4.07 – 3.89 (m, 1.51H), 3.27 (s, 1.5H)/3.20 – 3.18 (m, 0.6H), 2.81 – 2.67 (m, 2H), 2.36 – 2.29 (m, 1H), 2.22 (s, 4.24H)/ 2.17 (s, 1.61H), 1.78 – 1.05 (m, 4H), 1.70 (s, 2.2H)/1.52 – 1.50 (m, 0.9H), 1.49 (s, 2.75H)/1.43 (s, 6.57H); \(^1^3\)C NMR (150 MHz, CDCl\(_3\)) \(\delta\) 155.0, 154.9, 139.1, 137.32, 137.28, 136.8, 136.5, 131.8, 128.3, 128.0, 127.9, 126.02, 125.97, 117.3, 79.6, 79.3, 44.1, 38.7, 38.4, 35.2, 32.1, 29.9, 28.7, 28.6, 20.0, 19.8, 17.4, 12.9; FT-IR (thin film, KBr): \(\nu\) (cm\(^{-1}\)) 2925, 1692, 1419, 1161, 767; HRMS (Cl) calcd C\(_{22}\)H\(_{33}\)NO\(_2\) [M]+: 343.2511, found: 343.2503.

9. NMR Spectra for the substrates and products

\(^1\)H NMR of 2a
$^{13}$C NMR of 2a

$^{19}$F NMR of 2a
$^1$H NMR of 2b

$^{13}$C NMR of 2b
$^{19}$F NMR of $2b$

$^1$H NMR of $2c$
$^{13}$C NMR of $2c$

$^{19}$F NMR of $2c$
$^1$H NMR of 2d

$^{13}$C NMR of 2d
$^{19}$F NMR of 2d

$^1$H NMR of 2e
$^{13}$C NMR of 2e

$^{19}$F NMR of 2e
$^1$H NMR of 2f

$^{13}$C NMR of 2f
$^{19}$F NMR of 2f

$^1$H NMR of 2g
$^{13}$C NMR of 2g

$^{19}$F NMR of 2g
$^1$H NMR of 2h

$^{13}$C NMR of 2h
$^{19}$F NMR of 2h

$^1$H NMR of 2i
$^{13}$C NMR of 2i

$^{19}$F NMR of 2i
$^1$H NMR of 2j

$^{13}$C NMR of 2j
$^{19}$F NMR of 2j

$^1$H NMR of 2k
$^{13}$C NMR of 2k

$^{19}$F NMR of 2k
$^1$H NMR of 2l

$^{13}$C NMR of 2l
$^{19}$F NMR of 2l

$^1$H NMR of 2m
\(^{13}\)C NMR of 2m

\(^{19}\)F NMR of 2m
$^1$H NMR of 2n

$^{13}$C NMR of 2n
$^{19}$F NMR of 2n

$^1$H NMR of 2o
$^{13}$C NMR of 2o

$^{19}$F NMR of 2o
$^1$H NMR of 2p

$^{13}$C NMR of 2p
$^{19}\text{F NMR of 2p}$

$^{1}\text{H NMR of 2q}$
$^{13}$C NMR of $2q$

$^{19}$F NMR of $2q$
$^1$H NMR of 2r

$^{13}$C NMR of 2r
$^{19}$F NMR of 2r

$^1$H NMR of 2s
$^{13}$C NMR of 2s

$^{19}$F NMR of 2s
$^1$H NMR of 2t

$^{13}$C NMR of 2t
$^{19}$F NMR of 2t

$^1$H NMR of 1ac
$^{13}$C NMR of 1ac

$^1$H NMR of 1ad
$^{13}$C NMR of 1ad

$^1$H NMR of 1ae
$^{13}\text{C NMR of 1ae}$

$^{1}\text{H NMR of 1af}$
$^{13}$C NMR of 1af

$^1$H NMR of 1ag
$^{13}$C NMR of 1ag

$^1$H NMR of 1ah
$^{13}$C NMR of 1ah

$^1$H NMR of 1ai
$^{13}$C NMR of 1ai

$^1$H NMR of 1aj
$^{13}$C NMR of 1aj

$^1$H NMR of 1ak
$^{13}$C NMR of 1ak

$^1$H NMR of 1al
$^{13}$C NMR of 1al

$^1$H NMR of 1am
$^{13}$C NMR of 1am

$^1$H NMR of 1an
$^{13}$C NMR of 1an

$^1$H NMR of 1ao
$^{13}$C NMR of 1ao

$^1$H NMR of 1ap
$^{13}$C NMR of 1ap

$^1$H NMR of 1aq
$^{13}$C NMR of 1aq

$^1$H NMR of 1ar
$^{13}$C NMR of 1ar

$^1$H NMR of 1as
$^{13}$C NMR of 1as

$^1$H NMR of 1bi
$^{13}$C NMR of 1bi

$^1$H NMR of 3a
$^{13}$C NMR of 3a

$^1$H NMR of 3b
**13C NMR of 3b**

![13C NMR spectrum of 3b](image1)

**1H NMR of 3c**

![1H NMR spectrum of 3c](image2)
$^{13}$C NMR of 3c

$^1$H NMR of 3d
$^{13}$C NMR of 3d

$^1$H NMR of 3e
$^{13}$C NMR of 3e

$^1$H NMR of 3f
$^{13}$C NMR of 3f

$^1$H NMR of 3g
$^{13}$C NMR of 3g

$^1$H NMR of 3h
$^{13}$C NMR of $3h$

$^1$H NMR of $3i$
$^{13}$C NMR of 3i

$^1$H NMR of 3j
$^{13}$C NMR of 3j

$^1$H NMR of 3k
$^{13}$C NMR of 3k

$^1$H NMR of 3l
$^{13}$C NMR of 3l

$^1$H NMR of 3m
$^{13}$C NMR of $3m$

$^1$H NMR of $3n$
$^{13}$C NMR of $3n$

$^1$H NMR of $3o$
$^{13}$C NMR of 3o

$^1$H NMR of 3p
$^{13}$C NMR of $3p$

$^1$H NMR of $3q$
$^{13}$C NMR of 3q

$^1$H NMR of 3r
$^{13}$C NMR of 3r

$^1$H NMR of 4a
$^{13}$C NMR of 4a

$^1$H NMR of 4b
$^{13}$C NMR of $4b$

$^1$H NMR of $4c$
$^{13}$C NMR of 4c

$^1$H NMR of 4d
$^{13}$C NMR of 4d

$^1$H NMR of 4e
$^{13}$C NMR of 4e

$^1$H NMR of 4f
$^{13}$C NMR of 4f

$^1$H NMR of 4g
$^{13}$C NMR of 4g

$^1$H NMR of 4h
$^{13}$C NMR of $4h$

$^1$H NMR of $4i$
$^{13}$C NMR of 4i

$^1$H NMR of 4j
$^{13}$C NMR of 4j

$^1$H NMR of 4k
$^{13}$C NMR of 4k

$^1$H NMR of 4l
$^{13}$C NMR of 4l

$^1$H NMR of 4m
$^{13}$C NMR of 4m

$^1$H NMR of 4n
$^{13}$C NMR of 4n

$^1$H NMR of 4o
$^{13}$C NMR of 4o

$^1$H NMR of 4p
$^{13}$C NMR of 4p

$^1$H NMR of 4p'}
$^{13}$C NMR of 4p

$^1$H NMR of 4q
$^{13}$C NMR of 4q

$^1$H NMR of 4r
$^{13}$C NMR of 4r

$^1$H NMR of 4s
$^{13}$C NMR of 4s

$^1$H NMR of 4t
$^{13}$C NMR of 4t

$^1$H NMR of 4u
$^{13}$C NMR of 4u

$^1$H NMR of 4v
$^{13}$C NMR of 4v

$^1$H NMR of 4w
$^{13}$C NMR of 4w

$^1$H NMR of 4x
$^{13}$C NMR of $4x$

$^1$H NMR of $5$
$^{13}$C NMR of 5

$^1$H NMR of 6
$^{13}$C NMR of 6

$^1$H NMR of 7
$^{13}$C NMR of 7

$^1$H NMR of 8a
$^{13}$C NMR of 8a

$^1$H NMR of 8b
$^{13}$C NMR of 8b

$^1$H NMR of 8c

S136
$^{13}$C NMR of 8c

$^1$H NMR of 9a
$^{13}$C NMR of 9a

$^1$H NMR of 9b
$^{13}$C NMR of 9b

$^1$H NMR of 9c
$^{13}$C NMR of 9c