Intermolecular Radical Addition to Ketoacids Enabled by Boron Activation

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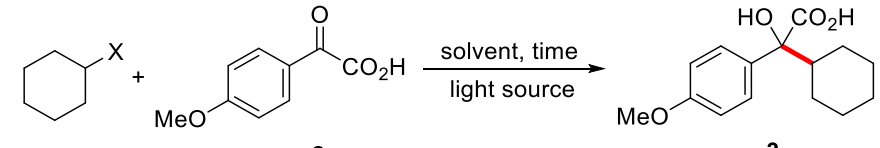
Supplementary Information

I. General Procedures

Unless otherwise noted, all reactions of substrates preparation were conducted in flame-dried glassware under a nitrogen atmosphere using anhydrous solvent passed through an activated alumina column (Innovative Technology). Commercially available reagents were used without further purification. Thin layer chromatography (TLC) was performed using Jiangyou TLC silica gel plates HSG F_{254} and visualized using UV light, and potassium permanganate. Flash chromatography was performed on Lisure science EZ purification system using the Santai technologies silica gel cartridge. Preparative thin layer chromatography separations were carried out on 0.25 or 0.50 mm E. Merck silica gel plates (60F-254). Photochemical reactions were carried out with a household 23W compact fluorescence lamp (white CFL) bought from nVc Lighting. ^{1}H NMR (500 MHz), ^{19}F NMR (376 MHz), ^{13}C NMR (126 MHz) and ^{11}B NMR (128 MHz) were recorded on a NMR spectrometer with $CDCl_3$ or DMSO-d_6 as the solvent, unless otherwise noted. Chemical shifts of ^{1}H, ^{13}C NMR spectra were reported in parts per million (ppm) using the residual solvent signals as references ($CDCl_3$: δ H = 7.26 ppm, δ C = 77.16 ppm). All coupling constants (*J* values) were reported in Hertz (Hz). Data for ^{1}H NMR were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, brs = broad singlet). IR spectra were recorded on a Thermo Scientific Nicolet 380 FT-IR spectrometer. MS experiments were performed on a Bruker maXis 4G instrument for HRMS-ESI, an Agilent 5973N instrument for EI-MS, and a Waters Micromass GCT Premier instrument for HRMS-EI. Optical absorption spectra were recorded on a Thermo Nanodrop 2000c UV/Vis spectrometer.

II. Detailed Reaction Optimizations

Table S1. Detailed Reaction Optimizations



1, X = $B(OH)_2$
5, X = BF_3K

entry[a]	X	solvent	time/h	light source	Conv.[b]	NMR yield[b]
1	$B(OH)_2$	CH_2Cl_2	5	23 W CFL	>95%	84%
2	$B(OH)_2$	1,2-DCE	5	23 W CFL	88%	59%
3	$B(OH)_2$	CH_3CN	5	23 W CFL	49%	19%
4	$B(OH)_2$	DMF	5	23 W CFL	<5%	<5%
5	$B(OH)_2$	HFIP	20	23 W CFL	39%	35%
6	$B(OH)_2$	CH_3OH	5	23 W CFL	6%	<5%
7	$B(OH)_2$	CH_2Cl_2	5	8 W blue LED	87%	76%
8	$B(OH)_2$	CH_2Cl_2	5	band-pass 475nm	75%	64%
9	$B(OH)_2$	CH_2Cl_2	5	no light	22%	21%
10	$B(OH)_2$	1,2-DCE	5	no light	17%	13%
11	$B(OH)_2$	1,2-DCE	5	no light (50 °C)	22%	14%
12	$B(OH)_2$	1,2-DCE	5	no light (80 °C)	15%	10%
13	BF_3K	CH_2Cl_2/H_2O 1:1	5	23 W CFL	>95%	95%(80%[c])
14	BF_3K	CH_3CN	5	23 W CFL	33%	7%
15	BF_3K	acetone	5	23 W CFL	13%	<5%
16	BF_3K	CH_2Cl_2/H_2O 1:1	5	no light	84%	49%
17	$B(OH)_2$	CH_2Cl_2/H_2O 1:1	5	23 W CFL	84%	69%

[a]Reaction conditions: **2** (0.10 mmol, 1.0 eq.), **1** or **5** (0.30 mmol, 3.0 eq.) in 2.0 mL solvent with a light source irradiation at room temperature in the atmosphere of nitrogen, unless otherwise noted. [b]Conversions and yields were determined by ^1H NMR analysis (1,3,5-trimethoxylbenzene as the external standard), and isolated yields were in parentheses. [c]Product was isolated after esterification with $TMSCHN_2$.

III. Mechanistic Investigations

The Emission Spectra of Light Sources

The emission spectra of light sources were in Figure S1 and S2. Emission spectrum of the household white CFL was measured by HR2000 High-Resolution Spectrometer (Ocean Optics). Photochemical reaction in band-pass 475 nm was carried with smart xenon lamp light source CEL-HXF300E/HXUV300E obtained from CEAULIGHT.

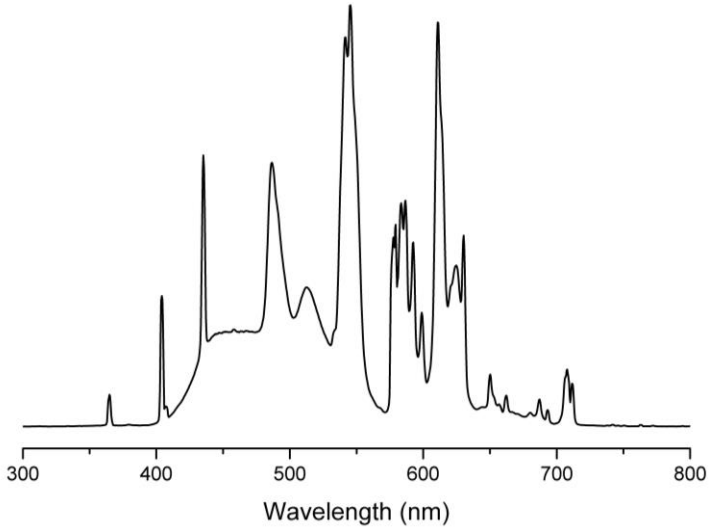


Figure S1. The emission spectrum of 23 W CFL.

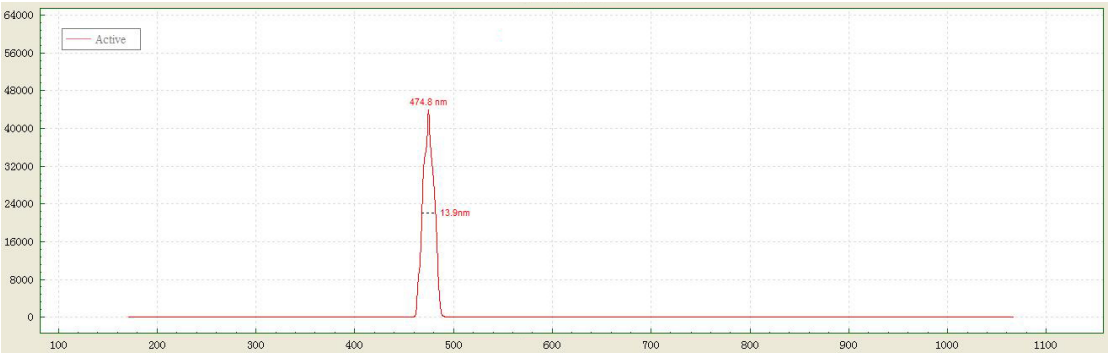


Figure S2. The emission spectrum of band-pass 475 nm.

Optical Absorption Spectra

Optical absorption spectra between α-ketoacid **2** (0.05 M) and organoboron compounds (0.05 M) in 1.0 mL CH_2Cl_2 or DMSO (for **5**) were recorded in 10 mm path quartz

cuvettes using a Thermo Nanodrop 2000c UV/Vis spectrometer. Upon mixing **2** with alkyl boronic acid (**16** or **41**), a red-shift spectrum was observed. However, upon mixing **2** with alkyl boronic ester **7** or trifluoroborate **5**, no new absorption band was observed.

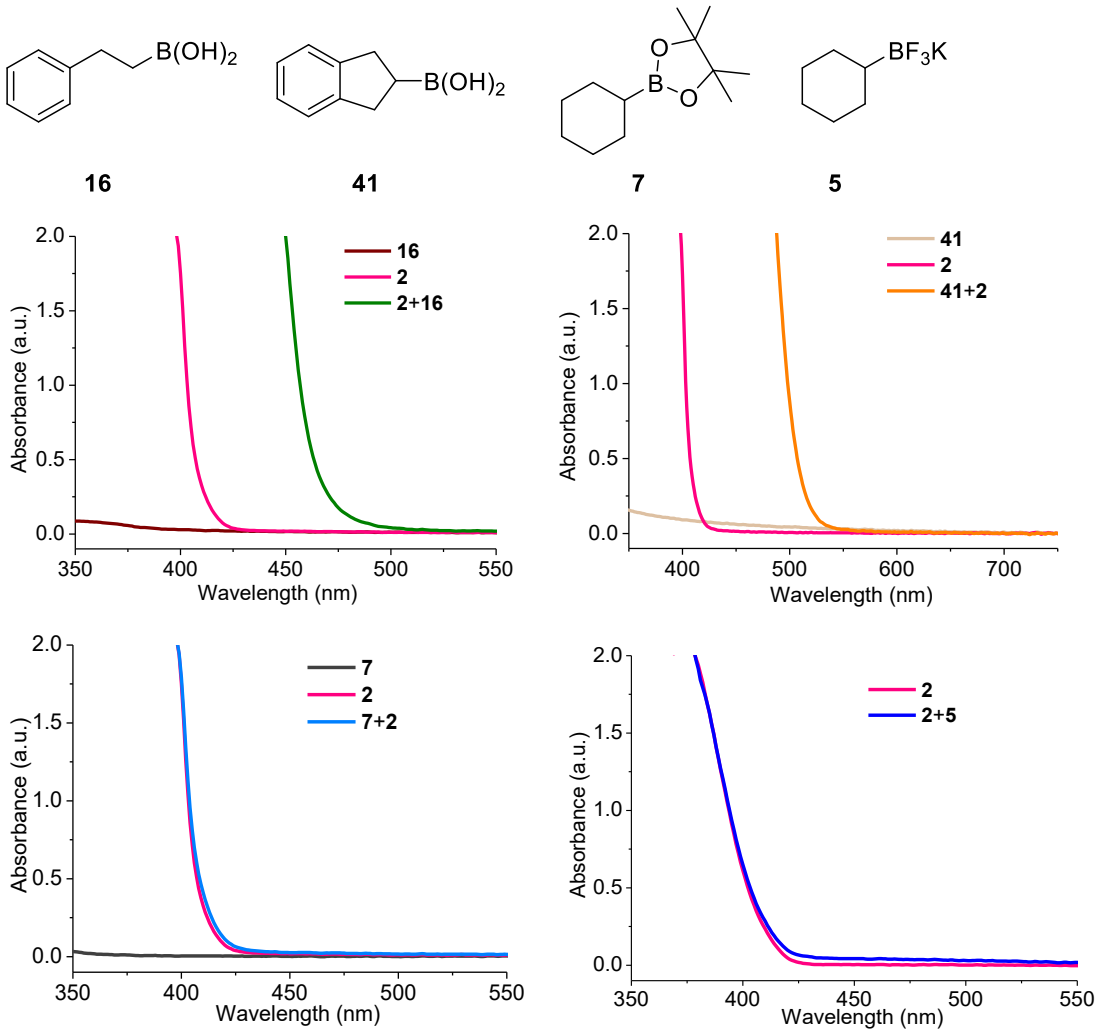
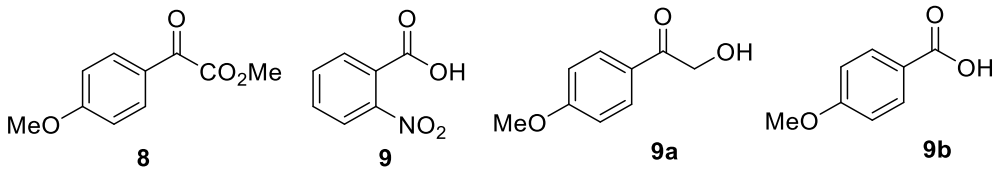


Figure S3. UV/vis absorption spectra of α-ketoacid 2 and boron compounds

Optical absorption spectra between cyclohexyl boronic acid **1** (0.05 M) and ketoacid's analogs (0.05 M) in 1.0 mL CH_2Cl_2 were recorded in 10 mm path quartz cuvettes using a Thermo Nanodrop 2000c UV/Vis spectrometer. When **1** was mixed with two analogs which have either similar structure or similar pKa to **2** (pKa 2.2), no new absorption band was observed.



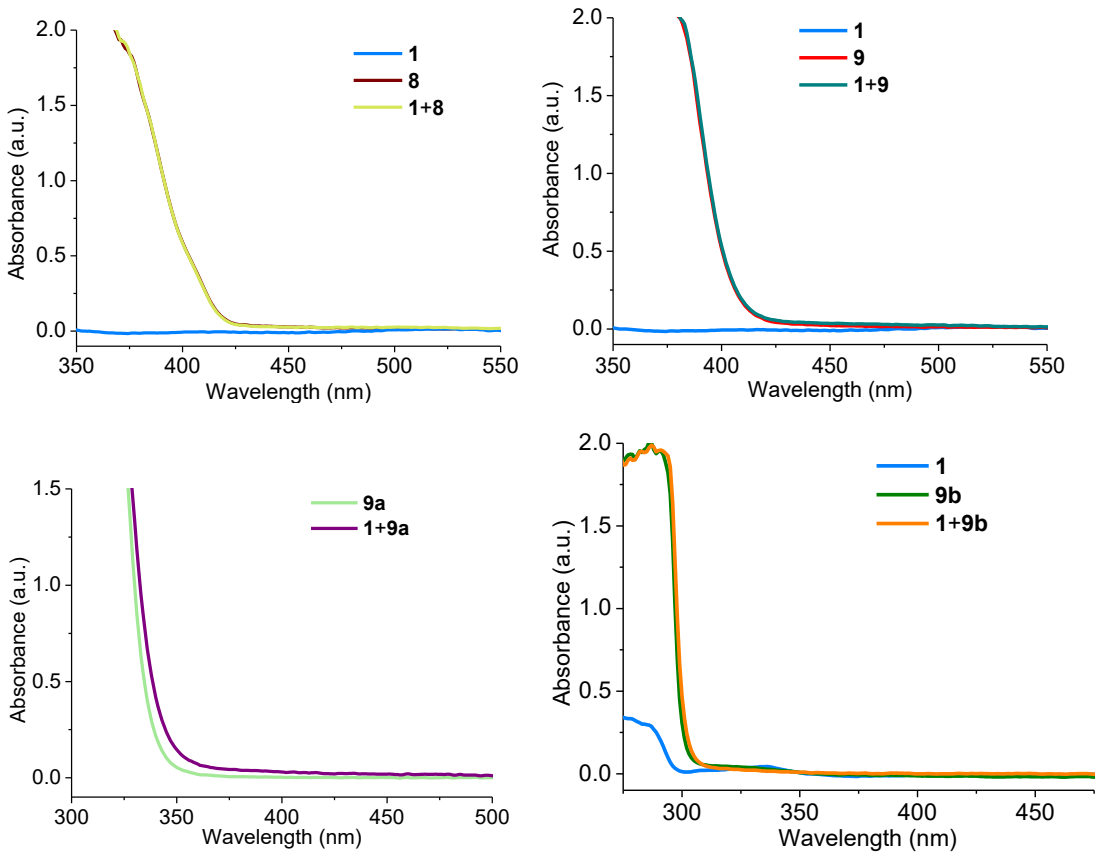


Figure S4. UV/vis spectra of boronic acid 1 and ketoacid's analogs.

Optical absorption spectra between ketoacid **2** (0.05 M), cyclohexyl-dihydropyridine **44** (0.05 M), and trimethyl borate **45** (0.05 M) in 1.0 mL CH_2Cl_2 (5% HFIP added) were recorded in 10 mm path quartz cuvettes using a Thermo Nanodrop 2000c UV/Vis spectrometer. When **2** was mixed with **45**, a red-shift spectrum was observed, while **44** had little effect on the spectra.

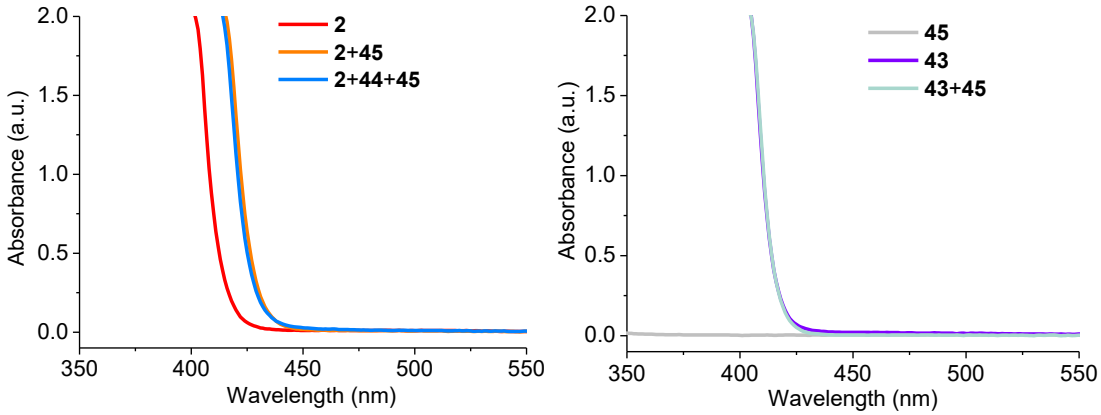


Figure S5. UV/vis spectra of ketoacid 2 and trimethyl borate 45.

Stoichiometry of the Molecular Complex in Solution

The Job's plot was constructed to evaluate the stoichiometry of the EDA complex[1] between boronic acid **1** and α-ketoacid **2**. We measured the absorption at 450 nm in DCM (5% HFIP was added to improve the solubility of **1**) solutions with different donor/acceptor ratios with the constant total concentration (0.05 M) of the two components. All the absorption spectra were recorded in 10 mm path quartz cuvettes using a Thermo Nanodrop 2000c UV/Vis spectrometer. The absorbance values were plotted against the molar fraction (%) of α-ketoacid **2**.

NMR Experiments

^{19}F NMR Titration Experiments

Solutions containing equal molar concentrations of the cyclohexyl boronic acid (**1**, 0.05 M in CH_2Cl_2) and ketoacid (**6**, 0.05 M in CH_2Cl_2) were prepared and mixed to cover the ratio of **6** from 20% to 100%. In NMR titration experiments, we observed ^{19}F NMR (376 MHz) signal of **6** shifted upfield with the addition of **1**, while ^{19}F NMR signal didn't shift only with concentration change of **6** without the addition of **1**.

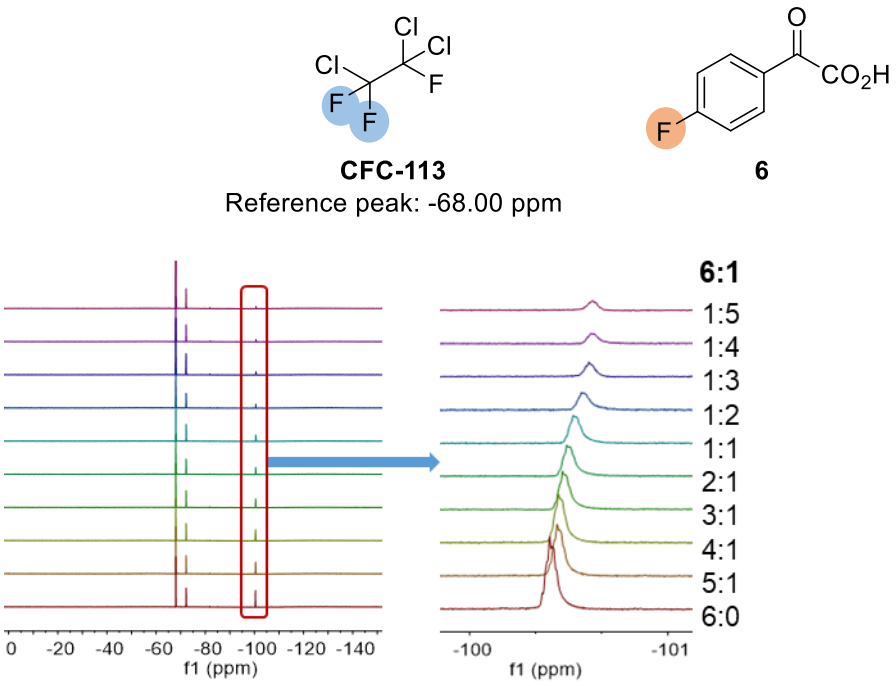


Figure S6. ^{19}F NMR titration between 6 and 1.

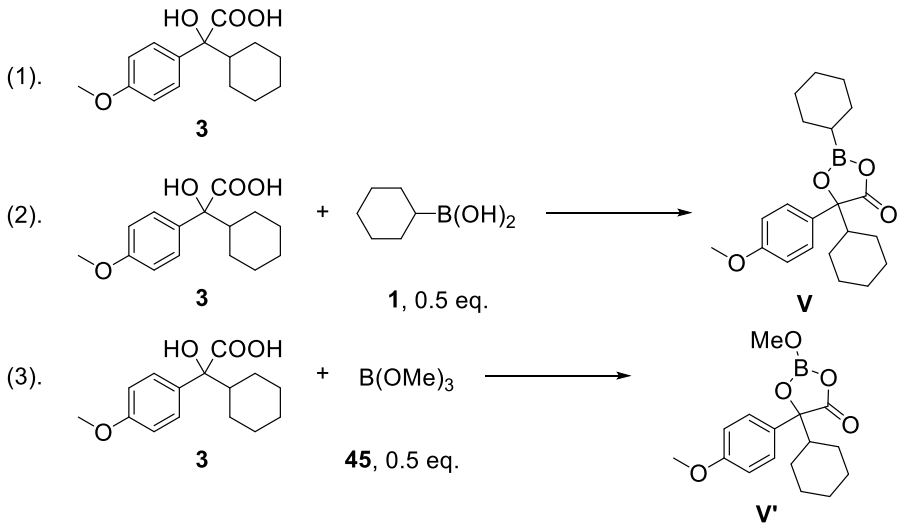
^{11}B NMR Experiments

Cyclohexyl boronic acid (**1**, 0.1 mmol) and α-ketoacid (**2**, 0.1 mmol) were mixed in 0.5 mL CH_2Cl_2. The ^{11}B NMR (128 MHz) signal of the boronic acid showed an up-field new peak at 13.3 ppm.

α-Ketoacid (**2**, 0.1 mmol), alkyl-DHP (**44**, 0.1 mmol), and trimethyl borate (**45**, 0.1 mmol) were mixed in 0.5 mL CH_2Cl_2 (5% HFIP was added). The ^{11}B NMR (128 MHz) signal showed an up-field new peak at 10.2 ppm.

Characterization of Intermediate V

The α-hydroxy acid (**3**, 1.0 eq.) and boron compound (**1** or **45**, 0.5 eq.) were mixed in 0.5 mL $CDCl_3$. The ^{1}H NMR (500 MHz) signals showed new peaks indicating the formation of the intermediate **V** or **V'**. We also detected ^{11}B NMR signals of these intermediates. The α-hydroxy acid (**3**, 0.5 eq.) and boron compound (**1** or **45**, 1.0 eq.) were mixed in 0.5 mL CH_2Cl_2. The ^{11}B NMR (128 MHz) signals showed down-field new peaks indicating the formation of the intermediate **V** or **V'**.[2]



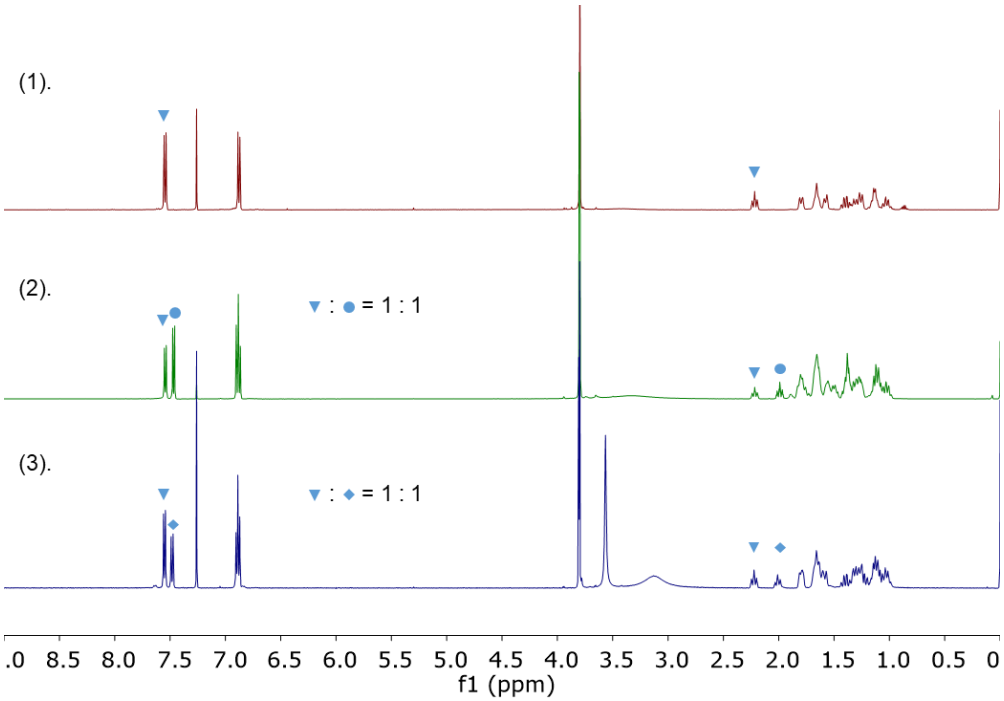
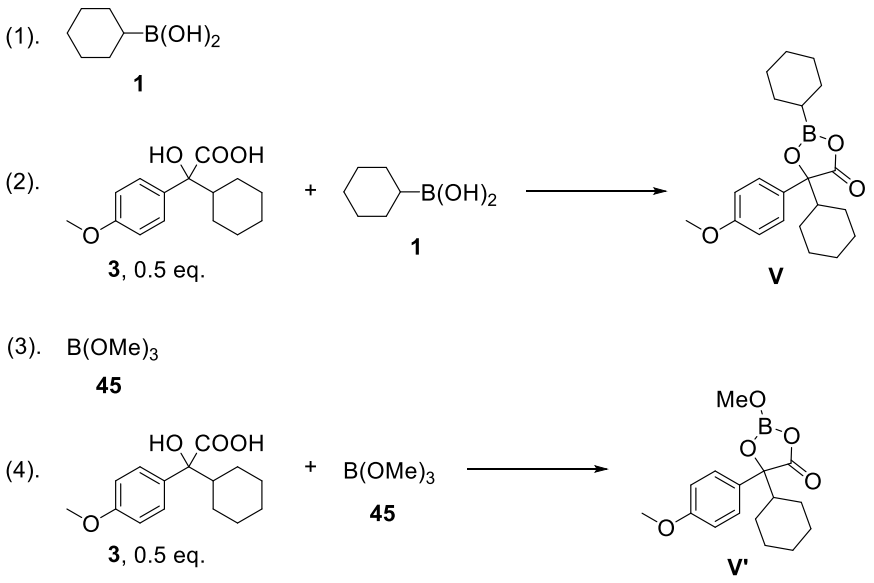


Figure S7. ^{1}H NMR spectrum of 3 and organoboron compounds.



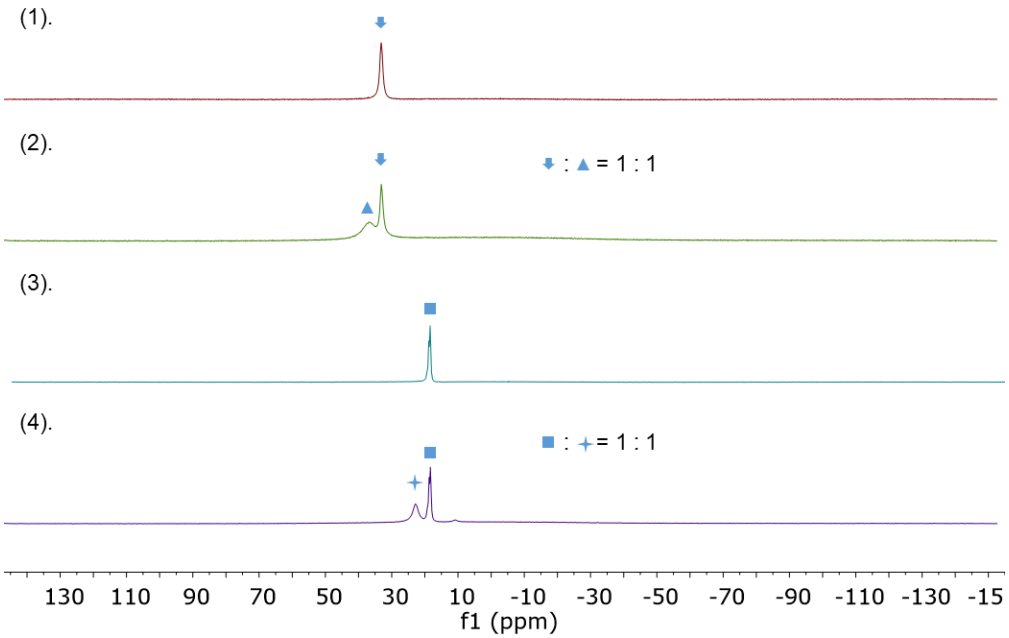


Figure S8. ^{11}B NMR spectrum of 3 and organoboron compounds.

Investigation of Radical Reaction Mechanism

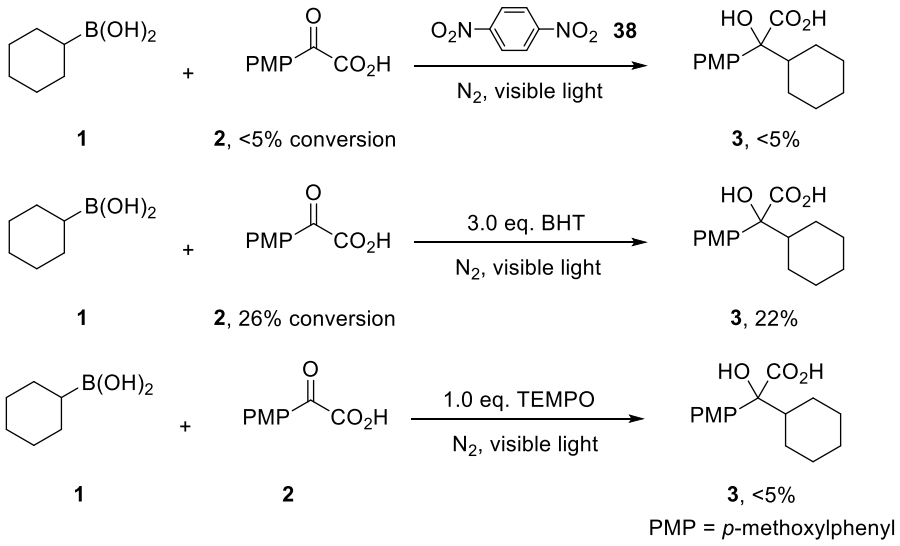


Figure S9. Radical inhibition experiments.

α-Ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl boronic acid **1** (38.4 mg, 0.3 mmol, 3.0 eq.), and the free radical inhibitor 1,4-dinitrobenzene **38** (16.8 mg, 0.1 mmol, 1.0 eq.) or butylated hydroxytoluene (BHT, 66.1 mg, 0.3 mmol, 3.0 eq.) or TEMPO (15.6 mg, 0.1 mmol, 1.0 eq.) were placed in a 4 mL clear-colored glass vial equipped with a

magnetic stir bar. After 2.0 mL CH_2Cl_2 was added, the vial was sealed in nitrogen atmosphere and exposed to 23 W CFL at room temperature with stirring for 5 h. Conversions and yields were then determined by ^{1}H NMR analysis, using 1,3,5-trimethoxybenzene as the external standard. We found the reaction was completely inhibited by the addition of radical scavenger 1,4-dinitrobenzene and TEMPO, and could be partially suppressed by BHT.

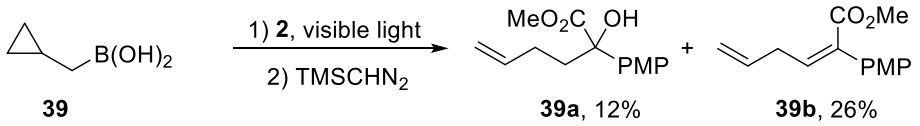


Figure S10. Radical clock experiment.

α-Ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.) and alkyl boronic acid **39** (48.6 mg, 0.3 mmol, 3.0 eq.) were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After 2.0 mL CH_2Cl_2 and 0.1 mL HFIP were added, the vial was sealed in nitrogen atmosphere and exposed to 23 W CFL at 4 ^oC with stirring. After 48 h, the reaction mixture was evaporated to dryness, then 2.0 mL CH_2Cl_2 and 0.6 mL CH_3OH were added, followed by 0.3 mL $TMSCHN_2$ (2.0 M in hexanes, 0.6 mmol, 6.0 eq.) dropwisely. After TLC indicated the complete consumption of α-hydroxy acid (typically 0.5), the reaction mixture was concentrated and purified directly by column chromatography to afford the α-hydroxy ester **39a** (3.1 mg, 12%, colorless oil) and **39b** (6.0 mg, 26%, colorless oil), respectively. Compound **39a**: TLC R_f = 0.40 (n-hexane); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.9 Hz, 2H), 6.88 (d, *J* = 8.9 Hz, 2H), 5.81 (ddt, *J* = 16.3, 10.2, 6.3 Hz, 1H), 5.02 (dq, *J* = 17.1, 1.6 Hz, 1H), 4.95 (ddt, *J* = 10.2, 1.9, 1.2 Hz, 1H), 3.80 (s, 3H), 3.77 (s, 3H), 3.72 (s, 1H), 2.28 - 1.94 (m, 4H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.0, 159.3, 138.0, 133.9, 126.9, 115.0, 113.8, 77.9, 55.4, 53.4, 38.9, 28.2; **IR** (KBr, thin film): 3502, 2955, 1730, 1511, 1249, 1178, 1097, 1034, 913, 835, 748 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $[C_{14}H_{18}O_4]^+$, 250.1205, found 250.1211. Compond **39b**: TLC R_f = 0.30 (n-hexane); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.25 (d, *J* = 8.8 Hz, 2H), 6.86 (d, *J* = 8.7 Hz, 2H), 6.11 (t, *J* = 7.6 Hz, 1H), 5.89 (ddt, *J* = 16.7, 10.1, 6.4 Hz, 1H), 5.13 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.07 (dd, *J* = 10.1, 1.5 Hz,

1H), 3.81 (s, 3H), 3.80 (s, 3H), 3.18 (ddt, *J* = 7.8, 6.4, 1.5 Hz, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.7, 159.4, 136.0, 135.7, 134.7, 130.4, 128.6, 116.2, 113.9, 55.4, 51.9, 34.4; **IR** (KBr, thin film): 3004, 2955, 1720, 1512, 1249, 1204, 1175, 1034, 913, 831, 748 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $[C_{14}H_{16}O_3]^+$, 232.1099, found 232.1097.

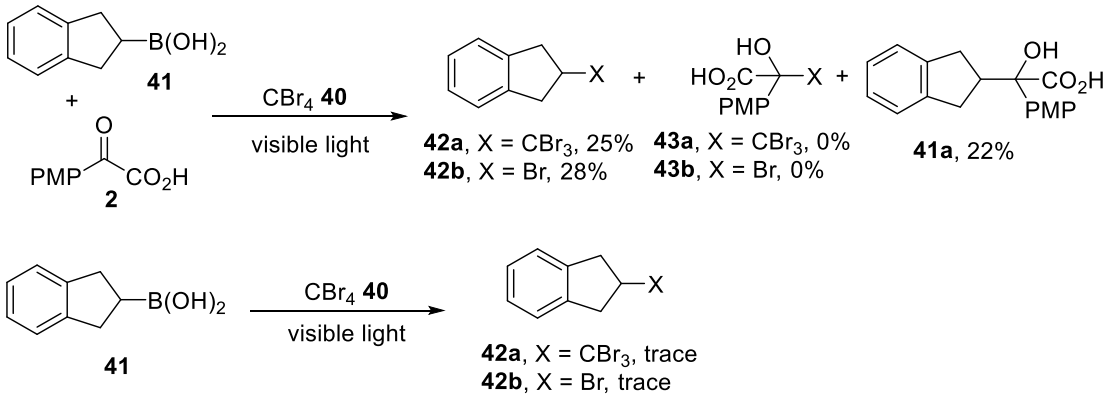


Figure S11. Alkyl radical trapping experiments.

α-Ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl boronic acid **41** (48.6 mg, 0.3 mmol, 3.0 eq.), and CBr_4 **40** (99.5 mg, 0.3 mmol, 3.0 eq.) were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After 2.0 mL CH_2Cl_2 was added, the vial was sealed in nitrogen atmosphere and exposed to 23 W CFL at room temperature with stirring. After 24 h, the reaction mixture was concentrated and purified by column chromatography using n-hexane as the eluent to afford **42a** (9.3 mg, 25%, colorless oil) and **42b** (5.6 mg, 28%, colorless oil), respectively. Without **2**, there was no significant reaction between **41** and CBr_4. Compound **42a**: TLC R_f = 0.40 (n-hexane); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.20 (s, 4H), 3.81 (p, *J* = 8.5 Hz, 1H), 3.38 (dd, *J* = 16.1, 8.3 Hz, 2H), 3.18 (dd, *J* = 16.3, 8.6 Hz, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 140.8, 127.0, 124.7, 64.1, 49.4, 39.5; **HRMS-EI** (m/z) $[M]^+$ calc'd for $[C_{10}H_9Br_3]^+$, 365.8254, found 365.8249. Compound **42b**: TLC R_f = 0.30 (n-hexane); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.30 - 7.16 (m, 4H), 4.83 - 4.70 (m, 1H), 3.51 (dd, *J* = 17.0, 6.3 Hz, 2H), 3.34 (dd, *J* = 16.9, 3.9 Hz, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 140.7, 127.1, 124.7, 49.7, 44.8; **HRMS-EI** (m/z) $[M]^+$ calc'd for $[C_9H_9Br]^+$, 195.9888, found 195.9890.

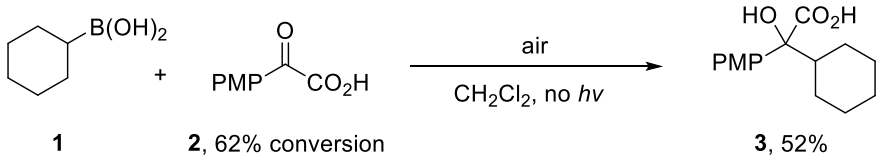


Figure S12. Alkyl radical initiation experiment.

α-Ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.) and alkyl boronic acid **1** (38.4 mg, 0.3 mmol, 3.0 eq.) were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After 2.0 mL CH_2Cl_2 was added, the vial was sealed in the atmosphere of air,[3] and kept in dark with stirring for 5 h at room temperature. Conversions and yields were then determined by ^{1}H NMR analysis, using 1,3,5-trimethoxybenzene as the external standard. The reaction went smoothly under traditional radical initiation conditions with air in the dark and gave the product in 52% yield, which suggested the radical chain reaction mechanism.

The On-Off-Light Experiment

Following the standard procedure, the reaction between alkyl boronic acid **1** (76.8 mg, 0.6 mmol, 3.0 eq.) and α-ketoacid **2** (36.0 mg, 0.2 mmol, 1.0 eq.) was conducted for on-off-light experiment. Aliquots of samples were taken out at various time points during the reaction. Crude ^{1}H NMR was taken on the concentrated crude reaction mixture and calculated using 1,3,5-trimethoxybenzene (16.8 mg, 0.1 mmol, 0.5 eq.) as an internal standard (**IS**). 1,3,5-trimethoxybenzene did not interfere with the reaction.

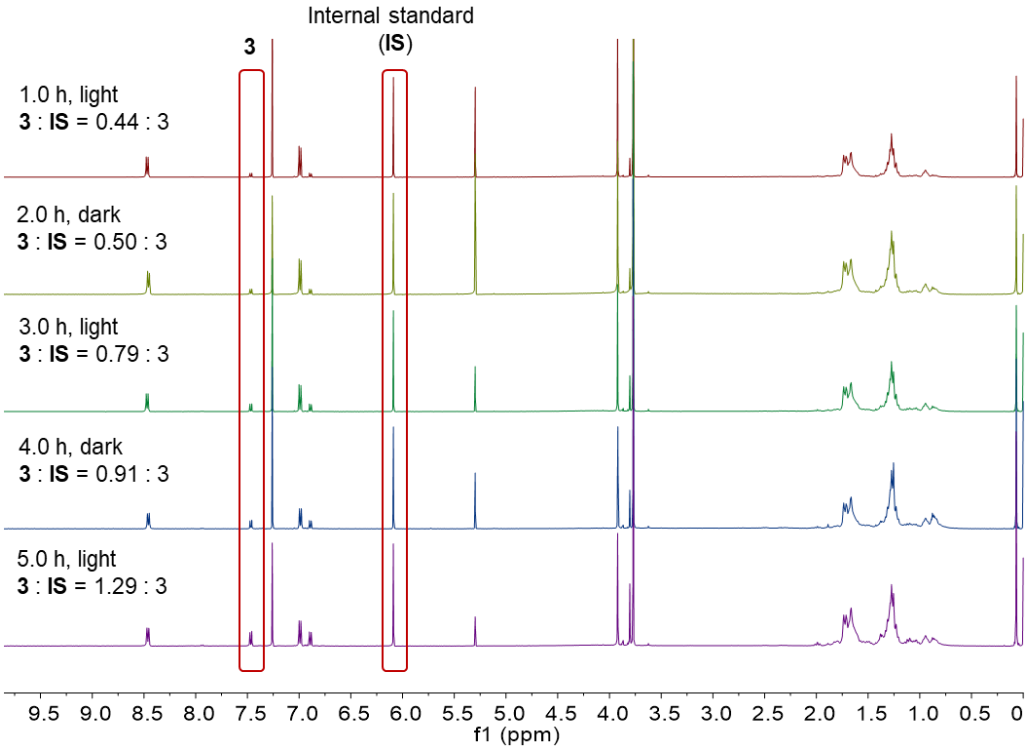
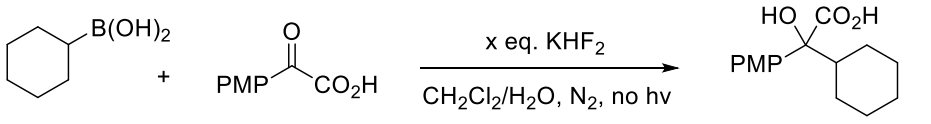


Figure S13. The on-off-light experiment.

Dark Reaction



1 **2**

	Conv. of **2**	NMR yield of **3**
1). x = 0	<5%	<5%
2). x = 1.0	46%	37%
3). x = 3.0	14%	9%
4). x = 6.0	<5%	<5%

Figure S14. Dark reaction.

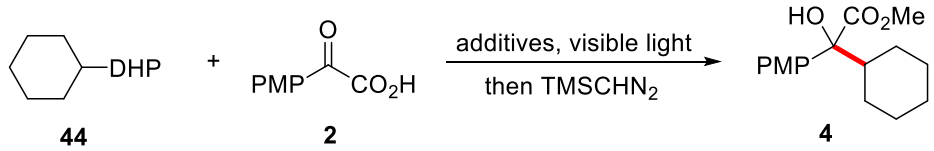
α-Ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl boronic acid **1** (38.4 mg, 0.3 mmol, 3.0 eq.), and x eq. of KHF_2 were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After 1.0 mL CH_2Cl_2 and 1.0 mL H_2O (predegassed with N_2) were added, the vial was sealed in nitrogen atmosphere at room temperature and kept in dark with stirring for 5 h. Conversions and yields were then determined by ^1H NMR analysis, using 1,3,5-trimethoxybenzene as the external standard. No dark reaction was observed without the addition of KHF_2, and different amount of KHF_2 resulted in

different yields, which suggested the fluoride ions from alkyl trifluoborates may contribute to the different dark reaction outcomes (See Table S1, entry 16).

VI. Dihydropyridine Derivatives as Alkyl Radical Precursors

Screening Data of Lewis acids

α-Ketoacid **2** (0.1 mmol, 1.0 eq.), alkyl-DHP **44** (0.15 mmol, 1.5 eq.) and Lewis acid (0.15 mmol, 1.5 eq.) were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After 2.0 mL CH_2Cl_2 and 0.1 mL HFIP was added, the vial was sealed in nitrogen atmosphere and exposed to 23 W CFL at room temperature with stirring. After 24 h, 600 μL CH_3OH was added, and the reaction mixture was esterificated with 0.3 mL $TMSCHN_2$ (2.0 M in hexanes, 0.6 mmol, 6.0 eq.) for 1 h. Conversions and yields were determined by ^1H NMR analysis.



44 **2** **4**

Screening of Lewis acids (NMR yield of **4**):

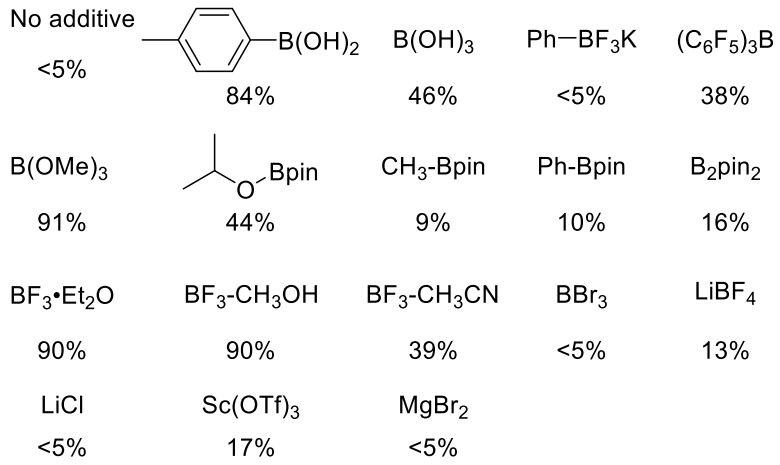


Figure S15. The detailed screening of Lewis acids.

Evidence of Radical Mechanism

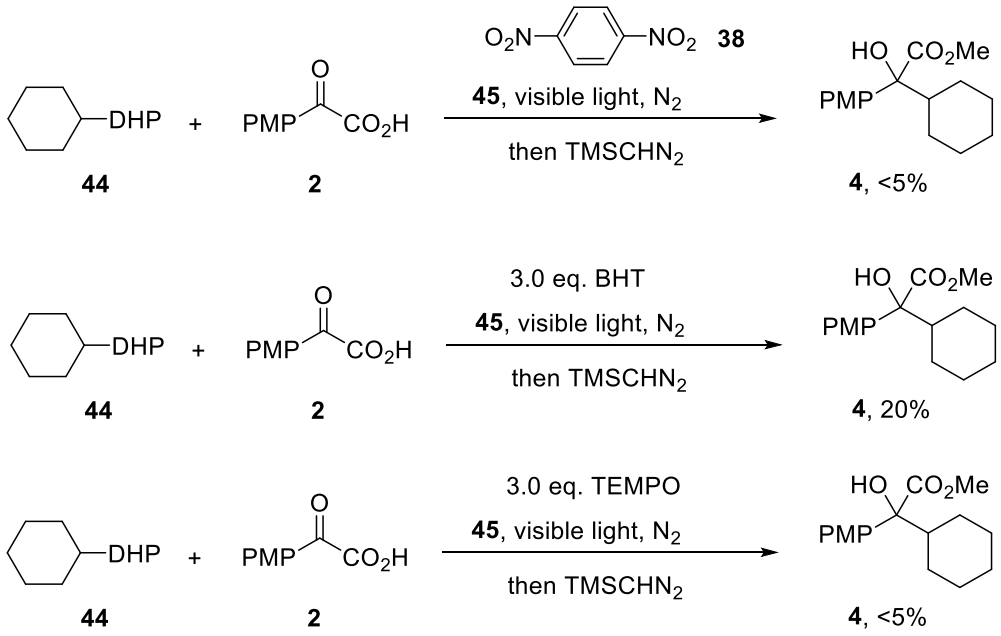
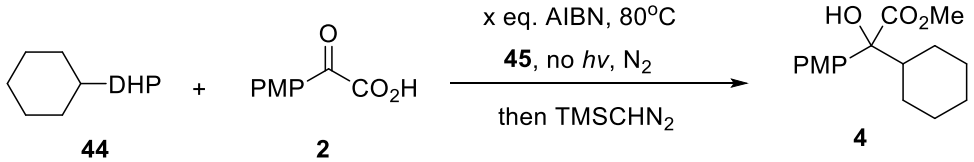


Figure S16. Radical inhibition experiments.

α-Ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **44** (50.4 mg, 0.15 mmol, 1.5 eq.), and the free radical inhibitor 1,4-dinitrobenzene **38** (50.4 mg, 0.3 mmol, 3.0 eq.) or butylated hydroxytoluene (BHT, 66.1 mg, 0.3 mmol, 3.0 eq.) or TEMPO (46.8 mg, 0.3 mmol, 3.0 eq.) were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After adding 2.0 mL CH_2Cl_2 and 0.1 mL HFIP, $B(OMe)_3$ **45** (16.7 μL, 0.15 mmol, 1.5 eq.) was injected via a pipette. Then the vial was sealed in nitrogen atmosphere and exposed to 23 W CFL at room temperature with stirring for 24 h. After esterfied with $TMSCHN_2$, conversions and yields were then determined by ^1H NMR analysis, using 1,3,5-trimethoxybenzene as the external standard. We found the reaction was completely inhibited by the addition of radical scavenger 1,4-dinitrobenzene and TEMPO, and could be partially suppressed by BHT.



1). 0.5 eq. AIBN 57%
2). 1.0 eq. AIBN 59%
3). no AIBN 16%

Figure S17. Radical initiation experiments.

α-Ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **44** (50.4 mg, 0.15 mmol, 1.5 eq.), and x eq. of the radical initiator AIBN were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After adding 2.0 mL 1,2-DCE and 0.1 mL HFIP, $B(OMe)_3$ **45** (16.7 μL, 0.15 mmol, 1.5 eq.) was injected via a pipette. Then the vial was sealed in nitrogen atmosphere and kept in dark, heating to 80 ^oC with stirring for 5 h. After esterfied with $TMSCHN_2$, conversions and yields were then determined by ^1H NMR analysis, using 1,3,5-trimethoxybenzene as the external standard. The reaction went smoothly and obtained 57-59% yields of the desired product with AIBN, while the heating without AIBN only gave 16% yield.

V. Continuous Flow Photoreactions

Detailed Setup

The easy-to-assemble flow reactor was constructed by winding one (or two) layers of FEP tube (fluorinated ethylene propylene tube, 1/32 inch I.D. x 1/16 inch O.D.) around a glass immersion well (d x l, 7.5 cm x 20 cm). A 23 W CFL was placed in vertical axis into the immersion well, and the immersion well was inserted into a Dewar flask. A total 46 m length of FEP tube covered 16 cm of the immersion well, possessing approximately 100 turns at first layer and 60 turns at second layer, which has a total internal volume of 22.8 mL. Circulating water cooling (ShangHaiQiaoYa, QYGDH-3006) was used to control the photoreaction at 20 ℃ constantly. The feed solutions were loaded into a flask under N_2, then pumped by HPLC pump (Scientific Systems, Inc., LC-Class Pump, 0 - 10 mL/min) and mixed together in a T-mixer (Valco, ZTIM, 1/16 inch O.D.). The effluent was collected, processed and analyzed.

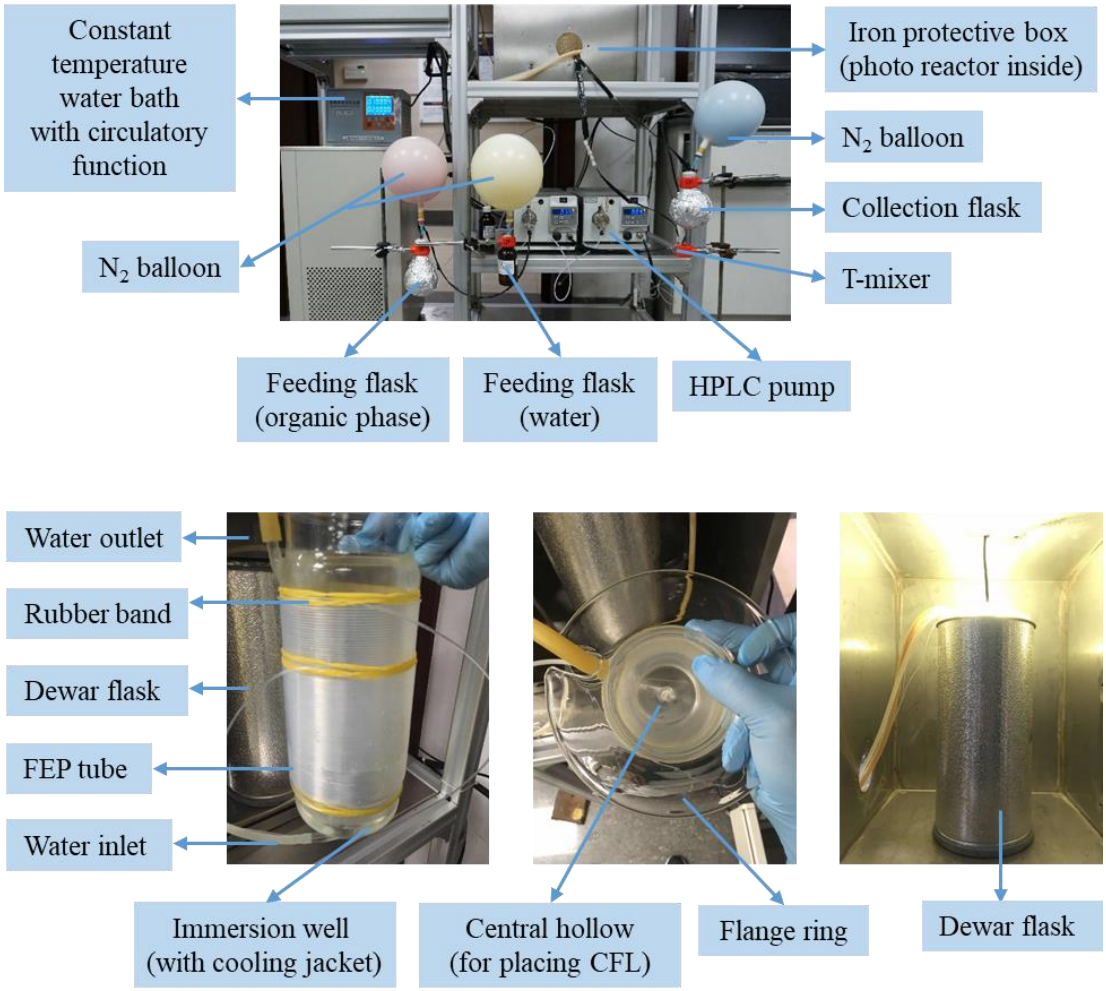


Figure S18. The detailed setup description of flow reactor.

Multi-gram Synthesis

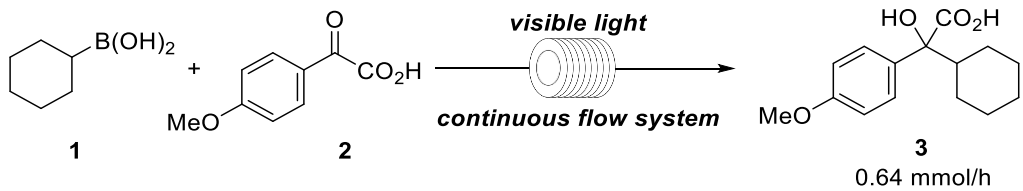


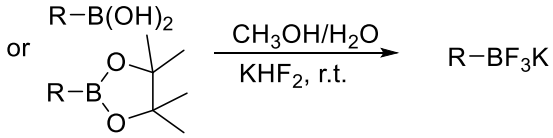
Figure S19. Multi-gram synthesis of α-hydroxy acid with flow system.

A solution of α-ketoacid (10.0 mmol, 1.0 eq.) and alkyl boronic acid (30.0 mmol, 3.0 eq.) in 210 mL CH_2Cl_2/HFIP (v/v 20:1, pre-degassed with N_2) was prepared as the reagent feed solution, and 40 mL distilled water (pre-degassed with N_2) as the aqueous feed solution, which was used for dissolving $B(OH)_3$ that generated during the reaction to prevent clogging. The two feed solutions were delivered by HPLC pump and mixed together in a T-mixer. Flow rate for the reagent feed solution and the aqueous feed solution were set at 0.30 mL/min and 0.05 mL/min, respectively, with a total residence time of 65 min. The mixed feed solution was irradiated under a household 23 W (6500 K) CFL at 20℃ adjusted by circulating water cooling. The initial 10 min of the effluent was abandoned, and the following 600 min of the effluent was collected. The effluent was separated and the organic phase was evaporated to dryness. 12 mL H_2O_2 (30% in water) was added at 30℃ in DMC (dimethyl carbonate) overnight to convert the remaining alkyl boronic acids to the corresponding alchols[4]. After extraction (EtOAc/brine) and evaporation, the crude was placed in high vacuum to remove the low boiling point alchol, then recrystallized from CH_2Cl_2/PE to afford the product α-hydroxy acid **3** as a white solid (1.69 g, 75%), reaching a productivity of 0.64 mmol/h: **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.54 (d, *J* = 8.9 Hz, 2H), 6.88 (d, *J* = 9.0 Hz, 2H), 3.80 (s, 3H), 3.42 (brs, 1H), 2.21 (tt, *J* = 11.8, 3.2 Hz, 1H), 1.82 - 1.77 (m, 1H), 1.71 - 1.53 (m, 3H), 1.45 - 1.22 (m, 3H), 1.18 - 0.99 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 180.2, 159.2, 132.0, 127.3, 113.7, 80.8, 55.4, 45.7, 27.5, 26.4, 26.4, 26.3, 25.6; **IR** (KBr, thin film): 3398, 2929, 2852, 1719, 1610, 1511, 1441, 1256, 1173, 1107, 911, 730 cm^{-1}; **HRMS-ESI** (m/z): $[M-H+2Na]^+$ calc'd for $[C_{15}H_{19}O_4Na_2]^+$, 309.1073, found 309.1078.

VI. Substrate Preparations and Characterizations

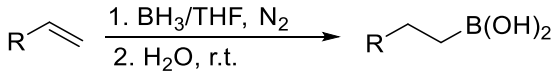
Synthesis of Alkyl Boron Compounds

Method A:

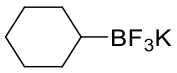


Following the literature procedure[5], to the solution of alkyl boronic acid or pinacol ester (10 mmol, 1.0 eq.) in 20 mL methanol was added saturated aqueous KHF_2 (15 mL, 4.69 g, 60 mmol, 6.0 eq., this solution was bubbled with nitrogen gas for 10 minutes). The resulting suspension was stirred for 2 h and then concentrated completely to dryness. The residue was extracted with hot acetone (3 ×30 mL), and the combined filtered extracts were concentrated to approximately 5 mL. Ether (or CH_2Cl_2) was added and the resultant precipitate was collected and dried to afford the potassium trifluoroborate as a white solid.

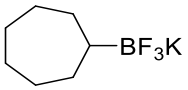
Method B:



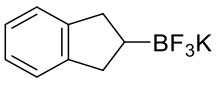
Following the literature procedure[5], an alkene (10.0 mmol, 1.0 eq.) in THF (2.0 mL) was added dropwise to a solution of BH_3•THF (20.0 mL, 20.0 mmol, 1.0 M solution in THF) at 0 °C. The mixture was stirred for 2 h at room temperature and H_2O (2.0 mL, bubbled with nitrogen gas for 10 minutes) was slowly and carefully added. After stirring for additional 3 h at room temperature, the reaction mixture was concentrated to 5 mL (not to dryness) in vacuo, diluted with ethyl acetate (30 mL), and washed with saturated aqueous bicarbonate (20 mL) and brine (20 mL). The organic layer was dried over sodium sulfate, filtered, and concentrated to approximately 5 mL. Petroleum ether was then added. The resultant precipitate was washed with petroleum ether and dried under vacuum to afford the alkyl boronic acid as a white solid.



Potassium cyclohexyltrifluoroborate (**5**). Following the method A, the reaction of cyclohexyl boronic acid **1** (1.28 g, 10 mmol, 1.0 eq.) afforded **5** as a white acicular crystal (1.48 g, 78%); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 1.56 (d, J = 9.7 Hz, 3H), 1.48 (d, J = 13.1 Hz, 2H), 1.10 - 0.98 (m, 3H), 0.88 (q, J = 12.7 Hz, 2H), -0.05 (s, 1H). The spectroscopic data were in accordance with literature[6].

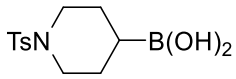


Potassium cycloheptyltrifluoroborate (**11**). Following the literature procedure[7], CuI (190 mg, 1 mmol, 0.10 eq.), PPh_3 (340 mg, 1.3 mmol, 0.13 eq.), LiOMe (0.76 g, 20 mmol, 2.0 eq.), and bis(pinacolato)diboron (5.08 g, 20 mmol, 2.0 eq.) were added to a 100 mL round-bottomed flask equipped with a stir bar. The vessel was evacuated and filled with nitrogen gas three times. DMF (20 mL) and the cycloheptyl bromide (1.77 g, 10 mmol, 1.0 eq.) were added by syringe under a nitrogen atmosphere. The resulting reaction mixture was stirred vigorously at 37 ºC for 24 h. The reaction mixture was filtered through celite over silica gel and washed with EtOAc. The filtrate was washed with brine, dried with Na_2SO_4, then concentrated and purified by column chromatography (100% hexanes) to afford the pinacol ester. Then follow the method A, the reaction of bromocycloheptane afforded **11** as a white acicular crystal (0.50 g, 25%); **^{1}H NMR** (500 MHz, DMSO-d_6) 1.59 (d, J = 10.8 Hz, 4H), 1.53 - 1.44 (m, 2H), 1.42 - 1.31 (m, 2H), 1.29 - 1.18 (m, 2H), 1.08 - 0.97 (m, 2H), 0.07 (s, 1H); **^{13}C NMR** (126 MHz, DMSO-d_6) δ 30.7, 30.3, 29.7, 28.6; **^{19}F NMR** (376 MHz, DMSO-d_6) δ -143.6.

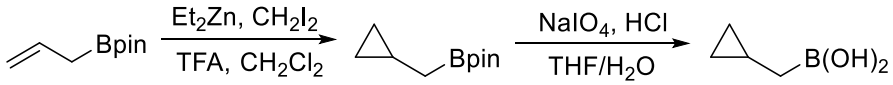


Potassium cyclopentyltrifluoroborate (**12**). Following the general procedure B and A, the reaction of 1H-indene (1.2 mL, 10 mmol) afforded borate **12** as a white solid (0.64 g, 28% yield); **^{1}H NMR** (500 MHz, acetone-d_6) δ 7.07 (dd, J = 5.3, 3.3 Hz, 2H), 6.95 (dd, J = 5.6, 3.2 Hz, 2H), 2.75 (d, J = 9.8 Hz, 4H), 1.43 - 1.20 (m, 1H); **^{13}C NMR**

(126 MHz, acetone-d_6) δ 148.1, 125.6, 124.6, 36.6, 36.6; **^{19}F NMR** (376 MHz, acetone-d_6) δ -150.4.

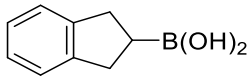


(1-tosylpiperidin-4-yl)boronic acid (**15**). Following the literature method[7], 4-iodo-1-tosylpiperidine (5.51 g, 15 mmol, 1.0 eq.), CuI (288 mg, 1.5 mmol, 0.10 eq.), PPh_3 (528 mg, 2.0 mmol, 0.13 eq.), LiOMe (1.15 g, 30 mmol, 2.0 eq.), and bis(pinacolato)diboron (5.89 g, 23 mmol, 1.5 eq.) were added to a 100 mL round-bottomed flask equipped with a stir bar. The vessel was evacuated and filled with nitrogen gas three times. DMF (30 mL) was added by syringe under a nitrogen atmosphere. The resulting reaction mixture was stirred vigorously at 37 ºC for 24 h. The reaction mixture was filtered through celite over silica gel and washed with EtOAc. The filtrate was washed with brine, dried with Na_2SO_4, then concentrated and purified by column chromatography (EtOAc/hexanes = v/v 1:5) to afford the pinacol ester. Then follow the method A, the pinacol ester afforded trifluoroboronate as a white solid (2.28 g, 44%). According to literature procedure[8], to a solution of potassium trifluoroborate (1.73 g, 5.0 mmol) in acetonitrile (50 mL) and water (15 mL) was added 1.90 mL trimethylsilylchloride (15 mmol, 3.0 eq.). The mixture was stirred at room temperature for 2 h and then concentrated to a volume of ca. 15 mL. 50 mL water was added. The mixture was extracted with ethyl acetate (3 x 30 mL). The combined extracts were washed with brine, dried over anhydrous Na_2SO_4, filtered, and evaporated to dryness to give the boronic acid **15** as a white powder (1.33 g, 94%); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 7.59 (d, J = 8.3 Hz, 2H), 7.44 (s, 2H), 7.43 (d, J = 7.0 Hz, 2H), 3.38 (d, J = 11.5 Hz, 2H), 2.50 (s, 3H), 2.21 (td, J = 11.1, 2.8 Hz, 2H), 1.64 (dd, J = 13.7, 3.7 Hz, 2H), 1.49 - 1.37 (m, 2H), 0.62 (tt, J = 11.2, 3.7 Hz, 1H); **^{13}C NMR** (126 MHz, DMSO-d_6) δ 143.2, 132.6, 129.7, 127.4, 47.1, 43.1, 32.9, 26.6, 21.0; **HRMS-ESI** (m/z): $[M+H]^+$ calc'd for $[C_{12}H_{19}O_4NBS]^+$, 284.1122, found 284.1132.



39

(cyclopropylmethyl)boronic acid (**39**). Following the literature method[9], a DCM solution of Et_2Zn (20 mL in 1.0 M hexanes, 20 mmol, 2.0 eq.) was cooled to -40 ^oC. Trifluoroacetic acid (1.49 mL, 20 mmol, 2.0 eq.) was then added dropwise by syringe over 5 min. After an additional 20 min, CH_2I_2 (1.61 mL, 20 mmol, 2.0 eq.) was added dropwise via syringe. After an additional 20 min, allyl boronic acid pinacol ester (1.88 mL, 10 mmol, 1.0 eq.) was added via syringe and the cooling bath was removed. After an additional 30 min, the reaction was quenched with sat. aqueous NH_4Cl (20 ml) and the layers were separated. The aqueous layer was extracted with ether (20 mL x 3). The combined organic layers were dried over Na_2SO_4, filtered, and concentrated by rotavap at 0^oC - 10 ^oC to avoid the loss of product. The crude product was purified with silica gel column chromatography (3% EtOAc in hexanes) as a colorless oil (1.62 g, 89%): TLC R_f = 0.69 (EtOAc/hexanes = 1/20). According to another literature[10], the purified alkyl boronic ester (0.89 g, 4.8 mmol, 1.0 eq.) was dissolved in 12.5 mL of water/THF mixture (1:4). $NaIO_4$ (3.14 g, 14.6 mmol, 3.0 eq.) was added and the mixture was stirred for 30 min. Then aqueous HCl (0.55 mL, 1 N) was added and the mixture was stirred for 3 h at room temperature until the alkyl boronic ester was completely consumed monitored by TLC. The reaction mixture was extracted from water with Et_2O (20 mL x 3). The combined organic phase were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated to 10 mL mixture. The residue was then recrystallized from Et_2O with hexanes to give the desired product **39** as a white solid (0.36 g, 74%): **^{1}H NMR** (500 MHz, DMSO-*d*$_6$) δ 7.38 (s, 2H), 0.79 - 0.63 (m, 1H), 0.55 (d, *J* = 6.9 Hz, 2H), 0.39 - 0.25 (m, 2H), -0.07 - -0.10 (m, 2H); **^{13}C NMR** (126 MHz, DMSO-*d*$_6$) 6.7, 5.9; **IR** (KBr, thin film): 3275, 3073, 3000, 2874, 1351, 1247, 1145, 1098, 825, 766 cm^{-1}.

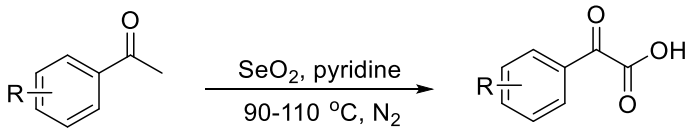


(2,3-dihydro-1H-inden-2-yl)boronic acid (**41**). Following the method B, the reaction

of 1H-indene (3.58 g, 30 mmol, 1.0 eq.) afforded boronic acid **41** as a white solid (1.33 g, 27%); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 7.55 (s, 2H), 7.17 (dd, J = 5.4, 3.3 Hz, 2H), 7.06 (dd, J = 5.5, 3.2 Hz, 2H), 2.94 - 2.78 (m, 4H), 1.67 - 1.58 (m, 1H); **^{13}C NMR** (126 MHz, DMSO-d_6) 144.6, 125.6, 123.9, 35.3.

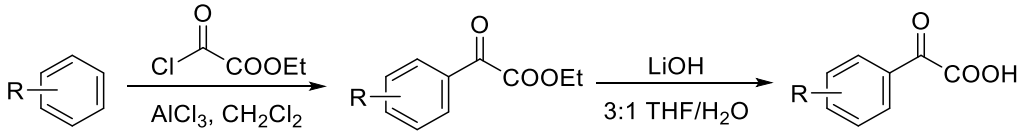
Synthesis of α-Ketoacid

Method A:



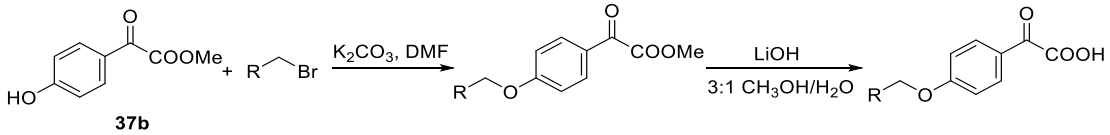
Following the literature procedure[11], the substituted aryl-methylketone (10 mmol, 1.0 eq.) and selenium dioxide (SeO_2, 15 mmol, 1.5 eq.) were added to a dry, three-necked round-bottomed flask. The flask was then flushed with nitrogen, followed by adding anhydrous pyridine (20 mL) via a syringe. The reaction mixture was heated in an oil bath to 110 °C for 1 h, and then the bath temperature was reduced to 90 °C for several hours. After completion of the reaction, as determined by TLC, the solution containing precipitated selenium was filtered, and the residue was washed with ethyl acetate (20 mL). The combined filtrate was concentrated and dissolved in 50 mL ethyl acetate. The organic layer was treated with 1 N HCl (50 mL) in a separating funnel to wash away the remaining pyridine. Then 1N NaOH (50 mL) was added and the aqueous layer was separated, followed by acidification using 1N HCl to about pH 1.0. The mixture was extracted with ethyl acetate (3 x 50 mL), and the combined organic layers were dried (anhydrous Na_2SO_4) and concentrated on a rotary evaporator. The crude arylglyoxylic acid products were purified by silica-gel column chromatography or recrystallization with CH_2Cl_2/hexanes.

Method B:



Following the literature procedure[12], in a three-necked round-bottomed flask mounted with a cooling system under inert conditions, $AlCl_3$ (22 mmol, 2.2 eq.) was suspended in CH_2Cl_2 (20 mL) at 0 °C. To this mixture mono-ethyl oxalyl chloride (22 mmol, 2.2 eq.) was added dropwise in about 15 min. At 0 °C an arene (10 mmol, 1.0 eq.) was added dropwise in about 10 min. Then the solution was stirred at r.t. for 2 h. After completion of the reaction, as determined by TLC, the mixture was cooled and carefully added 20 g crushed ice and 20 mL of concentrated hydrochloric acid. Extraction was performed with CH_2Cl_2 (3 x 50 mL), the organic layer was collected and washed with 1 N NaOH (50 mL) and brine (50 mL). After the organic layer was separated and dried over Na_2SO_4, the solvent was evaporated and the crude ethyl ester product was purified by column chromatography or directly subjected to hydrolysis. The ethyl ester (10 mmol, 1.0 eq.) from the previous step was dissolved in 15 mL THF and 5 mL H_2O, and LiOH (50 mmol, 5.0 eq.) was added. After stirring for 3 h at room temperature, the basic reaction mixture was washed with dichloromethane (3 x 30 mL). The aqueous phase was separated and acidified with 1M aqueous HCl solution. The resulting mixture was extracted with ethyl acetate (3 x 30 mL) and the combined organic layers were washed with brine (30 mL) and dried over Na_2SO_4. The solvent was evaporated and the residue was recrystallized from CH_2Cl_2/hexanes.

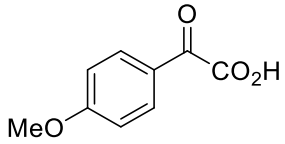
Method C:



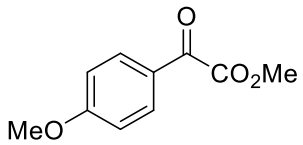
37b

Methyl 2-(4-hydroxyphenyl)-2-oxoacetate **37b** was prepared according to the literature[13]. **37b** (10 mmol, 1.0 eq.), halogen compounds (20 mmol, 2.0 eq.) and K_2CO_3 (20 mmol, 2.0 eq.) in DMF (20 mL) were stirred at room temperature for 6 h. The reaction mixture was slowly poured into water (100 mL) and extracted with ethyl ether (3 x 30 mL). The combined organic layers were washed with brine (30 mL), dried over Na_2SO_4 and concentrated in vacuo. The crude material was purified by flash column chromatography before hydrolysis. The methyl ester was dissolved in MeOH/H_2O (15

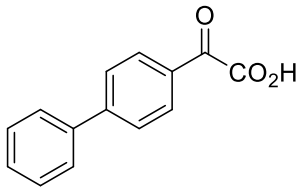
mL/5 mL), and LiOH (1.5 eq.) was added. After stirred for 3 h at room temperature, the basic reaction mixture was washed with dichloromethane (3 x 30 mL). The aqueous phase was separated and acidified with 1 M aqueous HCl solution. The resulting mixture was extracted with ethyl acetate (3 x 30 mL) and the combined organic layers were washed with brine (30 mL) and dried over Na_2SO_4. The residual was filtered and evaporated to give the corresponding α-ketoacid, and was recrystallized from CH_2Cl_2/hexanes.



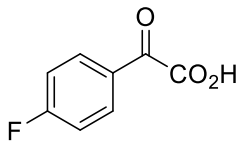
2-(4-methoxyphenyl)-2-oxoacetic acid (**2**)**.** Following the method A, the reaction of 1-(4-methoxyphenyl)ethan-1-one (3.00 g, 20 mmol) afforded α-ketoacid **2** as a white solid (2.81g, 78% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.47 (d, *J* = 9.0 Hz, 2H), 6.99 (d, *J* = 9.0 Hz, 2H), 3.92 (s, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 183.1, 165.8, 162.6, 134.1, 125.0, 114.5, 55.8; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_9H_7O_4]^-$, 179.0350, found 179.0349.



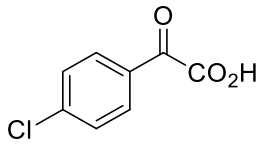
Methyl 2-(4-methoxyphenyl)-2-oxoacetate (**8**). Following the method B, the reaction of anisole (2.17 g, 20 mmol) and methyl oxalyl chloride (5.27 g, 43 mmol) afforded α-ketoester **8** as a white solid (2.55g, 66% yield); TLC R_f = 0.42 (PE/EA=5:1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 9.0 Hz, 2H), 6.97 (d, *J* = 9.0 Hz, 2H), 3.96 (s, 3H), 3.90 (s, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 184.6, 165.2, 164.5, 132.8, 125.6, 114.4, 55.8, 52.8; **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{10}H_{10}O_4Na]^+$, 217.0471, found 217.0477.



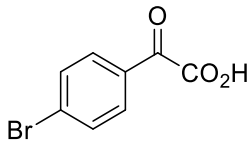
2-([1,1'-biphenyl]-4-yl)-2-oxoacetic acid (**20**). Following the method A, the reaction of 1-([1,1'-biphenyl]-4-yl)ethan-1-one (1.96 g, 10 mmol, 1.0 eq.) afforded α-ketoacid **20** as a yellow solid (1.58 g, 70%); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.51 (d, *J* = 8.6 Hz, 2H), 7.77 (d, *J* = 8.5 Hz, 2H), 7.68 - 7.64 (m, 2H), 7.53 - 7.48 (m, 2H), 7.47 - 7.42 (m, 1H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 183.7, 161.2, 148.5, 139.4, 132.3, 129.2, 129.0, 130.5, 127.7, 127.5; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{14}H_9O_3]^-$, 225.0557, found 225.0549.



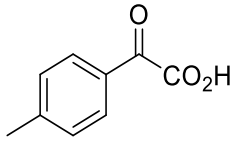
2-(4-fluorophenyl)-2-oxoacetic acid (**21**)**.** Following the method A, the reaction of 1-(4-fluorophenyl)ethan-1-one (1.38 g, 10 mmol, 1.0 eq.) afforded α-ketoacid **21** as a pale yellow crystal (1.09 g, 65% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 9.11 (brs, 1H), 8.48 (dd, *J* = 8.7, 5.4 Hz, 2H), 7.22 (t, *J* = 8.6 Hz, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 182.8, 167.5 (d, *J* = 260.2 Hz), 162.5, 134.5 (d, *J* = 10.2 Hz), 128.3, 116.6 (d, *J* = 22.2 Hz); **^{19}F NMR** (376 MHz, $CDCl_3$) δ -100.8 (d, *J* = 24.9 Hz); **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_8H_4FO_3]^-$, 167.0150, found 167.0139.



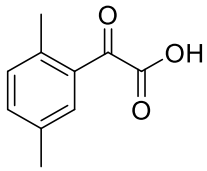
2-(4-chlorophenyl)-2-oxoacetic acid (**22**). Following the method B, the reaction of chlorobenzene (1.13 g, 10 mmol, 1.0 eq.) afforded α-ketoacid **22** as a white flaky crystal (0.96 g, 52% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.37 (d, *J* = 8.6 Hz, 2H), 7.52 (d, *J* = 8.7 Hz, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 183.8, 161.7, 142.6, 132.6, 130.4, 129.5; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_8H_4ClO_3]^-$, 182.9854, found 182.9853.



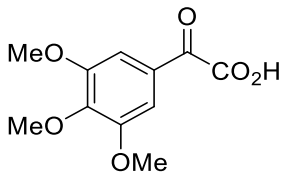
2-(4-bromophenyl)-2-oxoacetic acid (**23**). Following the method A, the reaction of 1-(4-bromophenyl)ethan-1-one (1.99 g, 10 mmol, 1.0 eq.) afforded α-ketoacid **23** as a pale yellow solid (1.52 g, 66%); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.28 (d, *J* = 8.8 Hz, 2H), 7.69 (d, *J* = 8.6 Hz, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 183.9, 161.9, 132.6, 132.6, 131.7, 130.7; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_8H_4O_3Br]^-$, 226.9349, found 226.9342.



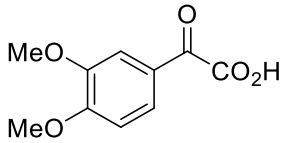
2-oxo-2-(p-tolyl)acetic acid (**24**). Following the method B, the reaction of toluene (2.13 mL, 20 mmol, 1.0 eq.) afforded α-ketoacid **24** as a white flaky crystal (1.88 g, 57%); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.32 (d, *J* = 8.3 Hz, 2H), 7.33 (d, *J* = 8.0 Hz, 2H); δ. 2.46 (s, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 185.0, 163.2, 147.2, 131.3, 129.8, 129.5, 22.1; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_9H_7O_3]^-$, 163.0401, found 163.0404.



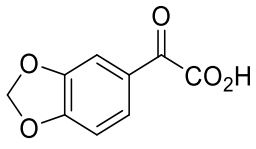
2-(2,5-dimethylphenyl)-2-oxoacetic acid (**25**). Following the method B, the reaction of *p*-xylene (1.07 g, 10 mmol, 1.0 eq.) afforded α-ketoacid **25** as a white acicular crystal (1.20 g, 67%); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 10.02 (brs, 1H), 7.79 (d, *J* = 1.8 Hz, 1H), 7.32 (dd, *J* = 7.9, 2.1 Hz, 1H), 7.19 (d, *J* = 7.8 Hz, 1H), 2.53 (s, 3H), 2.36 (s, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 188.5, 166.8, 138.7, 135.8, 135.1, 133.3, 132.3, 130.5, 21.1, 20.8; **IR** (KBr, thin film): 2968, 2927, 1701, 1501, 1281, 1241, 1175, 1011, 781, 677, 518 cm^{-1}; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{10}H_9O_3]^-$, 177.0557, found 177.0558.



2-oxo-2-(3,4,5-trimethoxyphenyl)acetic acid (**26**)**.** Following the method A, the reaction of 1-(3,4,5-trimethoxyphenyl)ethan-1-one (1.80 g, 10 mmol, 1.0 eq.) afforded α-ketoacid **26** as a yellow needle-like crystal (1.63 g, 67% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.74 (s, 2H), 3.99 (s, 3H), 3.93 (s, 6H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 182.9, 161.2, 153.1, 145.4, 126.5, 109.2, 61.3, 56.5; **IR** (KBr, thin film): 2985, 2947, 2841, 1730, 1645, 1577, 1465, 1317, 1118, 987, 865, 776 cm^{-1}; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{11}H_{11}O_6]^-$, 239.0561, found 239.0565.

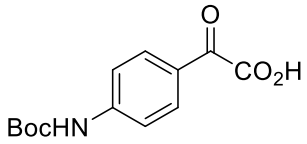


2-(3,4-dimethoxyphenyl)-2-oxoacetic acid (**27**)**.** Following the method A, the reaction of 1-(3,4-dimethoxyphenyl)ethan-1-one (1.80 g, 10 mmol, 1.0 eq.) afforded α-ketoacid **27** as a yellow solid (1.86 g, 88% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.31 (dd, J = 8.6, 2.0 Hz, 1H), 7.84 (d, J = 2.0 Hz, 1H), 6.95 (d, J = 8.6 Hz, 1H), 4.00 (s, 3H), 3.96 (s, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 181.9, 160.8, 156.1, 149.4, 128.6, 124.9, 112.6, 110.7, 56.5, 56.2; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{10}H_9O_5]^-$, 209.0455, found 209.0457.

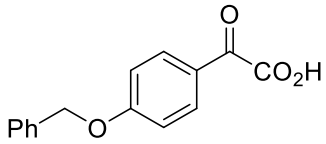


2-(benzo[d][1,3]dioxol-5-yl)-2-oxoacetic acid (**28**)**.** Following the method B, the reaction of 1,3-benzodioxole (1.22 g, 10 mmol, 1.0 eq.) afforded α-ketoacid **28** as a yellow solid (0.61 g, 32% yield); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 7.53 (dd, J = 8.1, 1.8 Hz, 1H), 7.38 (d, J = 1.7 Hz, 1H), 7.12 (d, J = 8.1 Hz, 1H), 6.20 (s, 2H); **^{13}C NMR**

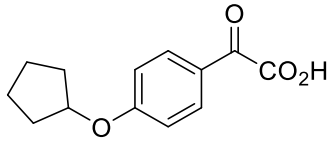
(126 MHz, DMSO-d_6) δ 186.8, 166.3, 153.3, 148.4, 127.6, 126.4, 108.6, 107.3, 102.6; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_9H_5O_5]^-$, 193.0142, found 193.0142.



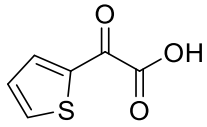
2-(4-((*tert*-butoxycarbonyl)amino)phenyl)-2-oxoacetic acid (**29**). Following the method A, the reaction of *tert*-butyl (4-acetylphenyl)carbamate (1.18 g, 5 mmol, 1.0 eq.) afforded α-ketoacid **29** as a yellow crystal (0.15 g, 11%); **^{1}H NMR** (500 MHz, acetone-d_6) δ 8.86 (s, 1H), 7.98 (d, J = 8.5 Hz, 2H), 7.71 (d, J = 8.5 Hz, 2H), 1.50 (s, 9H); **^{13}C NMR** (126 MHz, acetone-d_6) δ 186.8, 165.9, 153.3, 147.0, 132.1, 127.2, 118.4, 81.1, 28.4; **IR** (KBr, thin film): 3334, 2980, 1735, 1674, 1585, 1527, 1369, 1232, 1151, 1055, 856, 771 cm^{-1}; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{13}H_{14}NO_5]^-$, 264.0877, found 264.0881.



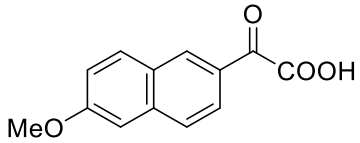
2-(4-(benzyloxy)phenyl)-2-oxoacetic acid (**30**)**.** Following the method C, the reaction of methyl 2-(4-hydroxyphenyl)-2-oxoacetate **37b** (0.54 g, 3 mmol, 1.0 eq.) and benzyl bromide (1.03 g, 6 mmol, 2.0 eq.) afforded α-ketoacid **30** as a white solid (0.53 g, 69% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.45 (d, J = 9.2 Hz, 2H), 7.44 - 7.36 (m, 5H), 7.07 (d, J = 9.1 Hz, 2H), 5.18 (s, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 181.9, 165.1, 161.0, 135.7, 134.7, 128.9, 128.6, 127.7, 125.0, 115.4, 70.6; **IR** (KBr, thin film): 3066, 1740, 1673, 1597, 1510, 1260, 1166, 974, 850, 739 cm^{-1}; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{15}H_{11}O_4]^-$, 255.0663, found 255.0669.



2-(4-(cyclopentyloxy)phenyl)-2-oxoacetic acid (**31**)**.** Following the method C, the reaction of methyl 2-(4-hydroxyphenyl)-2-oxoacetate **37b** (0.54 g, 3 mmol, 1.0 eq.) and cyclopentyl bromide (0.89 g, 6 mmol, 2.0 eq.) afforded α-ketoacid **31** as a white solid (0.65 g, 69% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.41 (d, *J* = 8.9 Hz, 2H), 6.94 (d, *J* = 9.0 Hz, 2H), 4.88 (tt, *J* = 6.0, 2.6 Hz, 1H), 2.00 - 1.91 (m, 2H), 1.90 - 1.76 (m, 4H), 1.71 - 1.61 (m, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 184.5, 164.5, 164.3, 133.6, 124.4, 115.7, 80.2, 32.9, 24.1; **IR** (KBr, thin film): 2962, 2873, 1743, 1673, 1597, 1567, 1509, 1263, 1163, 973, 851, 621 cm^{-1}; **HRMS-ESI** (m/z): $[M-H+2Na]^+$ calc'd for $[C_{13}H_{13}O_4Na_2]^+$, 279.0604, found 279.0601.

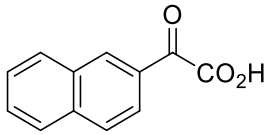


2-oxo-2-(thiophen-2-yl)acetic acid (**32**). Following the method A, the reaction of 1-(thiophen-2-yl)ethan-1-one (2.53 g, 20 mmol, 1.0 eq.) afforded α-ketoacid **32** as a yellow crystal (1.73 g, 56%); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.75 (brs, 1H), 8.50 (d, *J* = 3.6 Hz, 1H), 7.95 (d, *J* = 4.8 Hz, 1H), 7.26 - 7.24 (m, 1H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 175.4, 159.9, 140.3, 140.0, 136.4, 129.4; **HRMS-ESI** (m/z): $[M-H+2Na]^+$ calc'd for $[C_6H_3O_3NaS]^+$, 200.9593, found 200.9594.

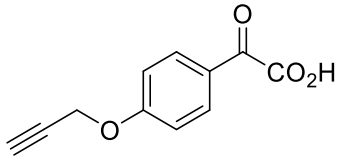


2-(6-methoxynaphthalen-2-yl)-2-oxoacetic acid (**33**) Following the general procedure A, the reaction of 1-(6-methoxynaphthalen-2- yl)ethan-1-one (4.00 g, 20 mmol) afforded α-ketoacid **33** as a yellow solid (2.29 g, 50%); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 8.51 (s, 1H), 8.12 (d, *J* = 8.9 Hz, 1H), 7.97 (d, *J* = 8.7 Hz, 1H), 7.91 (d, *J* = 8.6 Hz, 1H), 7.45 (s, 1H), 7.30 - 7.27 (m, 1H), 3.92 (s, 3H); **^{13}C NMR** (126 MHz, DMSO-d_6) δ 188.5, 166.5, 160.3, 138.0, 132.7, 131.8, 127.9, 127.3, 127.1, 124.1, 120.0, 106.4, 55.6; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{13}H_9O_4]^-$, 229.0506, found

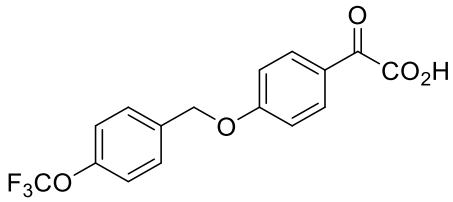
229.0507.



2-(naphthalen-2-yl)-2-oxoacetic acid (**34**) Following the general procedure A, the reaction of 1-(naphthalen-2-yl)ethan-1-one (3.48 g, 20 mmol) afforded α-ketoacid **34** as a yellow solid (0.54g, 14%); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 8.61 (s, 1H), 8.22 (d, J = 8.2 Hz, 1H), 8.11 (d, J = 8.6 Hz, 1H), 8.04 (d, J = 8.3 Hz, 1H), 8.01 - 7.93 (m, 1H), 7.74 (t, J = 7.5 Hz, 1H), 7.66 (t, J = 7.5 Hz, 1H); **^{13}C NMR** (126 MHz, DMSO-d_6) δ 188.7, 166.2, 135.8, 132.9, 132.0, 130.0, 129.8, 129.3, 129.2, 127.9, 127.5, 123.4; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{12}H_7O_3]^-$, 199.0401, found 199.0402.

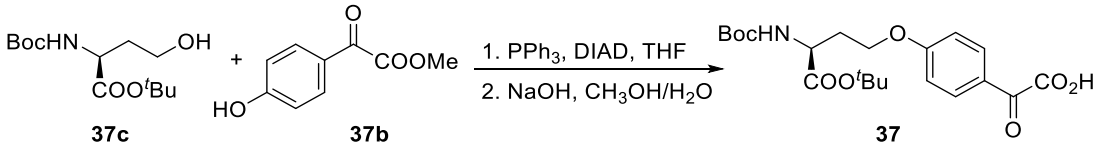


2-oxo-2-(4-(prop-2-yn-1-yloxy)phenyl)acetic acid (**35**)**.** Following the method C, the reaction of methyl 2-(4-hydroxyphenyl)-2-oxoacetate **37b** (0.54 g, 3 mmol, 1.0 eq.) and 3-bromoprop-1-yne (0.71 g, 6 mmol, 2.0 eq.) afforded α-ketoacid **35** as a pale yellow solid (0.33 g, 55% yield); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 7.91 (d, J = 8.7 Hz, 2H), 7.18 (d, J = 8.5 Hz, 2H), 4.95 (d, J = 2.4 Hz, 2H), 3.64 (s, 1H); **^{13}C NMR** (126 MHz, DMSO-d_6) δ 187.6, 166.7, 162.4, 131.9, 125.5, 115.4, 79.0, 78.4, 56.0; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{11}H_7O_4]^-$, 203.0350, found 203.0342.



2-oxo-2-(4-((4-(trifluoromethoxy)benzyl)oxy)phenyl)acetic acid (**36**)**.** Following the method C, the reaction of methyl 2-(4-hydroxyphenyl)-2-oxoacetate **37b** (0.54 g, 3 mmol, 1.0 eq.) and 1-(bromomethyl)-4-(trifluoromethoxy)benzene (1.53 g, 6 mmol, 2.0

eq.) afforded α-ketoacid **36** as a pale yellow solid (0.46 g, 45% yield); **^{1}H NMR** (500 MHz, DMSO-d_6) δ 7.90 (d, J = 8.7 Hz, 2H), 7.61 (d, J = 8.3 Hz, 2H), 7.40 (d, J = 8.2 Hz, 2H), 7.21 (d, J = 8.6 Hz, 2H), 5.27 (s, 2H); **^{13}C NMR** (126 MHz, DMSO-d_6) δ 187.7, 166.7, 163.4, 148.1, 135.7, 132.0, 129.8, 125.2, 121.1, 119.1, 115.4, 68.8; **^{19}F NMR** (376 MHz, DMSO-d_6) δ -56.9; **IR** (KBr, thin film): 3389, 1731, 1672, 1598, 1461, 1425, 1123, 815, 780, 532 cm^{-1}; **HRMS-ESI** (m/z): [M-H]$^-$ calc'd for [$C_{16}H_{10}F_3O_5$]$^-$, 339.0486, found 339.0486.

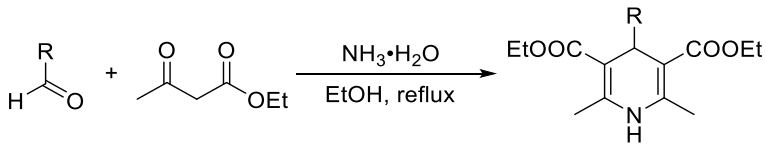


2-(4-(4-(tert-butoxy)-3-((tert-butoxycarbonyl)amino)-4-oxobutoxy)phenyl)-2-oxoacetic acid (**37**). **37b** and **37c** were synthesized according to the literature procedure[13-14]. Firstly, α-ketoester was synthesized through mitsunobu reaction. **37c** (a thick oil, 1.13 g, 4 mmol, 1.0 eq.), **37b** (0.76 g, 4.2 mmol, 1.05 eq.) and PPh_3 (1.26 g, 4.8 mmol, 1.2 eq.) were added to a round-bottomed flask, and then flushed it with nitrogen, followed by adding anhydrous THF (20 mL) via a syringe. The reaction mixture was cooled in an ice bath and diisopropyl azodicarboxylate (DIAD, 0.95 mL, 4.8 mmol, 1.2 eq.) was added dropwise. Then the solution was stirred at r.t. for 24 h. After completion of the reaction, as determined by TLC, the solution was concentrated and purified by silica-gel column chromatography (30% EtOAc in hexanes) to afford α-ketoester, *tert*-butyl N-(*tert*-butoxycarbonyl)-O-(4-(2-methoxy-2-oxoacetyl)phenyl)-*L*-homoserinate (1.39 g, 77%). Then following the literature method[15], in a 50 mL round-bottomed flask equipped with a magnetic stirring bar was dissolved the obtained α-ketoester (1.39 g, 3.2 mmol) in 25 mL of methanol and the solution was cooled to 0 ^{o}C. After 10 min, 3.5 mL of 1 N NaOH was added and the solution turned from colorless to yellow. It was stirred at 0 ^{o}C for 15 min. Nine drops of 1 N HC1 were added, and the solution was evaporated in vacuo. The yellow residue was dissolved in 40 mL of ethyl acetate and washed twice with 30-mL portions of 1 N HC1, twice with 30-mL portions of water, and once with 30 mL of brine. The organic layer was dried over anhydrous

Na_2SO_4, filtered, and evaporated in vacuo to afford **37** as a yellow sticky foam (0.89 g, 66%, basic hydrolysis has an effect on the chirality); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.29 (d, *J* = 8.4 Hz, 2H), 6.95 (d, *J* = 8.5 Hz, 2H), 5.31 (m, 1H), 4.41 (d, *J* = 7.3 Hz, 1H), 4.18 - 4.14 (m, 2H), 2.37 - 2.32 (m, 1H), 2.24 - 2.18 (m, 1H), 1.48 (s, 9H), 1.43 (s, 9H).; **^{13}C NMR** (126 MHz, $CDCl_3$) δ 183.5, 171.5, 164.6, 163.2, 155.7, 133.8, 125.3, 114.8, 82.7, 80.4, 65.0, 51.7, 32.1, 28.4, 28.1; **IR** (KBr, thin film): 3364, 2979, 2934, 1718, 1678, 1600, 1511, 1369, 1259, 1165, 850, 738 cm^{-1}; **HRMS-ESI** (m/z): $[M-H]^-$ calc'd for $[C_{21}H_{28}O_8N]^-$, 422.1820, found 422.1818.

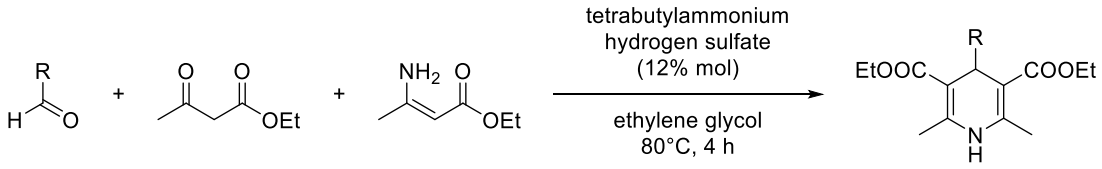
Synthesis of Alkyl-DHPs

Method A:



Following the literature procedure with slight modifications[16], the reaction flask was charged with ethyl acetoacetate (2.6 g, 20 mmol), aldehyde (10 mmol), and ethanol (20 mL). To the above solution, ammonium hydroxide (20 mmol) was added slowly. Then the system was heated to reflux with stirring. After completion of the reaction, as determined by TLC, the solution was cooled, concentrated and purified by silica-gel column chromatography (PE/EtOAc) and followed by recrystallization (EtOH/PE) to afford the desired product.

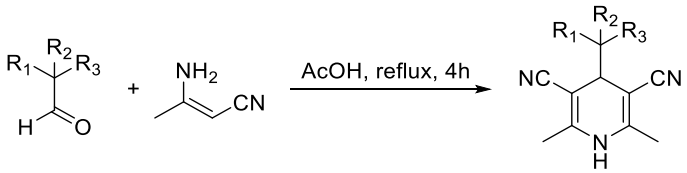
Method B:



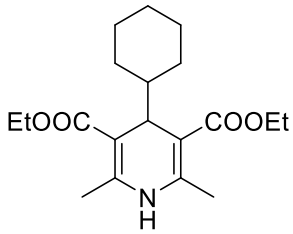
Following the literature procedure with slight modifications[17], ethyl-3-aminocrotonate (1.0 eq.) and ethylene glycol (2.5 M) were added to a flask under nitrogen. Next, ethyl acetoacetate (1.0 eq.), aldehyde (1.0 eq.) and tetrabutylammonium hydrogen sulfate

(TBAHS, 12 mol%) were added sequentially. The solution was heated at 80 °C for 4 hours, then cooled and diluted with ethyl acetate. 50 mL brine was added and the mixture was extracted with ethyl acetate (3 x 50 mL). The combined organic layers were dried (anhydrous Na_2SO_4) and concentrated on a rotary evaporator. The crude was purified by silica-gel column chromatography (PE/EtOAc) and followed by recrystallization (EtOH/PE) to afford the desired product.

Method C:



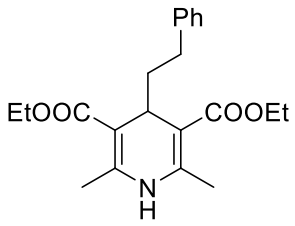
Following the literature procedure with slight modifications[18]. To a stirred solution of 3-aminocrotononitrile (20 mmol, 2.0 equiv.) in AcOH (10 mL) was added corresponding aldehyde (10 mmol, 1.0 equiv.). The reaction mixture was heated to reflux for 4 h. After removed most of the solvent under reduced pressure, the reaction was diluted in EtOAc (30 mL) and quenched with saturated aq. $NaHCO_3$ (30 mL). The mixture was washed with brine (15 mL) and extracted with EtOAc (3 x 30 mL). The combined organic layer was dried (Na_2SO_4) and concentrated in vacuo. The crude was purified by silica-gel column chromatography (PE/EtOAc or CH_2Cl_2/MeOH) and followed by recrystallization (EtOH/PE) to afford the desired product.



Diethyl 4-cyclohexyl-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate (44).

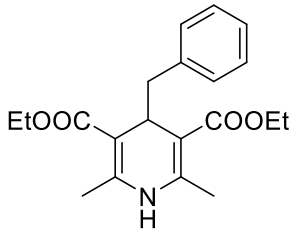
Following the general procedure A, the reaction of cyclohexanecarbaldehyde (1.12 g, 10 mmol) afforded the desired product **44** as a white solid (1.80 g, 53% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 5.66 (s, 1H), 4.25 - 4.07 (m, 4H), 3.91 (d, J = 5.7 Hz, 1H), 2.29 (s, 6H), 1.71 - 1.60 (m, 2H), 1.58 - 1.49 (m, 3H), 1.29 (t, J = 7.1 Hz, 6H), 1.26 - 1.15

(m, 1H), 1.11 - 1.01 (m, 3H), 0.97 - 0.85 (m, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.8, 144.6, 102.0, 59.7, 45.9, 38.5, 28.9, 26.8, 26.7, 19.6, 14.5; **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{19}H_{29}O_4NNa]^+$, 358.1989, found 358.1993.



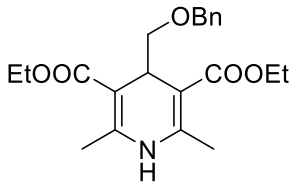
Diethyl 2,6-dimethyl-4-phenethyl-1,4-dihydropyridine-3,5-dicarboxylate (50).

Following the general procedure A, the reaction of 3-phenylpropanal (1.32 mL, 10 mmol) afforded the desired product **50** as a white solid (1.75 g, 49% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.25 - 7.20 (m, 2H), 7.16 - 7.09 (m, 3H), 5.72 (brs, 1H), 4.26 - 4.11 (m, 4H), 4.06 (t, J = 5.8 Hz, 1H), 2.58 - 2.51 (m, 2H), 2.30 (s, 6H), 1.73 - 1.62 (m, 2H), 1.29 (t, J = 7.2 Hz, 6H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.1, 145.2, 143.2, 128.4, 128.3, 125.5, 103.1, 59.8, 38.5, 33.4, 31.5, 19.6, 14.6; **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{21}H_{27}O_4NNa]^+$, 380.1832, found 380.1833.

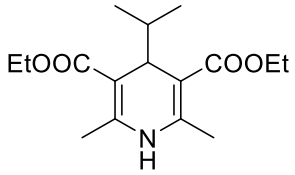


Diethyl 4-benzyl-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate (51).

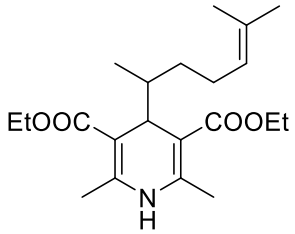
Following the general procedure A, the reaction of 2-phenylacetaldehyde (1.20 g, 10 mmol) afforded the desired product **51** as a white solid (1.30 g, 38% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.21 -7.09 (m, 3H), 7.07 - 6.96 (m, 2H), 5.36 (s, 1H), 4.19 (t, J = 5.5 Hz, 1H), 4.12 - 3.97 (m, 4H), 2.58 (d, J = 5.5 Hz, 2H), 2.17 (s, 6H), 1.23 (t, J = 7.1 Hz, 6H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 167.9, 145.4, 139.4, 130.2, 127.4, 125.7, 102.0, 59.7, 42.4, 35.6, 19.3, 14.5; **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{20}H_{25}O_4NNa]^+$, 366.1676, found 366.1671.



Diethyl 4-((benzyloxy)methyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate (52). Following the general procedure B, the reaction of 2-(benzyloxy)acetaldehyde (1.00 g, 6.7 mmol) afforded the desired product **52** as a white solid (1.70 g, 68% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.31 - 7.19 (m, 5H), 5.77 (s, 1H), 4.48 (s, 2H), 4.24 (t, *J* = 5.6 Hz, 1H), 4.18 - 4.10 (m, 4H), 3.33 (d, *J* = 5.6 Hz, 2H), 2.27 (s, 6H), 1.24 (t, *J* = 7.1 Hz, 6H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.0, 145.6, 139.2, 128.2, 127.3, 127.2, 100.6, 73.3, 72.4, 59.8, 34.2, 19.6, 14.5; **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{21}H_{27}O_5NNa]^+$, 396.1781, found 396.1782.

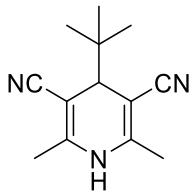


Diethyl 4-isopropyl-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate (53). Following the general procedure B, the reaction of isobutyraldehyde (0.91 mL, 10 mmol) afforded the desired product **53** as a white solid (1.40 g, 47% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 5.62 (brs, 1H), 4.26 - 4.08 (m, 4H), 3.91 (d, *J* = 5.4 Hz, 1H), 2.29 (s, 6H), 1.62 - 1.53 (m, 1H), 1.29 (t, *J* = 7.1 Hz, 6H), 0.74 (d, *J* = 6.9 Hz, 6H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.8, 144.6, 101.9, 59.7, 38.9, 35.7, 19.6, 18.6, 14.5; **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{16}H_{25}O_4NNa]^+$, 318.1676, found 318.1677.



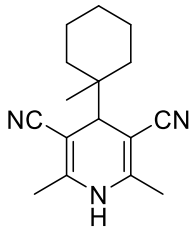
Diethyl 2,6-dimethyl-4-(6-methylhept-5-en-2-yl)-1,4-dihydropyridine-3,5-dicarboxylate (54).

Following the general procedure B, the reaction of 2,6-dimethylhept-5-enal (1.60 mL, 10 mmol) afforded the desired product **54** as a colorless semi-solid (1.31 g, 36% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 5.91 (brs, 1H), 5.00 (t, *J* = 6.8 Hz, 1H), 4.24 - 4.04 (m, 4H), 3.98 (d, *J* = 4.4 Hz, 1H), 2.26 (d, *J* = 3.7 Hz, 6H), 2.04 - 1.90 (m, 1H), 1.91 - 1.79 (m, 1H), 1.62 (s, 3H), 1.54 (s, 3H), 1.43 - 1.30 (m, 2H), 1.26 (td, *J* = 7.1, 2.7 Hz, 6H), 1.01 - 0.90 (m, 1H), 0.70 (d, *J* = 6.8 Hz, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 169.1, 168.7, 145.0, 144.8, 130.8, 125.3, 102.1, 101.3, 59.7, 59.6, 41.0, 38.0, 32.8, 26.1, 25.8, 19.4, 19.3, 17.8, 15.0, 14.4, 14.4; **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{21}H_{33}O_4NNa]^+$, 386.2302, found 386.2301.



4-(tert-butyl)-2, 6-dimethyl-1,4-dihydropyridine-3,5-dicarbonitrile (55)

Following the general procedure C, the reaction of pivalaldehyde (0.86 g, 10 mmol) afforded the desired product **55** as an amber solid (0.78 g, 36% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 6.87 (s, 1H), 2.86 (s, 1H), 2.17 (s, 6H), 0.94 (s, 9H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 148.7, 120.7, 81.5, 46.6, 41.0, 26.2, 18.5; **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{13}H_{17}N_3Na]^+$, 238.1315, found 238.1318.



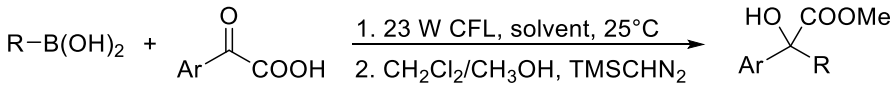
2,6-dimethyl-4-(1-methylcyclohexyl)-1,4-dihydropyridine-3,5-dicarbonitrile (56)

Following the general procedure C, the reaction of 1-methylcyclohexane-1-carbaldehyde (1.68 g, 13 mmol) afforded the desired product **56** as a white solid (0.47 g, 14% yield); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 6.49 (brs, 1H), 3.02 (s, 1H), 2.18 (s, 6H), 1.67 - 1.52 (m, 3H), 1.45 - 1.23 (m, 6H), 1.29 - 1.13 (m, 1H), 0.82 (s, 3H); **^{13}C NMR**

(126 MHz, $CDCl_3$) δ 149.4, 120.8, 80.2, 45.7, 43.5, 34.1, 26.3, 21.7, 19.1, 18.3; **IR** (KBr, thin film): 3296, 3236, 3114, 2927, 2853, 2198, 1650, 1506, 1436, 1289, 1022, 801, 737 cm^{-1}. **HRMS-ESI** (m/z): $[M+Na]^+$ calc'd for $[C_{16}H_{21}N_3Na]^+$, 278.1628, found 278.1622.

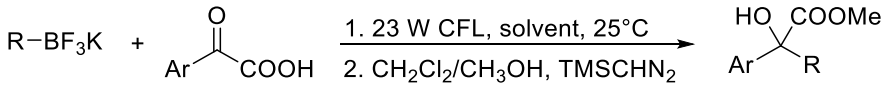
VII. Product Characterizations

Standard Procedure A:



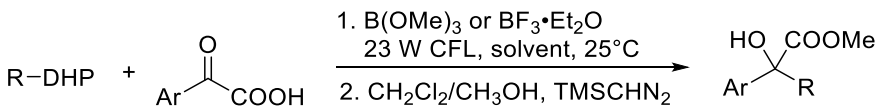
α-Ketoacid (0.1 mmol, 1.0 eq.) and alkyl boronic acid (0.3 mmol, 3.0 eq.) were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After 2.0 mL solvent was added, the vial was sealed in nitrogen atmosphere and exposed to 23 W CFL (distance: 8.0 cm, irradiance intensity: 3.08 mW/cm^2) at room temperature with stirring. After 5-48 h, the reaction mixture was esterified with $TMSCHN_2$: 0.6 mL CH_3OH was added, followed by 0.3 mL $TMSCHN_2$ (2.0 M in hexanes, 0.6 mmol, 6.0 eq.) added dropwise. After TLC indicated the complete consumption of α-hydroxy acid (typically 0.5 h), the reaction mixture was concentrated and purified directly by column chromatography to afford the product α-hydroxy ester.

Standard Procedure B:



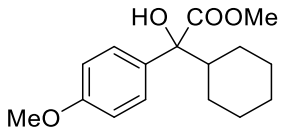
α-Ketoacid (0.1 mmol, 1.0 eq.) and alkyl trifluoroborate (0.3 mmol, 3.0 eq.) were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After 1.0 mL CH_2Cl_2 and 1.0 mL H_2O (predegassed with N_2) were added, the vial was sealed in nitrogen atmosphere and exposed to 23 W CFL (distance: 8.0 cm, irradiance intensity: 3.08 mW/cm^2) at room temperature with stirring. After 5-48 h, the reaction mixture was esterified with $TMSCHN_2$: the reaction mixture was evaporated to dryness, then 2.0 mL CH_2Cl_2 and 0.6 mL CH_3OH were added, followed by 0.3 mL $TMSCHN_2$ (2.0 M in hexanes, 0.6 mmol, 6.0 eq.) added dropwise. After TLC indicated the complete consumption of α-hydroxy acid (typically 0.5 h), the reaction mixture was concentrated and purified directly by column chromatography to afford the product α-hydroxy ester.

Standard Procedure C:



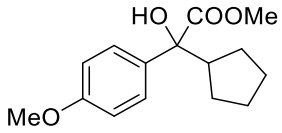
α-Ketoacid (0.1 mmol, 1.0 eq.) and alkyl-DHP (0.15 mmol, 1.5 eq.) were placed in a 4 mL clear-colored glass vial equipped with a magnetic stir bar. After 2.0 mL CH_2Cl_2 and 0.1 mL HFIP were added, the boron reagent was injected and the vial was sealed in nitrogen atmosphere and exposed to 23 W CFL (distance: 8.0 cm, irradiance intensity: 3.08 mW/cm^2) at room temperature with stirring. After 24 h, the reaction mixture was esterificated with $TMSCHN_2$: 0.6 mL CH_3OH was added, followed by 0.3 mL $TMSCHN_2$ (2.0 M in hexanes) added dropwise. After TLC indicated the complete consumption of α-hydroxy acid (typically 0.5 h), the reaction mixture was concentrated and purified directly by column chromatography to afford the product α-hydroxy ester.

*The heating effect from CFL irradiation conditions above is minimal. With 5-48 hours' irradiation, the increase of temperature is less than 10^{o}C.

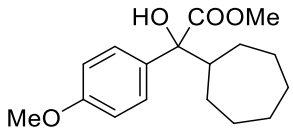


Methyl 2-cyclohexyl-2-hydroxy-2-(4-methoxyphenyl)acetate (**4**). Following the standard procedure B, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **4** as a white solid (22.3 mg, 80% yield) after flash chromatography (3% EtOAc in hexanes). While following the standard procedure C, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **44** (50.3 mg, 0.15 mmol, 1.5 eq.) and $B(OMe)_3$ (16.7 μL, 0.15 mmol, 1.5 eq.) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 24 h were then esterfied to afford target product **4** as a white solid (25.3 mg, 91% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.70 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.54 (d, *J* = 7.9 Hz, 2H), 6.87 (d, *J* = 7.6 Hz, 2H), 3.80 (s, 3H), 3.77 (s, 3H), 3.64 (s, 1H), 2.21 - 2.16 (m, 1H), 1.79 (d, *J* = 11.7 Hz, 1H), 1.68 - 1.61 (m, 2H), 1.44 - 1.37 (m, 2H), 1.34 - 1.21 (m, 2H), 1.16

- 1.04 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.5, 159.0, 132.9, 127.3, 113.5, 80.9, 55.3, 53.3, 45.8, 27.5, 26.5, 26.5, 26.3, 25.6; **IR** (KBr, thin film): 3511, 2933, 2853, 1725, 1609, 1509, 1452, 1250, 1173, 1035, 835, 758 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{16}H_{22}O_4$, 278.1518, found 278.1516.

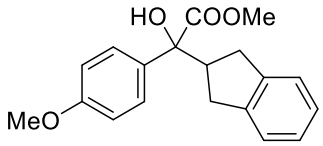


Methyl 2-cyclopentyl-2-hydroxy-2-(4-methoxyphenyl)acetate (**10a**). Following the standard procedure B, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl trifluoroborate **10** (Potassium cyclopentyltrifluoroborate, CAS 1040745-70-7, 52.8 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 12 h were then esterfied to afford target product **10a** as a white solid (19.9 mg, 75% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.46 (EtOAc/hexanes = 1/10); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.9 Hz, 2H), 6.86 (d, *J* = 8.9 Hz, 2H), 3.80 (s, 3H), 3.76 (s, 3H), 3.69 (s, 1H), 2.87 (p, *J* = 8.3 Hz, 1H), 1.72 - 1.62 (m, 1H), 1.63 - 1.41 (m, 5H), 1.38 - 1.30 (m, 2H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.5, 159.0, 134.0, 127.3, 113.5, 79.1, 55.4, 53.3, 47.3, 27.0, 26.5, 26.5, 26.1; **IR** (KBr, thin film): 3511, 2953, 2868, 1725, 1609, 1510, 1440, 1249, 1176, 1036, 831, 775 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{15}H_{20}O_4$, 264.1362, found 264.1363.

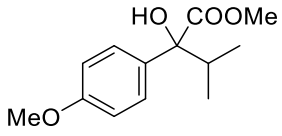


Methyl 2-cycloheptyl-2-hydroxy-2-(4-methoxyphenyl)acetate (**11a**). Following the standard procedure B, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl trifluoroborate **11** (61.2 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 12 h were then esterfied to afford target product **11a** as a white solid (19.5 mg, 67% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.43 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.53 (d, *J* = 8.8 Hz, 2H), 6.87 (d, *J* = 8.9 Hz, 2H),

3.80 (s, 3H), 3.76 (s, 3H), 3.64 (s, 1H), 2.41 (tt, J = 9.4, 3.6 Hz, 1H), 1.79 - 1.67 (m, 1H), 1.64 - 1.42 (m, 8H), 1.38 - 1.19 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.7, 159.0, 133.5, 127.3, 113.6, 82.3, 55.3, 53.3, 46.5, 29.7, 28.4, 28.2, 27.5, 27.4, 27.4; **IR** (KBr, thin film): 3511, 2927, 2855, 1725, 1608, 1509, 1462, 1248, 1178, 1094, 831, 758 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{17}H_{24}O_4Na]^+$, 315.1567, found 315.1569.

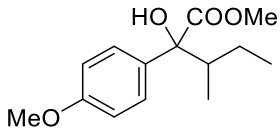


Methyl 2-(2,3-dihydro-1H-inden-2-yl)-2-hydroxy-2-(4-methoxyphenyl)acetate (**12a**). Following the standard procedure B, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl trifluoroborate **12** (67.2 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **12a** as a white solid (23.0 mg, 74% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.52 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.61 (d, J = 8.9 Hz, 2H), 7.17 (d, J = 6.3 Hz, 1H), 7.15-7.05 (m, 3H), 6.91 (d, J = 8.9 Hz, 2H), 3.83 (s, 3H), 3.82 (s, 3H), 3.77 (s, 1H), 3.51 (p, J = 8.9 Hz, 1H), 3.04 (dd, J = 15.4, 9.2 Hz, 1H), 2.88 (ddd, J = 16.0, 12.6, 8.9 Hz, 2H), 2.63 (dd, J = 16.0, 8.7 Hz, 1H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.0, 159.3, 142.8, 142.6, 133.3, 127.2, 126.4, 126.3, 124.5, 124.4, 78.7, 55.4, 53.5, 47.4, 33.7, 33.4; **IR** (KBr, thin film): 3504, 2952, 2838, 1726, 1608, 1510, 1458, 1249, 1177, 1034, 832, 746 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{19}H_{20}O_4Na]^+$, 335.1254, found 335.1259.



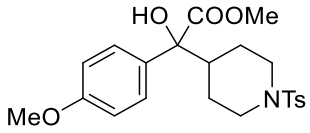
Methyl 2-hydroxy-2-(4-methoxyphenyl)-3-methylbutanoate (**13a**). Following the standard procedure B, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl boronic acid **13** (isopropylboronic acid, CAS 80041-89-0, 26.4 mg, 0.3 mmol) in 2.0 mL

CH_2Cl_2 for 12 h were then esterfied to afford target product **13a** as a white solid (16.8 mg, 71% yield) after flash chromatography (3% EtOAc in hexanes). While following the standard procedure C, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **53** (44.3 mg, 0.15 mmol, 1.5 eq.) and $B(OMe)_3$ (16.7 μL, 0.15 mmol, 1.5 eq.) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 24 h were then esterfied to afford target product **13a** as a white solid (22.3 mg, 94% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.67 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.54 (d, *J* = 8.9 Hz, 2H), 6.87 (d, *J* = 8.9 Hz, 2H), 3.80 (s, 3H), 3.77 (s, 3H), 3.62 (s, 1H), 2.57 (p, *J* = 6.7 Hz, 1H), 0.96 (d, *J* = 6.6 Hz, 3H), 0.71 (d, *J* = 7.7 Hz, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.6, 159.1, 133.3, 127.3, 113.5, 80.8, 55.4, 53.3, 35.8, 17.3, 15.8; **IR** (KBr, thin film): 3512, 2968, 2875, 1727, 1609, 1510, 1464, 1249, 1173, 1035, 832, 780 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{13}H_{18}O_4$, 238.1205, found 238.1211;

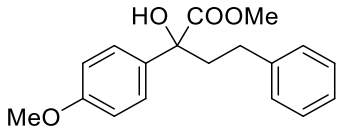


Methyl 2-hydroxy-2-(4-methoxyphenyl)-3-methylpentanoate (**14a**). Following the standard procedure B, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), boronic acid **14** (buntane-2-boronic acid, CAS 88496-88-2, 30.6 mg, 0.3 mmol) in 2.0 mL CH_2Cl_2 for 12 h were then esterfied to afford target product **14a** as a white solid (18.9 mg, 75% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.53 (EtOAc/hexanes = 1/9), two diastereoisomers showed partially separated NMR signals; **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.54 (dd, *J* = 9.0, 3.5 Hz, 4H), 6.87 (dd, *J* = 8.9, 1.9 Hz, 4H), 3.80 (s, 6H), 3.76 (s, 6H), 3.65 (s, 1H), 3.61 (s, 1H), 2.33 - 2.22 (m, 2H), 1.40 - 1.26 (m, 2H), 1.24 - 1.13 (m, 1H), 1.09 - 0.97 (m, 1H), 0.95 (dd, *J* = 8.5, 6.8 Hz, 6H), 0.79 (t, *J* = 7.5 Hz, 3H), 0.69 (d, *J* = 6.8 Hz, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.7, 176.5, 159.1, 159.0, 133.4, 133.2, 127.3, 127.3, 113.6, 113.5, 81.5, 81.4, 55.3, 53.3, 53.3, 42.7, 42.5, 24.8, 22.6, 13.7, 12.4, 12.4, 12.2; **IR** (KBr, thin film): 3512, 2963, 2877, 1727, 1609, 1509, 1463, 1252, 1148, 1036, 830, 773 cm^{-1}; **HRMS-ESI** (m/z)

$[M+Na]^+$ calc'd for $[C_{14}H_{20}O_4Na]^+$, 275.1254, found 275.1260.

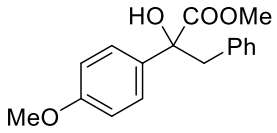


Methyl 2-hydroxy-2-(4-methoxyphenyl)-2-(1-tosylpiperidin-4-yl)acetate (**15a**). Following the standard procedure A, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl boronic acid **15** (84.9 mg, 0.3 mmol) in 2.0 mL CH_2Cl_2 for 24 h were then esterfied to afford target product **15a** as a white solid (34.1 mg, 79% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.23 (EtOAc/hexanes = 1/3); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.61 (d, *J* = 8.2 Hz, 2H), 7.44 (d, *J* = 8.9 Hz, 2H), 7.30 (d, *J* = 7.9 Hz, 2H), 6.83 (d, *J* = 8.9 Hz, 2H), 3.88 - 3.82 (m, 1H), 3.78 (s, 3H), 3.74 (s, 3H), 3.72 - 3.70 (m, 1H), 3.58 (s, 1H), 2.42 (s, 3H), 2.28 - 2.21 (m, 1H), 2.14 - 2.00 (m, 2H), 1.81 (qd, *J* = 12.5, 4.4 Hz, 1H), 1.49 (qd, *J* = 13.1, 4.7 Hz, 1H), 1.46 - 1.37 (m, 1H), 1.24 - 1.16 (m, 1H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 175.3, 159.3, 143.5, 133.2, 131.9, 129.7, 127.9, 127.0, 113.7, 79.7, 55.4, 53.5, 46.6, 46.3, 43.6, 26.2, 24.5, 21.6; **IR** (KBr, thin film): 3500, 2953, 2841, 1730, 1608, 1509, 1455, 1249, 1164, 1094, 933, 727 cm^{-1}; **HRMS-ESI** (m/z) $[M+H]^+$ calc'd for $[C_{22}H_{28}NO_6S]^+$, 434.1632, found 434.1635.

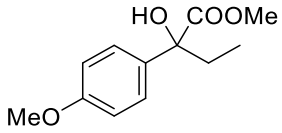


methyl 2-hydroxy-2-(4-methoxyphenyl)-4-phenylbutanoate (**16a**). Following the standard procedure A, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl boronic acid **16** (phenylethylboronic acid, CAS 34420-17-2, 45.0 mg, 0.3 mmol) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 48 h were then esterfied to afford target product **16a** as a colorless oil (15.7 mg, 52% yield) after flash chromatography (3% EtOAc in hexanes). While following the standard procedure C, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **50** (53.6 mg, 0.15 mmol, 1.5 eq.) and $BF_3 \cdot Et_2O$ (18.9 μL, 0.15 mmol, 1.5 eq.) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 24 h were then esterfied to

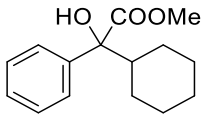
afford target product **16a** as a colorless oil (17.9 mg, 60% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.40 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$), δ 7.53 (d, *J* = 8.9 Hz, 2H), 7.29 - 7.26 (m, 2H), 7.19 - 7.16 (m, 3H), 6.89 (d, *J* = 8.9 Hz, 2H), 3.82 (s, 1H), 3.80 (s, 3H), 3.74 (s, 3H), 2.73 (ddd, *J* = 13.6, 11.5, 4.8 Hz, 1H), 2.58 (ddd, *J* = 13.6, 11.8, 5.1 Hz, 1H), 2.52 - 2.41 (m, 1H), 2.32 (ddd, *J* = 13.7, 11.8, 4.8 Hz, 1H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.0, 159.3, 141.8, 133.8, 128.6, 128.5, 126.9, 126.0, 113.8, 77.9, 55.4, 53.4, 41.6, 30.3; **IR** (KBr, thin film): 3503, 2954, 2836, 1729, 1510, 1249, 1178, 1102, 1032, 834, 748 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{18}H_{20}O_4Na]^+$, 323.1254, found 323.1262.



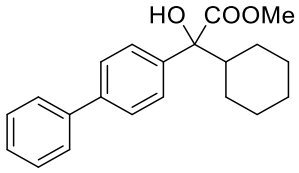
methyl 2-hydroxy-2-(4-methoxyphenyl)-3-phenylpropanoate (**17a**). Following the standard procedure B, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl trifluoroborate **17** (potassium benzyltrifluoroborate, CAS 329976-73-0, 59.4 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 48 h were then esterfied to afford target product **17a** as a colorless oil (18.6 mg, 65% yield) after flash chromatography (3% EtOAc in hexanes). While following the standard procedure C, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **51** (51.4 mg, 0.15 mmol, 1.5 eq.) and $BF_3 \cdot Et_2O$ (18.9 μL, 0.15 mmol, 1.5 eq.) in 2.0 mL HFIP for 24 h were then esterfied to afford target product **17a** as a colorless oil (18.6 mg, 65% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.45 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$), δ 7.59 (d, *J* = 9.0 Hz, 2H), 7.29 - 7.20 (m, 5H), 6.91 (d, *J* = 8.9 Hz, 2H), 3.82 (s, 3H), 3.73 (s, 3H), 3.58 (d, *J* = 13.5 Hz, 1H), 3.57 (s, 1H), 3.19 (d, *J* = 13.6 Hz, 1H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 175.1, 159.4, 135.9, 133.7, 130.6, 128.2, 127.1, 127.1, 113.7, 78.6, 55.4, 53.1, 46.1; **IR** (KBr, thin film): 3503, 2954, 2836, 1731, 1510, 1251, 1178, 1097, 1032, 836, 748, 701 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{17}H_{18}O_4Na]^+$, 309.1097, found 309.1105.



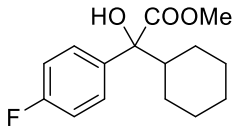
methyl 2-hydroxy-2-(4-methoxyphenyl)butanoate (**18a**). Following the standard procedure A, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol), alkyl boronic acid **18** (ethylboronic acid, CAS 4433-63-0, 22.2 mg, 0.3 mmol) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 48 h were then esterfied to afford target product **18a** as a colorless oil (13.3 mg, 59% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.41 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$), δ 7.49 (d, *J* = 9.0 Hz, 2H), 6.88 (d, *J* = 9.0 Hz, 2H), 3.80 (s, 3H), 3.77 (s, 3H), 3.69 (s, 1H), 2.20 (dq, *J* = 14.1, 7.3 Hz, 1H), 2.00 (dq, *J* = 14.7, 7.4 Hz, 1H), 0.91 (t, *J* = 7.3 Hz, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.2, 159.2, 134.0, 127.0, 113.7, 78.6, 55.4, 53.3, 32.7, 8.2; **IR** (KBr, thin film): 3504, 2956, 2837, 1729, 1609, 1511, 1248, 1178, 1147, 1033, 913, 833, 748 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{12}H_{16}O_4Na]^+$, 247.0941, found 247.0945.



Methyl 2-cyclohexyl-2-hydroxy-2-phenylacetate (**19a**). Following the standard procedure B, the reaction of α-ketoacid **19** (phenylglyoxylic acid, CAS 611-73-4, 15.3 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 24 h were then esterfied to afford target product **19a** as a colorless oil (13.7 mg, 55% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.70 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 7.4 Hz, 2H), 7.35 (t, *J* = 7.6 Hz, 2H), 7.30 - 7.25 (m, 1H), 3.78 (s, 3H), 3.68 (s, 1H), 2.29 - 2.18 (m, 1H), 1.84 - 1.78 (m, 1H), 1.70 - 1.59 (m, 2H), 1.49 - 1.40 (m, 2H), 1.37- 1.29 (m, 1H), 1.24 - 1.17 (m, 1H), 1.18 - 1.04 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.2, 140.9, 128.2, 127.5, 126.1, 81.2, 53.4, 45.9, 27.5, 26.5, 26.3, 25.6; **IR** (KBr, thin film): 3513, 2933, 2853, 1726, 1448, 1255, 1237, 1199, 1149, 1123, 731, 709 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{15}H_{20}O_3Na]^+$, 271.1305, found 271.1307.

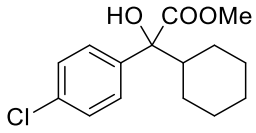


Methyl 2-([1,1'-biphenyl]-4-yl)-2-cyclohexyl-2-hydroxyacetate (**20a**). Following the standard procedure B, the reaction of α-ketoacid **20** (22.6 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 24 h were then esterfied to afford target product **20a** as a white solid (16.6 mg, 51% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.59 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.71 (d, *J* = 8.6 Hz, 2H), 7.63 - 7.55 (m, 4H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.38 - 7.32 (m, 1H), 3.81 (s, 3H), 3.71 (s, 1H), 2.36 - 2.22 (m, 1H), 1.88 - 1.77 (m, 1H), 1.71 - 1.63 (m, 2H), 1.51 - 1.40 (m, 2H), 1.39 - 1.24 (m, 2H), 1.20 - 1.06 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.2, 140.8, 140.4, 139.9, 128.9, 127.4, 127.2, 126.9, 126.6, 81.2, 53.5, 45.9, 27.5, 26.5, 26.3, 25.7; **IR** (KBr, thin film): 3511, 2932, 2853, 1725, 1486, 1449, 1254, 1238, 1005, 842, 747 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{21}H_{24}O_3$, 324.1725, found 324.1723.

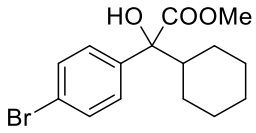


Methyl 2-cyclohexyl-2-(4-fluorophenyl)-2-hydroxyacetate (**21a**). Following the standard procedure A, the reaction of α-ketoacid **21** (16.8 mg, 0.1 mmol), alkyl boronic acid **1** (38.4 mg, 0.3 mmol) in 2.0 mL CH_2Cl_2 for 24 h were then esterfied to afford target product **21a** as a white solid (14.1 mg, 53% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.49 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.61 (dd, *J* = 9.0, 5.3 Hz, 2H), 7.05 - 6.98 (m, 2H), 3.78 (s, 3H), 3.68 (s, 1H), 2.20 - 2.14 (m, 1H), 1.84 - 1.74 (m, 1H), 1.68 - 1.62 (m, 2H), 1.45 - 1.38 (m, 2H), 1.35 - 1.26 (m, 1H), 1.21 - 1.03 (m, 4H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.1, 162.3 (d, *J* = 246.0 Hz), 136.5 (d, *J* = 3.1 Hz), 128.0 (d, *J* = 8.0 Hz), 115.0 (d, *J* = 21.3 Hz), 80.9, 53.5, 46.0, 27.5, 26.4, 26.3, 25.5; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -115.8; **IR** (KBr, thin film): 3511, 2933, 2854, 1728, 1603, 1506, 1238, 1160, 1094, 839, 758 cm^{-1}; **HRMS-ESI**

(m/z) $[M+Na]^+$ calc'd for $[C_{15}H_{19}O_3FNa]^+$, 289.1210, found 289.1210.

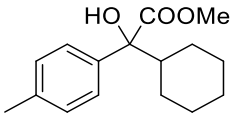


Methyl 2-cyclohexyl-2-(4-chlorophenyl)-2-hydroxyacetate (**22a**). Following the standard procedure B, the reaction of α-ketoacid **22** (18.5 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 24 h were then esterfied to afford target product **22a** as a white solid (12.7 mg, 45% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.50 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.6 Hz, 2H), 7.30 (d, *J* = 8.6 Hz, 2H), 3.78 (s, 3H), 3.68 (s, 1H), 2.21 - 2.11 (m, 1H), 1.84 - 1.75 (m, 1H), 1.69 - 1.60 (m, 2H), 1.45 - 1.36 (m, 2H), 1.35 - 1.24 (m, 1H), 1.20 - 1.03 (m, 4H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 175.9, 139.4, 133.5, 128.3, 127.7, 80.9, 53.6, 46.0, 27.5, 26.4, 26.2, 25.5; **IR** (KBr, thin film): 3509, 2933, 2854, 1728, 1490, 1255, 1238, 1095, 1015, 835, 760, 736 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{15}H_{19}ClNaO_3]^+$, 305.0915, found 305.0916.

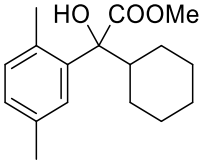


Methyl 2-cyclohexyl-2-(4-bromophenyl)-2-hydroxyacetate (**23a**). Following the standard procedure B, the reaction of α-ketoacid **23** (22.9 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 24 h were then esterfied to afford target product **23a** as a white solid (21.7 mg, 66% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.50 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.4 Hz, 2H), 7.46 (d, *J* = 8.8 Hz, 2H), 3.78 (s, 3H), 3.67 (s, 1H), 2.21 - 2.11 (m, 1H), 1.83 - 1.76 (m, 1H), 1.69 - 1.61 (m, 2H), 1.43 - 1.37 (m, 2H), 1.33 - 1.24 (m, 1H), 1.20 - 1.03 (m, 4H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 175.8, 140.0, 131.3, 128.1, 121.7, 81.0, 53.6, 46.0, 27.5, 26.4, 26.2, 25.5; **IR** (KBr, thin film): 3509, 2932, 2853, 1728, 1487, 1256, 1238, 1149, 1010, 784, 748 cm^{-1};

HRMS-ESI (m/z) $[M+Na]^+$ calc'd for $[C_{15}H_{19}BrNaO_3]^+$, 349.0410, found 349.0410.

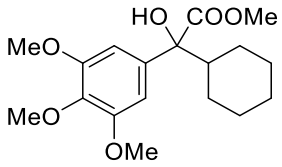


Methyl 2-cyclohexyl-2-hydroxy-2-(p-tolyl)acetate (**24a**). Following the standard procedure B, the reaction of α-ketoacid **24** (15.3 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 24 h were then esterfied to afford target product **24a** as a colorless oil (14.6 mg, 56% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.70 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.3 Hz, 2H), 7.15 (d, *J* = 8.1 Hz, 2H), 3.77 (s, 3H), 3.63 (s, 1H), 2.34 (s, 3H), 2.25 - 2.12 (m, 1H), 1.82 - 1.76 (m, 1H), 1.70 - 1.62 (m, 2H), 1.47 - 1.37 (m, 2H), 1.35 - 1.19 (m, 2H), 1.18 - 1.03 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.4, 137.9, 137.2, 128.9, 126.1, 81.1, 53.3, 45.8, 27.5, 26.5, 26.3, 25.6, 21.1; **IR** (KBr, thin film): 3512, 2932, 2853, 1725, 1510, 1449, 1237, 1172, 1005, 828, 753 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{16}H_{22}O_3$, 262.1569, found 262.1561.

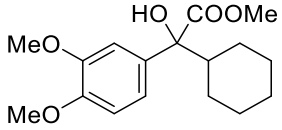


Methyl 2-cyclohexyl-2-(2,5-dimethylphenyl)-2-hydroxyacetate (**25a**). Following the standard procedure B, the reaction of α-ketoacid **25** (17.8 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 24 h were then esterfied to afford target product **25a** as a white solid (16.6 mg, 60% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.60 (EtOAc/hexanes = 1/10); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.29 (s, 1H), 7.04 - 6.96 (m, 2H), 3.73 (s, 3H), 3.56 (s, 1H), 2.47 - 2.42 (m, 1H), 2.40 (s, 3H), 2.33 (s, 3H), 1.84 - 1.74 (m, 2H), 1.72 -1.65 (m, 2H), 1.44 - 1.14 (m, 6H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.1, 137.5, 135.0, 134.6, 132.9, 128.5, 128.4, 81.9, 53.2, 43.7, 27.7, 26.7, 26.6, 26.5, 26.5, 21.8, 21.4; **IR** (KBr, thin film): 3510, 2927, 2851, 1723, 1448, 1255, 1235, 1100, 913, 810, 748 cm^{-1};

HRMS-ESI (m/z) $[M+Na]^+$ calc'd for $[C_{17}H_{24}O_3Na]^+$, 299.1618, found 299.1620.

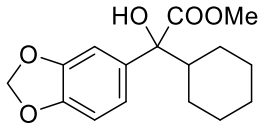


Methyl 2-cyclohexyl-2-hydroxy-2-(3,4,5-trimethoxyphenyl)acetate (**26a**). Following the standard procedure B, the reaction of α-ketoacid **26** (21.0 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **26a** as a white solid (22.6 mg, 67% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.45 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 6.86 (s, 2H), 3.86 (s, 6H), 3.83 (s, 3H), 3.79 (s, 3H), 3.63 (s, 1H), 2.16 - 2.09 (m, 1H), 1.82 - 1.75 (m, 1H), 1.70 - 1.58 (m, 2H), 1.42 - 1.38 (m, 2H), 1.32 - 1.22 (m, 2H), 1.15 - 1.04 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.0, 152.9, 137.4, 136.4, 103.4, 81.2, 60.9, 56.3, 53.4, 46.0, 27.6, 26.5, 26.4, 26.3, 25.6; **IR** (KBr, thin film): 3510, 3289, 2932, 2853, 1724, 1607, 1508, 1237, 1173, 1029, 835, 758 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{18}H_{26}O_6Na]^+$, 361.1622, found 361.1628.

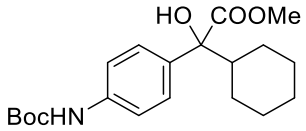


Methyl 2-cyclohexyl-2-(3,4-dimethoxyphenyl)-2-hydroxyacetate (**27a**). Following the standard procedure B, the reaction of α-ketoacid **27** (21.0 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **27a** as a white solid (21.5 mg, 70% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.37 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.19 (d, J = 2.1 Hz, 1H), 7.15 (dd, J = 8.4, 2.2 Hz, 1H), 6.83 (d, J = 8.5 Hz, 1H), 3.89 (s, 3H), 3.87 (s, 3H), 3.78 (s, 3H), 3.64 (s, 1H), 2.24 - 2.08 (m, 1H), 1.83 - 1.74 (m, 1H), 1.70 - 1.62 (m, 2H), 1.47 - 1.36 (m, 2H), 1.35 - 1.21 (m, 2H), 1.17 - 1.01 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.3, 148.7, 148.4, 133.4,

118.4, 110.8, 109.6, 80.9, 56.0, 56.0, 53.4, 45.9, 27.6, 26.5, 26.5, 26.3, 25.6; **IR** (KBr, thin film): 3510, 2933, 2853, 1725, 1515, 1464, 1449, 1260, 1236, 1117, 1028, 862, 754 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{17}H_{24}O_5$, 308.1624, found 308.1620.

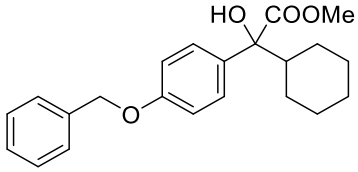


Methyl 2-(benzo[*d*][1,3]dioxol-5-yl)-2-cyclohexyl-2-hydroxyacetate (**28a**). Following the standard procedure B, the reaction of α-ketoacid **28** (19.4 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **28a** as a white solid (19.8 mg, 68% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.72 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.12 (d, *J* = 0.6 Hz, 2H), 6.77 (d, *J* = 8.8 Hz, 1H), 5.95 (s, 2H), 3.78 (s, 3H), 3.64 (s, 1H), 2.22 - 2.03 (m, 1H), 1.84 - 1.73 (m, 1H), 1.70 - 1.61 (m, 2H), 1.46 - 1.33 (m, 2H), 1.33 - 1.21 (m, 2H), 1.21 - 1.00 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.2, 147.7, 147.0, 134.9, 119.5, 107.9, 107.0, 101.2, 81.0, 53.4, 46.0, 27.5, 26.5, 26.5, 26.3, 25.5; **IR** (KBr, thin film): 3509, 2933, 2854, 1726, 1504, 1489, 1437, 1243, 1114, 1040, 937, 870, 757 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{16}H_{20}O_5Na]^+$, 315.1203, found 315.1200.

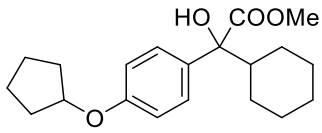


Methyl 2-(4-((tert-butoxycarbonyl)amino)phenyl)-2-cyclohexyl-2- hydroxyacetate (**29a**). Following the standard procedure B, the reaction of α-ketoacid **29** (26.6 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **29a** as a white solid (30.0 mg, 83% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.34 (EtOAc/hexanes = 1/10); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.53 (d, *J* = 8.8 Hz, 2H), 7.32 (d, *J* = 8.4 Hz, 2H), 6.52 (s, 1H), 3.76 (s, 3H), 3.64 (s, 1H), 2.28 - 2.12 (m, 1H), 1.78

(dd, J = 13.1, 3.0 Hz, 1H), 1.67 - 1.60 (m, 2H), 1.51 (s, 9H), 1.44 - 1.36 (m, 2H), 1.34 - 1.19 (m, 2H), 1.18 - 1.00 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.3, 152.9, 137.7, 135.4, 126.8, 118.3, 80.9, 53.4, 45.8, 28.5, 27.5, 26.5, 26.3, 25.6; **IR** (KBr, thin film): 3517, 3342, 2933, 2854, 1725, 1611, 1523, 1238, 1160, 1053, 839, 738 cm^{-1}; **HRMS-EI** (m/z) $[M-H_2O]^+$ calc'd for $C_{20}H_{27}NO_4$, 345.1940, found 345.1940.

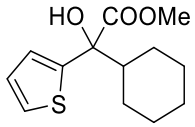


Methyl 2-(4-(benzyloxy)phenyl)-2-cyclohexyl-2-hydroxyacetate (**30a**). Following the standard procedure B, the reaction of α-ketoacid **30** (25.6 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **30a** as a white solid (30.2 mg, 85% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.42 (EtOAc/hexanes = 1/10); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.55 (d, J = 7.5 Hz, 2H), 7.44 (d, J = 7.6 Hz, 2H), 7.39 (t, J = 7.2 Hz, 2H), 7.36 - 7.30 (m, 1H), 6.96 (d, J = 7.5 Hz, 2H), 5.06 (s, 2H), 3.77 (s, 3H), 3.65 (s, 1H), 2.23 - 2.15 (m, 1H), 1.80 (d, J = 12.7 Hz, 1H), 1.66 (t, J = 7.3 Hz, 2H), 1.52 - 1.37 (m, 2H), 1.37 - 1.22 (m, 2H), 1.20 - 1.02 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.4, 158.3, 137.1, 133.1, 128.7, 128.1, 127.6, 127.4, 114.4, 80.9, 70.1, 53.3, 45.8, 27.4, 26.5, 26.3, 25.6; **IR** (KBr, thin film): 3511, 2932, 2853, 1724, 1607, 1508, 1453, 1238, 1172, 1025, 856, 736 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{22}H_{26}O_4$, 354.1831, found 354.1819.

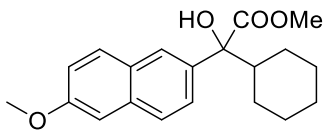


Methyl 2-cyclohexyl-2-(4-(cyclopentyloxy)phenyl)-2-hydroxyacetate (**31a**). Following the standard procedure B, the reaction of α-ketoacid **31** (23.4 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **31a** as a white solid (27.8 mg, 84% yield)

after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.56 (EtOAc/hexanes = 1/10); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.9 Hz, 2H), 6.83 (d, *J* = 8.9 Hz, 2H), 4.74 (tt, *J* = 6.0, 2.8 Hz, 1H), 3.76 (s, 3H), 3.62 (s, 1H), 2.22 - 2.13 (m, 1H), 1.95 - 1.74 (m, 7H), 1.69 - 1.57 (m, 4H), 1.47 - 1.37 (m, 2H), 1.34 - 1.22 (m, 2H), 1.19 - 1.03 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.5, 157.6, 132.3, 127.2, 115.0, 80.8, 79.2, 53.3, 45.7, 33.0, 27.5, 26.5, 26.4, 25.6, 24.2; **IR** (KBr, thin film): 3513, 2933, 2853, 1725, 1607, 1507, 1245, 1172, 1105, 990, 835, 759 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{20}H_{28}O_4Na]^+$, 355.1880, found 355.1877.

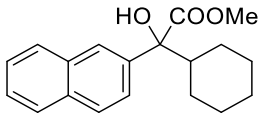


Methyl 2-cyclohexyl-2-hydroxy-2-(thiophen-2-yl)acetate (**32a**). Following the standard procedure A, the reaction of α-ketoacid **32** (15.6 mg, 0.1 mmol), alkyl boronic acid **1** (38.4 mg, 0.3 mmol) in 2.0 mL CH_2Cl_2 for 24 h were then esterfied to afford target product **32a** as a pale brown solid (8.5 mg, 33% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.73 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.22 (dd, *J* = 5.0, 1.2 Hz, 1H), 7.09 (dd, *J* = 3.6, 1.2 Hz, 1H), 6.98 (dd, *J* = 5.1, 3.6 Hz, 1H), 3.95 (s, 1H), 3.83 (s, 3H), 2.17 - 2.01 (m, 1H), 1.83 - 1.74 (m, 1H), 1.74 - 1.67 (m, 1H), 1.68 - 1.61 (m, 1H), 1.40 - 1.32 (m, 3H), 1.32 - 1.23 (m, 1H), 1.21 - 1.10 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 175.3, 146.2, 127.2, 124.8, 124.3, 80.5, 53.6, 47.5, 27.3, 26.4, 26.3, 26.2, 25.6; **IR** (KBr, thin film): 3502, 2931, 2853, 1730, 1436, 1261, 1239, 1150, 1114, 745, 699 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{13}H_{18}NaO_3S]^+$, 277.0869, found 277.0869.

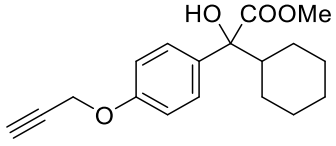


Methyl 2-cyclohexyl-2-hydroxy-2-(6-methoxynaphthalen-2-yl)acetate (**33a**). Following the standard procedure B, the reaction of α-ketoacid **33** (23.0 mg, 0.1 mmol),

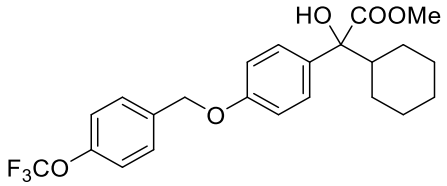
alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **33a** as a colorless oil (23.9 mg, 73% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.65 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.05 (d, *J* = 1.0 Hz, 1H), 7.75 (d, *J* = 8.9 Hz, 1H), 7.70 - 7.71 (m, 2H), 7.15 (dd, *J* = 8.9, 2.5 Hz, 1H), 7.12 (d, *J* = 2.5 Hz, 1H), 3.92 (s, 3H), 3.79 (s, 3H), 3.78 (s, 1H), 2.40 - 2.27 (m, 1H), 1.85 - 1.80 (m, 1H), 1.70 - 1.61 (m, 2H), 1.51 - 1.44 (m, 2H), 1.41 - 1.27 (m, 1H), 1.23 (d, *J* = 10.6 Hz, 1H), 1.17 - 1.07 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.3, 158.0, 136.0, 133.9, 130.0, 128.7, 126.7, 125.2, 124.7, 119.0, 105.5, 81.3, 55.5, 53.4, 45.7, 27.6, 26.5, 26.5, 26.3, 25.7; **IR** (KBr, thin film): 3510, 2933, 2853, 1725, 1604, 1483, 1266, 1220, 1166, 1031, 852, 732 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{20}H_{24}O_4$, 328.1675, found 328.1670.



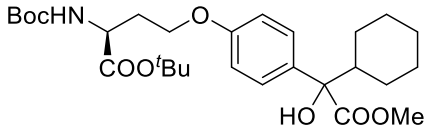
Methyl 2-cyclohexyl-2-hydroxy-2-(naphthalen-2-yl)acetate (**34a**). Following the standard procedure A, the reaction of α-ketoacid **34** (20.0 mg, 0.1 mmol), alkyl boronic acid **1** (38.4 mg, 0.3 mmol) in 2.0 mL CH_2Cl_2 for 24 h were then esterfied to afford target product **34a** as a white solid (15.3 mg, 51% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.40 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.15 (s, 1H), 7.89 - 7.85 (m, 1H), 7.83 (d, *J* = 8.7 Hz, 2H), 7.77 - 7.73 (m, 1H), 7.51 - 7.45 (m, 2H), 3.82 (s, 1H), 3.80 (s, 3H), 2.41 - 2.33 (m, 1H), 1.84 (d, *J* = 12.5 Hz, 1H), 1.70 - 1.62 (m, 2H), 1.54 - 1.46 (m, 2H), 1.40 - 1.29 (m, 1H), 1.24 - 1.08 (m, 4H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.2, 138.3, 133.2, 132.8, 128.5, 127.8, 127.5, 126.2, 126.2, 125.4, 124.2, 81.4, 53.5, 45.7, 27.6, 26.5, 26.5, 26.3, 25.7; **IR** (KBr, thin film): 3513, 3059, 2932, 2851, 1725, 1450, 1263, 1237, 1117, 909, 734 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{19}H_{22}O_3Na]^+$, 321.1461, found 321.1466.



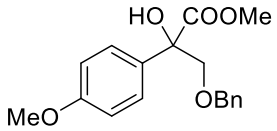
Methyl 2-cyclohexyl-2-hydroxy-2-(4-(prop-2-yn-1-yloxy)phenyl)acetate (**35a**). Following the standard procedure B, the reaction of α-ketoacid **35** (20.4 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **35a** as a white solid (23.6 mg, 78% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.57 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.9 Hz, 2H), 6.94 (d, *J* = 9.0 Hz, 2H), 4.68 (d, *J* = 2.4 Hz, 2H), 3.77 (s, 3H), 3.64 (s, 1H), 2.52 (t, *J* = 2.4 Hz, 1H), 2.21 - 2.12 (m, 1H), 1.82 - 1.75 (m, 1H), 1.67 - 1.62 (m, 2H), 1.45 - 1.36 (m, 2H), 1.32 - 1.20 (m, 2H), 1.17 - 1.04 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.4, 157.1, 133.8, 127.4, 114.5, 80.9, 78.7, 75.6, 55.9, 53.4, 45.8, 27.5, 26.5, 26.3, 25.6; **IR** (KBr, thin film): 3510, 3289, 2932, 2853, 1724, 1607, 1508, 1237, 1173, 1029, 835, 758 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{18}H_{22}O_4$, 302.1518, found 302.1515.



Methyl 2-cyclohexyl-2-hydroxy-2-(4-((4-(trifluoromethoxy)benzyl)oxy)phenyl) acetate (**36a**). Following the standard procedure B, the reaction of α-ketoacid **36** (34.0 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **36a** as a white solid (36.0 mg, 82% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.42 (EtOAc/hexanes = 1/10); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.8 Hz, 2H), 7.46 (d, *J* = 8.5 Hz, 2H), 7.24 (d, *J* = 8.2 Hz, 2H), 6.94 (d, *J* = 8.8 Hz, 2H), 5.05 (s, 2H), 3.77 (s, 3H), 3.65 (s, 1H), 2.27 - 2.11 (m, 1H), 1.84 - 1.76 (m, 1H), 1.70 - 1.62 (m, 2H), 1.46 - 1.37 (m, 2H), 1.36 - 1.19 (m, 2H), 1.16 - 1.06 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.4, 158.0, 135.9, 133.5, 128.9, 127.5, 121.2, 114.4, 80.9, 69.3, 53.4, 45.8, 27.5, 26.5, 26.5, 26.3, 25.6; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -57.9; **IR** (KBr, thin film): 3514, 2934, 2855, 1725, 1608, 1509, 1258, 1171, 1125, 1019, 835, 759 cm^{-1}; **HRMS-EI** (m/z) $[M]^+$ calc'd for $C_{23}H_{25}F_3O_5$, 438.1654, found 438.1649.

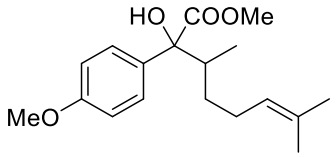


***tert*-butyl N-(*tert*-butoxycarbonyl)-O-(4-(1-cyclohexyl-1-hydroxy-2-methoxy-2-oxoethyl)phenyl)homoserinate** (**37a**). Following the standard procedure B, the reaction of α-ketoacid **37** (42.4 mg, 0.1 mmol), alkyl trifluoroborate **5** (57.0 mg, 0.3 mmol) in 1.0 mL CH_2Cl_2 and 1.0 mL H_2O for 5 h were then esterfied to afford target product **37a** as a white solid (47.0 mg, 90% yield) after flash chromatography (6% EtOAc in hexanes): TLC R_f = 0.34 (EtOAc/hexanes = 1/5); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.8 Hz, 2H), 6.84 (d, *J* = 8.9 Hz, 2H), 5.24 (d, *J* = 8.1 Hz, 1H), 4.35 (d, *J* = 6.8 Hz, 1H), 4.03 (td, *J* = 6.2, 2.8 Hz, 2H), 3.76 (s, 3H), 3.62 (s, 1H), 2.34 - 2.23 (m, 1H), 2.22 - 2.11 (m, 2H), 1.79 (dd, *J* = 13.1, 3.0 Hz, 1H), 1.68 - 1.60 (m, 2H), 1.46 (s, 9H), 1.43 (s, 9H), 1.42 - 1.36 (m, 1H), 1.33 - 1.19 (m, 3H), 1.16 - 1.02 (m, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.4, 171.5, 158.1, 155.5, 133.1, 127.3, 114.1, 82.1, 80.8, 64.4, 53.3, 52.0, 45.7, 32.0, 28.4, 28.1, 27.5, 26.5, 26.3, 25.5; **IR** (KBr, thin film): 3511, 3378, 2977, 2933, 2854, 1720, 1509, 1367, 1248, 1152, 1105, 836, 738 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{28}H_{43}NO_8Na]^+$, 544.2881, found 544.2882.

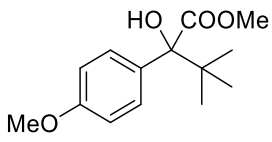


Methyl 3-(benzyloxy)-2-hydroxy-2-(4-methoxyphenyl)propanoate (**52a**). Following the standard procedure C, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **52** (56.0 mg, 0.15 mmol, 1.5 eq.) and $BF_3 \cdot Et_2O$ (18.9 μL, 0.15 mmol, 1.5 eq.) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 24 h were then esterfied to afford target product **52a** as a pale yellow oil (20.3 mg, 64% yield) after flash chromatography (6% EtOAc in hexanes): TLC R_f = 0.26 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.8 Hz, 2H), 7.40 - 7.27 (m, 5H), 6.87 (d, *J* = 8.7 Hz, 2H), 4.68 (d, *J* = 12.3 Hz, 1H), 4.60 (d, *J* = 12.3 Hz, 1H), 4.17 (d, *J* = 9.6 Hz, 1H), 3.87 (s, 1H),

3.81 - 3.76 (m, 6H), 3.62 (d, J = 9.6 Hz, 1H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 174.0, 159.6, 137.8, 130.2, 128.5, 127.9, 127.8, 126.9, 113.8, 78.7, 75.8, 73.8, 55.4, 53.2; **IR** (KBr, thin film): 3508, 2953, 2929, 2862, 1737, 1610, 1512, 1454, 1252, 1107, 835, 745 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{18}H_{20}NaO_5]^+$, 339.1203, found 339.1205 .

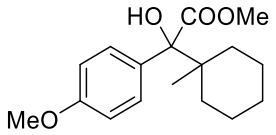


Methyl 2-hydroxy-2-(4-methoxyphenyl)-3,7-dimethyloct-6-enoate (**54a**). Following the standard procedure C, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **54** (54.0 mg, 0.15 mmol, 1.5 eq.) and $B(OMe)_3$ (16.7 μL, 0.15 mmol, 1.5 eq.) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 24 h were then esterfied to afford target product **54a** as a white solid (23.8 mg, 78% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.59 (EtOAc/hexanes = 1/9), two diastereoisomers showed partially separated NMR signals; **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.53 (d, J = 8.8 Hz, 4H), 6.87 (d, J = 8.8 Hz, 4H), 5.21 - 5.02 (m, 1H), 5.01 - 4.84 (m, 1H), 3.80 (s, 6H), 3.76 (s, 6H), 3.66 (s, 1H), 3.60 (s, 1H), 2.44 - 2.30 (m, 2H), 2.20 - 2.05 (m, 1H), 2.06 - 1.92 (m, 2H), 1.83 - 1.71 (m, 1H), 1.71 (s, 3H), 1.64 (s, 3H), 1.61 (s, 3H), 1.52 (s, 3H), 1.29 - 1.04 (m, 4H), 0.96 (d, J = 6.6, 3H), 0.71 (d, J = 6.9, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 176.6, 176.5, 159.1, 159.1, 133.3, 133.1, 131.9, 131.6, 127.4, 127.3, 124.5, 124.4, 113.5, 113.5, 81.6, 81.4, 55.3, 53.3, 53.2, 40.4, 40.0, 32.1, 29.8, 26.1, 25.9, 25.9, 25.8, 17.8, 17.7, 14.2, 12.7; **IR** (KBr, thin film): 3515, 2934, 1728, 1609, 1510, 1463, 1440, 1250, 1036, 831, 803 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{18}H_{26}NaO_4]^+$, 329.1723, found 329.1727.



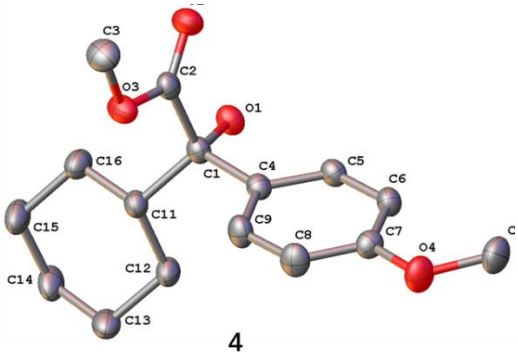
Methyl 2-hydroxy-2-(4-methoxyphenyl)-3,3-dimethylbutanoate (**55a**). Following

the standard procedure C, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **55** (32.3 mg, 0.15 mmol, 1.5 eq.) and $B(OMe)_3$ (16.7 μL, 0.15 mmol, 1.5 eq.) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 24 h were then esterfied to afford target product **55a** as a white solid (23.1 mg, 92% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.69 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.62 (d, *J* = 9.0 Hz, 2H), 6.85 (d, *J* = 9.0 Hz, 2H), 3.86 (s, 3H), 3.80 (s, 3H), 3.64 (s, 1H), 0.99 (s, 9H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 175.3, 159.1, 131.3, 128.7, 112.7, 83.1, 55.3, 52.9, 39.2, 25.9; **IR** (KBr, thin film): 3509, 2958, 1719, 1609, 1509, 1251, 1174, 1084, 1036, 836, 800, 779 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{14}H_{20}NaO_4]^+$, 275.1254, found 275.1254.



Methyl 2-hydroxy-2-(4-methoxyphenyl)-2-(1-methylcyclohexyl)acetate (**56a**). Following the standard procedure C, the reaction of α-ketoacid **2** (18.0 mg, 0.1 mmol, 1.0 eq.), alkyl-DHP **56** (38.3 mg, 0.15 mmol, 1.5 eq.) and $B(OMe)_3$ (16.7 μL, 0.15 mmol, 1.5 eq.) in 2.0 mL CH_2Cl_2 and 0.1 mL HFIP for 24 h were then esterfied to afford target product **56a** as a white solid (18.2 mg, 62% yield) after flash chromatography (3% EtOAc in hexanes): TLC R_f = 0.68 (EtOAc/hexanes = 1/9); **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.0 Hz, 2H), 6.84 (d, *J* = 8.1 Hz, 2H), 3.85 (s, 3H), 3.80 (s, 3H), 3.68 (s, 1H), 1.66 - 1.54 (m, 2H), 1.55 - 1.47 (m, 3H), 1.41 - 1.29 (m, 4H), 1.06 - 0.91 (m, 4H).; **^{13}C NMR** (126 MHz, $CDCl_3$) δ 175.3, 159.0, 130.8, 129.1, 112.6, 83.9, 55.3, 52.9, 42.1, 31.6, 31.0, 26.1, 22.1, 21.9, 17.6; **IR** (KBr, thin film): 3503, 2928, 2862, 1716, 1609, 1509, 1444, 1250, 1180, 1037, 833, 796 cm^{-1}; **HRMS-ESI** (m/z) $[M+Na]^+$ calc'd for $[C_{17}H_{24}NaO_4]^+$, 315.1567, found 315.1563.

VIII. X-Ray Crystallographic Data



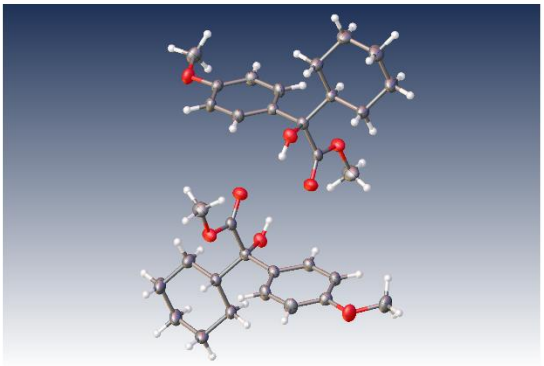


Table S2. Crystal data and structure refinement for **4**.

Identification code	mj19159_0m	
Empirical formula	C16 H22 O4	
Formula weight	278.33	
Temperature	170.02 K	
Wavelength	1.34139 Å	
Crystal system	Monoclinic	
Space group	P 1 21/c 1	
Unit cell dimensions	a = 10.9715(4) Å	= 90°.
	b = 16.4167(5) Å	= 102.014(2)°.
	c = 16.8365(6) Å	= 90°.
Volume	2966.10(18) $Å^3$	
Z	8	
Density (calculated)	1.247 Mg/m^3	
Absorption coefficient	0.462 mm^{-1}	
F(000)	1200	
Crystal size	0.12 x 0.08 x 0.06 mm^3	
Theta range for data collection	3.307 to 55.031°.	
Index ranges	-13<=h<=10, -19<=k<=20, -20<=l<=20	
Reflections collected	31924	
Independent reflections	5619 [R(int) = 0.0526]	
Completeness to theta = 53.594°	99.5 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7508 and 0.5864	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	5619 / 0 / 367	
Goodness-of-fit on F^2	1.022	

Final R indices [I>2sigma(I)]	R1 = 0.0398, wR2 = 0.1031
R indices (all data)	R1 = 0.0473, wR2 = 0.1095
Extinction coefficient	n/a
Largest diff. peak and hole	0.259 and -0.193 e.Å^{-3}

Table S3. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters (Å^{2}x 10^3)
for mj19159_0m. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(1)	9037(1)	6863(1)	3356(1)	28(1)
O(2)	8633(1)	6311(1)	1810(1)	34(1)
O(3)	10633(1)	6489(1)	1749(1)	31(1)
O(4)	12252(1)	3639(1)	4257(1)	37(1)
C(1)	10100(1)	6671(1)	3044(1)	23(1)
C(2)	9685(1)	6485(1)	2134(1)	24(1)
C(3)	10381(1)	6163(1)	934(1)	36(1)
C(4)	10701(1)	5871(1)	3413(1)	23(1)
C(5)	10053(1)	5354(1)	3824(1)	25(1)
C(6)	10545(1)	4607(1)	4125(1)	27(1)
C(7)	11694(1)	4366(1)	4003(1)	26(1)
C(8)	12371(1)	4881(1)	3603(1)	33(1)
C(9)	11876(1)	5623(1)	3313(1)	31(1)
C(10)	11554(2)	3069(1)	4616(1)	40(1)
C(11)	10982(1)	7414(1)	3203(1)	25(1)
C(12)	11491(1)	7538(1)	4113(1)	29(1)
C(13)	12324(1)	8291(1)	4274(1)	36(1)
C(14)	11634(2)	9050(1)	3908(1)	39(1)
C(15)	11157(2)	8939(1)	2999(1)	40(1)
C(16)	10328(1)	8186(1)	2820(1)	34(1)
O(5)	6308(1)	5395(1)	1591(1)	29(1)
O(6)	6848(1)	5891(1)	3143(1)	36(1)
O(7)	4846(1)	5854(1)	3235(1)	31(1)
O(8)	3685(1)	8804(1)	680(1)	34(1)
C(17)	5291(1)	5658(1)	1918(1)	23(1)
C(18)	5762(1)	5804(1)	2832(1)	25(1)
C(19)	5206(2)	6060(1)	4087(1)	44(1)

C(20)	4801(1)	6490(1)	1569(1)	23(1)
C(21)	5501(1)	6959(1)	1141(1)	28(1)
C(22)	5103(1)	7725(1)	857(1)	31(1)
C(23)	3990(1)	8037(1)	988(1)	25(1)
C(24)	3278(1)	7582(1)	1412(1)	28(1)
C(25)	3694(1)	6815(1)	1699(1)	28(1)
C(26)	2516(1)	9121(1)	769(1)	37(1)
C(27)	4299(1)	4978(1)	1755(1)	25(1)
C(28)	3849(1)	4826(1)	844(1)	32(1)
C(29)	2847(2)	4167(1)	687(1)	41(1)
C(30)	3309(2)	3378(1)	1124(1)	44(1)
C(31)	3788(2)	3518(1)	2028(1)	40(1)
C(32)	4780(1)	4183(1)	2186(1)	32(1)

Table S4. Bond lengths [Å] and angles [°] for mj19159_0m.

O(1)-H(1)	0.8400
O(1)-C(1)	1.4110(15)
O(2)-C(2)	1.2047(15)
O(3)-C(2)	1.3345(15)
O(3)-C(3)	1.4448(15)
O(4)-C(7)	1.3697(15)
O(4)-C(10)	1.4214(17)
C(1)-C(2)	1.5349(17)
C(1)-C(4)	1.5404(17)
C(1)-C(11)	1.5462(17)
C(3)-H(3A)	0.9800
C(3)-H(3B)	0.9800
C(3)-H(3C)	0.9800
C(4)-C(5)	1.3827(17)
C(4)-C(9)	1.3953(18)
C(5)-H(5)	0.9500
C(5)-C(6)	1.3925(18)
C(6)-H(6)	0.9500
C(6)-C(7)	1.3770(18)
C(7)-C(8)	1.3875(19)
C(8)-H(8)	0.9500

C(8)-C(9)	1.3807(19)
C(9)-H(9)	0.9500
C(10)-H(10A)	0.9800
C(10)-H(10B)	0.9800
C(10)-H(10C)	0.9800
C(11)-H(11)	1.0000
C(11)-C(12)	1.5309(17)
C(11)-C(16)	1.5314(17)
C(12)-H(12A)	0.9900
C(12)-H(12B)	0.9900
C(12)-C(13)	1.5281(18)
C(13)-H(13A)	0.9900
C(13)-H(13B)	0.9900
C(13)-C(14)	1.520(2)
C(14)-H(14A)	0.9900
C(14)-H(14B)	0.9900
C(14)-C(15)	1.5222(19)
C(15)-H(15A)	0.9900
C(15)-H(15B)	0.9900
C(15)-C(16)	1.5270(19)
C(16)-H(16A)	0.9900
C(16)-H(16B)	0.9900
O(5)-H(5A)	0.8400
O(5)-C(17)	1.4108(15)
O(6)-C(18)	1.2060(15)
O(7)-C(18)	1.3266(16)
O(7)-C(19)	1.4470(16)
O(8)-C(23)	1.3749(15)
O(8)-C(26)	1.4202(17)
C(17)-C(18)	1.5358(17)
C(17)-C(20)	1.5392(16)
C(17)-C(27)	1.5431(17)
C(19)-H(19A)	0.9800
C(19)-H(19B)	0.9800
C(19)-H(19C)	0.9800
C(20)-C(21)	1.3905(18)
C(20)-C(25)	1.3850(18)
C(21)-H(21)	0.9500

C(21)-C(22)	1.3834(18)
C(22)-H(22)	0.9500
C(22)-C(23)	1.3831(19)
C(23)-C(24)	1.3835(18)
C(24)-H(24)	0.9500
C(24)-C(25)	1.3910(18)
C(25)-H(25)	0.9500
C(26)-H(26A)	0.9800
C(26)-H(26B)	0.9800
C(26)-H(26C)	0.9800
C(27)-H(27)	1.0000
C(27)-C(28)	1.5308(17)
C(27)-C(32)	1.5327(17)
C(28)-H(28A)	0.9900
C(28)-H(28B)	0.9900
C(28)-C(29)	1.526(2)
C(29)-H(29A)	0.9900
C(29)-H(29B)	0.9900
C(29)-C(30)	1.523(2)
C(30)-H(30A)	0.9900
C(30)-H(30B)	0.9900
C(30)-C(31)	1.521(2)
C(31)-H(31B)	0.9900
C(31)-H(31A)	0.9900
C(31)-C(32)	1.5252(19)
C(32)-H(32A)	0.9900
C(32)-H(32B)	0.9900

C(1)-O(1)-H(1)	109.5
C(2)-O(3)-C(3)	116.39(10)
C(7)-O(4)-C(10)	117.52(11)
O(1)-C(1)-C(2)	108.72(10)
O(1)-C(1)-C(4)	110.96(10)
O(1)-C(1)-C(11)	107.15(10)
C(2)-C(1)-C(4)	104.29(9)
C(2)-C(1)-C(11)	111.98(10)
C(4)-C(1)-C(11)	113.70(10)
O(2)-C(2)-O(3)	123.53(11)

O(2)-C(2)-C(1)	123.74(11)
O(3)-C(2)-C(1)	112.61(10)
O(3)-C(3)-H(3A)	109.5
O(3)-C(3)-H(3B)	109.5
O(3)-C(3)-H(3C)	109.5
H(3A)-C(3)-H(3B)	109.5
H(3A)-C(3)-H(3C)	109.5
H(3B)-C(3)-H(3C)	109.5
C(5)-C(4)-C(1)	120.22(11)
C(5)-C(4)-C(9)	117.74(12)
C(9)-C(4)-C(1)	121.97(11)
C(4)-C(5)-H(5)	119.3
C(4)-C(5)-C(6)	121.47(12)
C(6)-C(5)-H(5)	119.3
C(5)-C(6)-H(6)	120.1
C(7)-C(6)-C(5)	119.73(12)
C(7)-C(6)-H(6)	120.1
O(4)-C(7)-C(6)	124.53(12)
O(4)-C(7)-C(8)	115.65(12)
C(6)-C(7)-C(8)	119.82(12)
C(7)-C(8)-H(8)	120.1
C(9)-C(8)-C(7)	119.85(12)
C(9)-C(8)-H(8)	120.1
C(4)-C(9)-H(9)	119.3
C(8)-C(9)-C(4)	121.36(12)
C(8)-C(9)-H(9)	119.3
O(4)-C(10)-H(10A)	109.5
O(4)-C(10)-H(10B)	109.5
O(4)-C(10)-H(10C)	109.5
H(10A)-C(10)-H(10B)	109.5
H(10A)-C(10)-H(10C)	109.5
H(10B)-C(10)-H(10C)	109.5
C(1)-C(11)-H(11)	107.9
C(12)-C(11)-C(1)	111.29(10)
C(12)-C(11)-H(11)	107.9
C(12)-C(11)-C(16)	110.64(10)
C(16)-C(11)-C(1)	111.00(10)
C(16)-C(11)-H(11)	107.9

C(11)-C(12)-H(12A)	109.3
C(11)-C(12)-H(12B)	109.3
H(12A)-C(12)-H(12B)	108.0
C(13)-C(12)-C(11)	111.44(10)
C(13)-C(12)-H(12A)	109.3
C(13)-C(12)-H(12B)	109.3
C(12)-C(13)-H(13A)	109.4
C(12)-C(13)-H(13B)	109.4
H(13A)-C(13)-H(13B)	108.0
C(14)-C(13)-C(12)	111.23(12)
C(14)-C(13)-H(13A)	109.4
C(14)-C(13)-H(13B)	109.4
C(13)-C(14)-H(14A)	109.6
C(13)-C(14)-H(14B)	109.6
C(13)-C(14)-C(15)	110.32(12)
H(14A)-C(14)-H(14B)	108.1
C(15)-C(14)-H(14A)	109.6
C(15)-C(14)-H(14B)	109.6
C(14)-C(15)-H(15A)	109.4
C(14)-C(15)-H(15B)	109.4
C(14)-C(15)-C(16)	111.24(11)
H(15A)-C(15)-H(15B)	108.0
C(16)-C(15)-H(15A)	109.4
C(16)-C(15)-H(15B)	109.4
C(11)-C(16)-H(16A)	109.1
C(11)-C(16)-H(16B)	109.1
C(15)-C(16)-C(11)	112.28(12)
C(15)-C(16)-H(16A)	109.1
C(15)-C(16)-H(16B)	109.1
H(16A)-C(16)-H(16B)	107.9
C(17)-O(5)-H(5A)	109.5
C(18)-O(7)-C(19)	116.23(11)
C(23)-O(8)-C(26)	116.83(10)
O(5)-C(17)-C(18)	108.09(10)
O(5)-C(17)-C(20)	111.38(10)
O(5)-C(17)-C(27)	107.13(10)
C(18)-C(17)-C(20)	105.25(9)
C(18)-C(17)-C(27)	111.61(10)

C(20)-C(17)-C(27)	113.33(10)
O(6)-C(18)-O(7)	123.72(12)
O(6)-C(18)-C(17)	123.32(11)
O(7)-C(18)-C(17)	112.91(10)
O(7)-C(19)-H(19A)	109.5
O(7)-C(19)-H(19B)	109.5
O(7)-C(19)-H(19C)	109.5
H(19A)-C(19)-H(19B)	109.5
H(19A)-C(19)-H(19C)	109.5
H(19B)-C(19)-H(19C)	109.5
C(21)-C(20)-C(17)	120.16(11)
C(25)-C(20)-C(17)	121.97(11)
C(25)-C(20)-C(21)	117.80(11)
C(20)-C(21)-H(21)	119.5
C(22)-C(21)-C(20)	120.91(12)
C(22)-C(21)-H(21)	119.5
C(21)-C(22)-H(22)	119.8
C(23)-C(22)-C(21)	120.50(12)
C(23)-C(22)-H(22)	119.8
O(8)-C(23)-C(22)	115.70(11)
O(8)-C(23)-C(24)	124.68(12)
C(22)-C(23)-C(24)	119.62(12)
C(23)-C(24)-H(24)	120.4
C(23)-C(24)-C(25)	119.28(12)
C(25)-C(24)-H(24)	120.4
C(20)-C(25)-C(24)	121.90(12)
C(20)-C(25)-H(25)	119.1
C(24)-C(25)-H(25)	119.1
O(8)-C(26)-H(26A)	109.5
O(8)-C(26)-H(26B)	109.5
O(8)-C(26)-H(26C)	109.5
H(26A)-C(26)-H(26B)	109.5
H(26A)-C(26)-H(26C)	109.5
H(26B)-C(26)-H(26C)	109.5
C(17)-C(27)-H(27)	107.8
C(28)-C(27)-C(17)	111.39(10)
C(28)-C(27)-H(27)	107.8
C(28)-C(27)-C(32)	110.05(10)

C(32)-C(27)-C(17)	111.79(10)
C(32)-C(27)-H(27)	107.8
C(27)-C(28)-H(28A)	109.4
C(27)-C(28)-H(28B)	109.4
H(28A)-C(28)-H(28B)	108.0
C(29)-C(28)-C(27)	111.06(11)
C(29)-C(28)-H(28A)	109.4
C(29)-C(28)-H(28B)	109.4
C(28)-C(29)-H(29A)	109.4
C(28)-C(29)-H(29B)	109.4
H(29A)-C(29)-H(29B)	108.0
C(30)-C(29)-C(28)	111.37(12)
C(30)-C(29)-H(29A)	109.4
C(30)-C(29)-H(29B)	109.4
C(29)-C(30)-H(30A)	109.3
C(29)-C(30)-H(30B)	109.3
H(30A)-C(30)-H(30B)	108.0
C(31)-C(30)-C(29)	111.48(12)
C(31)-C(30)-H(30A)	109.3
C(31)-C(30)-H(30B)	109.3
C(30)-C(31)-H(31B)	109.3
C(30)-C(31)-H(31A)	109.3
C(30)-C(31)-C(32)	111.56(12)
H(31B)-C(31)-H(31A)	108.0
C(32)-C(31)-H(31B)	109.3
C(32)-C(31)-H(31A)	109.3
C(27)-C(32)-H(32A)	109.4
C(27)-C(32)-H(32B)	109.4
C(31)-C(32)-C(27)	111.39(11)
C(31)-C(32)-H(32A)	109.4
C(31)-C(32)-H(32B)	109.4
H(32A)-C(32)-H(32B)	108.0

Symmetry transformations used to generate equivalent atoms:

Table S5. Anisotropic displacement parameters ($Å^2 x\ 10^3$) for mj19159_0m. The anisotropic displacement factor exponent takes the form: $-2\ ^2[\ h^2\ a^{*2}U^{11} + ... + 2\ h\ k\ a^*\ b^*\ U^{12}\ ]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(1)	25(1)	26(1)	34(1)	-3(1)	11(1)	0(1)
O(2)	27(1)	41(1)	33(1)	0(1)	3(1)	-6(1)
O(3)	29(1)	39(1)	26(1)	-5(1)	9(1)	-6(1)
O(4)	39(1)	27(1)	47(1)	9(1)	13(1)	9(1)
C(1)	23(1)	22(1)	26(1)	0(1)	8(1)	-1(1)
C(2)	26(1)	18(1)	30(1)	2(1)	7(1)	-1(1)
C(3)	41(1)	41(1)	28(1)	-7(1)	11(1)	-2(1)
C(4)	25(1)	21(1)	23(1)	-2(1)	6(1)	-3(1)
C(5)	23(1)	25(1)	28(1)	-1(1)	8(1)	-2(1)
C(6)	29(1)	24(1)	30(1)	2(1)	8(1)	-4(1)
C(7)	30(1)	22(1)	27(1)	-1(1)	5(1)	3(1)
C(8)	28(1)	33(1)	40(1)	3(1)	15(1)	5(1)
C(9)	30(1)	28(1)	37(1)	4(1)	15(1)	-1(1)
C(10)	50(1)	28(1)	41(1)	10(1)	10(1)	4(1)
C(11)	28(1)	22(1)	25(1)	1(1)	6(1)	-4(1)
C(12)	38(1)	23(1)	26(1)	2(1)	5(1)	-6(1)
C(13)	45(1)	33(1)	26(1)	-1(1)	1(1)	-12(1)
C(14)	57(1)	24(1)	33(1)	0(1)	8(1)	-13(1)
C(15)	59(1)	26(1)	32(1)	5(1)	4(1)	-10(1)
C(16)	42(1)	25(1)	30(1)	4(1)	0(1)	-3(1)
O(5)	26(1)	28(1)	36(1)	-3(1)	11(1)	1(1)
O(6)	26(1)	47(1)	34(1)	5(1)	2(1)	-8(1)
O(7)	29(1)	38(1)	26(1)	-5(1)	8(1)	-5(1)
O(8)	36(1)	26(1)	39(1)	9(1)	9(1)	6(1)
C(17)	22(1)	22(1)	26(1)	-1(1)	8(1)	1(1)
C(18)	26(1)	20(1)	29(1)	3(1)	6(1)	-3(1)
C(19)	48(1)	60(1)	27(1)	-10(1)	10(1)	-13(1)
C(20)	24(1)	22(1)	23(1)	-2(1)	5(1)	-1(1)
C(21)	24(1)	31(1)	30(1)	4(1)	9(1)	2(1)
C(22)	28(1)	32(1)	33(1)	9(1)	9(1)	-1(1)
C(23)	29(1)	22(1)	23(1)	2(1)	2(1)	2(1)
C(24)	26(1)	26(1)	32(1)	-1(1)	10(1)	3(1)
C(25)	28(1)	26(1)	32(1)	2(1)	12(1)	-1(1)
C(26)	42(1)	30(1)	38(1)	3(1)	9(1)	12(1)
C(27)	26(1)	21(1)	27(1)	0(1)	5(1)	-1(1)
C(28)	39(1)	26(1)	28(1)	0(1)	2(1)	-3(1)

C(29)	45(1)	36(1)	35(1)	-6(1)	-4(1)	-9(1)
C(30)	58(1)	28(1)	42(1)	-6(1)	3(1)	-14(1)
C(31)	53(1)	25(1)	39(1)	1(1)	3(1)	-10(1)
C(32)	38(1)	23(1)	32(1)	1(1)	1(1)	-2(1)

Table S6. Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($Å^2$x 10^3) for mj19159_0m.

	x	y	z	U(eq)
H(1)	8427	6588	3112	41
H(3A)	9761	6505	583	54
H(3B)	10059	5607	940	54
H(3C)	11152	6157	727	54
H(5)	9254	5513	3904	30
H(6)	10089	4264	4413	33
H(8)	13173	4723	3529	39
H(9)	12346	5972	3040	37
H(10A)	10741	2982	4255	59
H(10B)	11434	3281	5139	59
H(10C)	12007	2551	4703	59
H(11)	11705	7305	2941	30
H(12A)	10786	7599	4392	35
H(12B)	11975	7052	4338	35
H(13A)	12609	8367	4867	43
H(13B)	13069	8209	4038	43
H(14A)	12202	9525	4007	46
H(14B)	10925	9157	4173	46
H(15A)	11873	8884	2730	48
H(15B)	10676	9427	2774	48
H(16A)	10081	8110	2224	40
H(16B)	9560	8273	3030	40
H(5A)	6962	5626	1837	44
H(19A)	5716	6555	4150	67
H(19B)	5689	5611	4382	67
H(19C)	4458	6154	4307	67
H(21)	6263	6750	1042	33

H(22)	5598	8039	571	37
H(24)	2513	7790	1506	33
H(25)	3204	6505	1993	33
H(26A)	2374	9649	494	55
H(26B)	2517	9191	1348	55
H(26C)	1852	8743	528	55
H(27)	3567	5163	1976	30
H(28A)	3508	5338	575	38
H(28B)	4563	4657	607	38
H(29A)	2101	4360	876	49
H(29B)	2603	4063	96	49
H(30A)	2619	2978	1045	53
H(30B)	3986	3148	886	53
H(31B)	4145	3004	2285	48
H(31A)	3084	3676	2281	48
H(32A)	5525	3998	1991	38
H(32B)	5030	4283	2777	38

Table S7. Hydrogen bonds for mj19159_0m [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
O(1)-H(1)...O(6)	0.84	2.09	2.8437(13)	149.7

Symmetry transformations used to generate equivalent atoms.

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