Supporting Information

Transition-Metal-Free Photoredox Intermolecular α-Arylation of Ketones

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Supplementary Material

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General Information:

Moisture sensitive reactions were performed under argon atmosphere and sensitive reagents were added via syringe and cannula techniques. All glass wares were washed with detergent, rinsed with acetone and dried in an oven at 125 °C prior to use. Commercial reagents and solvents were purified according to procedures prescribed in Perrin’s handbook and stored over 4Å molecular sieves. Starting materials were prepared according to literature procedures. 9,10-Dimethoxyanthracene (DMA) was synthesized according to literature procedure.

Reactions were monitored by thin layer chromatography (TLC) which were performed on silica gel coated aluminium plates (MERCK, 60F254) and visualized by UV fluorescence and/or by staining with iodine, alcoholic solution of phosphomolybodic acid and ninhydrin. Column chromatography (CC) was performed on silica gel of mesh size 60–120, 100–200, 230–400 obtained from S. D. Fine Chemical Co. India or SRL India.

Infra-Red (IR) spectra were recorded on a Perkin-Elmer FT-IR Spectrometer. Nuclear Magnetic Resonance (NMR) spectra were recorded on a BRUKER 400 ULTRA SHIELD (400 MHz for ¹H and 101 MHz for ¹³C, respectively) instrument using deuterated solvent. Chemical shifts are reported in ppm. Proton coupling constants (J) are reported as absolute values in Hz and multiplicity (br, broadened; s, singlet; d, doublet; t, triplet; dd, doublet of doublet; dt, doublet of triplet; td, triplet of doublet; qd, quartet of doublet; dq, doublet of quartet; p, pictet; m, multiplet). Data for ¹³C NMR spectra are described in terms of chemical shift (δ in ppm) relative to the central line of CDCl₃ (δ 77.16). High resolution mass (HRMS) spectra were performed on Agilent Technologies 6530 Accurate-Mass Q-TOF LC/MS using electron spray ionization (ESI) technique. Gas
chromatography (GC) was performed on Agilent 7890B GC and 5977A MSD equipped with a split-mode capillary injection system and flame-ionization detectors using an Agilent HP-1 column (30 m, 0.32 mm ID).

**Evaluation of Thermodynamic Parameters**

The thermodynamic feasibility of ET between excited state of DMA and 1-phenyl-2-(phenylselanyl)ethanone was established by estimating Gibbs free energy change ($\Delta G_{et}$) for electron transfer using oxidation potential of donor (D) and reduction potential of acceptor (A) through Weller equation (eq.1).^3

$$\Delta G_{DS}^{+} = E_{1/2}^{ox}(D) - E_{1/2}^{red}(A) - E_{exc.}^{d}$$

**$E_{1/2}^{ox}$** of D = Oxidation potential of DMA

**$E_{1/2}^{red}$** of A = Reduction potential of 1-phenyl-2-(phenylselanyl)ethanone (1a, -1.28 eV)

**$E_{exc.}^{d}$** of D = Singlet state excitation energy of DMA

$$\Delta G_{DS}^{+} = 0.98 \text{ V} - (-1.28 \text{ V}) - 74 \text{ kcalM}^{-1}$$

$$\Delta G_{DS}^{+} = -21.88 \text{ kcalM}^{-1}$$

Similarly, ET feasibility from Anisole to DMA$^+$ was evaluated by estimating $\Delta G_{et}$ employing the Eq.1.

$$\Delta G_{et} = E_{1/2}^{ox}(D) - E_{1/2}^{red}(A)$$

**$E_{1/2}^{ox}$** = Oxidation potential of Anisole

**$E_{1/2}^{red}$** = Reduction potential of DMA$^+$

- $\Delta G_{et} = 1.76 \text{ V} - 28.81 \text{ kcalM}^{-1}$
- $\Delta G_{et} = 40.58 \text{ kcal/M-1} - 28.81 \text{ kcal/M}^{-1}$
- $\Delta G_{et} = 11.77 \text{ kcalM}^{-1}$

Similarly, ET feasibility from Toluene to DMA$^+$ was evaluated by estimating $\Delta G_{et}$ employing the Eq.1.

$$\Delta G_{et} = E_{1/2}^{ox}(D) - E_{1/2}^{red}(A)$$

**$E_{1/2}^{ox}$** = Oxidation potential of Toluene

**$E_{1/2}^{red}$** = Reduction potential of DMA$^+$

- $\Delta G_{et} = 1.98 \text{ V} - 28.81 \text{ kcalM}^{-1}$
- $\Delta G_{et} = 44.66 \text{ kcal/M-1} - 28.81 \text{ kcal/M}^{-1}$
- $\Delta G_{et} = 15.85 \text{ kcalM}^{-1}$
To a suspension of selenium dioxide (3 mmol) in 5mL dichloromethane containing diphenyl diselenide (3 mmol) and a catalytic amount of sulfuric acid (0.6 mmol) was added a solution of ketone (5 mmol) in 5mL of dichloromethane at 10 °C. The mixture was stirred for 10 h at 10 °C until the color change from yellow to reddish brown with the precipitation of amorphous selenium. The reaction mixture was poured into 100 mL of ether and washed with saturated aqueous sodium hydrogen carbonate (20 mL x 2). The organic layer was dried (MgSO$_4$) and evaporated to give a reddish oil, which was purified by silica gel column chromatography to afford A-phenylselenenyl carbonyl compound (53 to 84 % yield) and unreacted diphenyl diselenide (0.6 mmol).

1-phenyl-2-(phenylselanyl)ethanone (1a)

\[
\begin{align*}
\text{R}_f &= 0.60 \text{ (SiO}_2, \text{ ethyl acetate/hexane, 1:49); yellow liquid (58%);} \\
^1\text{H NMR} & (400 \text{ MHz, CDCl}_3) \delta 7.91 - 7.88 \text{ (m, 2H), 7.60 - 7.53 (m, 3H), 7.47 - 7.42 (m, 2H), 7.32 - 7.26 (m, 3H), 4.19 \text{ (s, 2H).}} \\
^13\text{C NMR} & (101 \text{ MHz, CDCl}_3) \delta 195.08, 135.51, 134.08, 133.38, 129.36, 129.13, 128.80, 128.71, 128.18, 32.81.
\end{align*}
\]

1-(phenylselanyl)propan-2-one (1b)

\[
\begin{align*}
\text{R}_f &= 0.60 \text{ (SiO}_2, \text{ ethyl acetate/hexane, 1:49); yellow liquid (53%);} \\
^1\text{H NMR} & (400 \text{ MHz, CDCl}_3) \delta 7.52 \text{ (ddd, } J = 3.9, 3.0, 1.4 \text{ Hz, 2H), 7.30 - 7.27 (m, 3H), 3.59 \text{ (s, 2H), 2.27 \text{ (s, 3H).}} \\
^13\text{C NMR} & (101 \text{ MHz, CDCl}_3) \delta 203.65, 133.51, 129.46, 128.46, 128.81, 128.07, 36.95, 28.15.
\end{align*}
\]

2-(phenylselanyl)cyclopentanone (1c)

\[
\begin{align*}
\text{R}_f &= 0.60 \text{ (SiO}_2, \text{ ethyl acetate/hexane, 1:49); yellow liquid (38%);} \\
^1\text{H NMR} & (400 \text{ MHz, CDCl}_3) \delta 7.61 - 7.58 \text{ (m, 2H), 7.35 - 7.25 (m, 3H), 3.77 - 3.73 (m, 1H), 2.37 - 2.26 (m, 2H), 2.23 - 2.12 (m, 1H), 2.08 - 1.88 \text{ (m, 3H).}} \\
^13\text{C NMR} & (101 \text{ MHz, CDCl}_3) \delta 214.54, 135.36, 129.23, 128.50, 127.91, 46.53, 36.37, 30.81, 21.04.
\end{align*}
\]
2-(phenylselanyl)cyclohexanone (1d)

\[
\begin{align*}
\text{SePh} & \quad \text{Ph} \\
\end{align*}
\]

\(R_f = 0.60 \) (SiO\(_2\), ethyl acetate/hexane, 1:49); yellow liquid (84%);
\(\text{H NMR (400 MHz, CDCl}_3\) \(\delta 7.57 – 7.53 \) (m, 2H), 7.32 – 7.25 (m, 3H), 3.93 (td, \(J = 5.3, 1.6 \text{ Hz}, 1H\), 3.00 (ddd, \(J = 15.7, 10.6, 5.9 \text{ Hz}, 1H\), 2.37 – 2.28 (m, 1H), 2.26 – 2.16 (m, 2H), 2.03 – 1.93 (m, 1H), 1.92 – 1.77 (m, 2H), 1.75 – 1.65 (m, 1H).

\(\text{C NMR (101 MHz, CDCl}_3\) \(\delta 208.02, 134.72, 129.30, 128.65, 128.21, 51.69, 38.61, 34.10, 26.98, 23.00.\)

1-phenyl-2-(phenylselanyl)ethanone (1e)

\[
\begin{align*}
\text{Ph} & \quad \text{SePh} \\
\end{align*}
\]

\(R_f = 0.60 \) (SiO\(_2\), ethyl acetate/hexane, 1:49); yellow liquid (45%);
\(\text{H NMR (400 MHz, CDCl}_3\) \(\delta 7.90 \) (dd, \(J = 8.4, 1.3 \text{ Hz}, 2H\), 7.57 – 7.51 (m, 1H), 7.47 – 7.40 (m, 4H), 7.38 – 7.33 (m, 1H), 7.29 – 7.24 (m, 2H), 4.69 (q, \(J = 6.8 \text{ Hz}, 1H\), 1.64 (d, \(J = 6.9 \text{ Hz}, 3H\).

\(\text{C NMR (101 MHz, CDCl}_3\) \(\delta 196.43, 136.76, 135.91, 132.98, 132.04, 129.15, 129.09, 128.62, 128.51, 39.82, 17.36.\)

1-(phenylselanyl)propan-2-one (1f)

\[
\begin{align*}
\text{SePh} & \quad \text{Ph} \\
\end{align*}
\]

\(R_f = 0.60 \) (SiO\(_2\), ethyl acetate/hexane, 1:49); yellow liquid (35%);
\(\text{H NMR (400 MHz, CDCl}_3\) \(\delta 7.57 – 7.52 \) (m, 2H), 7.37 – 7.27 (m, 3H), 3.83 (q, \(J = 7.0 \text{ Hz}, 1H\), 2.33 (s, 3H), 1.49 (d, \(J = 7.0 \text{ Hz}, 3H\).

\(\text{C NMR (101 MHz, CDCl}_3\) \(\delta 204.92, 135.87, 132.62, 129.28, 128.88, 46.12, 27.31, 16.48.\)

2-(phenylselanyl)cyclopentanone (1g)

\[
\begin{align*}
\text{SePh} & \quad \text{Ph} \\
\end{align*}
\]

\(R_f = 0.60 \) (SiO\(_2\), ethyl acetate/hexane, 1:49); yellow liquid (30%);
\(\text{H NMR (400 MHz, CDCl}_3\) \(\delta 7.40 – 7.36 \) (m, 2H), 7.32 – 7.27 (m, 1H), 7.24 – 7.18 (m, 2H), 3.35 (ddd, \(J = 14.9, 14.0, 6.3 \text{ Hz}, 1H\), 2.29 – 2.18 (m, 2H), 2.08 – 1.90 (m, 2H), 1.86 – 1.77 (m, 1H), 1.73 – 1.66 (m, 1H), 1.59 (qd, \(J = 4.2, 1.0 \text{ Hz}, 1H\), 1.28 (s, 3H).

\(\text{C NMR (101 MHz, CDCl}_3\) \(\delta 207.86, 137.59, 129.38, 129.06, 126.75, 55.38, 40.82, 37.28, 27.15, 24.95, 22.53.\)
General procedure for photoredox catalysis:

A mixture of 1 (1.0 mmol), arenes (2, 3 mmol) and a catalytic amount of 9,10-dimethoxyanthracene (DMA) (0.30 mmol) in acetonitrile (500 mL) was irradiated in the argon atmosphere utilizing visible-light (410 nm), obtained by using a combination of Pyrex and a CuSO₄·NH₃ solution filter from a 450-W Hanovia medium pressure mercury lamp in a specially designed double walled photoreactor. Progress of the reaction was monitored by following the disappearance of 1 by GC and HPLC (C18 reverse phase, ACN: H₂O/75:25). After 15-20 h of photo-irradiation, when almost all of the 1 was consumed, the solvent was removed by distillation under reduced pressure. After evaporation of the solvent, the mixture was purified by silica gel column chromatography to give respective α-arylated products 3 along with diphenyl diselenide. The yield was calculated based on the consumption of starting 1.

Characterization of products:

2-(4-methoxyphenyl)-1-phenylethanone (3aa)

\[
\begin{align*}
\text{R}_f & = 0.60 \text{ (SiO2, ethyl acetate/hexane, 1:9); white solid (76%);} \\
^1\text{H} \text{ NMR (400 MHz, CDCl}_3\text{) } & \delta 8.04 – 7.99 \text{ (m, 2H), 7.58 – 7.53 \text{ (m, 1H), 7.45 \text{ (dd, } J = 10.4, 4.7 \text{ Hz, 2H), 7.19 \text{ (d, } J = 8.6 \text{ Hz, 2H), 6.87 \text{ (d, } J = 8.6 \text{ Hz, 2H), 4.23 \text{ (s, 2H), 3.79 \text{ (s, 3H).}}} \\
^1\text{C} \text{ NMR (101 MHz, CDCl}_3\text{) } & \delta 198.05, 158.65, 136.73, 133.22, 130.59, 128.74, 128.71, 126.61, 114.26, 55.36, 44.74. \\
\text{HRMS (ESI) } m/z & \text{ calcd. for C}_{15}H_{15}O_2[M+H]^+ 227.1067, \text{ found 227.1067.}
\end{align*}
\]

2-(3,4-dimethoxyphenyl)-1-phenylethanone (3ab)

\[
\begin{align*}
\text{R}_f & = 0.30 \text{ (SiO2, ethyl acetate/hexane, 1:9); white solid (73%);} \\
^1\text{H} \text{ NMR (400 MHz, CDCl}_3\text{) } & \delta 8.04 – 7.97 \text{ (m, 2H), 7.58 \text{ (m, 1H), 7.45 \text{ (dd, } J = 6.7, 4.0 \text{ Hz, 1H), 7.50 – 7.42 \text{ (m, 2H), 6.82 – 6.77 \text{ (m, 3H), 4.23 \text{ (s, 2H), 3.85 \text{ (d, } J = 0.4 \text{ Hz, 6H).}}} \\
^1\text{C} \text{ NMR (101 MHz, CDCl}_3\text{) } & \delta 198.01, 149.12, 148.09, 136.68, 133.27, 128.74, 128.70, 127.04, 121.72, 112.59, 111.43, 55.97, 55.95, 45.20. \\
\text{HRMS (ESI) } m/z & \text{ calcd. for C}_{16}H_{17}O_3[M+H]^+ 257.1172, \text{ found 257.1174.}
\end{align*}
\]

2-(2,4-dimethoxyphenyl)-1-phenylethanone (3ac)

\[
\begin{align*}
\end{align*}
\]
R_f = 0.50 (SiO_2, ethyl acetate/hexane, 1:9); white solid (76%);

^1^H NMR (400 MHz, CDCl_3) δ 8.07 – 8.01 (m, 2H), 7.59 – 7.51 (m, 1H), 7.49 – 7.42 (m, 2H), 6.84 – 6.80 (m, 1H), 6.79 – 6.75 (m, 2H), 4.26 (s, 2H), 3.75 (s, 6H).

^1^3^C NMR (101 MHz, CDCl_3) δ 197.95, 153.64, 151.59, 137.03, 133.06, 128.63, 128.57, 124.86, 117.19, 112.87, 111.76, 56.16, 55.81, 40.21.

HRMS (ESI) m/z calcd. for C_{16}H_{17}O_3[M+H]^+ 257.1172, found 257.1181.

2-(2,5-dimethoxyphenyl)-1-phenylethanone (3ad)

R_f = 0.50 (SiO_2, ethyl acetate/hexane, 1:9); white solid (72%);

^1^H NMR (400 MHz, CDCl_3) δ 8.04 (dt, J = 8.5, 1.7 Hz, 2H), 7.58 – 7.52 (m, 1H), 7.49 – 7.41 (m, 2H), 7.11 – 7.05 (m, 1H), 6.51 – 6.44 (m, 2H), 4.21 (s, 2H), 3.80 (s, 3H), 3.77 (s, 3H).

^1^3^C NMR (101 MHz, CDCl_3) δ 198.39, 160.19, 158.19, 137.10, 132.93, 131.34, 128.58, 128.51, 116.11, 104.40, 98.83, 55.51, 55.45, 39.42.

HRMS (ESI) m/z calcd. for C_{16}H_{17}O_3[M+H]^+ 257.1182.

2-(benzo[d][1,3]dioxol-5-yl)-1-phenylethanone (3ae)

R_f = 0.60 (SiO_2, ethyl acetate/hexane, 1:9); white solid (77%);

^1^H NMR (400 MHz, CDCl_3) δ 8.00 (dd, J = 5.2, 3.3 Hz, 2H), 7.60 – 7.52 (m, 1H), 7.50 – 7.43 (m, 2H), 6.77 (d, J = 8.0 Hz, 2H), 6.71 (dd, J = 7.7, 1.8 Hz, 1H), 5.93 (s, 2H), 4.20 (s, 2H).

^1^3^C NMR (101 MHz, CDCl_3) δ 197.79, 147.95, 146.67, 136.60, 133.31, 128.76, 128.68, 128.14, 122.67, 110.02, 108.55, 101.11, 45.20.

HRMS (ESI) m/z calcd. for C_{15}H_{13}O_3[M+H]^+ 241.0859, found 241.0868.

1-phenyl-2-(p-tolyl)ethanone (3af)

R_f = 0.40 (SiO_2, ethyl acetate/hexane, 1:19); white solid (66%);

^1^H NMR (400 MHz, CDCl_3) δ 8.06 – 7.99 (m, 2H), 7.61 – 7.51 (m, 1H), 7.51 – 7.42 (m, 2H), 7.20 – 7.12 (m, 4H), 4.26 (s, 2H), 2.34 (s, 3H).

^1^3^C NMR (101 MHz, CDCl_3) δ 197.93, 136.73, 136.57, 133.19, 131.53, 129.49, 129.41, 128.71, 45.23, 21.17.

HRMS (ESI) m/z calcd. for C_{15}H_{15}O[M+H]^+ 211.1117, found 211.1122.

2-(2,4-dimethylphenyl)-1-phenylethanone (3ah)
2-(2,5-dimethylphenyl)-1-phenylethanone (3ai)

R_f = 0.40 (SiO_2, ethyl acetate/hexane, 1:19); white solid (73%);

^1^H NMR (400 MHz, CDCl_3) δ 8.07 – 8.02 (m, 2H), 7.59 (t, J = 7.4 Hz, 1H), 7.49 (dd, J = 11.5, 4.1 Hz, 2H), 7.04 (d, J = 9.9 Hz, 2H), 6.99 (d, J = 7.7 Hz, 1H), 4.29 (s, 2H), 2.33 (s, 3H), 2.25 (s, 3H).

^1^3^C NMR (101 MHz, CDCl_3) δ 197.80, 137.07, 136.85, 136.74, 133.19, 131.34, 130.45, 130.30, 128.74, 128.44, 126.90, 43.22, 21.11, 19.82.

HRMS (ESI) m/z calcd. for C_{16}H_{17}O[M+H]^+ 225.1274, found 225.1277.

2-mesityl-1-phenylethanone (3aj)

R_f = 0.40 (SiO_2, ethyl acetate/hexane, 1:19); white solid (72%);

^1^H NMR (800 MHz, CDCl_3) δ 8.10 (d, J = 8.0 Hz, 2H), 7.62 (t, J = 7.4 Hz, 1H), 7.53 (t, J = 7.7 Hz, 2H), 7.12 (d, J = 7.7 Hz, 1H), 7.02 (d, J = 7.6 Hz, 1H), 6.97 (s, 1H), 4.29 (s, 2H), 2.31 (s, 3H), 2.24 (s, 3H).

^1^3^C NMR (201 MHz, CDCl_3) δ 197.77, 137.09, 135.62, 133.77, 133.33, 133.24, 131.14, 130.38, 128.78, 128.45, 128.06, 43.54, 21.04, 19.43.

HRMS (ESI) m/z calcd. for C_{17}H_{19}O[M+H]^+ 239.1430, found 239.1431.

2-(4-(tert-butyl)phenyl)-1-phenylethanone (3ak)

R_f = 0.50 (SiO_2, ethyl acetate/hexane, 1:19); white liquid (77%);

^1^H NMR (800 MHz, CDCl_3) δ 8.04 (d, J = 7.8 Hz, 2H), 7.56 (t, J = 7.4 Hz, 1H), 7.47 (t, J = 7.7 Hz, 2H), 7.36 (d, J = 8.2 Hz, 2H), 7.22 (d, J = 8.1 Hz, 2H), 4.27 (s, 2H), 1.31 (s, 9H).
$^{13}$C NMR (201 MHz, CDCl$_3$) δ 197.95, 149.80, 136.79, 133.25, 131.52, 129.24, 128.76, 128.75, 125.75, 45.05, 34.56, 31.46.
HRMS (ESI) m/z calcd. for C$_{18}$H$_{21}$O[M+H]$^+$ 253.1587, found 253.1587.

2-((1,1'-biphenyl)-4-yl)-1-phenylethanone (3al)

$^{1}$H NMR (400 MHz, CDCl$_3$) δ 8.08 – 8.03 (m, 2H), 7.59 (dd, $J$ = 11.1, 4.0 Hz, 5H), 7.46 (dt, $J$ = 15.1, 7.8 Hz, 4H), 7.35 (t, $J$ = 8.4 Hz, 2H).
$^{13}$C NMR (101 MHz, CDCl$_3$) δ 197.68, 140.95, 139.99, 136.75, 133.69, 133.35, 130.04, 128.87, 128.81, 128.75, 127.55, 127.35, 127.19, 45.24.
HRMS (ESI) m/z calcd. for C$_{20}$H$_{17}$O[M+H]$^+$ 273.1274, found 273.1270.

2-(4-(dimethylamino)phenyl)-1-phenylethanone (3an)

$^{1}$H NMR (400 MHz, CDCl$_3$) δ 8.03 (dd, $J$ = 8.2, 1.0 Hz, 2H), 7.56 – 7.51 (m, 1H), 7.45 (dd, $J$ = 10.8, 4.4 Hz, 2H), 7.15 (d, $J$ = 8.5 Hz, 2H), 6.71 (d, $J$ = 8.7 Hz, 2H), 4.19 (s, 2H), 2.92 (s, 6H).
$^{13}$C NMR (101 MHz, CDCl$_3$) δ 198.41, 149.69, 136.86, 133.01, 130.12, 128.78, 128.65, 122.28, 113.06, 44.77, 40.75.
HRMS (ESI) m/z calcd. for C$_{16}$H$_{18}$NO[M+H]$^+$ 240.1383, found 240.1379.

1-(4-methoxyphenyl)propan-2-one (3ba)

$^{1}$H NMR (400 MHz, CDCl$_3$) δ 7.14 (d, $J$ = 8.7 Hz, 2H), 6.89 (d, $J$ = 8.7 Hz, 2H), 3.82 (s, 3H), 3.65 (s, 2H), 2.16 (s, 3H).
$^{13}$C NMR (101 MHz, CDCl$_3$) δ 206.93, 158.70, 130.42, 126.31, 114.21, 55.27, 50.14, 29.14.
HRMS (ESI) m/z calcd. for C$_{10}$H$_{13}$O$_2$[M+H]$^+$ 165.0910, found 165.0933.

1-(3,4-dimethoxyphenyl)propan-2-one (3bb)
R<sub>f</sub> = 0.30 (SiO<sub>2</sub>, ethyl acetate/hexane, 1:9); reddish liquid (73%);

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 6.85 (d, <i>J</i> = 8.1 Hz, 1H), 6.77 (dd, <i>J</i> = 8.1, 2.0 Hz, 1H), 6.72 (d, <i>J</i> = 2.0 Hz, 1H), 3.88 (s, 6H), 3.65 (s, 2H), 2.16 (s, 3H).
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 206.90, 149.11, 148.17, 126.73, 121.59, 112.38, 111.41, 55.90, 55.88, 50.61, 29.10.

HRMS (ESI) m/z calcd. for C<sub>11</sub>H<sub>15</sub>O<sub>3</sub>[M+H]<sup>+</sup> 195.1016, found 195.1042.

<sup>1</sup>-<wbr>(2,4-dimethoxyphenyl)propan-2-one (3bc)

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.02 (d, <i>J</i> = 8.5 Hz, 1H), 6.47 – 6.43 (m, 2H), 3.80 (s, 3H), 3.78 (s, 3H), 3.59 (s, 2H), 2.11 (s, 3H).
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 207.67, 160.31, 158.34, 131.43, 116.12, 104.32, 98.71, 55.45, 55.44, 44.94, 29.17.

HRMS (ESI) m/z calcd. for C<sub>11</sub>H<sub>15</sub>O<sub>3</sub>[M+H]<sup>+</sup> 195.1016, found 195.1042.

<sup>1</sup>-<wbr>(benzo[d][1,3]dioxol-5-yl)propan-2-one (3be)

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 6.77 (d, <i>J</i> = 7.9 Hz, 1H), 6.69 – 6.66 (m, 1H), 6.66 – 6.62 (m, 1H), 5.94 (s, 2H), 3.60 (s, 2H), 2.14 (s, 3H).
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 206.68, 148.03, 146.82, 131.43, 127.93, 122.63, 109.87, 108.60, 101.17, 50.67, 29.25.

HRMS (ESI) m/z calcd. for C<sub>10</sub>H<sub>11</sub>O<sub>3</sub>[M+H]<sup>+</sup> 179.0703, found 179.0691.

<sup>1</sup>-<wbr>(p-tolyl)propan-2-one (3bf)

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.15 (d, <i>J</i> = 7.9 Hz, 2H), 7.09 (d, <i>J</i> = 8.1 Hz, 2H), 3.66 (s, 2H), 2.34 (s, 3H), 2.14 (s, 3H).
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 206.84, 136.81, 131.30, 129.57, 129.37, 50.77, 29.27, 21.18.

HRMS (ESI) m/z calcd. for C<sub>10</sub>H<sub>13</sub>O[M+H]<sup>+</sup> 149.0961, found 149.0969.

<sup>1</sup>-<wbr>(3,4-dimethylphenyl)propan-2-one (3bg)

R<sub>f</sub> = 0.30 (SiO<sub>2</sub>, ethyl acetate/hexane, 1:9); reddish liquid (71%);

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.02 (d, <i>J</i> = 8.5 Hz, 1H), 6.47 – 6.43 (m, 2H), 3.80 (s, 3H), 3.78 (s, 3H), 3.59 (s, 2H), 2.11 (s, 3H).
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 207.67, 160.31, 158.34, 131.43, 116.12, 104.32, 98.71, 55.45, 55.44, 44.94, 29.17.

HRMS (ESI) m/z calcd. for C<sub>10</sub>H<sub>11</sub>O<sub>3</sub>[M+H]<sup>+</sup> 179.0703, found 179.0691.

<sup>1</sup>-<wbr>(benzo[d][1,3]dioxol-5-yl)propan-2-one (3be)

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 6.77 (d, <i>J</i> = 7.9 Hz, 1H), 6.69 – 6.66 (m, 1H), 6.66 – 6.62 (m, 1H), 5.94 (s, 2H), 3.60 (s, 2H), 2.14 (s, 3H).
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 206.68, 148.03, 146.82, 131.43, 127.93, 122.63, 109.87, 108.60, 101.17, 50.67, 29.25.

HRMS (ESI) m/z calcd. for C<sub>10</sub>H<sub>11</sub>O<sub>3</sub>[M+H]<sup>+</sup> 179.0703, found 179.0691.

<sup>1</sup>-<wbr>(p-tolyl)propan-2-one (3bf)

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.15 (d, <i>J</i> = 7.9 Hz, 2H), 7.09 (d, <i>J</i> = 8.1 Hz, 2H), 3.66 (s, 2H), 2.34 (s, 3H), 2.14 (s, 3H).
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 206.84, 136.81, 131.30, 129.57, 129.37, 50.77, 29.27, 21.18.

HRMS (ESI) m/z calcd. for C<sub>10</sub>H<sub>13</sub>O[M+H]<sup>+</sup> 149.0961, found 149.0969.
R_f = 0.60 (SiO_2, ethyl acetate/hexane, 1:9); yellow liquid (71%);

^1^H NMR (400 MHz, CDCl_3) δ 7.10 (d, J = 7.6 Hz, 1H), 6.98 (s, 1H), 6.94 (d, J = 7.7 Hz, 1H), 3.63 (s, 2H), 2.25 (s, 6H), 2.15 (s, 3H).

^13^C NMR (101 MHz, CDCl_3) δ 207.03, 137.08, 135.46, 131.72, 130.73, 130.11, 126.85, 50.80, 29.26, 19.83, 19.48.

HRMS (ESI) m/z calcd. for C_{11}H_{15}O[M+H]^+ 163.1117, found 163.1102.

1-(2,5-dimethylphenyl)propan-2-one (3bi)

R_f = 0.60 (SiO_2, ethyl acetate/hexane, 1:9); yellow liquid (71%);

^1^H NMR (400 MHz, CDCl_3) δ 7.08 (d, J = 7.7 Hz, 1H), 7.00 (d, J = 7.8 Hz, 1H), 6.96 (s, 1H), 3.67 (s, 2H), 2.31 (s, 3H), 2.21 (s, 3H), 2.14 (s, 3H).

^13^C NMR (101 MHz, CDCl_3) δ 206.65, 135.83, 133.73, 133.07, 131.20, 130.52, 128.20, 49.22, 29.35, 20.99, 19.25.

HRMS (ESI) m/z calcd. for C_{11}H_{15}O[M+H]^+ 163.1106.

1-mesitylpropan-2-one (3bj)

R_f = 0.60 (SiO_2, ethyl acetate/hexane, 1:9); white solid (70%);

^1^H NMR (800 MHz, CDCl_3) δ 6.89 (s, 2H), 3.74 (s, 2H), 2.28 (s, 3H), 2.22 (s, 6H), 2.15 (s, 3H).

^13^C NMR (201 MHz, CDCl_3) δ 206.83, 136.78, 136.61, 129.21, 129.13, 44.97, 29.44, 21.02, 20.40.

HRMS (ESI) m/z calcd. for C_{12}H_{17}O[M+H]^+ 177.1274, found 177.1257.

1-(4-(tert-butyl)phenyl)propan-2-one (3bk)

R_f = 0.50 (SiO_2, ethyl acetate/hexane, 1:9); white solid (69%);

^1^H NMR (800 MHz, CDCl_3) δ 7.36 (d, J = 8.2 Hz, 2H), 7.15 (d, J = 8.1 Hz, 2H), 3.67 (s, 2H), 2.16 (s, 3H), 1.32 (s, 9H).

^13^C NMR (201 MHz, CDCl_3) δ 206.84, 150.00, 131.24, 129.14, 125.78, 50.61, 34.55, 31.43, 29.40.

HRMS (ESI) m/z calcd. for C_{13}H_{19}O[M+H]^+ 191.1430, found 191.1459.

1-(1,1’-biphenyl)4-yl)propan-2-one (3bl)
$R_f = 0.50$ (SiO$_2$, ethyl acetate/hexane, 1:9); white solid (68%);

$^1$H NMR (800 MHz, CDCl$_3$) $\delta$ 7.62 – 7.54 (m, 4H), 7.44 (t, $J = 7.7$ Hz, 2H), 7.35 (t, $J = 7.4$ Hz, 1H), 7.28 (d, $J = 8.0$ Hz, 2H), 3.75 (s, 2H), 2.20 (s, 3H).

$^{13}$C NMR (201 MHz, CDCl$_3$) $\delta$ 206.56, 140.83, 140.17, 133.34, 129.97, 128.92, 127.63, 127.45, 127.19, 50.75, 29.57.

HRMS (ESI) $m/z$ calcd. for C$_{15}$H$_{15}$O$^{[M+H]}$ 211.1117, found 211.1096.

1-(4-(dimethylamino)phenyl)propan-2-one (3bn)

$R_f = 0.30$ (SiO$_2$, ethyl acetate/hexane, 1:9); yellow solid (61%);

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.07 (d, $J = 8.8$ Hz, 2H), 6.71 (d, $J = 8.8$ Hz, 2H), 3.58 (s, 2H), 2.94 (s, 6H), 2.12 (s, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 207.58, 149.84, 130.11, 122.13, 113.03, 50.33, 40.72, 29.02.

HRMS (ESI) $m/z$ calcd. for C$_{11}$H$_{16}$NO$^{[M+H]}$ 178.1226, found 178.1206.

2-(4-methoxyphenyl)cyclopentanone (3ca)

$R_f = 0.40$ (SiO$_2$, ethyl acetate/hexane, 1:9); white solid (70%);

$^1$H NMR (800 MHz, CDCl$_3$) $\delta$ 7.12 (d, $J = 8.6$ Hz, 2H), 6.88 (d, $J = 8.7$ Hz, 2H), 3.79 (s, 3H), 3.27 (dd, $J = 11.5, 8.7$ Hz, 1H), 2.54 – 2.40 (m, 2H), 2.32 – 2.23 (m, 1H), 2.15 (dddd, $J = 15.0, 8.8, 4.5, 2.2$ Hz, 1H), 2.07 (dddd, $J = 24.1, 11.6, 6.4$ Hz, 1H), 1.95 – 1.88 (m, 1H).

$^{13}$C NMR (201 MHz, CDCl$_3$) $\delta$ 218.63, 158.57, 130.50, 129.17, 114.13, 55.35, 54.67, 38.37, 31.88, 20.86.

HRMS (ESI) $m/z$ calcd. for C$_{12}$H$_{15}$O$_2$N$^{[M+H]}$ 191.1067, found 191.1059.

2-(3,4-dimethoxyphenyl)cyclopentanone (3cb)

$R_f = 0.30$ (SiO$_2$, ethyl acetate/hexane, 1:9); white solid (72%);

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 6.83 (d, $J = 8.7$ Hz, 1H), 6.75 – 6.69 (m, 2H), 3.87 (s, 3H), 3.85 (s, 3H), 3.26 (dd, $J = 11.1, 8.5$ Hz, 1H), 2.54 – 2.41 (m, 2H), 2.34 – 2.22 (m, 1H), 2.20 – 2.02 (m, 2H), 1.99 – 1.84 (m, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 218.39, 149.08, 148.12, 130.97, 120.13, 111.63, 111.44, 56.02, 55.97, 54.97, 38.41, 31.88, 20.86.

HRMS (ESI) $m/z$ calcd. for C$_{13}$H$_{17}$O$_3$N$^{[M+H]}$ 221.1172, found 221.1170.

2-(2,4-dimethoxyphenyl)cyclopentanone (3cc)
S13

2-(2,5-dimethoxyphenyl)cyclopentanone (3cd)

R_f = 0.30 (SiO_2, ethyl acetate/hexane, 1:9); white solid (73%);

^1^H NMR (400 MHz, CDCl_3) δ 6.80 (d, J = 8.9 Hz, 1H), 6.74 (dd, J = 8.9, 3.0 Hz, 1H), 3.74 (s, 3H), 3.72 (s, 3H), 3.31 (dd, J = 11.0, 8.4 Hz, 1H), 2.43 – 2.30 (m, 3H), 2.20 – 2.07 (m, 2H), 1.93 – 1.80 (m, 1H).

^13^C NMR (101 MHz, CDCl_3) δ 219.14, 153.75, 151.21, 129.62, 117.02, 112.49, 112.38, 56.01, 55.79, 52.71, 38.31, 31.26, 21.63.

HRMS (ESI) m/z calcd. for C_{13}H_{17}O_3 [M+H]^+ 221.1172, found 221.1170.

2-(benzo[d][1,3]dioxol-5-yl)cyclopentanone (3ce)

R_f = 0.40 (SiO_2, ethyl acetate-hexane, 1:9); white liquid (73%);

^1^H NMR (800 MHz, CDCl_3) δ 6.77 (d, J = 7.9 Hz, 1H), 6.67 (d, J = 1.6 Hz, 1H), 6.64 (dd, J = 7.9, 1.6 Hz, 1H), 5.93 (s, 2H), 3.24 (dd, J = 11.6, 8.6 Hz, 1H), 2.50 – 2.42 (m, 2H), 2.30 – 2.23 (m, 1H), 2.14 (dddt, J = 13.1, 8.7, 6.4, 2.1 Hz, 1H), 2.04 (ddd, J = 24.2, 12.0, 6.4 Hz, 1H), 1.94 – 1.87 (m, 1H).

^13^C NMR (201 MHz, CDCl_3) δ 218.30, 147.91, 146.59, 132.16, 121.41, 108.63, 108.45, 101.09, 55.22, 38.36, 32.01, 20.81.

HRMS (ESI) m/z calcd. for C_{12}H_{13}O_3 [M+H]^+ 205.0859, found 205.0855.

2-(p-tolyl)cyclopentanone (3cf)

R_f = 0.60 (SiO_2, ethyl acetate/hexane, 1:9); yellowish solid (67%);

^1^H NMR (400 MHz, CDCl_3) δ 7.18 – 7.13 (d, 2H), 7.09 (dd, J = 8.1, 2.0 Hz, 2H), 3.33 – 3.25 (m, 1H), 2.54 – 2.42 (m, 2H), 2.34 (s, 3H), 2.32 – 2.23 (m, 1H), 2.21 – 2.05 (m, 2H), 2.00 – 1.88 (m, 1H).

^13^C NMR (101 MHz, CDCl_3) δ 218.38, 136.59, 135.52, 129.41, 128.10, 55.10, 38.47, 31.89, 21.15, 20.94.

HRMS (ESI) m/z calcd. for C_{12}H_{15}O [M+H]^+ 175.1046.

2-(3,4-dimethylphenyl)cyclopentanone (3cg)
$R_f = 0.60$ (SiO$_2$, ethyl acetate/hexane, 1:9); yellowish solid (61%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.10 (d, $J = 7.7$ Hz, 1H), 6.95 (s, 1H), 6.94 – 6.90 (m, 1H), 3.26 (dd, $J = 11.0$, 9.0 Hz, 1H), 2.53 – 2.42 (m, 2H), 2.35 – 2.26 (m, 1H), 2.25 (s, 3H), 2.24 (s, 3H), 2.20 – 2.05 (m, 2H), 1.99 – 1.87 (m, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 218.69, 136.88, 136.04, 135.33, 130.00, 129.59, 125.60, 55.24, 38.53, 32.07, 21.00, 19.96, 19.49.

HRMS (ESI) m/z calcd. for C$_{13}$H$_{17}$O[M+H]$^+$ 189.1274, found 189.1269.

2-(2,4-dimethylphenyl)cyclopentanone (3ch)

$R_f = 0.60$ (SiO$_2$, ethyl acetate/hexane, 1:9); yellowish sticky liquid (63%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.02 (s, 1H), 6.99 (d, $J = 7.9$ Hz, 1H), 6.90 (d, $J = 7.8$ Hz, 1H), 3.53 – 3.45 (m, 1H), 2.54 – 2.43 (m, 2H), 2.35 (dd, $J = 10.7$, 8.8 Hz, 1H), 2.30 (s, 3H), 2.29 (s, 3H), 2.23 – 2.12 (m, 1H), 2.09 – 1.88 (m, 2H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 219.00, 136.66, 136.54, 134.57, 131.48, 127.38, 127.05, 52.83, 38.72, 31.82, 21.12, 21.04, 19.94.

HRMS (ESI) m/z calcd. for C$_{13}$H$_{17}$O[M+H]$^+$ 189.1274, found 189.1272.

2-(2,5-dimethylphenyl)cyclopentanone (3ci)

$R_f = 0.40$ (SiO$_2$, ethyl acetate/hexane, 1:9); colorless sticky liquid (67%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.08 (d, $J = 7.7$ Hz, 1H), 6.97 (d, $J = 7.7$, 1.1 Hz, 1H), 6.81 (s, 1H), 3.53 – 3.46 (m, 1H), 2.55 – 2.44 (m, 2H), 2.35 (dd, $J = 10.6$, 5.5 Hz, 1H), 2.29 (s, 3H), 2.27 (s, 3H), 2.23 – 2.14 (m, 1H), 2.10 – 1.88 (m, 2H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 219.03, 137.46, 135.72, 133.65, 130.54, 128.22, 127.74, 53.13, 38.86, 31.87, 21.16, 21.14, 19.54.

HRMS (ESI) m/z calcd. for C$_{13}$H$_{17}$O[M+H]$^+$ 189.1274, found 189.1272.

2-(4-(tert-butyl)phenyl)cyclopentanone (3ck)

$R_f = 0.70$ (SiO$_2$, ethyl acetate/hexane, 1:9); yellowish solid (71%);

$^1$H NMR (800 MHz, CDCl$_3$) δ 7.37 (d, $J = 7.6$ Hz, 2H), 7.14 (d, $J = 7.6$ Hz, 2H), 3.33 – 3.29 (t, 1H), 2.52 – 2.45 (m, 2H), 2.33 – 2.26 (m, 1H), 2.19 – 2.09 (m, 2H), 1.97 – 1.89 (m, 1H), 1.32 (s, 9H).

$^{13}$C NMR (201 MHz, CDCl$_3$) δ 218.54, 149.72, 135.40, 127.85, 125.65, 55.00, 38.53, 34.53, 31.82, 31.44, 20.97.

HRMS (ESI) m/z calcd. for C$_{15}$H$_{21}$O[M+H]$^+$ 217.1587, found 217.1574.
2-[(1,1'-biphenyl]-4-yl)cyclopentanone (3cl)

\[
\begin{align*}
\text{C} & \quad \text{Ph} \\
\end{align*}
\]

R<sub>f</sub> = 0.80 (SiO<sub>2</sub>, ethyl acetate/hexane, 1:19); white solid (75%);

1<sup>H</sup> NMR (800 MHz, CDCl<sub>3</sub>) δ 7.60 – 7.57 (m, 4H), 7.44 (t, J = 7.7 Hz, 2H), 7.35 (t, J = 11.8 Hz, 1H), 7.29 (d, J = 8.1 Hz, 2H), 3.39 (dd, J = 11.1, 8.5 Hz, 1H), 2.58 – 2.49 (m, 1H), 2.33 (dd, J = 15.6, 10.7, 8.9 Hz, 1H), 2.23 – 2.14 (m, 2H), 2.00 – 1.94 (m, 1H).

13<sup>C</sup> NMR (201 MHz, CDCl<sub>3</sub>) δ 218.30, 141.06, 140.05, 137.62, 128.92, 128.73, 127.55, 127.38, 127.26, 55.26, 38.59, 31.91, 21.05.

HRMS (ESI) m/z calcd. for C<sub>17</sub>H<sub>17</sub>O[M+H]<sup>+</sup> 237.1274, found 237.1263.

2-(4-methoxyphenyl)cyclohexanone (3da)

\[
\begin{align*}
\quad & \quad \text{O Me} \\
\end{align*}
\]

R<sub>f</sub> = 0.40 (SiO<sub>2</sub>, ethyl acetate/hexane, 1:9); white solid (77%);

1<sup>H</sup> NMR (400 MHz, CDCl<sub>3</sub>) δ 7.07 (d, J = 8.7 Hz, 2H), 6.88 (d, J = 8.7 Hz, 2H), 3.80 (s, 3H), 3.57 (dd, J = 12.3, 5.5 Hz, 1H), 2.56 – 2.49 (m, 1H), 2.49 – 2.40 (m, 1H), 2.29 – 2.22 (m, 1H), 2.18 – 2.10 (m, 1H), 2.04 – 1.94 (m, 2H), 1.88 – 1.75 (m, 2H).

13<sup>C</sup> NMR (101 MHz, CDCl<sub>3</sub>) δ 210.82, 158.52, 130.95, 129.54, 113.90, 56.67, 55.31, 42.29, 35.40, 27.96, 25.50.

HRMS (ESI) m/z calcd. for C<sub>13</sub>H<sub>17</sub>BrO<sub>2</sub>[M+H]<sup>+</sup> 205.1223, found 205.1253.

2-(3,4-dimethoxyphenyl)cyclohexanone (3db)

\[
\begin{align*}
\quad & \quad \text{O Me} \\
\end{align*}
\]

R<sub>f</sub> = 0.30 (SiO<sub>2</sub>, ethyl acetate/hexane, 1:9); white solid (73%);

1<sup>H</sup> NMR (400 MHz, CDCl<sub>3</sub>) δ 6.83 (d, J = 8.2 Hz, 1H), 6.68 (d, J = 8.3, 1.8 Hz, 1H), 6.65 (d, J = 1.9 Hz, 1H), 3.85 (s, 6H), 3.56 (dd, J = 12.0, 5.5 Hz, 1H), 2.54 – 2.38 (m, 2H), 2.14 (dt, J = 15.5, 4.8 Hz, 1H), 2.06 – 1.95 (m, 2H), 1.88 – 1.75 (m, 2H).

13<sup>C</sup> NMR (101 MHz, CDCl<sub>3</sub>) δ 210.73, 148.79, 147.97, 131.39, 120.45, 111.93, 111.16, 57.01, 55.91, 55.88, 42.26, 35.29, 27.89, 25.43.

HRMS (ESI) m/z calcd. for C<sub>14</sub>H<sub>19</sub>O<sub>3</sub>[M+H]<sup>+</sup> 235.1329, found 235.1363.

2-(2,4-dimethoxyphenyl)cyclohexanone (3dc)

\[
\begin{align*}
\quad & \quad \text{O Me} \\
\end{align*}
\]

R<sub>f</sub> = 0.30 (SiO<sub>2</sub>, ethyl acetate/hexane, 1:9); white solid (71%);

1<sup>H</sup> NMR (400 MHz, CDCl<sub>3</sub>) δ 7.02 (d, J = 8.2 Hz, 1H), 6.48 (dt, J = 6.9, 2.4 Hz, 2H), 3.86 (dd, J = 12.9, 5.4 Hz, 1H), 3.80 (s, 3H), 3.75 (s, 3H), 2.55 – 2.43 (m, 2H), 2.23 – 2.11 (m, 2H), 2.06 – 1.94 (m, 2H), 1.89 – 1.71 (m, 2H).

13<sup>C</sup> NMR (101 MHz, CDCl<sub>3</sub>) δ 210.35, 159.78, 157.94, 129.12, 120.40, 104.24, 98.74, 55.49, 55.38, 50.55, 42.39, 33.70, 27.71, 25.87.

HRMS (ESI) m/z calcd. for C<sub>14</sub>H<sub>19</sub>O<sub>3</sub>[M+H]<sup>+</sup> 235.1329, found 135.1365.
2-(2,5-dimethoxyphenyl)cyclohexanone (3dd)

\[
\text{R}_f = 0.30 \text{ (SiO}_2, \text{ethyl acetate/hexane, 1:9); white solid (74%);}^{1} \text{H NMR (400 MHz, CDCl}_3) \delta 6.84 - 6.73 \text{ (m, 2H), 6.71 (d, } J = 2.7 \text{ Hz, 1H), 3.90 (dd, } J = 12.8, 5.2 \text{ Hz, 1H), 3.76 (s, 3H), 3.73 (s, 3H), 2.57 - 2.44 \text{ (m, 2H), 2.19 (ddd, } J = 16.5, 9.3, 4.4 \text{ Hz, 2H), 2.08 - 1.95 \text{ (m, 2H), 1.82 (t, } J = 15.6 \text{ Hz, 2H).}
\]

\[^{13}C\text{ NMR (101 MHz, CDCl}_3) \delta 209.78, 153.59, 151.34, 129.22, 115.55, 111.92, 111.58, 56.15, 55.71, 51.25, 42.34, 33.41, 27.57, 25.70.\]

HRMS (ESI) \text{m/z calcd. for } C_{14}H_{19}O_3[\text{M+H}]^+ 235.1329, \text{ found 135.1363.}

2-(benzo[d][1,3]dioxol-5-yl)cyclohexanone (3de)

\[
\text{R}_f = 0.40 \text{ (SiO}_2, \text{ethyl acetate/hexane, 1:9); white solid (77%);}^{1} \text{H NMR (400 MHz, CDCl}_3) \delta 6.77 (d, } J = 7.9 \text{ Hz, 1H), 6.64 (d, } J = 1.7 \text{ Hz, 1H), 6.59 - 6.55 \text{ (m, 1H), 5.94 (s, 2H), 3.54 (dd, } J = 12.2, 5.4 \text{ Hz, 1H), 2.56 - 2.49 \text{ (m, 1H), 2.48 - 2.39 \text{ (m, 1H), 2.27 - 2.21 \text{ (m, 1H), 2.18 - 2.10 \text{ (m, 1H), 2.02 - 1.90 \text{ (m, 2H), 1.87 - 1.75 \text{ (m, 2H).}}}
\]

\[^{13}C\text{ NMR (101 MHz, CDCl}_3) \delta 210.60, 147.71, 146.55, 132.69, 121.65, 109.12, 108.30, 101.06, 57.25, 42.33, 35.53, 27.93, 25.54.\]

HRMS (ESI) \text{m/z calcd. for } C_{13}H_{14}O_3[\text{M+H}]^+ 219.1016, \text{ found 219.1049.}

2-(p-tolyl)cyclohexanone (3df)

\[
\text{R}_f = 0.60 \text{ (SiO}_2, \text{ethyl acetate/hexane, 1:9); white solid (68%);}^{1} \text{H NMR (400 MHz, CDCl}_3) \delta 7.18 (d, } J = 7.8 \text{ Hz, 2H), 7.06 (d, } J = 8.0 \text{ Hz, 2H), 3.60 (dd, } J = 11.9, 5.4 \text{ Hz, 1H), 2.58 - 2.41 \text{ (m, 2H), 2.36 (s, 3H), 2.32 - 2.23 \text{ (m, 1H), 2.20 - 2.12 \text{ (m, 1H), 2.10 - 1.95 \text{ (m, 2H), 1.90 - 1.77 \text{ (m, 2H).}}}
\]

\[^{13}C\text{ NMR (101 MHz, CDCl}_3) \delta 210.61, 136.49, 135.79, 129.15, 128.42, 57.07, 42.24, 35.17, 27.90, 25.41, 21.16.\]

HRMS (ESI) \text{m/z calcd. for } C_{13}H_{17}BrO[\text{M+H}]^+ 189.1274, \text{ found 189.1305.}

2-(3,4-dimethylphenyl)cyclohexanone (3dg)

\[
\text{R}_f = 0.60 \text{ (SiO}_2, \text{ethyl acetate/hexane, 1:9); white solid (63%);}^{1} \text{H NMR (400 MHz, CDCl}_3) \delta 7.12 (d, } J = 7.6 \text{ Hz, 1H), 6.94 - 6.87 \text{ (m, 2H), 3.56 (dd, } J = 12.0, 5.1 \text{ Hz, 1H), 2.48 (ddd, } J = 20.9, 19.6, 9.8 \text{ Hz, 2H), 2.29 (d, } J = 18.1 \text{ Hz, 1H), 2.26 (s, 6H), 2.19 - 2.11 \text{ (m, 1H), 2.11 - 1.97 \text{ (m, 2H), 1.89 - 1.76 \text{ (m, 2H).}}}
\]

\[^{13}C\text{ NMR (101 MHz, CDCl}_3) \delta 210.79, 136.54, 136.31, 135.25, 129.92, 129.79, 125.90, 57.14, 42.27, 35.12, 27.92, 25.45, 19.98, 19.52.\]
HRMS (ESI) m/z calcd. for C_{14}H_{19}O[M+H]^{+} 203.1430, found 203.1466.

2-(2,4-dimethylphenyl)cyclohexanone (3dh)

R_f = 0.60 (SiO\textsubscript{2}, ethyl acetate/hexane, 1:9); white solid (65%);

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 7.02 (d, \(J = 7.3\) Hz, 3H), 3.75 (dd, \(J = 12.8, 5.3\) Hz, 1H), 2.60 – 2.45 (m, 2H), 2.31 (s, 3H), 2.29 – 2.19 (m, 2H), 2.17 (s, 3H), 2.11 – 1.98 (m, 2H), 1.92 – 1.75 (m, 2H).

\textsuperscript{13}C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 210.29, 136.41, 136.05, 134.43, 131.27, 127.61, 126.81, 53.65, 42.64, 34.35, 27.90, 26.04, 21.09, 19.76.

HRMS (ESI) m/z calcd. for C_{14}H_{19}O[M+H]^{+} 203.1430, found 203.1460.

2-(2,5-dimethylphenyl)cyclohexanone (3di)

R_f = 0.60 (SiO\textsubscript{2}, ethyl acetate/hexane, 1:9); white solid (69%);

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 7.08 (d, \(J = 7.6\) Hz, 1H), 7.00 (d, \(J = 8.5\) Hz, 1H), 6.96 (s, 1H), 3.77 (dd, \(J = 12.9, 5.3\) Hz, 1H), 2.62 – 2.46 (m, 2H), 2.34 (s, 3H), 2.32 – 2.20 (m, 2H), 2.18 (s, 3H), 2.13 – 2.01 (m, 2H), 1.92 – 1.78 (m, 2H).

\textsuperscript{13}C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 210.19, 137.22, 135.32, 133.06, 130.25, 128.46, 127.67, 53.94, 42.64, 34.26, 27.86, 25.99, 21.27, 19.36.

HRMS (ESI) m/z calcd. for C_{14}H_{19}O[M+H]^{+} 203.1430, found 203.1462.

2-mesitylcyclohexanone (3dj)

R_f = 0.70 (SiO\textsubscript{2}, ethyl acetate/hexane, 1:9); white solid (69%);

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 6.87 (s, 2H), 3.76 (dd, \(J = 11.0, 7.3\) Hz, 1H), 2.66 (d, \(J = 16.1\) Hz, 1H), 2.43 (ddd, \(J = 16.3, 13.9, 5.1\) Hz, 1H), 2.26 (s, 3H), 2.20 (s, 6H), 2.18 (s, 3H), 2.17 – 2.09 (m, 2H), 2.07 – 1.96 (m, 2H), 1.90 – 1.69 (m, 2H).

\textsuperscript{13}C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 209.47, 136.19, 136.15, 134.11, 129.79, 52.28, 41.67, 31.95, 25.48, 25.42, 21.50, 20.93.

HRMS (ESI) m/z calcd. for C_{15}H_{21}O[M+H]^{+} 217.1587, found 217.1593.

2-(4-(tert-butyl)phenyl)cyclohexanone (3dk)

R_f = 0.70 (SiO\textsubscript{2}, ethyl acetate/hexane, 1:9); white solid (78%);

\textsuperscript{1}H NMR (800 MHz, CDCl\textsubscript{3}) \(\delta\) 7.36 (d, \(J = 8.1\) Hz, 2H), 7.08 (d, \(J = 8.1\) Hz, 2H), 3.59 (dd, \(J = 12.0, 5.4\) Hz, 1H), 2.53 (dd, \(J = 14.0, 3.6\) Hz, 1H), 2.45 (td, \(J = 12.8, 5.8\) Hz, 1H), 2.29 – 2.24 (m, 1H), 2.15 (ddd, \(J = 9.2, 3.1\) Hz, 1H), 2.06 – 1.98 (m, 2H), 1.82 (ddd, \(J = 11.2, 10.7, 3.6\) Hz, 2H), 1.32 (s, 9H).
$^{13}$C NMR (201 MHz, CDCl$_3$) δ 210.77, 149.60, 135.75, 128.21, 125.44, 57.01, 42.33, 35.22, 34.55, 31.50, 27.99, 25.46.

HRMS (ESI) m/z calcd. for C$_{16}$H$_{23}$O[M+H]$^+$ 231.1743, found 231.1781.

2-((1,1'-biphenyl)-4-yl)cyclohexanone (3dl)

\[
\begin{array}{c}
\text{Ph} \\
\text{O} \\
\end{array}
\]

R$_f$ = 0.50 (SiO$_2$, ethyl acetate/hexane, 1:9); white solid (80%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.59 (t, $J$ = 8.5 Hz, 4H), 7.44 (t, $J$ = 7.7 Hz, 2H), 7.34 (t, $J$ = 7.3 Hz, 1H), 7.24 (t, $J$ = 8.1 Hz, 2H), 3.67 (dd, $J$ = 12.3, 5.4 Hz, 1H), 2.61 – 2.44 (m, 2H), 2.36 – 2.28 (m, 1H), 2.22 – 2.13 (m, 1H), 2.05 (ddt, $J$ = 15.5, 14.3, 7.8 Hz, 2H), 1.86 (pd, $J$ = 12.1, 3.8 Hz, 2H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 210.53, 141.11, 139.93, 137.93, 129.06, 128.82, 127.27, 127.23, 57.23, 42.37, 35.32, 27.96, 25.51.

HRMS (ESI) m/z calcd. for C$_{18}$H$_{19}$O[M+H]$^+$ 251.1430, found 164.1448.

2-(4-(dimethylamino)phenyl)cyclohexanone (3dn)

\[
\begin{array}{c}
\text{NMe}_2 \\
\text{O} \\
\end{array}
\]

R$_f$ = 0.40 (SiO$_2$, ethyl acetate/hexane, 1:9); yellowish sticky solid (65%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.03 (d, $J$ = 8.6 Hz, 2H), 6.74 (d, $J$ = 8.8 Hz, 2H), 3.54 (dd, $J$ = 11.8, 5.4 Hz, 1H), 2.56 – 2.49 (m, 1H), 2.44 (dddd, $J$ = 13.5, 12.1, 5.8, 1.0 Hz, 1H), 2.29 – 2.21 (m, 1H), 2.17 – 2.09 (m, 1H), 2.05 – 1.95 (m, 2H), 1.89 – 1.74 (m, 2H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 211.29, 149.68, 129.08, 126.72, 112.81, 56.46, 42.20, 40.78, 35.16, 27.99, 25.40.

HRMS (ESI) m/z calcd. for C$_{15}$H$_{21}$NO[M+H]$^+$ 218.1539, found 218.1539.

2-(4-(diethylamino)phenyl)cyclohexanone (3do)

\[
\begin{array}{c}
\text{N}
\end{array}
\]

R$_f$ = 0.40 (SiO$_2$, ethyl acetate/hexane, 1:9); yellowish sticky solid (69%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 6.98 (d, $J$ = 8.8 Hz, 2H), 6.65 (d, $J$ = 8.8 Hz, 2H), 3.51 (dd, $J$ = 11.6, 5.4 Hz, 1H), 3.34 (q, $J$ = 7.1 Hz, 4H), 2.55 – 2.48 (m, 1H), 2.47 – 2.37 (m, 1H), 2.28 – 2.20 (m, 1H), 2.16 – 2.07 (m, 1H), 2.00 (ddt, $J$ = 16.2, 10.8, 7.4 Hz, 2H), 1.88 – 1.73 (m, 2H), 1.15 (t, $J$ = 7.1 Hz, 6H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 211.49, 146.87, 129.27, 125.34, 111.79, 56.42, 44.40, 42.20, 35.18, 28.02, 25.40, 12.78.

HRMS (ESI) m/z calcd. for C$_{16}$H$_{24}$NO[M+H]$^+$ 246.1852, found 246.1864.

2-(4-(dibenzylamino)phenyl)cyclohexanone (3dp)

\[
\begin{array}{c}
\text{N}
\end{array}
\]

R$_f$ = 0.50 (SiO$_2$, ethyl acetate/hexane, 1:9); yellowish sticky solid (45%);
$^1$H NMR (400 MHz, CDCl$_3$) δ 7.40 – 7.34 (m, 4H), 7.29 (d, $J = 23.6$ Hz, 6H), 7.00 (d, $J = 8.3$ Hz, 2H), 6.77 (d, $J = 7.9$ Hz, 2H), 4.68 (s, 4H), 3.55 (dd, $J = 11.2$, 4.4 Hz, 1H), 2.61 – 2.39 (m, 2H), 2.28 (d, $J = 11.1$ Hz, 1H), 2.15 (s, 1H), 2.04 (d, $J = 21.4$ Hz, 2H), 1.91 – 1.76 (m, 2H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 211.18, 148.22, 138.81, 129.20, 128.66, 126.91, 126.80, 112.46, 56.39, 54.28, 42.17, 35.14, 27.94, 25.38.

HRMS (ESI) m/z calcd. for C$_{26}$H$_{28}$NO$^+ [M+H]$ 370.2165, found 370.2169.

**2-(4-methoxyphenyl)-1-phenylethanone (3ed)**

![Structure](image)

$R_f = 0.60$ (SiO$_2$, ethyl acetate/hexane, 1:9); white solid (55%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.97 – 7.93 (m, 2H), 7.47 – 7.42 (m, 1H), 7.38 – 7.33 (m, 2H), 7.01 (d, $J = 8.4$ Hz, 1H), 6.45 (d, $J = 2.4$ Hz, 1H), 6.39 (dd, $J = 8.4$, 2.5 Hz, 1H), 5.00 (q, $J = 6.8$ Hz, 1H), 3.85 (s, 3H), 3.75 (s, 3H), 1.43 (d, $J = 6.8$ Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 201.68, 159.84, 156.85, 136.68, 132.62, 128.63, 128.60, 128.43, 122.69, 104.68, 98.99, 55.62, 55.40, 39.84, 17.85.

HRMS (ESI) m/z calcd. for C$_{17}$H$_{19}$O$_3$ [M+H]$^+ 271.3304$, found 271.3310.

**2-(3,4-dimethoxyphenyl)-1-phenylethanone (3ee)**

![Structure](image)

$R_f = 0.40$ (SiO$_2$, ethyl acetate/hexane, 1:9); white solid (57%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.95 (dd, $J = 8.4$, 1.2 Hz, 2H), 7.51 – 7.46 (m, 1H), 7.42 – 7.36 (m, 2H), 6.77 (d, $J = 1.1$ Hz, 1H), 6.73 (dd, $J = 2.1$, 1.1 Hz, 2H), 5.90 (dd, $J = 6.4$, 1.4 Hz, 2H), 4.60 (q, $J = 6.8$ Hz, 1H), 1.49 (d, $J = 6.9$ Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 200.37, 148.16, 146.62, 135.33, 132.94, 128.87, 128.63, 128.43, 122.69, 108.79, 108.22, 101.16, 47.53, 19.67.

HRMS (ESI) m/z calcd. for C$_{16}$H$_{15}$O$_3$ [M+H]$^+ 255.2880$, found 255.2884.

**2-(2,4-dimethoxyphenyl)-1-phenylethanone (3el)**

![Structure](image)

$R_f = 0.70$ (SiO$_2$, ethyl acetate/hexane, 1:9); white solid (53%);

$^1$H NMR (400 MHz, CDCl$_3$) δ 8.01 – 7.98 (m, 2H), 7.57 – 7.51 (m, 4H), 7.49 (dt, $J = 2.6$, 1.7 Hz, 1H), 7.44 – 7.30 (m, 7H), 4.75 (q, $J = 6.8$ Hz, 1H), 1.58 (d, $J = 6.9$ Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 200.44, 140.75, 140.57, 139.94, 136.57, 133.00, 128.93, 128.86, 128.67, 128.32, 127.83, 127.39, 127.13, 47.60, 19.63.

HRMS (ESI) m/z calcd. for C$_{21}$H$_{19}$O$_3$ [M+H]$^+ 287.3744$, found 287.3738.

**1-(4-methoxyphenyl)propan-2-one (3fa)**

![Structure](image)
Rf = 0.50 (SiO2, ethyl acetate/hexane, 1:9); yellow solid (58%);

\[^1\]H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 7.13 (d, \(J = 8.7\) Hz, 2H), 6.87 (d, \(J = 8.7\) Hz, 2H), 3.80 (s, 3H), 3.69 (q, \(J = 7.0\) Hz, 1H), 2.04 (s, 3H), 1.36 (d, \(J = 7.0\) Hz, 3H).

\[^13\]C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 209.27, 158.74, 132.65, 128.84, 114.34, 55.29, 52.86, 28.24, 17.27.

HRMS (ESI) \(m/z\) calcd. for C\textsubscript{11}H\textsubscript{15}O\textsubscript{2}\[M+H\]^+ 179.2351, found 179.2357.

1-(3,4-dimethoxyphenyl)propan-2-one (3f)

\[
\begin{array}{c}
\text{Me} \\
\text{Me} \\
\end{array}
\]

Rf = 0.40 (SiO2, ethyl acetate/hexane, 1:9); white solid (53%);

\[^1\]H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 7.61 – 7.55 (m, 4H), 7.47 – 7.42 (m, 2H), 7.38 – 7.32 (m, 1H), 7.32 – 7.28 (m, 2H), 3.80 (q, \(J = 7.0\) Hz, 1H), 2.10 (s, 3H), 1.44 (d, \(J = 7.0\) Hz, 3H).

\[^13\]C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 206.90, 149.11, 148.17, 126.73, 121.59, 112.38, 111.41, 55.90, 55.88, 50.61, 29.10.

HRMS (ESI) \(m/z\) calcd. for C\textsubscript{16}H\textsubscript{17}O\textsubscript{2}\[M+H\]^+ 225.3050, found 225.3056.

2-(4-methoxyphenyl)cyclohexanone (3ga)

\[
\begin{array}{c}
\text{O} \\
\text{Me} \\
\end{array}
\]

Rf = 0.50 (SiO2, ethyl acetate/hexane, 1:9); white solid (61%);

\[^1\]H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 7.09 (d, \(J = 8.9\) Hz, 2H), 6.88 (d, \(J = 8.9\) Hz, 2H), 3.79 (s, 3H), 2.67 – 2.58 (m, 1H), 2.42 – 2.32 (m, 1H), 2.27 (dt, \(J = 6.9, 4.2\) Hz, 1H), 1.95 (ddd, \(J = 9.6, 4.6, 2.2\) Hz, 1H), 1.76 – 1.66 (m, 4H), 1.24 (s, 3H).

\[^13\]C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 214.43, 158.25, 135.36, 127.28, 114.42, 55.36, 53.70, 39.84, 38.42, 28.62, 28.56, 21.96.

HRMS (ESI) \(m/z\) calcd. for C\textsubscript{14}H\textsubscript{19}O\textsubscript{2}\[M+H\]^+ 219.2989, found 219.2995.

2-(3,4-dimethoxyphenyl)cyclohexanone (3ge)

\[
\begin{array}{c}
\text{O} \\
\text{Me} \\
\end{array}
\]

Rf = 0.40 (SiO2, ethyl acetate/hexane, 1:9); white solid (58%);

\[^1\]H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 6.77 (d, \(J = 8.1\) Hz, 1H), 6.69 (d, \(J = 8.1\) Hz, 1H), 6.61 (dd, \(J = 8.1, 1.9\) Hz, 1H), 5.94 (dd, \(J = 2.9, 1.4\) Hz, 2H), 2.60 – 2.52 (m, 1H), 2.44 – 2.35 (m, 1H), 2.32 – 2.24 (m, 1H), 1.96 (ddt, \(J = 12.5, 6.4, 3.1\) Hz, 1H), 1.81 – 1.66 (m, 4H), 1.23 (s, 3H).

\[^13\]C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 214.08, 148.34, 146.23, 137.28, 119.40, 108.76, 106.77, 101.20, 54.09, 39.87, 38.52, 28.64, 28.48, 21.93.

HRMS (ESI) \(m/z\) calcd. for C\textsubscript{14}H\textsubscript{17}O\textsubscript{3}\[M+H\]^+ 233.2824, found 233.2820.
2-(2,4-dimethoxyphenyl)cyclohexanone (3gf)

\[
\text{R}_f = 0.40 \text{ (SiO}_2\text{, ethyl acetate/hexane, 1:9); white solid (53%);} \\
\]

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.16 (d, \(J = 8.1\) Hz, 2H), 7.07 (d, \(J = 8.3\) Hz, 2H), 2.70 – 2.62 (m, 1H), 2.38 (td, \(J = 13.0, 5.9\) Hz, 1H), 2.33 (s, 3H), 2.31 – 2.25 (m, 1H), 1.99 – 1.90 (m, 1H), 1.77 – 1.66 (m, 4H), 1.25 (s, 3H).

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta\) 214.45, 140.41, 136.32, 129.80, 126.10, 77.16, 54.13, 39.97, 38.31, 28.63, 28.60, 22.00, 21.06.

HRMS (ESI) \(m/z\) calcd. for C\(_{14}\)H\(_{19}\)O\([M+H]^+\) 203.2995, found 203.2997.

2-((2,2,6,6-tetramethylpiperidin-1-yl)oxy)cyclohexanone (5)

R\(_f\) = 0.30 (SiO\(_2\), ethyl acetate/hexane, 1:9); yellowish liquid (69%);

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 4.16 (ddd, \(J = 7.0, 4.1, 1.4\) Hz, 1H), 2.80 – 2.71 (m, 1H), 2.29 – 2.21 (m, 1H), 2.16 – 2.06 (m, 1H), 2.00 (ddd, \(J = 9.4, 7.9, 4.0, 3.1\) Hz, 1H), 1.94 – 1.83 (m, 2H), 1.80 – 1.69 (m, 1H), 1.58 (ddd, \(J = 6.9, 6.2, 3.1\) Hz, 1H), 1.48 – 1.40 (m, 4H), 1.25 (s, 2H), 1.16 (s, 6H), 1.12 (s, 3H), 0.98 (s, 3H).

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta\) 212.07, 89.38, 41.11, 40.38, 34.98, 28.62, 22.25, 20.34, 17.25.

HRMS (ESI) \(m/z\) calcd. for C\(_{15}\)H\(_{28}\)NO\(_2\)\([M+H]^+\) 254.3878, found 254.2098.

References

6. This setup was used in the absence of a commercially available LED source in this wavelength range, Any lamp emitting at 410 nm with appropriate intensity (ca.6.0×1015 photons per second) can be used.
$^1$H and $^{13}$C spectra of Starting Material
$^1$H and $^{13}$C spectra of (1a)
$^{1}H$ and $^{13}C$ spectra of (1b)
$^1$H and $^{13}$C spectra of (1c)
$^1$H and $^{13}$C spectra of (1d)
$^{1}H$ and $^{13}C$ spectra of (1e)
$^1$H and $^{13}$C spectra of (1f)
$^1$H and $^{13}$C spectra of (1g)
$^1$H and $^{13}$C spectra of Products
$^1$H and $^{13}$C spectra of (3aa)
$^{1}H$ and $^{13}C$ spectra of (3ab)
$^{1}$H and $^{13}$C spectra of (3ac)
$^1$H and $^{13}$C spectra of (3ad)
$^1$H and $^{13}$C spectra of (3ae)
$^1$H and $^{13}$C spectra of (3af)
$^1$H and $^{13}$C spectra of (3ah)
$^1$H and $^{13}$C spectra of (3ai)
$^1$H and $^{13}$C spectra of (3aj)
$^1$H and $^{13}$C spectra of (3ak)
$^{1}H$ and $^{13}C$ spectra of (3al)
$^{1}H$ and $^{13}C$ spectra of (3an)
$^1$H and $^{13}$C spectra of (3ba)
$^1$H and $^{13}$C spectra of (3bb)
$^1$H and $^{13}$C spectra of (3bc)
$^1$H and $^{13}$C spectra of (3be)
$^{1}H$ and $^{13}C$ spectra of (3bf)
$^1$H and $^{13}$C spectra of (3bg)
$^1$H and $^{13}$C spectra of (3bi)
$^1$H and $^{13}$C spectra of (3bj)
$^1$H and $^{13}$C spectra of (3bk)
$^1$H and $^{13}$C spectra of (3bi)
$^1$H and $^{13}$C spectra of (3bn)
$^1$H and $^{13}$C spectra of (3ca)
$^1$H and $^{13}$C spectra of (3cb)
$^{1}\text{H}$ and $^{13}\text{C}$ spectra of (3cc)
$^1$H and $^{13}$C spectra of (3cd)
$^{1}H$ and $^{13}C$ spectra of (3ce)
$\text{^{1}H and ^{13}C spectra of (3ef)}$
$^1$H and $^{13}$C spectra of (3cg)
$^{1}\text{H}$ and $^{13}\text{C}$ spectra of (3ch)
$^1$H and $^{13}$C spectra of (3ci)
$^{1}\text{H}$ and $^{13}\text{C}$ spectra of (3ck)
\( ^1H \) and \( ^{13}C \) spectra of (3cl)
$^1$H and $^{13}$C spectra of (3da)
$^1$H and $^{13}$C spectra of (3db)
$^{1}H$ and $^{13}C$ spectra of (3dc)
$^{1}H$ and $^{13}C$ spectra of (3dd)
$^1$H and $^{13}$C spectra of (3de)
$^1\text{H}$ and $^{13}\text{C}$ spectra of (3df)
$^1$H and $^{13}$C spectra of (3dh)
$^1$H and $^{13}$C spectra of (3di)
$^{1}H$ and $^{13}C$ spectra of (3dj)
$^1$H and $^{13}$C spectra of (3dk)
$^1$H and $^{13}$C spectra of (3dl)
$^1$H and $^{13}$C spectra of (3dn)
$^1$H and $^{13}$C spectra of (3do)
$^1$H and $^{13}$C spectra of (3dp)
$^{1}H$ and $^{13}C$ spectra of (3ed)
$^{1}$$H$ and $^{13}$$C$ spectra of (3ee)
$^{1}H$ and $^{13}C$ spectra of (3el)
$^1$H and $^{13}$C spectra of (3fa)
$^1\text{H}$ and $^{13}\text{C}$ spectra of (3fl)
$^1$H and $^{13}$C spectra of (3ga)
$^1$H and $^{13}$C spectra of (3ge)
$^1$H and $^{13}$C spectra of (3gf)
$^{1}H$ and $^{13}C$ spectra of (5)