Supporting Information

Palladium-catalyzed formal arylacylation of allenes employing acid chlorides and arylboronic acids

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1. Instrument

All manipulations were performed under an atmosphere of argon, using standard Schlenk-type glasswares on a dual-manifold Schlenk line. All solvents were dried and purified by usual procedures.\(^1\) \(^1\)H and \(^{13}\)C\(^{\text{1H}}\) NMR were measured with a JEOL ECX-400 spectrometer. The \(^1\)H NMR chemical shifts are reported relative to tetramethylsilane (TMS, 0.00 ppm) or residual protiated solvent (7.26 ppm) in CDCl\(_3\). The \(^{13}\)C NMR chemical shifts are reported relative to CDCl\(_3\) (77.0 ppm). EI-MS were recorded on a Shimadzu GCMS-QP2010. IR spectra were obtained on Shimazu IRTracer-100 FT-IR Spectrometer equipped with Shimazu MIRacle A (Ge) Single Reflection HATR. APCI-HRMS were obtained with Thermo Scientific Exactive. Elemental analysis was carried out at Center for Organic Elemental Microanalysis, Graduate School of Pharmaceutical Science, Kyoto University. Melting points were measured on a Yanako MP-J3 apparatus. Medium pressure liquid chromatography (MPLC) was performed on Biotage Isorera One with a silica gel column (Biotage SNAP Ultra 25 g, HP-Sphere 25\(\mu\)m). Preparative recycling GPC was performed with SHIMADZU LC-20AP System equipped with Shodex K-4002.5L column, a SHIMADZU SPD-20A, and SHIMADZU RID-10A using CHCl\(_3\) as the eluent at a flow rate of 14 mL min\(^{-1}\). GC analysis was carried out using Shimadzu GC-17A with a capillary column (CBP-5, 0.25 mm i.d. \(\times\) 25 \(\mu\)m).

2. Preparation of Substrate

Unless otherwise noted, commercially available chemicals were used as received. Anhydrous toluene was purchased from Kanto Chemical and further purified by passage through activated alumina under positive argon pressure as described by Grubbs et al.\(^2\)

\(\text{Pd}_2(\text{dba})_3\cdot\text{CHCl}_3\) was synthesized according to a literature.\(^3\) CuCl was purified according to a literature.\(^1\) Acid chlorides \(1a-j\) were used after distillation under vacuum. Boronic acids \(3a-i\) were used after recrystallization from water. Allenes \(2a-e, 2f\) and \(2g\) were synthesized according to literatures.

Preparation of \(2d\)

\[
\text{Cl} \quad \xrightarrow{\text{Mg, Et}_2\text{O}} \quad \text{ClMg} \quad \xrightarrow{\text{CuBr, THF}} \quad 2d
\]

Mg turnings (8.76 g, 360 mmol) were activated by evacuation and heating with stirring in a flask equipped with a reflux condenser and a dropping funnel. The flask was backfilled with argon and Et\(_2\)O (15 mL) was added. Then, \(\text{t}-\text{amyl chloride (37.2 mL, 300 mmol) was transferred to the dropping funnel. After, a small portion of \(\text{t}-\text{amyl chloride was added to the reaction flask (ca. 1 mL), the remaining \(\text{t}-\text{amyl chloride was diluted with Et}_2\text{O (45 mL) in the dropping funnel. The solution was slowly added to the flask in 2 h. Then, the reaction mixture was stirred under reflux for 1 h. The mixture was filtered with a Celite pad to afford Grignard-reagent solution. Next, a mixture of propargyl chloride (12.6 mL, 175 mmol) and CuBr (1.0 g, 7.0 mmol) in THF (120 mL) was cooled to –40 °C. Then, the Grignard-reagent solution was added dropwise in 1 h and stirred at –40 °C for 30 min. The resulting mixture was slowly warmed up to room temperature and stirred overnight at room temperature. The reaction mixture was poured}\quad \text{ClMg} \quad \xrightarrow{\text{CuBr, THF}} \quad 2d
\]

S2
into NH₄Cl aq. The product was extracted with Et₂O, dried over MgSO₄, and evaporated in vacuo. After distillation (200 tor, 30–40 °C), 2d was obtained in 34 % yield (6.61 g, 60 mmol).

**1H NMR (400 MHz, CDCl₃)**: δ: 5.02 (t, J = 6.6 Hz, 1H), 4.70 (d, J = 6.8 Hz, 2H), 1.34 (q, J = 7.6 Hz, 2H), 0.99 (s, 6H), 0.84 (t, J = 7.5 Hz, 3H).

**13C NMR (100 MHz, CDCl₃)**: δ: 206.70, 100.34, 76.02, 35.63, 34.32, 27.31, 8.98.

**IR (ATR)**: 839.0, 869.9, 1014.6, 1057.0, 1095.6, 1261.5, 1462.0, 1955.8, 2964.6 cm⁻¹.

**HRMS (APCI)**: Calcd. for C₈H₁₅ ([M+H]+), 111.1168. Found, 111.1173.

### 3. Experimental Procedure

#### 3.1. Typical procedure in Table 1 (Entry 1)

To a 10-mL Schlenk flask with a reflux condenser was added K₂PO₄·H₂O (92 mg, 0.40 mmol), and the whole system was dried under evacuation and heating with stirring. The flask was backfilled with argon and Pd₂(dba)·CHCl₃ (10.3 mg, 0.010 mmol, 5.0 mol %), CuCl (0.020 mmol, 10 mol %) and phenylboronic acid (3a, 36.6 mg, 0.30 mmol) were charged. The flask was evacuated and backfilled with argon three times. Then, toluene (3.6 mL) and MeCN (0.4 mL) were added to the flask. To the mixture, H₂O (14 μL, 0.80 mmol), cyclohexylallene (2a, 30 μL, 0.20 mmol) and 3-phenylpropionyl chloride (1a, 60 μL, 0.40 mmol) were added in this order, and the mixture was stirred at 50 °C for 3 h. After cooling to room temperature, the reaction mixture was analyzed by GC using tetradecane (50 μL) as an internal standard.

Regarding the isolation of (E)-4a, the reaction mixture was filtrated through a pad of silica gel and all volatiles were removed in vacuo. (E)-4a was obtained by MPLC (Hexane/EtOAc = 98/2) in 80% yield. The stereochemistry of the product (E)-4a was determined by 2D NMR measurements (See pages S41).

#### 3.2. Effect of base and additives

To a 10-mL Schlenk flask with a reflux condenser was added a base (0.40 mmol), and the whole system was dried under evacuation and heating with stirring. The flask was backfilled with argon, then Pd₂(dba)·CHCl₃ (10.3 mg, 0.010 mmol, 5.0 mol %), an additive (0.020 mmol, 10 mol %) and phenylboronic acid (3a, 36.6 mg, 0.30 mmol) were charged. The flask was evacuated and backfilled with argon three times. Then, toluene (3.6 mL) and MeCN (0.4 mL) were added to the flask. To the mixture, H₂O (14 μL, 0.80 mmol), cyclohexylallene (2a, 30 μL, 0.20 mmol) and 3-phenylpropionyl chloride (1a, 60 μL, 0.40 mmol) were added in this order, and the mixture was stirred at 50 °C for 3 h. After cooling to room temperature, the reaction mixture was analyzed by GC using tetradecane (50 μL) as an internal standard.
Table S1. Effect of bases

<table>
<thead>
<tr>
<th>Entry</th>
<th>Base</th>
<th>Total Yield of 4a (%)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>(E)-4a/Other Isomer&lt;sup&gt;c&lt;/sup&gt;</th>
<th>5 (mmol)</th>
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<tbody>
<tr>
<td>1</td>
<td>K&lt;sub&gt;3&lt;/sub&gt;PO&lt;sub&gt;4&lt;/sub&gt;</td>
<td>86 (80)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>96/4</td>
<td>0.034</td>
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<tr>
<td>2</td>
<td>Na&lt;sub&gt;3&lt;/sub&gt;PO&lt;sub&gt;4&lt;/sub&gt;</td>
<td>53</td>
<td>97/3</td>
<td>0.030</td>
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<tr>
<td>3</td>
<td>K&lt;sub&gt;2&lt;/sub&gt;CO&lt;sub&gt;3&lt;/sub&gt;</td>
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<td>96/4</td>
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<td>Cs&lt;sub&gt;2&lt;/sub&gt;CO&lt;sub&gt;3&lt;/sub&gt;</td>
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<td>97/3</td>
<td>0.020</td>
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<tr>
<td>5</td>
<td>Na&lt;sub&gt;2&lt;/sub&gt;CO&lt;sub&gt;3&lt;/sub&gt;</td>
<td>47</td>
<td>97/3</td>
<td>0.018</td>
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<tr>
<td>6</td>
<td>KOAc</td>
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<td>-</td>
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<td>KF</td>
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<td>97/3</td>
<td>0.015</td>
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<td>KOtBu</td>
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</table>

<sup>a</sup> Reaction conditions: 3-phenypropionyl chloride (1a, 0.40 mmol), cyclohexyllallene (2a, 0.20 mmol), phenylboronic acid (3a, 0.30 mmol), Pd<sub>2</sub>(dba)<sub>3·CHCl</sub> (0.010 mmol, 5.0 mol %), CuCl (0.020 mmol, 10 mol %), base (0.40 mmol), H<sub>2</sub>O (0.80 mmol) in toluene/MeCN = 9/1 (4.0 mL), at 50 ºC, for 3 h. <sup>b</sup> Yield by the GC internal standard method. <sup>c</sup> Determined by GC. <sup>d</sup> Isolated yield of (E)-4a.
### Table S2. Effect of additives

<table>
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<tr>
<th>Entry</th>
<th>Additive</th>
<th>Total Yield of 4a (%)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>(E)-4a/Other Isomer&lt;sup&gt;c&lt;/sup&gt;</th>
<th>5 (mmol)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<td>0.014</td>
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<td>2</td>
<td>CuCl</td>
<td>86 (80)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>96/4</td>
<td>0.034</td>
</tr>
<tr>
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<td>CuBr</td>
<td>61</td>
<td>97/3</td>
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<td>96/4</td>
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<td>CuOAc&lt;sub&gt;2&lt;/sub&gt;</td>
<td>79</td>
<td>96/4</td>
<td>0.024</td>
</tr>
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</table>

<sup>a</sup> Reaction conditions: 3-phenypropionyl chloride (1a, 0.40 mmol), cyclohexyllallene (2a, 0.20 mmol), phenylboronic acid (3a, 0.30 mmol), Pd<sub>2</sub>(dba)<sub>3</sub>·CHCl<sub>3</sub> (0.010 mmol, 5.0 mol %), additive (0.020 mmol, 10 mol %), K<sub>3</sub>PO<sub>4</sub> (0.40 mmol), H<sub>2</sub>O (0.80 mmol) in toluene/MeCN = 9/1 (4.0 mL), at 50 ºC, for 3 h. <sup>b</sup> Yield by the GC internal standard method. <sup>c</sup> Determined by GC. <sup>d</sup> Isolated yield of (E)-4a.

#### 3.3. General procedure in Table 2

To a 10-mL Schlenk flask with a reflux condenser was added K<sub>3</sub>PO<sub>4</sub>·H<sub>2</sub>O (92 mg, 0.40 mmol), and the whole system was dried under evacuation and heating with stirring. The flask was backfilled with argon, then Pd<sub>2</sub>(dba)<sub>3</sub>·CHCl<sub>3</sub> (10.3 mg, 0.010 mmol, 5.0 mol %), CuCl (2.0 mg, 0.020 mmol, 10 mol %) and phenylboronic acid (3a, 36.6 mg, 0.30 mmol) were charged. The flask was evacuated and backfilled with argon three times. Then, toluene (3.6 mL) and MeCN (0.4 mL) were added to the flask. To the mixture, H<sub>2</sub>O, cyclohexyllallene (2a, 30 μL, 0.20 mmol) and acid chloride (0.40 mmol) were added in this order, and the mixture was stirred at 50 ºC for 3 h. After cooling to room temperature, all volatiles were removed in vacuo. The product was isolated by MPLC or preparative recycling GPC. The stereochemistry of the product 4b–j was determined by 2D NMR measurements. As typical examples, NOESY spectra of 4g and 4h was shown in Section 5 (See pages S41 and S42).

#### 3.4. General procedure in Table 3

To a 10-mL Schlenk flask with a reflux condenser was added K<sub>3</sub>PO<sub>4</sub>·H<sub>2</sub>O (92 mg, 0.40 mmol), and the whole system was dried under evacuation and heating with stirring. The flask was backfilled with argon, then
Pd$_2$dba$_3$·CHCl$_3$ (10.3 mg, 0.010 mmol, 5.0 mol %), CuCl (2.0 mg, 0.020 mmol, 10 mol %) and phenylboronic acid (3a, 36.6 mg, 0.30 mmol) were charged. The flask was evacuated and backfilled with argon three times. Then, toluene (3.6 mL) and MeCN (0.4 mL) were added to the flask. To the mixture, H$_2$O, allene (0.20 mmol) and 3-phenylpropionyl chloride (1a, 60 μL, 0.40 mmol) were added in this order, and the mixture was stirred at 50 °C for 3 h. After cooling to room temperature, all volatiles were removed in vacuo. The product was isolated by MPLC or preparative recycling GPC. The stereochemistry of the product 4k–p was determined by 2D NMR measurements. As a typical example, a NOESY spectrum of 4n was shown in Section 5 (See page S42).

3.5. General procedure in Table 4

To a 10-mL Schlenk flask with a reflux condenser was added K$_3$PO$_4$·H$_2$O (92 mg, 0.40 mmol), and the whole system was dried under evacuation and heating with stirring. The flask was backfilled with argon, then Pd$_2$dba$_3$·CHCl$_3$ (10.3 mg, 0.010 mmol, 5.0 mol %), CuCl (2.0 mg, 0.020 mmol, 10 mol %) and boronic acid (0.30 mmol) were charged. The flask was evacuated and backfilled with argon three times. Then, toluene (3.6 mL) and MeCN (0.4 mL) were added to the flask. To the mixture, H$_2$O, cyclohexylallene (2a, 30 μL, 0.20 mmol) and 3-phenylpropionyl chloride (1a, 60 μL, 0.40 mmol) were added in this order, and the mixture was stirred at 50 °C for 3 h. After cooling to room temperature, all volatiles were removed in vacuo. The product was isolated by MPLC or preparative recycling GPC. The stereochemistry of the product 4q–x was determined by 2D NMR measurements. As a typical example, a NOESY spectrum of 4x was shown in Section 5 (See page S43).

\( (E) \)-2-benzyl-1-cyclohexyl-5-phenylpent-1-en-3-one (4a)

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

Isolated by MPLC (hexane/EtOAc = 98/2). Colorless oil. 53.3 mg, 80% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.28-7.10 (m, 10H), 6.52 (d, \(J = 9.5\) Hz, 1H), 3.69 (s, 2H), 2.98-2.93 (m, 2H), 2.90-2.85 (m, 2H), 2.48 (tdt, \(J = 10.9, 10.0, 3.6\) Hz, 1H), 1.76-1.55 (m, 5H), 1.33-1.06 (m, 5H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 200.66, 148.93, 141.53, 140.23, 138.13, 128.41, 128.38, 128.29, 128.17, 125.96, 125.77, 39.37, 38.35, 32.03, 31.41, 30.63, 25.74, 25.41. IR (ATR): 902.7, 974.1, 1030.0, 1074.4, 1126.4, 1178.5, 1450.5, 1494.8, 1602.9, 1633.7, 1668.4, 2850.8, 2926.0, 3026.3 cm\(^{-1}\). HRMS (APCI): Calcd. for C\(_{24}\)H\(_{29}\)O ([M+H]\(^{+}\)), 333.2213. Found, 333.2200.

\( (E) \)-2-benzyl-1-cyclohexyldec-1-en-3-one (4b)

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

Isolated by MPLC (hexane/EtOAc = 98/2). Colorless oil. 52.2 mg, 80% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.25-7.20 (m, 2H), 7.15-7.11 (m, 3H), 6.53 (d, \(J = 9.5\) Hz, 1H), 3.68 (s, 2H), 2.61 (t, \(J = 7.5\) Hz, 2H), 2.49 (tdt, \(J = 10.9, 10.0, 3.6\) Hz, 1H), 1.77-1.51 (m, 7H), 1.33-1.12 (m, 13H), 0.86 (t, \(J = 6.8\) Hz, 3H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 202.12, 148.34, 140.36, 138.24, 128.23, 128.16, 125.70, 38.31, 37.50, 32.10, 31.66, 29.22, 29.07, 25.77, 25.44, 24.88, 22.56, 14.04. IR (ATR): 746.5, 900.8, 972.1, 1030.0, 1074.4, 1132.2, 1450.5, 1494.8, 1668.4, 2852.7, 2926.0 cm\(^{-1}\). Anal. Calcd. for C\(_{23}\)H\(_{34}\)O: C, 84.60; H, 10.50. Found: C, 84.64; H, 10.64. EIMS: \(m/z\) 327 (26%, [M+1]\(^{+}\)), 326 (100, [M]\(^{+}\)), 243 (76), 227 (82), 117 (74), 91 (96).

\( (E) \)-3-benzyl-4-cyclohexyl-1-phenylbut-3-en-2-one (4c)

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

Isolated by MPLC (hexane/EtOAc = 98/2). Pale yellow oil. 51.2 mg, 80% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.28-7.03 (m, 10H), 6.66 (d, \(J = 10.0\) Hz, 1H), 3.95 (s, 2H), 3.67 (s, 2H), 2.48 (tdt, \(J = 10.9, 10.0, 3.6\) Hz, 1H), 1.76-1.56 (m, 5H), 1.32-1.09 (m, 5H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 199.19, 150.01, 139.96, 137.65, 135.32, 129.25, 128.40, 128.21, 128.14, 126.50, 125.72, 44.64, 38.37, 31.96, 31.47, 25.72, 25.33. IR (ATR): 746.5, 974.1, 1030.0, 1074.4, 1126.4, 1450.5, 1494.8, 1664.6, 2850.8, 2926.0 cm\(^{-1}\). HRMS (APCI): Calcd. for C\(_{23}\)H\(_{27}\)O ([M+H]\(^{+}\)), 319.2056. Found, 319.2053.

\( (E) \)-3-benzyl-4-cyclohexyl-1-phenoxypent-3-en-2-one (4d)
Isolated by preparative recycling GPC. Pale yellow oil. 56.0 mg, 84% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.24-7.18 (m, 4H), 7.17-7.09 (m, 3H), 6.93 (tt, $J = 7.5, 1.1$ Hz, 1H), 6.80-6.75 (m, 2H), 6.63 (d, $J = 10.0$ Hz, 1H), 4.92 (s, 2H), 3.71 (s, 2H), 2.53 (t, $J = 10.9, 10.4, 3.6$ Hz, 1H), 1.77-1.60 (m, 5H), 1.33-1.12 (m, 5H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 196.08, 157.93, 149.85, 139.60, 136.32, 129.43, 128.38, 128.24, 125.96, 121.32, 114.68, 70.27, 38.33, 31.93, 31.45, 25.70, 25.36. IR (ATR): 752.2, 785.0, 1030.0, 1130.3, 1174.7, 1230.6, 1450.5, 1494.8, 1599.0, 1631.8, 1687.7, 2850.8, 2926.0 cm$^{-1}$. Anal. Calcd. for C$_{23}$H$_{26}$O$_2$: C, 82.60; H, 7.84. Found: C, 82.86; H, 7.99. EIMS: m/z 334 (9%, [M]+), 227 (100), 117 (50), 91 (59).

methyl (E)-5-benzyl-6-cyclohexyl-4-oxohex-5-enoate (4e)

Isolated by MPLC (hexane/EtOAc = 95/5). Colorless oil. 43.5 mg, 69% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.25-7.20 (m, 2H), 7.16-7.11 (m, 3H), 6.62 (d, $J = 10.0$ Hz, 1H), 3.69 (s, 2H), 3.65 (s, 3H), 3.00 (t, $J = 6.8$ Hz, 2H), 2.58 (t, $J = 6.8$ Hz, 2H), 2.50 (t, $J = 10.9, 10.4, 3.6$ Hz, 1H), 1.79-1.57 (m, 5H), 1.34-1.11 (m, 5H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 199.21, 173.51, 149.16, 140.09, 137.75, 128.25, 128.04, 125.74, 51.62, 38.32, 32.30, 31.98, 31.37, 28.18, 25.70, 25.37. IR (ATR): 842.9, 902.7, 1030.0, 1076.3, 1126.4, 1166.9, 1215.2, 1361.7, 1437.0, 1450.5, 1494.8, 1670.4, 1737.9, 2850.8, 2926.0 cm$^{-1}$. HRMS (APCI): Calcd. for C$_{20}$H$_{27}$O$_3$ ([M+H]$^+$), 315.1955. Found, 315.1951.

(E)-2-benzyl-1,3-dicyclohexylprop-2-en-1-one (4f)

Isolated by MPLC (hexane/EtOAc = 98/2). Colorless oil. 37.5 mg, 60% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.25-7.20 (m, 2H), 7.14-7.10 (m, 3H), 6.49 (d, $J = 10.0$ Hz, 1H), 3.68 (s, 2H), 2.98 (tt, $J = 11.1, 3.2$ Hz, 1H), 2.50 (t, $J = 10.9, 10.0, 3.9$ Hz, 1H), 1.77-1.60 (m, 10H), 1.37-1.12 (m, 10H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 205.39, 147.57, 140.43, 137.22, 128.20, 128.14, 125.65, 44.38, 38.34, 32.13, 31.52, 29.71, 25.89, 25.83, 25.78, 25.47. IR (ATR): 734.9, 821.7, 906.5, 1030.0, 1074.4, 1118.7, 1141.9, 1255.7, 1311.6, 1450.5, 1494.8, 1664.6, 2852.7, 2926.0 cm$^{-1}$. Anal. Calcd. for C$_{22}$H$_{30}$O: C, 85.11; H, 9.74. Found: C, 84.91; H, 9.70. EIMS: m/z 310 (52%, [M$^+$]), 227 (100), 117 (42), 91 (40).

(E)-2-benzyl-1-cyclohexyl-4,4-dimethylpent-1-en-3-one (4g)
Isolated by preparative recycling GPC as mixture of inseparable isomers ($E/Z = 89/11$). Colorless oil. 32.4 mg, 57% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.30-7.12 (m, 5H), 6.09 (d, $J = 9.5$ Hz, 1H), 3.66 (s, 2H), 2.46 (ttd, $J = 10.9$, 9.5, 3.4 Hz, 1H), 1.79-1.59 (m, 5H), 1.36-1.07 (m, 5H), 1.11 (s, 9H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 210.51, 142.27, 139.82, 136.86, 128.49, 128.25, 125.87, 43.79, 37.80, 33.92, 32.47, 28.55, 25.84, 25.53. IR (ATR): 742.6, 902.7, 966.3, 1030.0, 1074.4, 1114.9, 1365.6, 1394.5, 1477.5, 1494.8, 1672.3, 2850.8, 2926.0 cm$^{-1}$. Anal. Calcd. for C$_{20}$H$_{28}$O: C, 84.45; H, 9.92. Found: C, 84.33; H, 9.96. HRMS (APCI): Calcd. for C$_{20}$H$_{29}$O ($[M+H]^+$), 285.2213. Found, 285.2211.

$(E)$-2-benzyl-3-cyclohexyl-1-phenylprop-2-en-1-one (4h)

Isolated by MPLC (hexane/EtOAc = 98/2). Pale yellow oil. 44.3 mg, 73% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.63-7.59 (m, 2H), 7.49-7.45 (m, 1H), 7.40-7.35 (m, 2H), 7.27-7.22 (m, 4H), 7.18-7.12 (m, 1H), 6.16 (d, $J = 10.0$ Hz, 1H), 3.87 (s, 2H), 2.59 (ttd, $J = 10.9$, 10.4, 3.6 Hz, 1H), 1.76-1.61 (m, 5H), 1.36-1.04 (m, 5H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 198.51, 151.67, 139.98, 138.71, 137.53, 131.50, 129.44, 128.37, 128.33, 127.99, 125.89, 38.44, 32.48, 32.05, 25.71, 25.40. IR (ATR): 711.7, 785.0, 960.6, 1028.1, 1070.5, 1176.6, 1226.7, 1276.9, 1315.5, 1446.6, 1494.8, 1597.1, 1649.1, 2850.8, 2924.1 cm$^{-1}$. Anal. Calcd. for C$_{22}$H$_{24}$O: C, 86.80; H, 7.95. Found: C, 86.95; H, 8.19. EIMS: m/z 305 (23%, [M+1]$^+$), 304 (100, [M]$^+$), 221 (55), 105 (81), 91 (43), 77 (42).

$(E)$-2-benzyl-3-cyclohexyl-1-(4-methoxyphenyl)prop-2-en-1-one (4i)

Isolated by MPLC (hexane/EtOAc = 98/2). Pale yellow oil. 44.1 mg, 66% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.66 (dt, $J = 9.4$, 2.5 Hz, 2H), 7.25-7.21 (m, 4H), 7.17-7.11 (m, 1H), 6.88 (dt, $J = 9.4$, 2.4 Hz, 2H), 6.08 (d, $J = 10.0$ Hz, 1H), 3.86 (s, 2H), 3.83 (s, 3H), 2.58 (ttd, $J = 10.9$, 10.4, 3.5 Hz, 1H), 1.75-1.64 (m, 5H), 1.36-1.08 (m, 5H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 197.41, 162.59, 149.48, 140.04, 137.41, 131.86, 131.10, 128.38, 125.87, 113.29, 55.37, 38.29, 32.93, 32.22, 25.77, 25.48. (One aromatic carbon peak was overlapped.) IR (ATR): 761.9, 842.9, 1030.0, 1168.9, 1228.7, 1253.7, 1448.5, 1508.3, 1599.0, 1641.4, 2924.1 cm$^{-1}$. HRMS (APCI): Calcd. for C$_{23}$H$_{27}$O$_2$ ([M+H]$^+$), 335.2006. Found, 335.1998.
Isolated by MPLC (hexane/EtOAc = 98/2). White solid. 49.1 mg, 72% yield. M.p. 80-81 ºC.

1H NMR (400 MHz, CDCl₃) δ: 7.55 (dt, J = 8.8, 2.3 Hz, 2H), 7.36 (dt, J = 8.9, 2.0 Hz, 2H), 7.27-7.20 (m, 4H), 7.17-7.12 (m, 1H), 6.12 (d, J = 9.5 Hz, 1H), 3.85 (s, 2H), 2.59 (tdd, J = 11.3, 10.0, 3.9 Hz, 1H), 1.7-1.62 (m, 5H), 1.36-1.05 (m, 5H).

13C NMR (100 MHz, CDCl₃) δ: 197.25, 151.60, 139.76, 137.85, 137.47, 136.97, 130.82, 128.43, 128.32, 128.29, 125.99, 38.43, 32.53, 32.06, 25.69, 25.37.

IR (ATR): 740.7, 754.2, 825.5, 947.1, 1014.6, 1226.7, 1275.0, 1302.0, 1446.6, 1494.8, 1589.3, 1645.3, 2846.9, 2924.1 cm⁻¹.


(E)-4-benzyl-1,7-diphenylhept-4-en-3-one (4k)

Isolated by MPLC (hexane/EtOAc = 98/2). Pale yellow oil. 42.5 mg, 60% yield. 1H NMR (400 MHz, CDCl₃) δ: 7.29-7.11 (m, 13H), 7.07-7.04 (m, 2H), 6.75 (t, J = 7.2 Hz, 1H), 3.64 (s, 2H), 2.96-2.91 (m, 2H), 2.89-2.85 (m, 2H), 2.71 (t, J = 7.7 Hz, 2H), 2.64-2.58 (m, 2H). 13C NMR (100 MHz, CDCl₃) δ: 200.17, 142.83, 141.36, 140.76, 140.72, 139.75, 128.50, 128.40, 128.34, 128.32, 128.29, 128.21, 126.23, 125.97, 125.83, 39.27, 34.74, 31.24, 31.10, 30.65.

IR (ATR): 939.3, 1030.0, 1452.4, 1494.8, 1602.9, 1678.1, 2927.9, 3026.3 cm⁻¹.


(E)-4-benzyl-6-methyl-1-phenylundec-4-en-3-one (4l)

Isolated by MPLC (hexane/EtOAc = 98/2). Colorless oil. 55.0 mg, 79% yield. 1H NMR (400 MHz, CDCl₃) δ: 7.29-7.09 (m, 10H), 6.47 (d, J = 10.4 Hz, 1H), 3.68 (s, 2H), 3.00-2.95 (m, 2H), 2.92-2.86 (m, 2H), 2.68-2.57 (m, 1H), 1.37-1.14 (m, 8H), 0.96 (d, J = 6.8 Hz, 3H), 0.85 (t, J = 6.8 Hz, 3H). 13C NMR (100 MHz, CDCl₃) δ: 200.59, 150.05, 141.49, 140.21, 138.67, 128.41, 128.37, 128.25, 128.20, 125.97, 125.74, 39.38, 36.82, 33.78, 31.85, 31.39, 30.70, 27.09, 22.51, 20.02, 13.99. IR (ATR): 734.9, 1030.0, 1076.3, 1124.5, 1452.4, 1494.8, 1602.9, 1668.4, 2926.0, 2956.9 cm⁻¹. Anal. Calcd. for C₂₅H₃₂O: C, 86.15; H, 9.25. Found: C, 86.08; H, 9.44. EIMS: m/z 348 (11%, [M+2]⁺), 250 (20), 149 (100), 105 (18), 91 (55).

(E)-4-benzyl-6,6-dimethyl-1-phenyloct-4-en-3-one (4m)

Isolated by MPLC (hexane/EtOAc = 98/2). Colorless oil. 57.6 mg, 90% yield. 1H NMR (400 MHz, CDCl₃) δ: 7.27-7.11 (m, 8H), 7.07 (d, J = 7.2 Hz, 2H), 6.67 (s, 1H), 3.86 (s, 2H), 2.97-2.93 (m, 2H), 2.88-2.83 (m, 2H), 1.47 (q, J = 7.4 Hz, 2H), 1.13 (s, 6H), 0.84 (t, J = 7.5 Hz, 3H). 13C NMR (100 MHz, CDCl₃) δ: 201.72, 151.76, 141.47, 139.97,
139.00, 128.38, 128.35, 128.23, 127.89, 125.94, 125.65, 39.82, 37.13, 36.61, 31.62, 30.72, 27.66, 9.22. IR (ATR): 729.1, 748.4, 987.6, 1030.0, 1076.3, 1155.4, 1452.4, 1494.8, 1602.9, 1672.3, 2962.7 cm⁻¹. Anal. Calcd. for C₂₃H₂₈O: C, 86.20; H, 8.81. Found: C, 86.41; H, 8.69.

EIMS: m/z 320 (10, [M]+), 250 (23), 249 (100), 105 (31), 91 (81).

(É)-2-benzyl-1,5-diphenylpent-1-en-3-one (4n)

Isolated by MPLC (hexane/EtOAc = 98/2). Pale yellow oil. 25.1 mg, 38% yield. ¹H NMR (400 MHz, CDCl₃) δ: 7.71 (s, 1H), 7.35-7.23 (m, 9H), 7.22-7.16 (m, 4H), 7.12 (d, J = 7.2 Hz, 2H), 3.95 (s, 2H), 3.12 (t, J = 7.5 Hz, 2H), 2.96 (t, J = 7.7 Hz, 2H). ¹³C NMR (100 MHz, CDCl₃) δ: 200.82, 141.35, 140.35, 139.48, 139.42, 135.30, 129.18, 128.87, 128.59, 128.46, 128.41, 127.93, 126.03, 39.82, 32.35, 30.54. (One aromatic carbon peak was overlapped.) IR (ATR): 750.3, 993.3, 1030.0, 1076.3, 1159.2, 1211.3, 1452.4, 1494.8, 1602.9, 1668.4, 3026.3 cm⁻¹.


EIMS: m/z 327 (21%, [M+1]+), 326 (81, [M]+), 235 (41), 221 (50), 115 (71), 91 (100).

4-benzyl-5-butyl-1-phenylnon-4-en-3-one (4o)

Isolated by MPLC (hexane/EtOAc = 97/3). Colorless oil. 58.8 mg, 81% yield. ¹H NMR (400 MHz, CDCl₃) δ: 7.28-7.11 (m, 8H), 7.05-7.02 (m, 2H), 3.63 (s, 2H), 2.75-2.66 (m, 2H), 2.63-2.57 (m, 2H), 1.46-1.23 (m, 8H), 0.89 (t, J = 7.2 Hz, 6H). ¹³C NMR (100 MHz, CDCl₃) δ: 207.33, 145.24, 141.28, 139.02, 135.23, 128.51, 128.30, 126.21, 125.84, 44.70, 35.06, 33.35, 31.87, 31.31, 30.60, 29.78, 23.01, 22.97, 13.95, 13.93. (2 aromatic carbon peaks were overlapped.) IR (ATR): 1030.0, 1074.4, 1138.0, 1454.3, 1494.8, 1602.9, 1687.7, 2929.9, 2956.9 cm⁻¹. HRMS (APCI): Calcd. for C₂₆H₃₅O ([M+H]+), 363.2682. Found, 363.2674.

3-phenyl-1-[(É)-9-phenylcyclonon-1-en-1-yl]propan-1-one (4p)

Isolated by MPLC (hexane/EtOAc = 98/2). Colorless oil. 60.4 mg, 91% yield. ¹H NMR (400 MHz, CDCl₃) δ: 7.27-7.20 (m, 6H), 7.17-7.08 (m, 4H), 6.84 (dd, J = 10.0, 8.2 Hz, 1H), 4.33 (dd, J = 12.2, 5.0 Hz, 1H), 2.98-2.78 (m, 4H), 2.71-2.62 (m, 1H), 2.47-2.33 (m, 2H), 1.98-1.90 (m, 1H), 1.75-1.42 (m, 8H). ¹³C NMR (100 MHz, CDCl₃) δ: 200.94, 144.24, 144.05, 143.32, 141.46, 128.33, 128.26, 128.09, 127.28, 125.87, 125.62, 42.11, 40.13, 31.46, 30.62, 28.45, 27.23, 26.42, 26.38, 25.82. IR (ATR): 750.3, 1138.0, 1452.4, 1494.8, 1600.9, 1668.4, 2924.1, 3026.3 cm⁻¹. Anal.
Calcd. for C_{24}H_{28}O: C, 86.70; H, 8.49. Found: C, 86.73; H, 8.71. **EIMS**: m/z 332 (24%, [M]+), 228 (27), 227 (88), 105 (56), 91 (100).

((E)-1-cyclohexyl-2-[(4-methoxyphenyl)methyl]-5-phenylpent-1-en-3-one (4q))

Isolated by MPLC (hexane/EtOAc = 97/3). Colorless oil. 59.1 mg, 82% yield. **H NMR (400 MHz, CDCl₃)** δ: 7.28-7.23 (m, 2H), 7.20-7.13 (m, 3H), 7.04 (dt, J = 8.6, 2.5 Hz, 2H), 6.78 (dt, J = 9.4, 2.5 Hz, 2H), 6.49 (d, J = 9.5 Hz, 1H), 3.76 (s, 3H), 3.62 (s, 2H), 2.97-2.92 (m, 2H), 2.90-2.85 (m, 2H), 2.49 (t, J = 10.9, 10.0, 3.6 Hz, 1H), 1.76-1.57 (m, 5H), 1.33-1.06 (m, 5H). **13C NMR (100 MHz, CDCl₃)** δ: 200.77, 157.69, 148.55, 141.54, 138.47, 132.26, 129.11, 128.39, 128.37, 125.95, 113.71, 55.19, 39.40, 38.30, 32.08, 30.63, 30.54, 25.75, 25.43. **IR (ATR)**: 750.3, 817.8, 1035.8, 1126.4, 1176.6, 1246.0, 1300.0, 1448.5, 1510.3, 1610.6, 1668.4, 2850.8, 2926.0 cm⁻¹. **Anal. Calcd.** for C_{25}H_{30}O₂: C, 82.83; H, 8.34. Found: C, 82.73; H, 8.43. **EIMS**: m/z 362 (47%, [M]+), 279 (87), 257 (32), 163 (32), 121 (100), 108 (35), 91 (54).

((E)-1-cyclohexyl-2-[(4-fluorophenyl)methyl]-5-phenylpent-1-en-3-one (4r))

Isolated by MPLC (hexane/EtOAc = 97/3). Colorless oil. 60.7 mg, 87% yield. **H NMR (400 MHz, CDCl₃)** δ: 7.26 (t, J = 7.2 Hz, 2H), 7.20-7.14 (m, 3H), 7.07 (dd, J = 8.8, 5.7 Hz, 2H), 6.90 (tt, J = 8.8, 2.3 Hz, 2H), 6.51 (d, J = 10.0 Hz, 1H), 3.64 (s, 2H), 2.98-2.94 (m, 2H), 2.91-2.86 (m, 2H), 2.45 (t, J = 10.9, 10.4, 3.6 Hz, 1H), 1.76-1.54 (m, 5H), 1.32-1.06 (m, 5H). **13C NMR (100 MHz, CDCl₃)** δ: 200.60, 161.14 (d, J = 244.1 Hz), 149.05, 141.41, 138.14, 135.88 (d, J = 3.8 Hz), 129.51 (d, J = 7.6 Hz), 128.40, 128.35, 125.97, 114.97 (d, J = 21.0 Hz), 39.22, 38.39, 31.99, 30.61, 30.58, 25.68, 25.37. **IR (ATR)**: 750.3, 821.7, 902.7, 1016.5, 1093.6, 1126.4, 1157.3, 1220.9, 1448.5, 1506.4, 1602.9, 1668.4, 2850.8, 2926.0 cm⁻¹. **HRMS (APCI)**: Calcd. for C_{24}H_{28}FO ([M+H]+), 351.2119. Found, 351.2106.

((E)-2-[(4-chlorophenyl)methyl]-1-cyclohexyl-5-phenylpent-1-en-3-one (4s))

Isolated by MPLC (hexane/EtOAc = 98/2). Colorless oil. 66.0 mg, 90% yield. **H NMR (400 MHz, CDCl₃)** δ: 7.29-7.22 (m, 2H), 7.22-7.13 (m, 5H), 7.04 (dt, J = 8.8, 2.3 Hz, 2H), 6.52 (d, J = 10.0 Hz, 1H), 3.63 (s, 2H), 2.99-2.93 (m, 2H), 2.91-2.86 (m, 2H), 2.44 (t, J = 10.9, 10.0, 4.1 Hz, 1H), 1.77-1.54 (m, 5H), 1.33-1.06 (m, 5H). **13C NMR (100 MHz, CDCl₃)** δ: 200.60, 161.14 (d, J = 244.1 Hz), 149.05, 141.41, 138.14, 135.88 (d, J = 3.8 Hz), 129.51 (d, J = 7.6 Hz), 128.40, 128.35, 125.97, 114.97 (d, J = 21.0 Hz), 39.22, 38.39, 31.99, 30.61, 30.58, 25.68, 25.37. **IR (ATR)**: 750.3, 821.7, 902.7, 1016.5, 1093.6, 1126.4, 1157.3, 1220.9, 1448.5, 1506.4, 1602.9, 1668.4, 2850.8, 2926.0 cm⁻¹. **HRMS (APCI)**: Calcd. for C_{24}H_{28}FO ([M+H]+), 351.2119. Found, 351.2106.
MHz, CDCl3) δ: 200.55, 149.28, 141.39, 138.76, 137.87, 131.48, 129.52, 128.42, 128.37, 126.01, 39.21, 38.44, 32.01, 30.79, 30.63, 25.69, 25.38. (One aromatic carbon peak was overlapped.) IR (ATR): 750.3, 902.7, 1014.6, 1091.7, 1126.4, 1178.5, 1448.5, 1491.0, 1668.4, 2850.8, 2926.0 cm⁻¹. Anal. Calcd. for C24H27OCl: C, 78.56; H, 7.42. Found: C, 78.48; H, 7.49.

EIMS: m/z 366 (11%, [M⁺]), 285 (33), 284 (21), 283 (100), 125 (30), 91 (41).

(E)-2-[(4-bromophenyl)methyl]-1-cyclohexyl-5-phenylpent-1-en-3-one (4t)

Isolated by preparative recycling GPC. Colorless oil. 69.3 mg, 84% yield. ¹H NMR (400 MHz, CDCl3) δ: 7.33 (dt, J = 9.1, 2.2 Hz, 2H), 7.28-7.24 (m, 2H), 7.20-7.14 (m, 3H), 6.98 (d, J = 8.2 Hz, 2H), 6.52 (d, J = 10.0 Hz, 1H), 3.61 (s, 2H), 2.98-2.94 (m, 2H), 2.90-2.86 (m, 2H), 2.43 (tdt, J = 10.9, 10.0, 3.6 Hz, 1H), 1.76-1.54 (m, 5H), 1.32-1.06 (m, 5H). ¹³C NMR (100 MHz, CDCl3) δ: 200.49, 149.30, 141.35, 139.27, 137.76, 131.28, 129.92, 128.40, 128.35, 125.99, 119.52, 39.18, 38.42, 31.98, 30.83, 30.60, 25.66, 25.35. IR (ATR): 750.3, 794.7, 902.7, 1014.6, 1072.4, 1126.4, 1178.5, 1406.1, 1448.5, 1487.1, 1666.5, 2850.8, 2926.0 cm⁻¹. HRMS (APCI): Calcd. for C25H28BrO ([M+H⁺]), 411.1318. Found, 411.1305.

4-[(E)-2-(cyclohexylmethylidene)-3-oxo-5-phenylpentyl]benzonitrile (4u)

Isolated by preparative recycling GPC. Pale yellow oil. 52.0 mg, 73% yield. ¹H NMR (400 MHz, CDCl3) δ: 7.51 (d, J = 8.2 Hz, 2H), 7.27-7.25 (m, 2H), 7.20-7.14 (m, 5H), 6.58 (d, J = 10.0 Hz, 1H), 3.71 (s, 2H), 3.01-2.96 (m, 2H), 2.91-2.88 (m, 2H), 2.40 (tdt, J = 10.9, 10.3, 3.4 Hz, 1H), 1.77-1.53 (m, 5H), 1.31-1.08 (m, 5H). ¹³C NMR (100 MHz, CDCl3) δ: 200.30, 150.08, 146.07, 141.17, 137.07, 132.07, 128.90, 128.40, 128.33, 126.04, 119.03, 109.59, 38.96, 38.57, 31.90, 31.62, 30.56, 25.57, 25.28. IR (ATR): 750.3, 819.8, 1126.4, 1176.6, 1448.5, 1496.8, 1606.7, 1666.5, 2225.9, 2850.8, 2926.0 cm⁻¹. HRMS (APCI): Calcd. for C25H28NO ([M+H⁺]), 358.2165. Found, 358.2159.

methyl 4-[(E)-2-(cyclohexylmethylidene)-3-oxo-5-phenylpentyl]benzoate (4v)

Isolated by MPLC (hexane/EtOAc = 95/5). Pale yellow oil. 61.9 mg, 79% yield. ¹H NMR (400 MHz, CDCl3) δ: 7.91 (dt, J = 8.5, 2.0 Hz, 2H), 7.28-7.24 (m, 2H), 7.20-7.15 (m, 5H), 6.55 (d, J = 10.0 Hz, 1H), 3.88 (s, 3H), 3.72 (s, 2H), 2.99-2.97 (m, 2H), 2.91-2.87 (m, 2H), 2.43 (tdt, J = 10.9, 10.0, 3.9 Hz, 1H), 1.74-1.54 (m, 5H), 1.30-1.06 (m,
$^{13}$C NMR (100 MHz, CDCl$_3$) δ: 200.42, 167.04, 149.62, 145.90, 141.33, 137.53, 129.62, 128.40, 128.34, 128.13, 127.73, 125.99, 51.90, 39.14, 38.49, 31.91, 31.46, 30.62, 25.64, 25.32. IR (ATR): 752.2, 902.7, 1020.3, 1107.1, 1178.5, 1278.8, 1345.0, 1496.8, 1608.6, 1668.4, 1720.5, 2850.8, 2926.0 cm$^{-1}$. HRMS (APCI): Calcd. for C$_{26}$H$_{31}$O$_3$ ([M+H]$^+$), 391.2268. Found, 391.2254.

(Isolated by preparative recycling GPC. Pale yellow oil. 68.1 mg, 89% yield. $^1$H NMR (400 MHz, CDCl$_3$) δ: 8.13 (d, $J = 8.6$ Hz, 1H), 7.86-7.83 (m, 1H), 7.68 (d, $J = 8.2$ Hz, 1H), 7.56-7.46 (m, 2H), 7.32-7.24 (m, 3H), 7.22-7.15 (m, 3H), 6.98 (dd, $J = 7.2$, 0.9 Hz, 1H), 6.71 (d, $J = 10.0$ Hz, 1H), 4.13 (s, 2H), 3.07-3.02 (m, 2H), 2.94-2.89 (m, 2H), 2.36-2.26 (m, 1H), 1.68-1.54 (m, 5H), 1.26-1.07 (m, 5H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 200.70, 150.07, 141.53, 137.19, 135.56, 133.73, 132.03, 128.69, 128.45, 126.61, 126.01, 125.84, 125.51, 125.44, 123.95, 123.50, 39.41, 38.22, 32.00, 30.72, 28.05, 25.71, 25.28. (One aromatic carbon peak was overlapped.) IR (ATR): 750.3, 771.5, 790.8, 902.7, 1076.3, 1126.4, 1398.4, 1448.5, 1494.8, 1668.4, 2850.8, 2924.1 cm$^{-1}$. HRMS (APCI): Calcd. for C$_{28}$H$_{31}$O ([M+H]$^+$), 383.2369. Found, 383.2361.

(E)-1-cyclohexyl-2-(naphthalen-1-ylmethyl)-5-phenylpent-1-en-3-one (4w)

(4E,6E)-4-(cyclohexylmethylidene)-1,7-diphenyhept-6-en-3-one (4x)

Isolated by MPLC (hexane/EtOAc = 98/2). Colorless oil. 44.2 mg, 62% yield. $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.31-7.24 (m, 6H), 7.21-7.15 (m, 4H), 6.48 (d, $J = 10.0$ Hz, 1H), 6.34 (d, $J = 15.9$ Hz, 1H), 6.14 (dt, $J = 15.9$, 6.3 Hz, 1H), 3.22 (dd, $J = 6.6$, 1.1 Hz, 2H), 3.01-2.97 (m, 2H), 2.95-2.90 (m, 2H), 2.45 (dt, $J = 10.8$, 10.0, 3.6 Hz, 1H), 1.77-1.63 (m, 5H), 1.36-1.07 (m, 5H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 200.41, 148.98, 141.53, 137.58, 137.15, 130.18, 130.8, 128.42, 128.40, 128.30, 126.90, 125.98, 39.21, 38.15, 32.14, 30.73, 29.20, 25.75, 25.44. (2 aromatic carbon peaks were overlapped.) IR (ATR): 900.8, 964.4, 1030.0, 1074.4, 1126.4, 1178.5, 1448.5, 1494.8, 1668.4, 2850.8, 2924.1, 3026.3 cm$^{-1}$. Anal. Calcd. for C$_{26}$H$_{30}$O: C, 87.10; H, 8.43. Found: C, 86.79; H, 8.48. EIMS: m/z 359 (18%, [M+1]$^+$), 358 (46, [M]$^+$), 275 (81), 207 (27), 105 (64), 91(100).
5. NMR Charts

$^1$H NMR spectrum of 2d
$^{13}$C $^1$H NMR spectrum of 2d
$^1$H NMR spectrum of 4a
$^{13}$C $^1$H NMR spectrum of 4a
$^1$H NMR spectrum of $4c$
$^{13}$C $^1$H NMR spectrum of 4c
$^1$H NMR spectrum of 4e
$^{13}$C\{\(^1\)H\} NMR spectrum of \(4e\)
$^1$H NMR spectrum of 4g
$^{13}$C {$^1$H} NMR spectrum of 4g
$^1$H NMR spectrum of 4i
$^{13}$C $^1$H NMR spectrum of 4i
$^{1}$H NMR spectrum of 4k
$^{13}$C $^{1}$H NMR spectrum of 4k

\[
\text{Ph} - \text{C} = \text{C} - \text{Ph}
\]
\(^1\)H NMR spectrum of 4o
$^{13}$C $^{1}$H NMR spectrum of 46
$^1$H NMR spectrum of 4r
$^{13}$C $^{1}$H NMR spectrum of 4r
$^1$H NMR spectrum of 4t
$^{13}$C $^1$H NMR spectrum of 4t
$^1$H NMR spectrum of 4u
$^{13}$C $^{1}H$ NMR spectrum of 4u
$^1$H NMR spectrum of 4v
$^{13}$C $^1$H NMR spectrum of 4v
$^1$H NMR spectrum of 4w

![NMR Spectrum Image]
$^{13}$C $^1$H NMR spectrum of 4w
noesy spectrum of 4a

noesy spectrum of 4g
noesy spectrum of 4h

noesy spectrum of 4n
6. Reference


