Supporting Information for

One-pot Relay Reduction-Isomerization of β-Trifluoromethylated-α,β-Unsaturated Ketones to chiral β-Trifluoromethylated Saturated Ketones Over Combined Catalysts in Aqueous Medium

Xuelin Xia, Meng Wu, Ronghua Jin, Tanyu Cheng, Guohua Liu*

Key Laboratory of Resource Chemistry of Ministry of Education, Shanghai Key Laboratory of Rare Earth Functional Materials, Shanghai Normal University, No.100 Guilin Rd, Shanghai 200241, P. R. China

<table>
<thead>
<tr>
<th>Content</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental General, preparation and reaction</td>
<td>S2</td>
</tr>
<tr>
<td>Figure S1 FT-IR spectra of 2 and catalyst 3</td>
<td>S3</td>
</tr>
<tr>
<td>Figure S2 XPS spectrum of [RuCl2(p-cymene)]2</td>
<td>S3</td>
</tr>
<tr>
<td>Figure S3 TEM images of catalyst 3 viewed along [100] (a) and [001] (b) directions.</td>
<td>S4</td>
</tr>
<tr>
<td>Figure S4 One-pot enantioselective reduction-isomerization of β-trifluoromethylated-α,β-unsaturated ketones to chiral β-trifluoromethylated saturated ketones.</td>
<td>S5</td>
</tr>
<tr>
<td>Figure S5 Enantioselective reductions of β-trifluoromethylated-α,β-unsaturated ketones to chiral chiral β-trifluoromethylated alcohols.</td>
<td>S23</td>
</tr>
<tr>
<td>Figure S6 Reusability of catalyst 3 for enantioselective reduction of 4,4,4-trifluoro-1,3-diphenylbut-2-enone to (R)-4,4,4-trifluoro-1,3-diphenylbut-2-enol</td>
<td>S41</td>
</tr>
<tr>
<td>Figure S7 $^1$H-NMR, $^{13}$C-NMR a and GC-MS of all chiral products.</td>
<td>S43</td>
</tr>
</tbody>
</table>
Experimental

1. General

All experiments, which are sensitive to moisture or air, were carried out under an Ar atmosphere using the standard Schlenk techniques. (R,R)-1,2-diphenylenediamine, [RuCl₂(p-Cymene)]₂, 1,2-bis(triethoxysilyl)ethylene, surfactant P123 (CH₂-CH₂O)₂₀(CH₂(CH₃)CH₂O)₇₀(CH₂CH₂O)₂₀ and tetraethoxysilane (TEOS) were purchased from Sigma-Aldrich Company Ltd. Compounds (R,R)-4-(trimethoxysilyl)ethylphenylsulfonyl-1,2-diphenylethlenediamine was synthesized according to the reported literatures [J. Mater. Chem. 2010, 20, 1970]

2. Preparation of ArDPEN-PMO (2). In a typical synthesis, 2.0 g of structure-directing agent, pluronic P123, was fully dissolved in a mixture of 80 mL hydrochloric acid (0.2 N) and 6.0 g KCl and the mixture was stirred at room temperature for 1.0 h. Then, 3.36 mL (9.10 mmol) of 1,2-bis(triethoxysilyl)ethane was added as the silica precursor at 40 °C. After pre-hydrolysis period of 40 min., 0.24 g (0.48 mmol) of (R,R)-DPEN-SO₂Ph(CH₂)₂Si(OMe)₃ was added. The reaction mixture was stirred at 40 °C for 24 h and aged at 100 °C for 24 h. The resulting solid was filtered and rinsed with excess ethanol before being dried overnight on a filter. The surfactant template was removed by refluxing in acidic ethanol (400 mL per gram) for 24 h. The solid was filtered and rinsed with ethanol again, and dried at 60 °C under reduced pressure overnight to afford 2 (1.36 g) in the form of a white powder. IR (KBr) cm⁻¹: 3443.5 (s), 2978.5 (w), 2928.8 (w), 1627.2 (m), 1460.2 (w), 1416.5 (w), 1382.7 (w), 1273.4 (m), 1164.1 (s), 1096.5 (s), 1028.9 (s), 919.7 (m), 766.7 (m), 699.1 (m), 438.8 (m); ¹³C CP MAS NMR (161.9 MHz): 150.0, 137.5, 128.7 (C of Ph and Ar), 76.1–69.2 (C of –CH₂Ph–), 59.4 (O-CH₂CH₃), 28.8 (C of –CH₂Ar), 16.3 (O-CH₂CH₃), 5.2 (C of –CH₂Si) ppm; ²⁹Si MAS/NMR (79.4 MHz): T¹ (δ = −49.1 ppm), T² (δ = −57.6 ppm), T³ (δ = −65.0 ppm).

3. General procedure for the reuse experiments using 4,4,4-trifluoro-1,3-diphenylbut-2-enone as a substrate.

The catalyst 3 (291.0 mg, 0.030 mmol of Ru based on ICP analysis), 4,4,4-trifluoro-1,3-diphenylbut-2-enone (1.50 mmol), HCO₂Na (2.04 g, 30.0 mmol), 20.0 mL of water were added sequentially to a 50.0 mL round-bottom flask. The mixture was then stirred at room temperature (20 °C) for 17 h. After completion of the reaction, the catalyst was separated by centrifugation (10,000 rpm). The collected solids were transferred to a fresh 50.0 mL round-bottom flask and 4,4,4-trifluoro-1,3-diphenylbut-2-enone (1.50 mmol), HCO₂Na (2.04 g, 30.0 mmol) and 20.0 mL of water were added again for next recycle. The aqueous solution was extracted with ethyl ether (3 × 3.0 mL). The combined ethyl ether extracts were washed with NaHCO₃ and brine, and then dehydrated with Na₂SO₄. After evaporation of ethyl ether, the residue was purified by silica gel flash column chromatography to afford the desired products.
Figure S1. FT-IR spectra of 2 and catalyst 3.

Figure S2. XPS spectrum of $[\text{RuCl}_2(p\text{-cymene})]_2$. 
Figure S3. TEM images of catalyst 3 viewed along [100] (a) and [001] (b) directions.

(a) [100] direction.

(b) [001] direction.
Figure S4. One-pot enantioselective reduction-isomerization of β-trifluoromethylated-α,β-unsaturated ketones to chiral β-trifluoromethylated saturated ketones. [The products were analyzed by a HPLC with a UV-Vis detector using a Daicel OD-H or OJ-H chiralcel column (Φ0.46×25 cm)].

Translation of Chinese to English is as follows:

6a: (R)-4,4,4-trifluoro-1,3-diphenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
6b: (R)-4,4,4-trifluoro-3-(4-fluorophenyl)-1-phenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
6c: (R)-3-(4-chlorophenyl)-4,4,4-trifluoro-1-phenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
6d: (R)-3-(4-bromophenyl)-4,4,4-trifluoro-1-phenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
6e: (R)-3-(3-bromophenyl)-4,4,4-trifluoro-1-phenylbutan-1-one (4e): (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
**6f**: (R)-4,4,4-trifluoro-1-phenyl-3-(4-(trifluoromethyl)phenyl)butan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
6g: \((R)-4,4,4\text{-trifluoro-1-phenyl-3-(p-tolyl)butan-1-one}\) (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
6h: (R)-4,4,4-trifluoro-3-(4-methoxyphenyl)-1-phenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
6i: (R)-4,4,4-trifluoro-3-methyl-1-phenylbutan-1-one (HPLC: Chiracel OJ-H, detected at 254 nm, eluent: n-hexane/2-propanol = 99/1, flow rate = 0.5 mL/min, 25 °C).
6j: (R)-1-(4-chlorophenyl)-4,4,4-trifluoro-3-phenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC)
6k: (R)-1-(4-bromophenyl)-4,4,4-trifluoro-3-phenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
6l: *(R)-4,4,4-trifluoro-3-phenyl-1-(p-tolyl)butan-1-one* (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
6m: \((R)-4,4,4\text{-trifluoro}-1\text{-}(4\text{-methoxyphenyl})-3\text{-phenylbutan-1-one}\) (4m): \(\text{HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C.}\)
6n: \((R)-1-(3\text{-chlorophenyl})-4,4,4\text{-trifluoro-3-phenylbutan-1-one}\) (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 97/3, flow rate = 1.0 mL/min, 25 ºC)
6o: (R)-1-(3-bromophenyl)-4,4,4-trifluoro-3-phenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 97/3, flow rate = 1.0 mL/min, 25 ºC).
6p: (R)-4,4,4-trifluoro-1-(2-methoxyphenyl)-3-phenylbutan-1-one (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 97/3, flow rate = 1.0 mL/min, 25 ºC).
6q: (R)-1-(4-bromophenyl)-4,4,4-trifluoro-3-(4-fluorophenyl)butan-1-one (HPLC: Chiracel OJ-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.5 mL/min, 25 ºC).
6r: (R)-1,3-bis(4-bromophenyl)-4,4,4-trifluorobutan-1-one (4o): (HPLC: Chiracel OJ-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.5 mL/min, 25 ºC).
**Figure S5.** Enantioselective reductions of β-trifluoromethylated-α,β-unsaturated ketones to chiral chiral β-trifluoromethylated alcohols. [The products were analyzed by a HPLC with a UV-Vis detector using a Daicel OD-H or AD-H chiralcel column (Φ0.46×25 cm). Please see literatures (Catal. Sci. Technol. 2015, 5, 1750; Angew. Chem. Int. Ed. 2012, 51, 6467).]

**Translation of Chinese to English is as follows:**

5a: \((R,E)-4,4,4\)-trifluoro-1,3-diphenylbut-2-en-1-ol (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
5b: \((R,E)-4,4,4\text{-trifluoro-3-(4-fluorophenyl)-1-phenylbut-2-en-1-ol}\) (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
5c: (R,E)-3-(4-chlorophenyl)-4,4,4-trifluoro-1-phenylbut-2-en-1-ol (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
5d: (R,E)-3-(4-bromophenyl)-4,4,4-trifluoro-1-phenylbut-2-en-1-ol (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
5e: (R,E)-3-(3-bromophenyl)-4,4,4-trifluoro-1-phenylbut-2-en-1-ol (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
\( \text{5f: (R,E)-4,4,4-trifluoro-1-phenyl-3-(4-(trifluoromethyl)phenyl)but-2-en-1-ol} \) (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 97/3, flow rate = 1.0 mL/min, 25 °C).
5g: (R,E)-4,4,4-trifluoro-1-phenyl-3-(p-tolyl)but-2-en-1-ol (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
5h: (R,E)-4,4,4-trifluoro-3-(4-methoxyphenyl)-1-phenylbut-2-en-1-ol: (HPLC: ChiracelOD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
5i: \((R,E)\)-4,4,4-trifluoro-3-methyl-1-phenylbut-2-en-1-ol: (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
5j: \((R,E)\)-1-(4-chlorophenyl)-4,4,4-trifluoro-3-phenylbut-2-en-1-ol: (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
5k: (R,E)-1-(4-bromophenyl)-4,4,4-trifluoro-3-phenylbut-2-en-1-ol: (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).

<table>
<thead>
<tr>
<th>ID#</th>
<th>名称</th>
<th>保留时间</th>
<th>峰#</th>
<th>面积</th>
<th>高度</th>
<th>面积%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5k</td>
<td>6.297</td>
<td>1</td>
<td>844864</td>
<td>303603</td>
<td>50.27%</td>
</tr>
<tr>
<td>2</td>
<td>5k</td>
<td>7.107</td>
<td>2</td>
<td>3951025</td>
<td>296030</td>
<td>48.72%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID#</th>
<th>名称</th>
<th>保留时间</th>
<th>峰#</th>
<th>面积</th>
<th>高度</th>
<th>面积%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5k.286</td>
<td>6.288</td>
<td>1</td>
<td>430005</td>
<td>130866</td>
<td>97.01%</td>
</tr>
<tr>
<td>2</td>
<td>5k.299</td>
<td>7.299</td>
<td>2</td>
<td>124525</td>
<td>6749</td>
<td>2.993%</td>
</tr>
</tbody>
</table>
$\textit{S}^\ast$ (\textit{R},\textit{E})-4,4,4-trifluoro-3-phenyl-1-(p-tolyl)but-2-en-1-ol: (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
5m: \((R,E)\)-4,4,4-trifluoro-1-(4-methoxyphenyl)-3-phenylbut-2-en-1-ol: (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
$5n$: (R,E)-1-(3-chlorophenyl)-4,4,4-trifluoro-3-phenylbut-2-en-1-ol (HPLC: Chiracel AD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
$\text{5\textbf{w}: (R,E)-1-(3-bromophenyl)-4,4,4-trifluoro-3-phenylbut-2-en-1-ol}$ (HPLC: Chiracel AD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 °C).
$5p$: $(R,E)$-4,4,4-trifluoro-1-(2-methoxyphenyl)-3-phenylbut-2-en-1-ol (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 97/3, flow rate = 1.0 mL/min, 25 °C).
5q: (R,E)-1-(4-bromophenyl)-4,4,4-trifluoro-3-(4-fluorophenyl)but-2-en-1-ol: (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
5r: (R,E)-1,3-bis(4-bromophenyl)-4,4,4-trifluorobut-2-en-1-ol: (HPLC: Chiracel OD-H, detected at 254 nm, eluent: n-hexane/2-propanol = 95/5, flow rate = 1.0 mL/min, 25 ºC).
Figure S6. Reusability of catalyst 3 for enantioselective reduction of 4,4,4-trifluoro-1,3-diphenylbut-2-enone to (R)-4,4,4-trifluoro-1,3-diphenylbut-2-enol.

Recycle 2.

Recycle 3.

Recycle 4.
Figure S7. $^1$H-NMR, $^{13}$C-NMR and GC-MS of all chiral products.

6a: (R)-4,4,4-Trifluoro-1,3-diphenylbutan-1-one

Yield: 96% (97% ee, 100% es); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 3.52 (dd, 1H, $J$ = 18 Hz, $J$ = 4.5 Hz), 3.64 (dd, 1H, $J$ = 18 Hz, $J$ = 4.5 Hz), 4.18-4.29 (m, 1H), 7.21-7.96 (m, 10H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 38.5 (q, $J$ = 2 Hz), 44.9 (q, $J$ = 27.7 Hz), 127.2 (q, $J$ = 280 Hz), 128.3, 128.5, 128.9, 129.0, 129.2, 133.8, 134.8 (q, $J$ = 2 Hz), 136.5, 195.5; GC/MS (m/z): 278.09; HPLC (OD-H, elute: n-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C) $t_1$ = 5.1 min, $t_2$ = 6.6 min.
(R)-4,4,4-trifluoro-1,3-diphenylbutan-1-one

Chemical Formula: C_{18}H_{13}F_{3}O

Exact Mass: 278.09
6b: (R)-4,4,4-Trifluoro-3-(4-fluorophenyl)-1-phenylbutan-1-one

Yield: 96% (92% ee, 98% es); \( ^1H \) NMR (400 MHz, CDCl\(_3\)): \( \delta \) 3.51 (dd, \( J = 3.99, 17.76 \) Hz, 1H), 3.59 (dd, \( J = 9.40, 17.76 \) Hz, 1H), 4.22–4.30 (m, 1H), 7.04–7.13 (m, 2H), 7.24–7.65 (m, 5H), 7.83–7.85 (m, 2H); \( ^{13}C \) NMR (100 MHz, CDCl\(_3\)): \( \delta \) 38.3 (q, \( J = 2 \) Hz), 44.2 (q, \( J = 28 \) Hz), 115.7 (d, \( J = 21 \) Hz), 126.3 (q, \( J = 278.4 \) Hz), 128.0, 128.8, 130.6, 130.7, 133.7, 136.2, 162.6 (d, \( J = 246.1 \) Hz), 195.1; GC/MS (m/z): 296.08; HPLC (OD-H, elute: \( n \)-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C) \( t_1 \) = 5.2 min, \( t_2 \) = 6.1 min.
(R)-4,4,4-trifluoro-3-(4-fluorophenyl)-1-phenylbutan-1-one
Chemical Formula: C_{16}H_{12}F_4O
Exact Mass: 296.08
6c: (R)-3-(4-Chlorophenyl)-4,4,4-trifluoro-1-phenylbutan-1-one

Yield: 97% (95% ee, 100% es); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta3.60\) (dd, 1H, \(J = 17.9\) Hz, \(J = 4.3\) Hz), \(3.68\) (dd, 1H, \(J = 17.8\) Hz, \(J = 9.1\) Hz), \(4.21-4.33\) (m, 1H), \(7.30-7.36\) (m, 4H), \(7.46\) (t, 2H, \(J = 7.8\) Hz), \(7.61\) (t, 1H, \(J = 7.4\) Hz), \(7.92\) (d, 2H, \(J = 7.3\) Hz); \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta38.2\) (q, \(J = 2\) Hz), \(44.6\) (q, \(J = 27\) Hz), \(126.9\) (q, \(J = 277.7\) Hz), \(128.3\), \(129.0\), \(129.2\), \(130.6\), \(133.3\) (q, \(J = 1.5\) Hz), \(133.9\), \(134.6\), \(136.4\), \(195.2\); GC/MS (m/z): 312.05; HPLC (OD-H, elute: \(n\)-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25°C) \(t_1 = 5.8\) min, \(t_2 = 7.2\) min.
(R)-3-(4-Chlorophenyl)-4,4,4-Trifluoro-1-phenylbutan-1-one

Chemical Formula: C_{19}H_{15}ClF_3O

Exact Mass: 342.05
6d: (R)-3-(4-Bromo-phenyl)-4,4,4-trifluoro-1-phenylbutan-1-one

Yield: 95% (94% ee, 98% es); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 3.58 (dd, 1H, \(J = 3\) Hz, \(J = 18\) Hz), 3.67 (dd, 1H, \(J = 9\) Hz, \(J = 18\) Hz), 4.21 (m, 1H), 7.25-7.28 (m, 2H), 7.43-7.48 (m, 3H), 7.56-7.60 (m, 2H), 7.90-7.93 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 38.2 (q, \(J = 2\) Hz), 44.6 (q, \(J = 27\) Hz), 122.7, 126.9 (q, \(J = 279\) Hz), 128.3, 129.0, 130.9, 132.1, 133.8, 133.9, 136.4, 195.2; GC/MS (m/z): 356.00; HPLC (OD-H, elute: \(n\)-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25°C) \(t_1 = 5.2\) min, \(t_2 = 6.2\) min.
(R)-3-(4-bromophenyl)-4,4,4-trifluoro-1-phenylbutan-1-one

Chemical Formula: C₁₇H₁₂BrF₃O

Exact Mass: 356.00
6e: (R)-3-(3-Bromoephenvyl)-4,4,4-trifluoro-1-phenylbutan-1-one.

Yield: 94% (95% ee, 100% es); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 3.58 (dd, 1H, $J = 3$ Hz, $J = 18$ Hz), 3.67 (dd, 1H, $J = 9$ Hz, $J = 18$ Hz), 4.20 (m, 1H), 7.21-7.28 (m, 1H), 7.33-7.41 (m, 1H), 7.42-7.53 (m, 3H), 7.56-7.65 (m, 2H), 7.90-7.98 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 38.4 (q, $J = 2$ Hz), 44.7 (q, $J = 27$ Hz), 122.9, 127.0 (q, $J = 278$ Hz), 128.1, 128.3, 129.0, 130.4, 131.7, 132.2, 133.8, 133.9, 136.3, 195.1; GC/MS (m/z): 356.00; HPLC (OD-H, elute: $n$-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C) $t_1 = 8.2$ min, $t_2 = 10.5$ min.
(R)-3-(3-bromophenyl)-4,4,4-trifluoro-1-phenylbutan-1-one
Chemical Formula: C_{18}H_{12}BrF_{3}O
Exact Mass: 356.00
6f: (R)-4,4,4-Trifluoro-1-phenyl-3-(4’-(trifluoromethyl)phenyl)butan-1-one

Yield: 97% (93% ee, 98% es); ¹H NMR (400 MHz, CDCl₃): δ 3.64 (dd, J = 3 Hz, J = 18 Hz), 3.74 (dd, J = 9 Hz, J = 18 Hz), 4.32 (m, J = 7.45-7.62 (m, J = 7H), 7.91-7.94 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 38.1 (q, J = 1.5 Hz), 44.7 (q, J = 28 Hz), 123.9 (q, J = 271 Hz), 125.7 (q, J = 4 Hz), 126.6 (q, J = 278 Hz), 128.0, 128.8, 129.5, 130.6 (q, J = 32 Hz), 133.8, 136.0, 138.6, 194.8; GC/MS (m/z): 346.08; HPLC (OD-H, elute: n-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C) t₁ = 6.5 min, t₂ = 8.3 min
(R)-4,4,4-trifluoro-1-phenyl-3-(4-(trifluoromethyl)phenyl)butan-1-one
Chemical Formula: C\textsubscript{17}H\textsubscript{12}F\textsubscript{6}O
Exact Mass: 346.08
**6g: (R)-4,4,4-trifluoro-1-phenyl-3-p-tolylbutan-1-one**

Yield: 96% (93% ee, 99% es); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 2.32 (s, 3H), 3.59 (dd, 1H, \(J = 17.7\) Hz, \(J = 3.9\) Hz), 3.73 (dd, 1H, \(J = 17.8\) Hz, \(J = 9.2\) Hz), 4.19–4.25 (m, 1H), 7.16 (d, 2H, \(J = 7.7\) Hz), 7.30 (d, 2H, \(J = 7.7\) Hz), 7.46 (t, 2H, \(J = 7.6\) Hz), 7.58 (t, 1H, \(J = 7.2\) Hz), 7.94 (d, 2H, \(J = 7.6\) Hz); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 20.0, 37.2 (q, \(J = 1.5\) Hz), 43.3 (q, \(J = 27\) Hz), 125.9 (q, \(J = 277\) Hz), 127.0, 127.6, 127.8, 128.3, 130.4 (q, \(J = 2\) Hz), 131.5, 132.5, 135.2, 137.0, 194.3; GC/MS (m/z): 292.11; HPLC (OD-H, elute: \(n\)-hexanes/\(i\)-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 \(^\circ\)C) \(t_1 = 5.4\) min, \(t_2 = 6.1\) min.
6h: (R)-4,4,4-Trifluoro-3-(4-methoxyphenyl)-1-phenylbutan-1-one

Yield: 92% (93% ee, 95% es); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 3.56 (dd, 1H, \(J = 4\) Hz, \(J = 18\) Hz), 3.68 (dd, 1H, \(J = 9\) Hz, \(J = 18\) Hz), 3.77 (s, 3H), 4.12-4.27 (m, 1H), 6.85-6.89 (m, 2H), 7.30-7.33 (m, 2H), 7.43-7.48 (m, 2H), 7.54-7.60 (m, 1H), 7.91-7.95 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 38.6 (q, \(J = 2\) Hz), 44.3 (q, \(J = 27\) Hz), 55.4, 114.3, 126.7 (q, \(J = 2\) Hz), 127.3 (q, \(J = 277\) Hz), 128.3, 128.9, 130.3, 133.7, 136.6, 159.7, 195.7; GC/MS (m/z): 308.10; HPLC (OD-H, elute: n-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C) \(t_1 = 14.4\) min, \(t_2 = 15.0\) min.
(R)-4,4,4-trifluoro-3-(4-methoxyphenyl)-1-phenylbutan-1-one
Chemical Formula: C_{11}H_{15}F_{3}O_{2}
Exact Mass: 308.10
6i: (R)-4,4,4-Trifluoro-3-methyl-1-phenylbutan-1-one

Yield: 97% (88% ee, 98% es);^1^H NMR (400 MHz, CDCl₃): δ 1.19 (d, J = 6 Hz, 3H), 2.98-3.06 (m, 2H), 3.26-3.35 (m, 1H), 7.49 (t, J = 7 Hz, 2H), 7.60 (t, J = 7 Hz, 1H), 7.97 (d, J = 7 Hz, 2H); ^1^C NMR (100 MHz, CDCl₃): δ 13.3 (q, J = 2 Hz), 33.9 (q, J = 27 Hz), 38.5 (q, J = 2 Hz), 128.0, 128.3 (q, J = 276 Hz), 128.8, 133.6, 136.5, 196.4; GC/MS (m/z): 216.08; HPLC (OJ-H, elute: n-hexanes/i-PrOH = 99/1, detector: 254 nm, flow rate: 0.5 mL/min, 25 °C) t₁ = 12.8 min, t₂ = 13.4 min.
(R)-4,4,4-trifluoro-3-methyl-1-phenylbutan-1-one
Chemical Formula: C_{11}H_{13}F_{3}O
Exact Mass: 216.08
6j: (R)-1-(4-Chlorophenyl)-4,4,4-trifluoro-3-phenyl-1-butanone

Yield: 96% (88% ee, 97% es); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$3.53 (dd, 1H, $J$ = 17.8 Hz, $J$ = 4.4 Hz), 3.64 (dd, 1H, $J$ = 17.8 Hz, $J$ = 8.8Hz), 4.12–4.26 (m, 1H), 7.28–7.40 (m, 7H), 7.82 (d, 2H, $J$ = 8.6 Hz); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$38.5 (q, $J$ = 2 Hz) 45.0 (q, $J$ = 27 Hz), 127.0 (q, $J$ = 277.8 Hz), 128.6, 129.0, 129.2, 129.3, 129.7, 134.6 (q, $J$ = 2 Hz), 134.8, 140.3, 194.3; GC/MS (m/z): 312.05; HPLC (OD-H, elute: n-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25$^0$C) $t_1$ = 6.3 min, $t_2$ = 7.2 min.
(R)-1-(4-chlorophenyl)-4,4,4-trifluoro-3-phenylbutan-1-one
Chemical Formula: C_{16}H_{12}ClF_{3}O
Exact Mass: 312.05
6k: \((R)\)-1-(4-Bromophenyl)-4,4,4-trifluoro-3-phenylbutan-1-one

Yield: 95% (94% ee, 100% es); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 3.57 \) (dd, 1H, \(J = 17.7 \text{ Hz}, J = 4.4 \text{ Hz})\), 3.66 (dd, 1H, \(J = 17.7 \text{ Hz}, J = 8.8 \text{ Hz})\), 4.16–4.30 (m, 1H), 7.30–7.40 (m, 5H), 7.60 (d, 2H, \(J = 8.5 \text{ Hz})\), 7.78 (d, 2H, \(J = 8.5 \text{ Hz})\); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta 38.3 \) (q, \(J = 2 \text{ Hz})\), 44.8 (q, \(J = 27 \text{ Hz})\), 126.9 (q, \(J = 277.7 \text{ Hz})\), 128.4, 128.8, 129.0, 129.1, 129.6, 132.1, 134.4 (q, \(J = 2 \text{ Hz})\), 135.0, 194.4; GC/MS (m/z): 356.00; HPLC (OD-H, elute: n-hexanes/i-ProOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 \(^\circ\)C) \(t_1 = 6.2 \text{ min}, t_2 = 7.1 \text{ min}\).
(R)-1-(4-bromophenyl)-4,4,4-trifluoro-3-phenylbutan-1-one

Chemical Formula: C_{19}H_{16}BrF_3O

Exact Mass: 356.00
6l: (R)-4,4,4-Trifluoro-1-(4-methylphenyl)-3-phenyl-1-butanone

Yield: 95% (90% ee, 95% es); H NMR (400 MHz, CDCl₃): δ 2.40, (s, 3H), 3.53-3.60 (m, 1H), 3.68 (ddd, J = 1.9, 8.9, 17.8 Hz, 1H), 4.21-4.28 (m, 1H), 7.24-7.38(m, 7H), 7.81-7.84(m, 2H); C NMR (100 MHz, CDCl₃): δ 21.7, 38.1(q, J = 2 Hz), 44.8 (q, J= 27.7Hz), 127.0(q, J= 279.2 Hz), 128.2, 128.3, 128.7, 129.0, 129.4, 129.8, 133.8, 134.6, 144.5, 194.9; GC/MS (m/z): 292.11; HPLC (OD-H, elute: n-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C) t₁ = 4.8 min, t₂ = 5.5 min.
(R)-4,4,4-trifluoro-3-phenyl-1-(p-tolyl)butan-1-one
Chemical Formula: C_{17}H_{15}F_{3}O
Exact Mass: 292.11
6m: (R)-4,4,4-Trifluoro-1-(4-methoxyphenyl)-3-phenyl-1-butanone

Yield: 92% (90% ee, 100% es); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta \) 3.53 (dd, \(J = 3.9, 17.4 \text{ Hz}, 1\)H), 3.65 (dd, \(J = 9.0, 17.4 \text{ Hz}, 1\)H), 3.85 (s, 3H), 4.18-4.31 (m, 1H), 6.92 (d, \(J = 8.4 \text{ Hz}, 2\)H), 7.29-7.40 (m, 5H), 7.91 (d, \(J = 8.7 \text{ Hz}, 2\)H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta \) 38.0 (q, \(J = 1.5 \text{ Hz}\)), 45.1 (q, \(J = 27.7 \text{ Hz}\)), 55.7, 114.0, 127.3 (q, \(J = 278.2 \text{ Hz}\)), 128.4, 128.9, 129.2, 129.6, 130.6, 135.0, 164.0, 194.0; GC/MS (m/z): 308.10; HPLC (OD-H, elute: \(n\)-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C) \(t_1 = 8.2 \text{ min}\), \(t_2 = 10.0 \text{ min}\).
(R)-4,4,4-trifluoro-1-(4-methoxyphenyl)-3-phenylbutan-1-one
Chemical Formula: C_{22}H_{18}F_{3}O_{2}
Exact Mass: 308.10
**6n: (R)-1-(3-Chlorophenyl)-4,4,4-trifluoro-3-phenyl-1-butanone**

Yield: 95% (93% ee, 99% es); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 3.58 (dd, 1H, $J$ = 17.8 Hz, $J$ = 4.4 Hz), 3.68 (dd, 1H, $J$ = 17.8 Hz, $J$ = 8.8 Hz), 4.21–4.32 (m, 1H), 7.28–7.58 (m, 7H), 7.85 (d, 2H, $J$ = 8.6 Hz); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 38.7 (q, $J$ = 2 Hz), 45.0 (q, $J$ = 27 Hz), 126.3, 127.0 (q, $J$ = 277.8 Hz), 128.4, 128.6, 129.2, 130.3, 133.7, 134.6 (q, $J$ = 2 Hz), 135.4, 138.0, 194.3; GC/MS (m/z): 312; HPLC (OD-H, elute: Hexanes/i-PrOH = 97/3, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C), $t_1$ = 5.6 min, $t_2$ = 7.6 min
(R)-1-(3-chlorophenyl)-4,4,4-trifluoro-3-phenylbutan-1-one

Chemical Formula: C_{16}H_{12}ClF_{3}O

Exact Mass: 312.05
6o: (R)-1-(3-Bromophenyl)-4,4,4-trifluoro-3-phenylbutan-1-one

Yield: 96% (93% ee, 100% es); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 3.57 (dd, 1H, $J = 17.7$ Hz, $J = 4.4$ Hz), 3.66 (dd, 1H, $J = 17.7$ Hz, $J = 8.8$ Hz), 7.27–7.42 (m, 5H), 4.18–4.33 (m, 1H), 7.62 (d, 2H, $J = 8.5$ Hz), 7.88 (d, 2H, $J = 8.5$ Hz); $^{13}$C NMR (100MHz, CDCl$_3$): $\delta$ 38.6 (q, $J = 2$ Hz), 45.0 (q, $J = 27$ Hz), 126.7, 127.0 (q, $J = 277.9$ Hz), 128.6, 128.9, 129.2, 130.5, 133.7, 134.6 (q, $J = 2$ Hz), 136.6, 138.2, 194.2; GC/MS (m/z): 356; HPLC (OD-H, elute: Hexanes/i-PrOH = 97/3, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C), $t_1 = 5.6$ min, $t_2 = 7.6$ min.
6p: (R)-4,4,4-Trifluoro-1-(2-methoxyphenyl)-3-phenyl-1-butanone

Yield: 95% (92% ee, 100% es); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 3.63 (dd, 1H, \(J = 13.2\) Hz, \(J = 1.0\) Hz), 3.74 (dd, 1H, \(J = 17.9\) Hz, \(J = 3.2\) Hz), 3.95 (s, 3H), 4.16–4.28 (m, 1H), 6.94–7.10 (m, 2H), 7.57–7.61 (m, 1H), 7.28–7.40 (m, 5H), 7.45–7.51 (m, 1H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 43.6 (q, \(J = 2\) Hz), 45.3 (q, \(J = 27\) Hz), 55.7, 111.7, 121.0, 127.2 (q, \(J = 277.9\) Hz), 127.6, 128.3, 128.7, 129.4, 130.8, 134.2, 135.1 (q, \(J = 1.5\) Hz), 158.8, 197.7; GC/MS (m/z): 308; HPLC (OD-H, elute: Hexanes/i-PrOH = 97/3, detector: 254 nm, flow rate: 1.0 mL/min, 25 °C), \(t_1 = 6.8\) min, \(t_2 = 7.2\) min
(R)-4,4,4-trifluoro-1-(2-methoxyphenyl)-3-phenylbutan-1-one
Chemical Formula: C_{17}H_{13}F_3O_2
Exact Mass: 308.10
6q: (R)-1-(4-bromophenyl)-4,4,4-trifluoro-3-(4-fluorophenyl)butan-1-one

Yield: 95% (91% ee, 100% es); $^1$H NMR (400 MHz, CDCl$_3$):$\delta$ 3.52–3.67 (m, 2H), 4.21 (dd, $J$ = 9.4, 4.4 Hz, 1H), 7.02–7.07 (m, 2H), 7.28–7.39 (m, 2H), 7.61–7.63 (m, 2H), 7.78–7.81 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$):$\delta$ 38.3 (q, $J$ = 2 Hz), 44.2 (q, $J$ = 28 Hz), 115.7 (d, $J$ = 2 Hz), 126.7 (q, $J$ = 278 Hz), 129.0, 129.5, 130.6, 130.7, 132.1, 134.9, 162.6 (d, $J$ = 246 Hz), 194.2; GC/MS (m/z): 373.99; HPLC (OJ-H, elute: n-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.5 mL/min, 25 °C) $t_1$ = 15.2 min, $t_2$ = 19.4 min.
(R)-1-(4-bromophenyl)-4,4,4-trifluoro-3-(4-fluorophenyl)butan-1-one
Chemical Formula: C₂₀H₁₁BrF₄O
Exact Mass: 373.99
$6r$: (R)-4,4,4-Trifluoro-1,3-bis(4-bromophenyl)butan-1-one

Yield: 94% (90% ee, 97% es); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 3.51–3.65 (m, 2H), 4.18 (dd, $J = 9.4, 4.4$ Hz, 1H), 7.23–7.29 (m, 2H), 7.44–7.49 (m, 2H), 7.57–7.62 (m, 2H), 7.74–7.79 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ = 38.1 (q, $J = 1.5$ Hz), 44.4 (q, $J = 27$ Hz), 122.6, 126.5 (q, $J = 279$ Hz), 129.1, 129.5 (d, $J = 2$ Hz), 130.6, 131.9, 132.1, 133.4 (d, $J = 1.7$ Hz), 134.8, 194.0; GC/MS (m/z): 433.91; HPLC (OJ-H, elute: $n$-hexanes/i-PrOH = 95/5, detector: 254 nm, flow rate: 1.5 mL/min, 25 °C) $t_1 = 11.9$ min, $t_2 = 12.9$ min.
78

Chemical Formula: $C_{16}H_{11}Br_{2}F_{3}O$

Exact Mass: 433.91

(R)-1,3-bis(4-bromophenyl)-4,4,4-trifluorobutan-1-one