Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry. This journal is © The Royal Society of Chemistry 2022

Supporting information for:

Deracemization of Racemic Alcohols Combining

Photooxidation and Biocatalytic Reduction

Jianfeng Wang, ‡^{a,b} Yongzhen Peng, ‡^b Jian Xu*^c and Qi Wu, *^b

^aXingzhi College, Zhejiang Normal University, Lanxi 321100, China. E-mail: jeffwong34@163.com

^bDepartment of Chemistry, Zhejiang University, Hangzhou 310027, China. E-mail: wuqi1000@163.com

^cCollege of Biotechnology and Bioengineering, Zhejiang University of Technology, Hangzhou 310014, China. Email:

jianxu@zjut.edu.cn

‡ These authors contributed equally

Table of Contents

1. General information	S2
2. Characterization data	S4
3. NMR spectra	S7
4. GC data	S19
5. References	S26

1. General information

Unless otherwise noted, all reagents were obtained commercially and used without further purification. The ¹H and ¹³C NMR spectra were recorded with a Bruker AMX400 MHz spectrometer using TMS as an internal standard in CDCl₃. All known products were characterized by comparison of ¹H and ¹³C NMR data with those reported in the literature. Yields and stereoselectivity were determined by chiral GC with Agilent CP-chirasil-Dex CB column or chiral HPLC with a Chiralpak OJ-H column (250 mm×4.6 mm, n-hexane/2-propanol as the mobile phase) and a UV detector (220 nm). Absolute configuration was confirmed by comparison with literature values. The power of the *LEDs* is 8W and the source spectrum is 450-455 nm.

Preparation of reductases (KtCR and Ras-ADH)

100 µL stored bacteria was first incubated in 5 mL LB media with Kanamycin (50 µg/mL) and then shaking at 37 °C for overnight. 5 mL preculture was added to 500 mL fresh LB medium with 50 µg/mL Kanamycin. The cultures were shaken at 37 °C until OD_{600} at 0.6 and cooled at 4 °C for 30 min, then isopropyl β -thiogalactopyranoside (IPTG) was added to a final concentration of 0.5 mM to induce reductases expression at 25 °C. Cells were harvested by centrifugation, and resuspended in buffer (50 mM sodium phosphate buffer, pH 6.5 for KtCR and Ras-ADH) for whole-cell reaction. In order to obtain the crude enzyme solution and determine the protein concentration, the cell suspension was then repeated freezing and thawing for 3 times, and released the target proteins by sonication. The cell lysate was removed by centrifugation. The supernatant was used for SDS-PAGE analysis of KtCR and Ras-ADH, and the result was shown in Figure S1.



Figure S1 SDS-PAGE analysis of KtCR and Ras-ADH crude extract and purified protein. Lane 1: cell free extract of KtCR; Lane 2: cell free extract of Ras-ADH; Lane 3 and 10: protein markers; Lane 4-9: BAS 0.25, 0.50, 0.75, 1.00,

1.50, 2.00 mg/ml; Lane 11: purified protein of KtCR; Lane 12: purified protein of Ras-ADH.

Preparation of racemic alcohols

The given ketone (2 mmol) was added into a stirred solution of NaBH₄ (5 mmol) in methanol (10 mL) at room temperature (20 °C). The solution was stirred until the complete disappearance of ketone substrate indicated by TLC. The crude product was evaporated in vacuo and diluted in dichloromethane (20 mL), and then washed with water (10 mL). The organic phase was separated and dried over anhydrous sodium sulfate, and then evaporated in vacuum.

General procedure for one-pot reaction

SAS (5.0 mM, 20% mol) was dissolved in 2 ml mixture solution of acetonitrile and water (30% v/v acetonitrile as cosolvent) containing substrate (25mM) in a 25 ml conical flask. After irradiation with blue *LEDs* (5 cm away from the conical flask) for 12 hours (the reaction time could be extended to ensure no residual alcohols), 10 mL whole cell culture of ketoreductase (resuspended in 50 mM sodium phosphate buffer, pH 6.5) with glucose (250 mM) was added into the photocatalytic mixture and shaken at 30 °C for overnight. The bio-reduction was performed until the complete consumption of phenethyl alcohols determined by GC which ensure the incomplete optical yields of products are due to enzyme specificity. The solution was extracted with equal volume of ethyl acetate for three times, and the stereoselectivity was then determined by chiral GC. The turnover numbers of the two reductase (KtCR and Ras-ADH) used for the model substrate was 2000 and 1250, respectively.



Figure S2 UV-Vis spectra of non-irradiated SAS and irradiated SAS in water for 2 h.

Scaling-up one-pot reaction catalyzed by photocatalyst and ketoreductase

The scale-up reaction was performed as follows: SAS (0.2 mmol, 20 mol%) and 1 mmol 1a was

dissolved in 40 mL mixture solution of acetonitrile and water (30% v/v acetonitrile as cosolvent) in a 1000 ml conical flask. The reaction mixture was irradiated with blue *LEDs* (8W×4, 450-455 nm, 5 cm away from the conical flask) for 20 hours (the reaction time could be extended to ensure no residual alcohols). 400 ml whole-cell culture of ketoreductase (resuspended in 50 mM sodium phosphate buffer, pH 6.5) with glucose (10 mmol) was added into the photocatalytic reaction mixture and shaken at 30 °C for overnight. The reaction solution was extracted with ethyl acetate for three times, then the organic phase was dried over anhydrous sodium sulfate and concentrated in vacuum. The obtained crude product was further separated and purified by flash column chromatography.

2. Characterization data

OH 1-phenylethanol (1a)

¹H NMR (400 MHz, CDCl₃) δ 7.44-7.31 (m, 4H), 7.31-7.22 (m, 1H), 4.89 (q, *J* = 6.5 Hz, 1H), 1.49 (d, *J* = 6.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 145.8, 128.5, 127.5, 125.4, 70.4, 25.2. HRMS (EI-TOF): m/z [M]⁺ calc. for C₈H₁₀O⁺[M]⁺: 122.0732, found:122.0733.

F 2-fluoro-1-phenylethanol (1b)

¹H NMR (400 MHz, CDCl₃) δ 7.39-7.29 (m, 5H), 5.10-4.90 (m, 1H), 4.61-4.26 (m, 2H), 2.64 (s, 1H). ¹³C NMR (100 MHz, CDCl₃) δ 138.1 (d, *J* = 8.5 Hz), 128.8-128.35 (m), 126.4 (s), 88.1 (s), 86.4 (s), 73.0 (d, *J* = 19.4 Hz). HRMS (EI-TOF): *m/z* [M]⁺ calc. for C₈H₉FO: 140.0637, found: 140.0636.

1-(4-fluorophenyl)ethanol¹ (1c)

¹H NMR (400 MHz, CDCl₃): δ 7.37-7.30 (m, 2H), 7.06-6.99 (m, 2H), 4.88 (q, J = 6.3 Hz, 1H), 1.47 (d, J = 6.4 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃): δ 162.2(d, J_{C-F} = 243.0 Hz), 141.5(d, J_{C-F} = 3.0 Hz), 127.0(d, J_{C-F} = 8.0 Hz), 115.3(d, J_{C-F} = 21.0 Hz), 69.8, 25.3. HRMS (EI-TOF): m/z [M]⁺ calc. for C₈H₉FO: 140.0637, found: 140.0636.

1-(4-trifluoromethyl)ethanol (1d)

¹H NMR (400 MHz, CDCl₃) δ 7.61 (d, *J* = 8.2 Hz, 2H), 7.49 (d, *J* = 8.2 Hz, 2H), 4.96 (q, *J* = 6.5 Hz, 1H), 1.50 (d, *J* = 6.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 149.7, 129.6(q, *J*_{C-F} = 64 Hz), 128.2 125.7, 125.5(d, *J*_{C-F} = 3.7 Hz), 122.8, 120.1, 69.8, 25.4. HRMS (EI-TOF): *m/z* [M]⁺ calc. for C₉H₉F₃O: 190.0605, found: 190.0606.

1-(2-chlorophenyl)ethanol (1e)

¹H NMR (400 MHz, CDCl₃) δ 7.59 (dd, J = 7.7, 1.6 Hz, 1H), 7.35 – 7.24 (m, 2H), 7.20 (td, J = 7.6, 1.7 Hz, 1H), 5.29 (q, J = 6.4 Hz, 1H), 1.49 (d, J = 6.4 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 143.0, 131.6, 129.4, 128.4, 127.2, 126.4, 67.0, 23.5. HRMS (EI-TOF): m/z [M]⁺ calc. for C₈H₉ClO: 156.0342, found: 156.0342.

1-(3-chlorophenyl)ethanol (1f)

¹H NMR (400 MHz, CDCl₃) δ 7.30 – 7.22 (m, 3H), 4.87 (q, J = 6.5 Hz, 1H), 1.48 (d, J = 6.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 147.9, 134.4, 129.8, 127.6, 125.6, 123.6, 69.8, 25.3. HRMS (EI-TOF): m/z [M]⁺ calc. for C₈H₉ClO: 156.0342, found: 156.0342.

1-(4-chlorophenyl)ethanol (1g)

¹H NMR (400 MHz, CDCl₃) δ 7.31 (s, 3H), 4.88 (q, *J* = 6.5 Hz, 1H), 1.47 (d, *J* = 6.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 144.3, 133.1, 128.6, 126.8, 69.8, 25.3. HRMS (EI-TOF): *m/z* [M]⁺ calc. for C₈H₉ClO: 156.0342, found: 156.0343.

Br OH

1-(2-bromophenyl)ethanol²(1h)

¹H NMR (400 MHz, CDCl₃) δ 7.58 (dd, J = 7.8, 1.6 Hz, 1H), 7.50 (dd, J = 8.0, 1.1 Hz, 1H), 7.37 – 7.29 (m, 1H), 7.11 (td, J = 7.7, 1.7 Hz, 1H), 5.22 (qd, J = 6.3, 3.2 Hz, 1H), 2.23 (d, J = 3.1 Hz, 1H), 1.47 (d, J = 6.4 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 144.6, 132.7, 128.8, 127.9, 126.7, 121.7, 69.2, 23.6.¹³C NMR (100 MHz, CDCl₃) δ 144.6, 132.7, 128.8, 127.9, 126.7, 121.7, 69.2, 23.6. HRMS (EI-TOF): m/z [M]⁺ calc. for C₈H₉OBr: 199.9837, found: 199.9835.

1-(3-bromophenyl)ethanol (1i)

¹H NMR (400 MHz, CDCl₃) δ 7.53 (d, *J* = 1.7 Hz, 1H), 7.45 – 7.34 (m, 1H), 7.29 (d, *J* = 7.7 Hz, 1H), 7.21 (t, *J* = 7.8 Hz, 1H), 4.86 (q, *J* = 6.4 Hz, 1H), 1.48 (d, *J* = 6.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 148.1, 130.5, 130.1, 128.6, 124.0, 122.6, 69.8, 25.3. ¹³C NMR (100 MHz, CDCl₃) δ 148.1, 130.5, 130.1, 128.6, 124.0, 122.6, 69.8, 25.3. HRMS (EI-TOF): m/z [M]⁺ calc. for C8H9BrO: 199.9837, found: 199.9837.

1-(4-bromophenyl)ethanol³ (1j)

¹H NMR (400 MHz, CDCl₃) δ 7.49 – 7.42 (m, 2H), 7.24 (t, J = 7.4 Hz, 2H), 4.85 (q, J = 6.4 Hz, 1H), 2.05 (s, 1H), 1.46 (d, J = 6.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 144.8, 131.6, 127.2, 121.2, 69.8, 25.3. HRMS (EI-TOF): *m/z* [M]⁺ calc. for C₈H₉OBr: 199.9837, found: 199.9839.

1-(2-methoxyphenyl)ethanol (1k)

¹H NMR (400 MHz, CDCl₃) δ 7.34 (dd, *J* = 7.5, 1.5 Hz, 1H), 7.25 (ddd, *J* = 9.4, 7.0, 1.7 Hz, 1H), 6.96 (td, *J* = 7.5, 0.9 Hz, 1H), 6.88 (d, *J* = 8.2 Hz, 1H), 3.86 (s, 3H), 1.50 (d, *J* = 6.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 156.7, 133.4, 128.3, 126.1, 120.8, 110.4, 66.6, 55.3, 22.8. HRMS (EI-TOF): *m/z* [M]⁺ calc. for C₉H₁₂O₂: 152.0837, found: 152.0837.

1-(3-methoxyphenyl)ethanol (11)

¹H NMR (400 MHz, CDCl₃) δ 7.28 – 7.23 (m, 1H), 7.02 – 6.88 (m, 2H), 6.86 – 6.76 (m, 1H), 3.81 (s, 3H), 1.48 (d, *J* = 6.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 159.8, 147.6, 129.6, 117.7, 112.9, 110.9, 70.4, 55.2, 25.2. HRMS (EI-TOF): *m/z* [M]⁺ calc. for C₉H₁₂O₂: 152.0837, found: 152.0838.

3. NMR spectra

1-phenylethanol (1a)





2-fluoro-1-phenylethanol (1b)





1-(4-fluorophenyl)ethanol (1c)



1-(4-trifluoromethyl)ethanol (1d)





1-(2-chlorophenyl)ethanol (1e)



1-(3-chlorophenyl)ethanol (1f)



1-(4-chlorophenyl)ethanol (1g)





1-(2-bromophenyl)ethanol (1h)

00 190 180

170 160 150

140

130 120 110

100 90 80 70 fl (ppm)

60 50

-5. 0E+07

-0.0E+00

--5.0E+07

40 30 20

10 0 -10

1-(3-bromophenyl)ethanol (1i)



1-(4-bromophenyl)ethanol (1j)



1-(2-methoxyphenyl)ethanol (1k)



1-(3-methoxyphenyl)ethanol (11)





4. GC data

_

1a, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 8.1 min, T_S = 8.7 min, Temperature conditions: initial temperature 100 °C, 2 °C/min to 140 °C, then 40°C/min to 200 °C, holding 1 min).

Uhromatogram						
10.0UV(x10,000)					Max	Intensity : 313,035,439
Racemic	19				Time 9.114	Inten. 70
7.5 Maccinic		0				
5.0-		N				
2.5-						
			~			
0.0		*				
	0.0 0.		9.0 9.5	, ,	0.0 1	0.5 min
Besults - Peak Table						
Peak Table Compound Group	Calibration Curve	•				
Peak# Ret. Time	Area	Height	Conc.	Units	Bark	Compound ID#
2 8.66	5 760388.1	61718.0	49. 43145			
Chromatogram						
2 cuV(x10,000)					Max	Intensity : 182,939,697
Table 3 (h	2)_1a				Time 9.617	Inten. 469
$\frac{100005,(11)}{2.02}$	<u>)-1a</u>					
1.5		0				
1.0-		\cap	\			
1			\ \			
0.6		1				
0.5			1			
0.5						
0.5	7.75 8.00	8.25	8.50 8.75	9.00	9.25 9.5	0 9.75 min
0.5 0.0 7.00 725 7.50	7.75 8.00	8.25	8.50 8.75	9.00	9.25 9.5	i0 9.75 min
0.5 0.0 7.5 7.55 7.50 • Peak Table Peak Table Compound Group	7.75 8.00	* 8.25	8.50 8.75	9.00	9.25 9.5	0 9.75 min
0.5- 0.0- 7.00 7.25 7.50 A Results - Peak Table Peak Table [Compound] Group Peaks Ret. Time	7.75 8.00 Calibration Curve	* 8.25 e] Height	8.50 8.75 Conc.	9.00 Units	9.25 9.5	0 9.75 min
0.5 0.7 7.0 7.25 7.50 Peak Table Peak Table [Compound] Group Peak Table [Compound] Group Peak Ret. Time 1 8.39	7.75 8.00 Calibration Curve Area 5 129799.6	* 8.25 e Height 13205.4	8.50 8.75 Conc. 100.00000	9.00 Units	9.25 9.5	Cospound ID#
0.5 0.6 7.00 7.25 7.50 Pecult - Pecul - Table Pecult - Pecult - Pecult - Able Pecult - Res. Table 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6	7.75 8.00	8.25 e Height 13205.4	8.50 8.75 Conc. 100.00000	9.00 Units	9.25 9.5	Compound ID#
0.5 0.0 7.0 7.25 7.50 1 Peak Table Peak Table Peak K Table Reak Table Reak Table Reak Table Reak Table Reak Table	7.75 8.00 Calibration Curv Area 5 120799.6	* 8.25 e] Height 13205.4	8.50 8.75 Cenc. 100,00000	9.00 Units	9.25 9.5	0 9.75 min
0.5 7.50 7.25 7.50 Penuta - Peak Table Peak Table Compand Group Peak Ret. Time Chromatogram	7.75 8.00 Calibration Curv Area 5 123799.6	e Height 13205.4	8.50 8.75 Cenc. 100,00000	9.00 Units	9.25 9.5	0 9.75 mn
0.5 0.0 7.05 7.25 7.50 Pesk Table Pesk Table Pe	7.75 8.00 Calibration Curve Area 5 129799.6	e Height 13205.4	2.50 2.75 Conc. 100.00000	9.00 Units	9.25 9.5 eark Maa Tme 9.591	0 \$.75 min Compound ID# cutensky: 147.574.909 inten. 1.583
0.5 0.6 7.5 7.5 Peak Table Peak Tabl	7.75 8.80 Calibration Curve Area 129799.6	8 25 e) Height 13205.4	2.50 2.75 Conc. 100.00000	9.00 Units	9.25 9.5 •••••k	0 9.75 mm Compressed ID# Compressed ID# Com
0.5 7.0 7.25 7.50 Peeukt - Peek Table Peek Table [Conpound] Group Peeukt Ret. Time 0.30 Peeukt Able] Conpound] Group Peeukt Ret. Time 0.30 Peeukt Able] Conpound] Group Peeukt Able] Conpound] Group	7.75 8.50 Calibration Curve Area 129799.6 129799.6	e] Height 13205.4	8.50 8.75 Conc. 100.00000	9.00 Wnits	925 95 Bark Has Time 9391	Ceepound ID#
Cromatogram Source 4, (2)	7.75 8.80 Calibration Curve Area 1 120709.6 5 5 5 -1a	e Height 13205.4	2. 0 0.75	Units	9,25 9.5	Compound ID#
Chromatogram Source 4 C	7.75 8.50 Calibration Curve Area 129799.6 129799.6 D)-1a D)	* * Keight 13205.4	6.50 8.75	9.00 Units	S25 S5	0 5.75 min Compound ID# Compound ID# Compound ID# Compound ID#
0.5 0.0 7.0 7.25 7.50 Peak Table Peak Table Pea	7.75 8.60 Culibration Curve Area Area 129799.6 5 5 129799.6	* * Keight 13205.4	6 30 8.75	9.00 Units	925 95	0 9.75 min Compound ID# (ntensty: 147.574.609 Inten. 1.583
0.5 0.6 7.0 7.25 7.50 Text Table (Conputed Group Text Table (Conputed Group 10 (Cromatogram 5.0 10 (C	7.75 8.80 Calibration Curve 5 129799.8 5 129799.8	* sl25 Height 13205.4	2.50 2.55 2.50 2.55 100.0000	Units	9.25 9.5 Bark Idas Time 9.591	0 9.75 mm Compound IDP Compound IDP cintensty: 147.574.609 Piten. 1.583
0.5 7.0 7.25 7.50 7.	7.75 8.00 Calibration Curve Area 120799.8 120799.8 5)-1a	* 8.25 Neight 13205.4	250 2.55	Vnits	925 93	Compound ID#
0.5 0.6 7.0 7.25 7.50 Peak Table [Consound] Group Peak Table [Consound] Group Peak Table [Consound] Group Chromatogram 5.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	7.75 8.80 Calibration Curve Area 5 129799.8 5)-1a 7.75 8.80	* 825 Neight 13205.4	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	9.00 Wmits	925 95	Compound ID#
0.5 7.0 7.25 7.50 Pest Table [Conpetend Group Pest Table [Conpetend Group Pest Table [Conpetend Group Pest Table [Conpetend Group Chromatogram 5.0 7.25 7.50 7.55 7.50 7.55 7.50 7.55 7.50 7.55 7.50 7.55 7.50 7.55 7.50 7.55 7.50	7.75 8.60 Culibration Curve Area Area 3 129799.6 5 5 129799.6 5 7.75 8.60	* 8-25 N=i cht 13205.4	6.50 8.75	9.00	925 93	0 5.75 min Compound ID# Compound ID# Comp
0.5 7.5 7.5 7.5 7.5 7.5 7.5 7.5 7	7.75 8.00 Calibration Curve 5 129799.6 5)-1a 7.75 8.00 7.75 8.00	* * Height 15205-4	2.50 2.55 100.0000	9.50 Unitx 9.50	925 95	0 9.75 mm Compound IDP Compound IDP Compound IDP Pilen. 1.563 0 9.75 mm
0.5 0.6 7.0 7.25 7.50 Peak Table [Conpound] Group Peak Table [Conpound] Group Crromatogram 5.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	7.75 8.00 Calibration Curve Acces 5 120799.6 5 5 5 7.75 8.00 Calibration Curve 2 217021.7	* * * * * * * * * * * * * *	2.50 2.55 Cene: 100.0000 2.50 2.57 2.50 2.76 100.0000 2.50	Units Units Sbo	9.25 9.5 Bark Has 100 9.25 9.5 9.25 9.5 Bark	Compound ID#

1b, chiral GC (Agilent CP-chirasil-Dex CB, T_S = 6.3 min, T_R = 6.7 min, Temperature conditions: initial

temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).

10.0 UV(x10,000)) gram					Time	Max Int 7.312 I	ensity: 186, nten.	23,45
7.5 <u>Ra</u>	cemic 1b								
5.0									
25-		\wedge	\wedge						
0.0		*	*						
5.50	5.75 6.00	6.25 6.50	6.75	7.00 7.25	7.50	7.75	8.00	8.25	m
Results - Peak	Table								
Peak Table C	ompound Group C	alibration Curv	e						
Peak#	Ret. Time	Area	Height	Conc.	Units	ar	k	Compound	d ID4
1	6.323	310153.7	41100.1	49.85542					
0	6 657	311052 5	35134.0	50 14459					

2.5 <mark>UV(x10,000)</mark>						Ma:	x Intensity : 125,224,866
^{2.0} <u>Tab</u>	ole 3, (S)	<u>-1b</u>				1116 0.000	- India 1,000
0.5		\bigwedge	<u>\</u> *				
5.50 5	.75 6.00	6.25 6.5	0 6.75	7.00 7.25	7.50	7.75 8.	00 8.25 min
Results Peak Peak Table Com	Table npound Group Ret.Time	Calibration Cur Area	ve Height	Conc.	Units	Bark	Compound Th#
1	6.407	88551.6	11149.5	100.00000			

0.0 5.0 5.75 6.00 6.25 6.50 7.50 7.55 7.50 7.75 8.00 8.25 mm 1 Pends -Peak Table Peak Table Compound foroup Calibration Curve Peak Ret. Time Area Neight Conc. Vaits Bark Compound ID# 1 6.728 1066226.3 23413.1 100.00000

1c, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 4.9 min, T_S = 5.3 min, Temperature conditions: initial

temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).

Chromatogram							
5.0UV(x10,000)					Max Time 5.915	Intensity : 133,592,657
4.0 Ra	cemic 1	•				1116 0.010	
3.0-		<u>-</u>					
			Δ	0			
2.0			$ \rangle$	\square			
1.0-			1	\mathbb{I}			
0.0		~	-	*			
3.50 3.	75 4.00 4	.25 4.50	4.75 5.00	5.25 5.50	5.75 6.0	6.25	6.50 6.75 min
1 Results - Peak	Table						
Peak Table Co	mpound Group	Calibration Cu	rvel				
Peak#	Ret. Time	Area	Height	Conc.	Units	B ark	Compound ID#
	4.881	189014.4	24405.7	50.09207			
	5.205	100519.0	22000.0	48. 80185			1
Chromatogram	i i						
5.0UV(x10,000))					Max Time 6 252	Intensity : 186,576,350
4 T-1	-1- 2 (D	1.				100 0.202	anten. 01,007
<u>1a</u>	$\frac{516}{5}, (K)$	<u>)-1c</u>					
3.0-							
2.0			\wedge				
1.0-			$\left \right\rangle$				
0.0			1	-*			
3.50 3	75 4.00	4.25 4.50	4.75 5.00	5.25 5.50	5.75 6.0	0 6.25	6.50 6.75 min
•							•
Besults · Peak	Table						
Perte	mpound Group	Calibration Cu	rve V. i . h a	C	W-14-		Company 1 TRA
1 reaks	4.896	206492.8	22853.8	100.00000	onits	Bark	Compound IB+
Chanalaman							
_ chiomatogram							u latenaitu : 152 936 83
5.0	2					Time 6.22	2 Inten5,00
4.0- Tab	le 4. (S)	-1c					
3.0-	10 1, (<i></i>)						
2.0-				\wedge			
1.0-							
0.0					<u>.</u>		
0.0	75 4.00 4	1.25 4.50	4.75 5.00	5.25 5.50	¥. 5.75 6.	00 6.25	6.50 6.75 m
0.0	75 4.00 4	4.25 4.50	4.75 5.00	5.25 5.50	<u>↓</u> 5.75 6.	00 6.25	6.50 6.75 m
0.0 3.50 3.	75 4.00 4 Table	.25 4.50	4.75 5.00	* 5.25 5.50	5.75 6.	00 6.25	6.50 6.75 m
0.0 3.50 3. U Results - Peak	75 4.00 4 Table mpound Group	Calibration Cu	4.75 5.00	5.25 5.50	.₩. 5.75 6.	b0 6.25	6.50 6.75 m
0.0 3.50 3. 1 Results - Peak eak Table Co Peak#	75 4.00 4 Table npound Group	Calibration Cu	4.75 5.00	5.25 5.50	.♥. 5.75 6. Units	00 6.25	6.50 6.75 m
0.0 3.50 3. 1 Results - Peak reak Table Co Peak#	75 4.00 4 Table mpound Group Bet. Time 5.303	5.25 4.50 Calibration Cu Area 187718.8	4.75 5.00	* 5.25 5.50 Conc. 100,00000	₩ 5.75 6. Units	00 6.25	6.50 6.75 m

1d, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 5.9 min, T_S = 6.5 min, Temperature conditions: initial

temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).



c.uV(x10,000)					Max	Intensity : 18	34,193,03
4.0 3.0 2.0	ole 4, (S)-	<u>1d</u>		Λ		Time 7.780	Inten.	25,67
0.0	4.5 5.0	s.s	6.0	6.5 7.0	7.5	8.0	8.5	
Results - Peak Peak Table Co	Table mpound Group Ca	libration Curv	re					
Peak#	Ret. Time 6. 548	Area 322728.8	Height 34828.3	Совс. 100.00000	Units	∎ark	Compor	ind ID4

1e, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 9.5 min, T_S = 10.9 min, Temperature conditions: initial

temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).



UV(x10.000)						Max Ir	tensity : 167	518,373
1.00 <u>Tab</u>	ole 4, (S)	<u>-1e</u>				Time	9.876	Inten.	1,571
0.50				ſ					
7.5	8.0 8.5	9.0 9.5	10.0	10.5 11.0	11.5	12.0	12.5	13.0	min
B Results - Peak	Table								
Peak Table Co	mpound Group	Calibration Curv	re						
Peak#	Bet. Time	Area	Height	Conc.	Units	a	rk	Compour	d ID#
1	11.076	40316.4	4969.6	100.00000					

1f, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 9.9 min, T_S = 10.5 min, Temperature conditions: initial temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).

10.0 ^{UV(x10,000)}					Time 8.748	Intensity : 192,190,288 Inten. 38,654
7.5 Racemic 1f						
5.0-		Λ	٨			
			$\left[\right]$			
2.5						
0.0			*			
75 80 85	90 95	10.0	10.5 11.0	115	12.0 12.9	5 13.0 min
	3.0 5.5	10.0	10.0		12.0 12.0	
Results - Peak Table						
Peak Table Compound Group	Calibration Curve					
Peak# Ret.Time	Area	Height	Conc.	Units	∎ark	Compound ID#
2 9.896	732079.1 724007.8	54378.7	49, 72284			
Chromatogram						
2 cuV(x10,000)					Max	Intensity : 174,630,245
T 11 0 (D)	10				Time 11.942	Inten. 11,603
1^{20} Table 3, (R)	<u>-11</u>	٨				
1.5		1				
1.0						
0.5						
			<u></u>			
		-				
7.5 8.0 8.5	9.0 9.5	10.0	10.5 11.0	11.5	12.0 12	5 13.0 min
Besuits - Peak Table						
Peak Table Compound Group	Calibration Curve	1				
Peak# Ret. Time	Area	Height	Conc.	Units	ark	Compound ID#
1 10.070	202185.8	18927.7	100.00000			
Chromatogram						
e oUV(x10,000)					Me	x Intensity : 168,653,004
0.0					Time 11.71	8 Inten. 29,199
1.0 Table 4, (S)	<u>-1f</u>					
3.0-	_		Λ			
2.0						
10						
0.0			*			
7.5 8.0 8.5	9.0 9.5	10.0	10.5 11.0	11.5	12.0 1	2.5 13.0 min
Regulte - Reak Table						
Peak Table Compound Common	Calibration Comm	.1				
Peak# Ret. Time	Area	Height	Cenc.	Units	Bark	Compound Th#
1 10.602	200200 0	"er Cur	COMC.	ULLUS	- au A	Compound 10+
1 10.000	536506.0	33006.3	100.00000			

1g, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 10.1 min, T_S = 10.8 min,Temperature conditions: initial temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).







1h, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 13.0 min, T_S = 15.1 min, Temperature conditions:

initial temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).



Chromatogram								
1.0cUV(x10,000)							Max Intensit	y: 151,921,357
1.20						Time 16	3.565 Inten.	-1,250
1.00 Tabl	e 4, (R)-	<u>1h</u>						
0.75					٨			
0.50					11			
0.25								
0.00			· · ·		* *			
10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	min
<u> </u>								•
B Results - Peak	Table							
Peak Table Com	npound Group	Calibration Cur	ve					
Peak#	Bet. Time	Area	Height	Conc.	Units	ark	Co	npound ID#
1	15.098	74653.4	7496.2	100.00000				

1i, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 13.4 min, T_S = 13.9 min,Temperature conditions: initial temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).

Chromatogram						11	
2.0 <u>Ra</u>	<u>cemic 1i</u>					Time 15.683	Inten. 9,531
1.0							
11.0	11.5 12.0	12.5 13.0	13.5	14.0 14.5	15.0	15.5 16.0	16.5 mir
Peak Table	Table	libration Curv	•]				
Peak#	Ret. Time	Årea	Height	Conc.	Units	Bark	Compound ID#
1	13.361	125880.2	9775.1	50.83884			
2	13.941	121726.1	9468.2	49.16116			
	-						



Chromatogram)					Max	Intensity : 140,555,673
2.0 <u>Tat</u>	ole 4, (S)-	<u>·1i</u>		٥		Time 15.700	Inten. 7,125
1.5-				\bigwedge			
0.0	11.5 12.0	12.5 13.0) 13.5	14.0 14.5	15.0	15.5 16.0) 16.5 min
Results · Peak Peak Table Co	Table mpound Group	Calibration Curv	re				
Peak#	Ret.Time	Area	Height	Conc.	Units	ark	Compound ID#
2	13.431 13.930	2422.1 218296.7	361.3 18256.7	1.09736 98.90264			

1j, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 13.7 min, T_S = 14.5 min, Temperature conditions: initial temperature 120 °C, 2 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).

Chromatogram					1.00	
2.5 <u>uV(x10,000)</u>					Max Time 15.648	Intensity: 173,251,690 Inten. 7,469
2.0 Racemic 1j		Δ	Λ			
1.5-		1				
1.0-				/		
0.5				\langle		
0.0		+				
11.0 11.5 12.0	12.5 13.0	13.5	14.0 14.5	15.0	15.5 16.0) 16.5 min
Results - Peak Table						
Peak Table Compound Group	Calibration Curv	e				
Peak# Ret. Time 1 13, 728	Area 301694.4	Height 20853.7	Conc. 50, 13508	Units	∎ark	Compound ID#
2 14.516	300068.7	19286.8	49.86492			
11						
Chromatogram						
2 5 ^{UV(x10,000)}					Max	Intensity : 150,499,655
Table 3 (R)	-1i				Time 15.321	inten. 7,125
1000000000000000000000000000000000000	<u></u>]					
1.5			^			
1.0-			Λ			
0.5-						
0.0						
1.0 11.5 12.0	12.5 13.0	13.5	14.0 14.5	15.0	15.5 16.	0 16.5 min
						<u> </u>
Results · Peak Table Reak Table Command Group	Calibratian Com					
Peak# Ret. Time	Area	Height	Conc.	Units	ark	Compound ID#
1 13.842	142151.8	11713.9	100.00000			
UV(x10.000)					Max	Intensity : 174.121.507
5.0					Time 15.795	Inten. 19,063
^{4.0} <u>Table 4, (S)-</u>	lj		Λ			
3.0						
2.0						
1.0			1	1		
			1			
Earch					-	
110 115 100	1.495	49.5	110			
11.0 11.5 12.0	12.5 13.0	13.5	14.0 14.5	15.0	15.5 16.1	0 16.5 min
11.0 11.5 12.0	12.5 13.0	13.5	14.0 14.5	15.0	15.5 16.1	0 16.5 min
11.0 11.5 12.0 Besults - Peak Table Peak Table Compound Group	12.5 13.0 Calibration Curv	e]	14.0 14.5	15.0	15.5 16.	0 16.5 min
11.0 11.5 12.0 Peak Table Compound Group Peak Table Ret. Time	12.5 13.0 Calibration Curv	13.5 e	14.0 14.5	15.0 Units	15.5 16.	0 16.5 min Compound ID#

1k, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 9.1 min, T_S = 9.6 min, Temperature conditions: initial

temperature 120 °C, 1 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).



Chromatogram	<u>,</u>					May	Intensity : 153	742 570
2.0 <u>Tak</u>	ole 4, (<i>R</i>)	-1 <u>k</u>				Time 10.745	Inten.	6,953
1.5 1.0 0.5			\bigwedge					
7.0	7.5 8.0	8.5	9.0	9.5 10	.0 10.5	11.0	11.5	min
Results · Peak	Table							
Peak Table Con	mpound Group	Calibration Cur	ve					
Peak#	Ret. Time	Area	Height	Conc.	Units	Bark	Compour	ad ID#
1	9,136	170064.0	16037.0	97.75920				
2	9.688	3898.1	508.3	2.24080				

1I, chiral GC (Agilent CP-chirasil-Dex CB, T_R = 12.9 min, T_S = 13.6 min, Temperature conditions: initial temperature 120 °C, 1 °C/min to 160 °C, then 40 °C/min to 200 °C, holding 1 min).

Chromatogram							
5.0 ^{UV(x10,000})					Max	Intensity : 171,617,555
4.0 <u>Ra</u>	cemic 11					Time 14.740	Inten1,906
3.0			Λ	0			
2.0			$\left[\right]$	$\left \right\rangle$			
1.0							
0.0			-	*	<u></u>		
10.0 10	0.5 11.0	11.5 12.0	12.5 13.0	13.5 14.0	14.5 15.0	15.5	16.0 16.5 min
Results · Peak	Table						
Peak Table Co	mpound Group	Calibration Cur	ve				
1 reak#	Ket. Time 12.936	Area 484630.9	Height 29548.8	50.63838	Units	ark	Compound 19#
2	13.595	472411.9	25111.4	49.36162			
Chromatogram							
uV(x1,000)						Ma	k Intensity : 137,852,536
1	1 0 (D)					Time 15.463	Inten. 2,598
5.0- <u>Tab</u>	le $3, (R)$	<u>-11</u>					
1							
2.5-							
1			r	\			
1				the			
0.0-			^				
10.0 10	.5 11.0	11.5 12.0	12.5 13.0	13.5 14.0	14.5 15.1	0 15.5	16.0 16.5 min
E Posulto Posk	Tabla						
Peak Table Co	naue	Calibration Cur					
Peak#	Ret. Time	Area	Height	Conc.	Units	ark	Compound ID#
1	13.214	24906.3	1566.6	100.00000			
-							
Chromatogram							
uV(x1,000)						Ma	x Intensity : 172,604,213
						1006 10.044	/ John 2 770
	1 4 (0)						4 Inten. 2,770
5.0 <u>Tal</u>	ole 4, (S)	-11					4 Inten. 2,770
5.0 <u>Tal</u>	ole 4, (S)	-11					4 Inten. 2,770
5.0 <u>Tal</u>	ole 4, (S)	-11					4 Inten. 2,770
5.0 <u>Tal</u> 2.5	ole 4, (S)	-11		\wedge			4 Inten. 2,770
5.0- 2.5-	ole 4, (S)	-11		\wedge	k		4 Inten. 2,770
5.0- <u>Tal</u> 2.5-	ole 4, (<i>S</i>)	<u>-11</u>		<u> </u>	k		4 Inten. 2,770
5.0- <u>Tal</u> 2.5- 0.0-	ole 4, (S)	11 11.5 12.0	12.5 13.0	13.5 14.0	14.5 15.	0 15.5	4 Inten. 2,770
5.0 Tal	ole 4, (S)	- 11 11.5 12.0	12.5 13.0	13.5 14.0	¥ 14.5 15.	0 15.5	4 Inten. 2,770
5.0- 2.5- 0.0- 10.0 11 - Results · Peak Peak Table C.	ble 4, (S)	11.5 12.0	12.5 13.0	13.5 14.0	¥ 14.5 15.	0 15.5	4 Inten. 2,770
5.0 Tal 2.5 0.0 1 10.0 1 1 Results · Peak Peak Table (c, Peak	ole 4, (S)		12.5 13.0	135 140	14.5 15. Vnits	0 15.5	4 Inten. 2,770
5.0 2.5 0.0 10.0 11.0 1 Results - Peak Peak 1	ble 4, (S)	- 11 11.5 12.0 Calibration Cu Area 3 25352.6	12.5 13.0 rve Height 1743 4	13.5 14.0 Cone. 100.00000	14.5 15. Units	0 15.5 Bark	4 Inten. 2,770

5. References

1 J. Xu, M. Arkin, Y. Z. Peng, et al.W. H. Xu, H. L. Yu, X. F. Lin, Q. Wu, Green Chem., 2019, 21: 1907-

1911.

- 2 B. Schulte, R. Fröhlich, A. Studer, *Tetrahedron* 2008, 64(52): 11852-11859.
- 3 T. Mandal, S. Jana, J. Dash, Eur. J. Org. Chem. 2017, 2017(33): 4972-4983.