Supporting Information

Pd-Catalyzed Cross-Couplings of α-(Acyloxy)-tri-*n*-butylstannanes with Alkenyl, Aryl and Heteroaryl Electrophiles

Mohan Goli, Anyu He and J. R. Falck*

Departments of Biochemistry and Pharmacology, University of Texas Southwestern Medical Center, Dallas, Texas 75390 USA

E-mail: j.falck@UTSouthwestern.edu

General Procedures. All reactions were maintained under an argon atmosphere. Anhydrous solvents (THF, DME, benzene)) were freshly distilled from sodium benzophenone ketyl or from CaH_2 (CH_2Cl_2, toluene) under argon. Unless otherwise noted, commercially available materials were used without further purification. Flash chromatography (FC) was performed using E. Merck silica gel 60 (240–400 mesh). Thin layer chromatography (TLC) was performed using pre-coated plates purchased from E. Merck (silica gel 60 PF254, 0.25 mm). NMR spectra were recorded in $CDCl_3$ on spectrometers at operating frequencies of 300/400/500 MHz (^{1}H) or 75/100/125 MHz (^{13}C) as indicated in the individual spectrum. Chemical shifts (δ) are given in ppm relative to residual solvent (usually chloroform δ = 7.26 for ^{1}H NMR or δ = 77.23 for proton decoupled ^{13}C NMR) and coupling constants (*J*) in Hz. Multiplicity is tabulated as s for singlet, d for doublet, t for triplet, q for quadruplet, and m for multiplet. Optical rotations were measured at room temperature and corrected to 20 ºC on a Rudolph Research Analytical Autopol® IV polarimeter. LC/MS spectra were obtained with an Agilent 1200 series API-LC/MSD spectrometer. High resolution mass spectral analyses were kindly provided by Professor Kasem Nithipatikom at the Medical College of Wisconsin Mass Spectroscopy Facility. Enantiomeric excesses, expressed as % ee, were determined via HPLC with chiral columns as specified in the individual experimental descriptions and verified using appropriate racemic mixtures.

Experimental

Cross-Coupling Procedure using Iodo- or Triflate-electrophiles. A Schlenk tube was charged with α-(acyloxy)-tri-*n*-butylstannane (0.16 mmol), 1,2-bis(diphenylphosphino)ethane]dichloropalladium(II) (0.016 mmol, 10 mol%), and anhydrous THF (3 mL) and then degassed via four alternating high vacuum-argon cycles. The iodo- or triflate electrophile (0.24 mmol) in THF (2 mL) was added via syringe. After stirring under argon at 45 ºC for 10 h, the reaction mixture was diluted with Et_2O (10 mL) and filtered through a short pad of neutral alumina. The filter cake was washed with Et_2O (2 × 20 mL) and the combined organic filtrates were washed with water, brine,

and evaporated *in vacuo*. The residue was purified by silica gel chromatography or preparative TLC to furnish the adduct in the indicated yields.

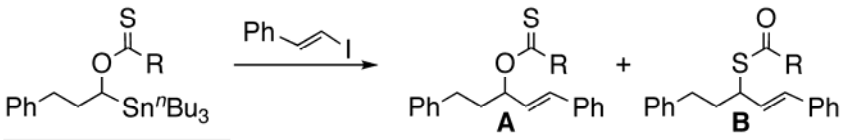
Cross-Coupling Procedure using Bromo-electrophiles. Same procedure as above, except the 1,2-bis(diphenylphosphino)ethane]dichloropalladium(II) was replaced with the Buchwald catalyst chloro(2-di-*tert*-butylphosphino-2',4',6'-tri-*iso*-propyl-1,1'-biphenyl)[2-(2-aminoethyl)phenyl] palladium(II).

Synthesis of α-(Acyloxy)-tri-*n*-butylstannanes. Acid chloride (6.30 mmol) in dry CH_2Cl_2 (5 mL) was added slowly to a 0 ºC solution of α-(hydroxy)stannane[1] (4.70 mmol), triethylamine (1.2 g, 0.0118 mmol) and a catalytic amount of DMAP in dry CH_2Cl_2 (15 mL). After stirring at room temperature for 6-7 h, the reaction mixture was washed with water (20 mL). The aqueous phase was back-extracted with CH_2Cl_2 (2 × 50 mL) and the combined extracts were washed with water (2 × 20 mL), brine (20 mL), dried over Na_2SO_4 and concentrated to dryness. The residue was purified by SiO_2 chromatography (70-230 mesh) eluting with 2-5% EtOAc/hexane to gave the α-(acyloxy)-tri-*n*-butylstannane as a colorless oil.

Reagents. Iodide **4**[2], 2-halo-2-cyclohexen-1-one **6/7**,[3] **9/10**,[4] triflate **12**,[5] vinyl iodide **15**,[6] and 6-halo-indole **17**/**18**[7] were prepared according to literature procedures. Stannyl diastereomers and enantiomers were prepared as previous described.[1] All other reagents were commercial and used as received.

Reaction Optimization

Table A. Representative Thione-Derivatives.



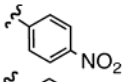
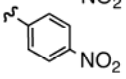
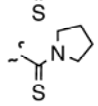
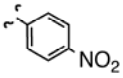
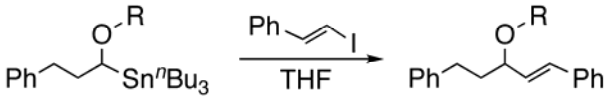
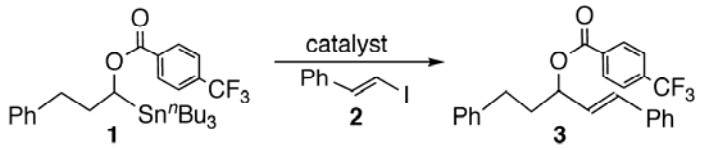
entry	R	catalyst	temp (°C)	**A** yield (%)	**B** yield (%)
1		CuTC	60	0	0
2		CuI	80	15	0
3		CuTC	65	0	0
4		CuI	85	0	0
5		CuTC	25	35	55
6		CuTC	25	23	10
7		CuI	65	0	0
8		CuTC/ $Pd_2(dba)_3$	70	0	0
9		CuTC/ $Pd(PPh_3)_4$	70	0	0
10		$Pd(dppe)Cl_2$	45	30	50
11		$Pd(dppe)Cl_2$	45	25	38
12		$Pd(dppe)Cl_2$	45	10	30
13		$Pd(dppe)Cl_2$	60	0	0
14		$Pd(dppe)Cl_2$	60	0	0
15		$Pd(dppe)Cl_2$	45	25	10
16		$Pd(dppe)Cl_2$	60	0	0

Table B. Selected Misc. *O*-Derivatives.



entry	R	catalyst	temp (°C)	yield (%)
1	C(O)CF_3	Pd(dppe)Cl_2	45	28
2	C(O)CF_3	Pd(PPh_3)$_4$	65	15
3	C(O)CF_3	Pd(CH_3CN)Cl_2	65	0
4	C(O)CF_3	Pd(tBu$_3$P)$_2$	65	0
5	P(S)Me_2	Pd(dppe)Cl_2	70	0
6	P(S)Ph_2	Pd(dppe)Cl_2	70	0
7	CH_2C(O)-N	Pd(dppe)Cl_2	70	0
8	C(O)C(S)-N	Pd(dppe)Cl_2	70	0
9	C(O)CH_2PPh_2	Pd(dppe)Cl_2	70	0
10	CH_2OC(O)-N	Pd(dppe)Cl_2	70	0
11	C(O)-N	Pd(dppe)Cl_2	70	10
12	C(O)-S	Pd(dppe)Cl_2	70	0
13	S	Pd(dppe)Cl_2	70	0

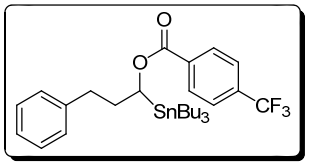
Table C. Pd Catalyst Survey[a,b]



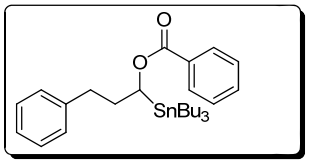
entry	catalyst	yield (%)
1	Pd(acetonitrile)tetrafluoroborate	35
2	$Pd(dppf)_2Cl_2$	10
3	Diisopropyl(phenylimidazol-2ylide-3-chloropyridyl)Pd(II)Cl_2	5
4	Pd(0)(dppf)	5
5	Chloro(di-2norbronyl phosphino(dimethylamino-1,1-biphenyl)Pd(II)	0
6	Tris(dibenzlideneactone)Pd(0)	5
7	$Pd(PPh_3)_4$	15
8	$Pd(MeCN)_2Cl_2$	4
9	Bis[di-(*tert*-butyl)(N,N-dimethylphenyl)phosphine]palladium(II) chloride	2
10	$PdCl_2[PtBu_2(4\text{-}CF_3\text{-}Ph)]_2$	18
11	Allyl[1,3-bis(2,6-diisopropylphenyl)imidazol-2-ylidene]chloropalladium(II)	10
12	1,1-Bis(di-cyclohexylphosphino)ferrocene palladium dichloride	15
13	Bis[di-(*tert*-butyl)(4-trifluoromethylphenyl)phosphine]palladium(II) chloride	5
14	$\{[P(t\text{-}Bu)_3]PdBr\}_2$	3
15	Bis(tricyclohexylphosphine)Pd(II)	10
16	Chloro(2-di-*tert*-butylphosphino-2',4',6'-tri-*iso*-propyl-1,1'-biphenyl)[2-(2-aminoethyl)phenyl]palladium(II)	65
17	Chloro(2-dicyclohexylphosphino-2',6'-dimethoxy-1,1'-biphenyl)[2-(2-aminoethylphenyl)]palladium(II) methyl-*tert*-butyl ether adduct	20
18	Chloro[2-(dicyclohexylphosphino)-3,6-dimethoxy-2',4',6'-tri-*iso*-propyl-1,1'-biphenyl][2-(2-aminoethyl)phenyl]palladium(II)	10
19	Chloro(2-dicyclohexylphosphino-2',6'-di-*iso*-propoxy-1,1'-biphenyl)[2-(2-aminoethylphenyl)]palladium(II), methyl-*tert*-butyl ether adduct	15
20	Chloro(2-dicyclohexylphosphino-2',4',6'-tri-*iso*-propyl-1,1'-biphenyl)[2-(2-aminoethyl)phenyl]palladium(II) methyl-*tert*-butyl ether adduct	15
21	Bis(dibenzonitrile)Pd Cl_2	10
22	tris(dibenzylideneactone)dipalladium	10
23	$PdCl_2$	0
24	$Pd(dba)_3$	24
25	Di-bromo-bis(tri-*tert*-butylphosphine)Pd(II)	5
26	Bis[(tri-*tert*-butyl)(4-trifluromethyl)phosphine]Pd(II) Cl_2	5
27	Diisopropyl(phenylimidazol-2-ylide-3-chloropyridyl)Pd(II)	10
28	Chloro(di-2-norbronylphosphino(dimethylamino-1,1-biphenyl)Pd(II)	15
29	Bi(diphenylphosphino)ferrocene$PdCl_2$	30
30	1,1'-bis(di-*tert*-butylphosphino)ferrocene Pd(II) Cl_2	15
31	Pd(II) acetate	10
32	Bis(benzonitrile)Pd(II) Cl_2	5
33	Bis(triethylphosphine)Pd(II) Cl_2	10
34	$Pd(PPh_3)_2Cl_2$	5
35	Bis(dibenzylideneactone)dipalladium	10

[a]Reaction conditions: α-(acyloxy)stannane **1** (1 equiv), **2** (1.5 equiv), Pd catalyst (10 mol%), THF, 45 ºC, 8-12 h. [b]Equivalent reactions conducted with CuI, CuCN, and CuTC alone or in combination with the Pd catalysts offered no advantages in yields or reaction rates.

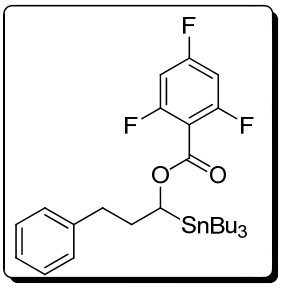
Compound Characterization



3-Phenyl-1-(tri-*n*-butylstannyl)propyl 4-(trifluoromethyl)benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 8 Hz, 2H), 7.70 (d, *J* = 8 Hz, 2H), 7.29-7.18 (m, 5H), 5.13-5.08 (m, 1H), 2.82-2.77 (m, 1H), 2.61-2.69 (m, 1H), 2.43-2.38 (m, 1H), 2.18-2.13 (m, 1H), 1.53-1.46 (m, 6H), 1.28-1.24 (m, 7H), 0.93-0.82 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.4, 141.3, 134.1, 134.0, 129.8, 128.5, 126.0, 125.3, 125.2, 72.6, 36.1, 34.5, 29.2, 29.0, 27.9, 27.8, 27.5, 27.2, 26.9, 13.6, 9.8.

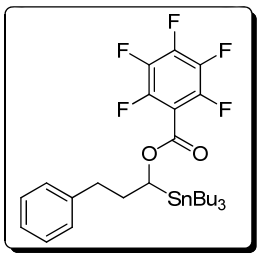


3-Phenyl-1-(tri-*n*-butylstannyl)propyl benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8 Hz, 2H), 7.56-7.16 (m, 8H), 5.07-5.04 (m, 1H), 2.85-2.81 (m, 1H), 2.80-2.67 (m, 1H), 2.41-2.34 (m, 1H), 2.16-2.10 (m, 1H), 1.53-1.44 (m, 6H), 1.29-1.23 (m, 7H), 0.94-0.82 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.9, 141.9, 132.7, 130.8, 129.5, 128.7, 128.6, 128.5, 128.4, 126.0, 71.8, 36.4, 34.5, 34.3, 29.3, 29.2, 29.1, 27.9, 27.8, 127.6, 27.5, 27.3, 13.8, 9.7.

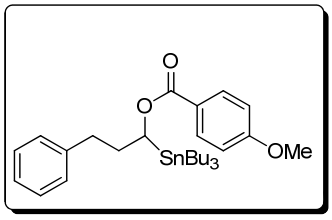


3-Phenyl-1-(tri-*n*-butylstannyl)propyl 2,4,6-trifluorobenzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32-7.27 (m, 5H), 6.75 (t, *J* = 6 Hz, 2H), 5.13-5.10 (m, 1H), 2.86-2.78 (m, 1H), 2.69-2.62 (m, 1H), 2.37-2.33 (m, 1H), 2.11-2.07 (m, 1H), 1.52-1.49 (m ,6H), 1.33-1.28 (m, 7H), 0.90-0.87 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.0, 141.6, 134.0,

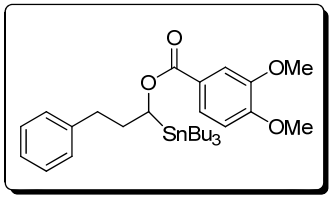
128.6, 128.5, 126.0, 101.3, 101.2, 101.0, 77.4, 36.2, 34.2, 29.2, 29.1, 29.06, 27.5, 27.3, 27.1, 13.7, 9.6.



3-Phenyl-1-(tri-*n*-butylstannyl)propyl 2, 3, 4, 5 6-pentafluorobenzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30-7.16 (m, 5H), 5.16-5.13 (m, 1H), 2.83-2.76 (m, 1H), 2.67-2.61 (m, 1H), 2.35-2.32 (m, 1H), 2.09-2.04 (m, 1H), 1.53-1.44 (m, 6H), 1.31-1.25 (m ,7H), 0.96-0.84 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.2, 141.4, 128.6, 128.5, 126.1, 74.6, 36.2, 34.2, 29.3, 29.2, 29.1, 27.6, 27.3, 27 2, 13.7, 9.7.

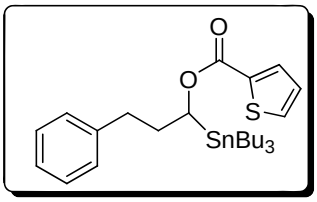


3-Phenyl-1-(tri-*n*-butylstannyl)propyl 4-methoxybenzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 8 Hz, 2H), 7.27-7.17 (m, 5H), 6.82 (d, *J* = 8 Hz, 2H), 5.12-5.06 (m, 1H), 2.81-2.73 (m, 1H), 2.61-2.65 (m, 1H), 2.42-2.33 (m, 1H), 2.15-2.12 (m, 1H), 1.54-1.49 (m, 6H), 1.42-1.26 (m, 7H), 0.93-0.82 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 163.5 141.8, 131.4, 128.5, 128,4, 125.9, 123.2, 113.6, 71.3, 55.4, 36.3, 34.4, 29.3, 29.2, 27.8, 27.5, 27.3, 27.2, 13.8, 8.3.

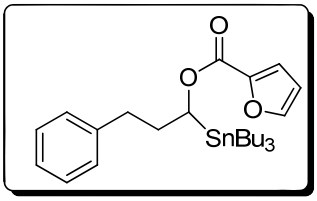


3-Phenyl-1-(tri-*n*-butylstannyl)propyl 3,4-dimethoxybenzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 8 Hz, 1H), 7.29-7.16 (m, 5H), 6.52-6.42 (m, 2H), 4.97-4.94 (m, 1H), 3.87 (s, 3H), 3.84 (s, 3H), 2.80-2.71 (m, 1H), 2.69-2.66 (m, 1H), 2.35-2.29 (m, 1H),

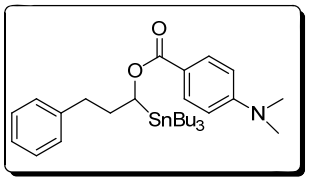
2.13-2.05 (m, 1H), 1.56-1.46 (m, 6H), 1.29-1.24 (m, 7H), 0.95-0.82 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 163.9, 161.0, 141.1, 133.5, 128.5, 128,4, 125.8, ,113.3, 104.4, 99.0, 71.1, 55.9, 55.4, 36.4, 34.4, 29.1, 29.0, 27.6, 27.5, 13.8, 9.7.



3-Phenyl-1-(tri-*n*-butylstannyl)propyl thiophene-2-carboxylate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (d, *J* = 1.2 Hz, 1H), 7.48 (d, *J* = 1.2 Hz, 1H), 7.38-7.04 (m, 6H), 5.04-5.00 (m, 1H), 2.81-2.70 (m, 1H), 2.71-2.67 (m, 1H), 2.36-2.23 (m, 1H), 2.12-2.08 (m, 1H), 1.52-1.43 (m, 6H), 129-1.23 (m, 7H) , 0.94-0.82 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.5, 141.5, 134.3, 132.8, 131.8, 128.5, 127.7, 125.9, 71.9, 36.2, 34.2, 29.2, 29.1, 29.0, 27.8, 27.5, 13.7, 9.8.

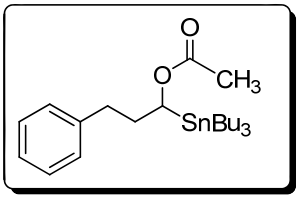


3-Phenyl-1-(tri-*n*-butylstannyl)propyl furan-2-carboxylate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 1.6 Hz, 1H), 7.38-7.04 (m, 6H), 6.50 (dd *J* = 1.2, 3.2 Hz, 1H), 5.05-5.00 (m, 1H), 2.82-2.71 (m, 1H), 2.73-2.66 (m, 1H), 2.34-2.21 (m, 1H), 2.13-2.06 (m, 1H), 1.50-1.45 (m, 6H), 1.30-1.23 (m, 7H), 0.94-0.82 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.1, 146.0, 145.1, 141.5, 128.5, 128.4, 125.8, 117.0, 111.7, 71.6, 36.1, 34.2, 29.1, 29.0, 28.9, 27.7, 27.4, 13.6, 9.7.

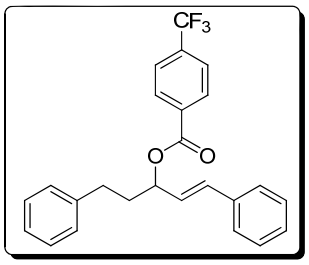


3-Phenyl-1-(tri-*n*-butylstannyl)propyl 4-(dimethylamino)benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, *J* = 9.6 Hz, 1H), 7.31-7.19 (m, 5H), 6.80 (d, *J* = 9.6 Hz, 1H), 5.00-5.95 (m, 1H), 3.05 (s, 6H), 2.87-2.79 (m, 1H), 2.77-2.69 (m, 1H), 2.35-2.22 (m,

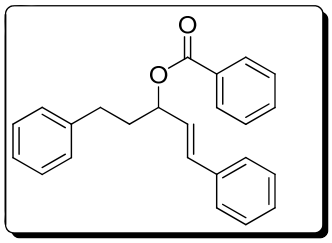
1H), 2.12-2.06 (m, 1H), 154-1.45 (m, 6H), 1.31-1.24 (m, 7H), 0.95-0.83 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.5, 153.3, 142.2, 131.2, 128.7, 126.5, 117.9, 110.7, 70.7, 41.2, 40.2, 36.7, 34.6, 29.4, 27.7, 14.0, 10.0.



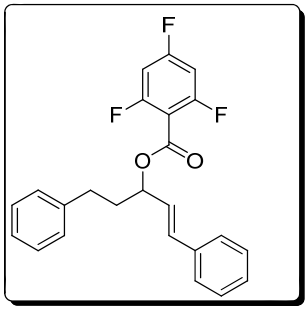
3-Phenyl-1-(tri-*n*-butylstannyl)propyl acetate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32-7.17 (m, 5H), 4.80- 4.76 (m, 1H), 2.76-2.70 (m, 1H), 2.68-2.60 (m, 1H), 2.27-2.20 (m, 1H) 2.04 (s, 3H), 2.02-2.00 (m, 1H), 1.51-1.46 (m, 6H), 1.34-1.26 (m, 7H), 0.95-0.87 (m, 14H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.2, 141.7, 128.5, 128.4, 125.9, 71.2, 36.1, 34.3, 29.1, 29.0, 20.9, 27.6, 27.4, 13.7, 9.7.



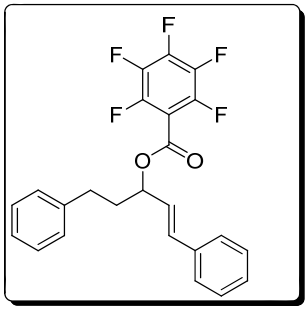
(*E*)-1,5-Diphenylpent-1-en-3-yl-4-(trifluoromethyl)benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (d, *J* = 8 Hz, 2H), 7.71 (d, *J* = 8 Hz, 2H), 7.39 (d, *J* = 8, 2H), 7.33-7.26 (m, 6H), 7.25 (d, *J* = 8 Hz, 2H), 6.72 (d, *J* = 16 Hz, 1H), 6.29 (dd , *J* = 16, 7 Hz, 1H), 5.72-5.56 (m, 1H), 2.79-2.75 (m, 2H), 2.30-2.25 (m, 1H), 2.20-2.13 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$**)** δ 164.8, 141.2, 136.2, 133.9, 133.7, 130.2, 128.8, 128.7, 128.5, 128.3, 127.0, 126.8, 126.3, 125.7, 125.6, 125.5, 75.8, 36.3, 31.8. HRMS calcd for $C_{25}H_{22}F_3O_2$ $[M+1]^+$ 411.1572, found 411.1574.



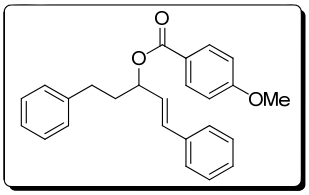
(*E*)-1,5-Diphenylpent-1-en-3-yl-benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 8 Hz, 2H), 7.57-7.38 (m, 3H), 7.33-7.20 (m, 10H), 6.73 (d, *J* = 16 Hz, 1H), 6.30 (dd, *J* = 16, 7 Hz, 1H), 5.72-5.68 (m, 1H), 2.81-2.76 (m, 2H), 2.29-2.22 (m, 1H), 2.19-2.12 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.3, 141.4, 136.4, 133.2, 133.1, 129.8, 128.8, 128.7, 128.6, 128.5, 128.2, 127.5, 126.8, 126.2, 75.0, 36.5, 31.8. HRMS calcd for $C_{24}H_{23}O_2$ $[M+1]^+$ 343.1698, found 343.1699.



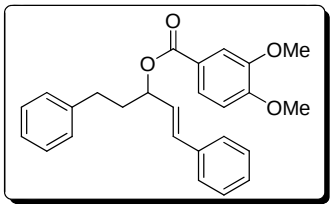
(*E*)-1,5-Diphenylpent-1-en-3-yl-2,4,6-trifluorobenzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40-7.20 (m, 10H), 6.78-6.75 (m ,2H), 6.74 (d, *J* = 16 Hz, 1H), 6.24 (dd, *J* = 16, 7 Hz ,1H), 5.71-5.68 (m, 1H), 2.82-2.74 (m, 2H), 2.22-2.21 (m ,1H), 2.10-2.04 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.3, 141.2, 136.3, 133.7, 128.8, 128.7, 128.6, 128.5 ,128.3, 126.9, 126.7, 126.6, 126.3, 126.2, 101.5, 101,3, 101.1, 76.5, 36.4, 31.5. HRMS calcd for $C_{24}H_{20}F_3O_2$ $[M+1]^+$ 397.1415, found 397.1415.



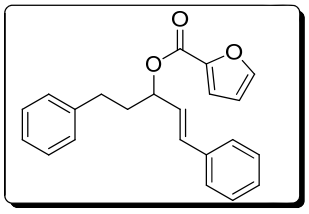
(*E*)-1,5-Diphenylpent-1-en-3-yl-2, 3, 4, 5-pentafluorobenzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39-7.17 (m, 10H), 6.75 (d, *J* = 16 Hz, 1H), 6.21 (dd, *J* = 16, 8 Hz, 1H), 5.71-5.66 (m, 1H), 2.78-2.73 (m, 2H), 2.23-2.19 (m, 1H), 2.13-2.05 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.1, 141.0, 134.4, 128.8, 128.7, 128.6, 128.5, 126.9, 126.6, 126.4, 126.0, 66.5, 36.3, 31.5. HRMS calcd for $C_{24}H_{18}F_5O_2$ $[M+1]^+$ 433.1227, found 433.1224.



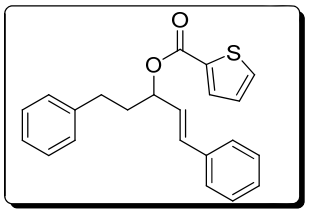
(*E*)-1,5-Diphenylpent-1en-3-yl-4-methoxybenzoate.^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, *J* = 8 Hz, 2H), 7.37-7.20 (m, 10H), 6.94 (d, *J* = 8 Hz, 2H), 6.72 (d, *J* = 16, 1H), 6.26 (dd, *J* = 16, 7 Hz, 1H) 5.70-5.62 (m, 1H), 3.85 (s, 3H), 2.80-2.75 (m, 2H), 2.29-2.21 (m, 1H), 2.16-2.11 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.8, 141.6, 132.8, 131.9, 128.8., 128.7, 128.6, 128.1, 127.8, 126.8, 126.2, 113.8, 74.6, 55.7, 36.6, 31.8. HRMS calcd for $C_{25}H_{25}O_3$ $[M+1]^+$ 373.1804, found 373.1801.



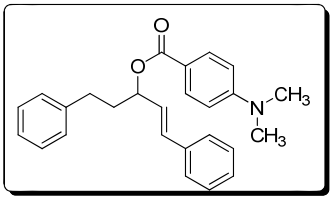
(*E*)-1,5-Diphenylpent-1en-3-yl-3, 4-dimethoxybenzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 9 Hz, 1H), 7.38-7.19 (m, 10H), 6.72 (d, *J* = 16 Hz, 1H), 6.51-6.48 (m, 2H), 6.26 (dd, *J* = 16, 7 Hz, 1H), 5.69-5.65 (m, 1H), 3.89 (s, 3H), 3.85 (s, 3H), 2.83-2.75 (m, 1H) 2.24-2.16 (m, 1H), 2.12-2.06 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.4, 141.8,136.9, 136.7, 133.9, 132.6, 128.7, 128.6, 128.5, 128.2, 128.0, 126.8, 126.1, 104.7, 99.1, 74.2, 56.1, 55.7, 36.6, 31.79. HRMS calcd for $C_{26}H_{27}O_4$ $[M+1]^+$ 403.1909, found 403.19011.



(*E*)-1,5-Diphenylpent-1-en-3-yl-furan-2-carboxylate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58-7.57 (m, 1H), 7.38-7.12 (m, 10H), 7.10 (d, *J* = 4 Hz, 1H), 6.69 (d, *J* = 16 Hz, 1H), 6.51-6.49 (m, 1H), 6.24 (dd, *J* = 16, 7 Hz, 1H), 5.68-5.63 (m, 1H), 2.77-2.72 (m, 1H), 2.25-2.20 (m, 2H), 2.13-2.11 (m, 1H), 2.09-2.04 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.2, 146.5, 144.9, 141.2, 136.3, 133.6, 128.7, 128.6, 128.5, 128.2, 127.1, 126.8, 126.2, 118.1, 112.0, 75.1, 36.3, 31.7. HRMS calcd for $C_{22}H_{21}O_3$ $[M+1]^+$ 333.1491, found 333.1492.

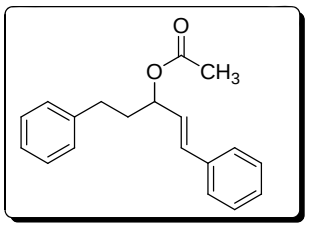


(*E*)-1,5-Diphenylpent-1en-3-yl-thiophene-2-carboxylate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (dd, *J* = 1.2, 4 Hz, 1H), 7.56 (dd, *J* = 1.2, 4.6 Hz, 1H), 7.36-7.18 (m, 10H), 7.11-7.09 (m, 1H), 6.70 (d, *J* = 16 Hz, 1H), 6.24 (dd, *J* = 16, 7 Hz, 1H), 5.63-5.561 (m, 1H), 2.80-2.75 (m, 2H), 2.25-2.20 (m, 1H), 2.13-2.06 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.8, 141.4, 136.4, 133.6, 133.6, 133.3, 132.6, 128.8, 128.7, 128.6, 128.2, 128.0, 127.3, 126.9, 126.2, 75.3, 36.5, 31.7. HRMS calcd for $C_{22}H_{21}O_2S$ $[M+1]^+$ 349.1262, found 349.1262.

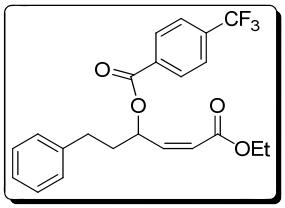


(*E*)-1,5-Diphenylpent-1-en-3-yl-4-(dimethylamino)benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 7 Hz, 2H), 7.39-7.19 (m, 10H), 6.70 (d, *J* = 7 Hz, 2H), 6.67 (d, *J* =

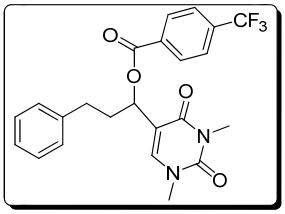
16 Hz, 1H), 6.29 (dd, *J* = 12, 7 Hz, 1H), 5.69-5.67 (m, 1H), 3.06 (s, 6H), 2.90-2.76 (m, 2H), 2.55-2.20 (m, 1H), 2.14-2.11 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.2, 141.3, 139.4, 132.3, 131.5, 128.7, 128.6, 128.4, 127.9, 126.8, 126.1, 110.9, 73.8, 40.33, 36.72, 31.8. HRMS calcd for $C_{26}H_{28}NO_2$ $[M+1]^+$ 386.2120, found 386.2123.



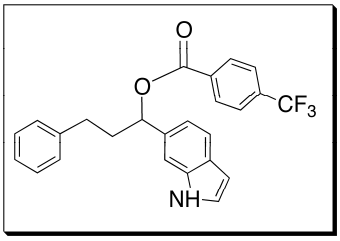
(*E*)-1,5-Diphenylpent-1-en-3-yl acetate. ^{1}H NMR (400 MHz, $CDCl_3$**)** δ 7.31-7.18 (m, 10H), 6.61 (d, *J* = 16 Hz, 1H), 6.14 (dd, *J* = 16, 8 Hz, 1H), 5.43-5.40 (m, 1H), 2.70-2.65 (m, 2H), 2.10-2.08 (m, 1H), 2.04 (s, 3H), 2.01-1.98 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 141.5, 136.4, 133.0, 128.8, 128.7, 128.6, 128.2, 127.6, 126.5, 126.2, 74.5, 36.3, 31.7, 21.5. HRMS calcd for $C_{19}H_{21}O_2$ $[M+1]^+$ 281.1542, found 281.1547.



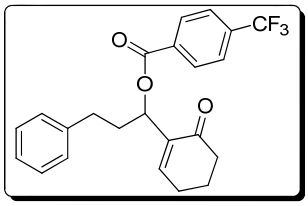
(*Z*)-6-Ethoxy-6-oxo-1-phenylhex-4-en-3-yl-4-(trifluoromethyl)benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 8 Hz, 2H), 7.69 (d, *J* = 8 Hz, 2H), 7.26-7.16 (m, 5H), 6.54-6.52 (m, 1H), 6.19 (dd**,** *J* = 12, 8 Hz, 1H), 5.90 (d, *J* = 12 Hz, 1H), 4.20 (q, *J* = 7.2 Hz, 2H), 2.83-2.79 (m, 2H), 2.22-2.16 (m, 2H), 1.30-1.24 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.5, 164.9, 146.5, 141.2, 130.2, 128.6, 128.5, 128.2, 125.6, 125.5, 125.4, 125.2, 121.4, 73.1, 60.7, 35.7, 31.9, 14.4. HRMS calcd for $C_{22}H_{22}O_4F_3$ $[M+1]^+$ 407.1470, found 407.1468.



1-(1,3-Dimethyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-5-yl)-3-phenylpropyl-4-(trifluoromethyl)benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 8 Hz, 2H), 7.73 (d, *J* = 8 Hz, 2H), 7.41-7.22 (m, 5H), 6.19-6.04 (m, 1H), 3.41 (s, 6H) 2.62-2.53 (m, 2H), 2.42-2.44 (m, 1H), 2.28-2.25 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.3, 165.7, 147.5, 141.7, 129.9, 128.6, 128.5, 126.2, 126.1, 125.6, 125.5, 118.3, 72.8, 36.2, 34.5, 29.2, 27.6. HRMS calcd for $C_{23}H_{22}F_3O_4$ $[M+1]^+$ 447.1532, found 447.1534.

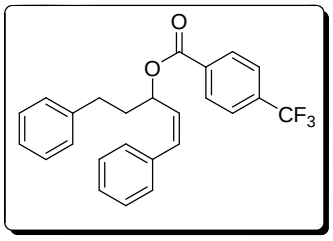


1-(1H-Indol-6-yl)-3-phenylpropyl-4-(trifluoromethyl)benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 8 Hz, 2H), 7.98 (s, 1H), 7.70 (d, *J* = 8, 2H), 7.45 (d, *J* = 8, 1H), 7.27-7.15 (m, 7H), 6.54-6.48 (m, 1H), 2.61-2.52 (m, 2H), 2.45-2.43 (m, 1H), 2.27-2.22 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.7, 141.6, 130.5, 129.9, 129.7, 128.7, 128.6, 126.1, 125.6, 125.5, 125.1, 113.1, 102.2, 72.8, 29.2, 27.6 . HRMS calcd for $C_{25}H_{21}F_3NO_2$ $[M+1]^+$ 424.1524, found 424.1525.

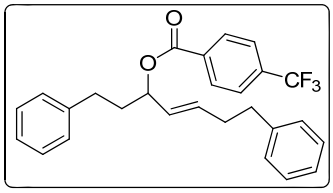


1-(6-Oxocycohex-1-enyl)-3-phenylpropyl4-(trifluoromethyl)benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 8 Hz, 2H), 7.76 (d, *J* = 8 Hz, 2H), 7.27-7.18 (m, 5H), 7.1 (t, *J* = 4 Hz, 1H), 6.21-6.05 (m, 1H), 3.10-3.08 (m, 2H), 2.96 (t, *J* = 7 Hz, 2H), 2.61-2.60 (m, 2H), 2.21-2.26 (m, 2H), 2.12-2.08 (m, 1H), 1.98-1.96 (m, 1H); ^{13}C NMR (100 MHz,

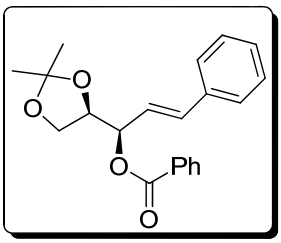
$CDCl_3$) δ 192.4, 159.6, 141.2, 129.8, 128.6, 128.5, 126.1, 125.5, 104.1, 72.7, 37.4, 30.1, 29.1, 27.5, 23.0. HRMS calcd for $C_{23}H_{22}F_3O_3$ $[M+1]^+$ 403.1521, found 403.1519.



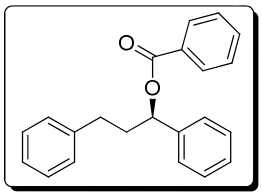
(*Z*)-1,5-Diphenylpent-1-en-3-yl-4-(trifluoromethyl)benzoate. ^1H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8 Hz, 2H), 7.69 (d, *J* = 8 Hz, 2H), 7.35-7.20 (m, 10H), 6.70 (d, *J* = 12 Hz, 1H), 5.95 (dd, *J* = 13, 6 Hz, 1H), 5.35-5.38 (m, 1H), 2.76-2.71 (m, 2H), 2.31-2.52 (m, 1H), 2.20-2.13 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 141.3, 136.4, 133.8, 133.1, 130.1, 128.7, 128.6, 128.4, 128.2, 127.1, 126.7, 126.2, 125.5, 125.4, 125.2, 76.1, 35.8, 32.1. HRMS calcd for $C_{25}H_{22}F_3O_2$ $[M+1]^+$ 411.1572, found 411.1575.



***(E)*-1,7-Diphenylhept-4-en-3-yl 4-(trifluoromethyl)benzoate.** ^1H NMR (400 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8 Hz, 2H), 7.68 (d, *J* = 8 Hz, 2H), 7.34-7.21 (m, 10H), 6.19-6.20 (m, 2H), 5.80-5.87 (m, 1H), 2.61-2.78 (m, 4H), 2.35-2.39 (m, 1H), 1.94-2.09 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2, 141.7, 141.5, 134.5, 133.5, 133.4, 132.5, 132.4, 128.8, 128.7, 128.6, 128.5, 128.4, 128.3, 127.9, 127.8, 126.3, 126.2, 125.1, 125.4, 75.3, 36.4, 35.5, 34.2, 32.3. HRMS calcd for $C_{27}H_{26}F_3O_2$ $[M+1]^+$ 439.1885 found 439.1884.

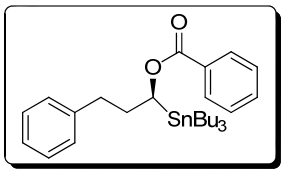


(*RE*)-1-((*R*)-2-2,dimethyl-1,3-dioxolan-4-yl)-3-phenylallyl benzoate. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 6 Hz, 2H), 7.58-7.26 (m, 8H), 6.67 (d, *J* = 16 Hz, 1H), 6.32 (dd, *J* = 16, 9 Hz, 1H), 4.45-4.42 (m, 1H), 4.15-4.10 (m, 2H), 4.05-4.004 (m, 1H), 3.95-3.93 (m, 1H), 1.25 (s, 3H), 1.24 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.3, 136.9, 133.4, 129.5, 128.8, 128.7, 128.4, 127.8, 126.7, 125.5, 110.1, 78.5, 67.9, 26.8, 26.5. HRMS calcd for $C_{21}H_{23}O_4$ $[M+1]^+$ 339.1596, found 339.1599.

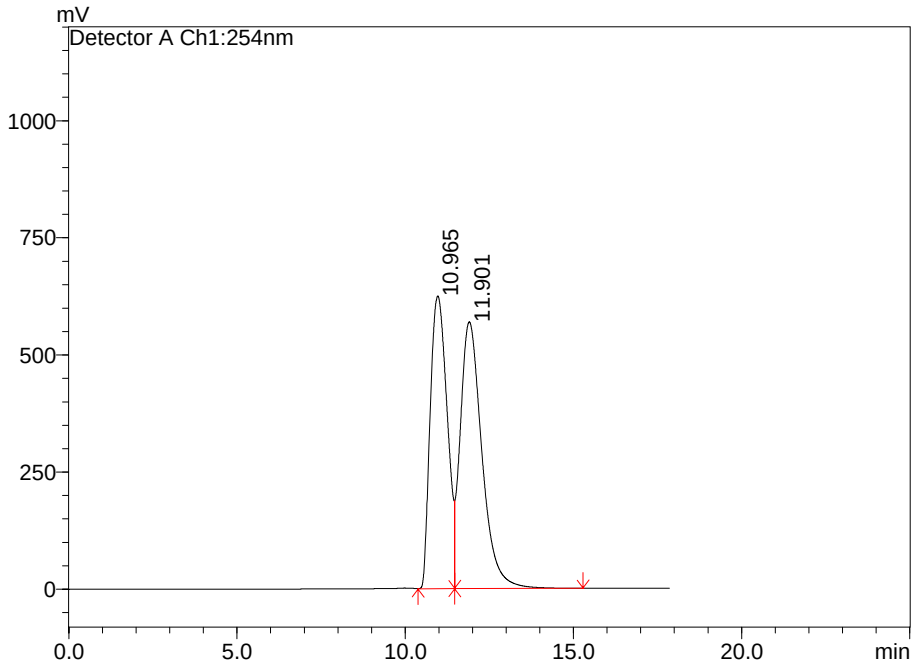


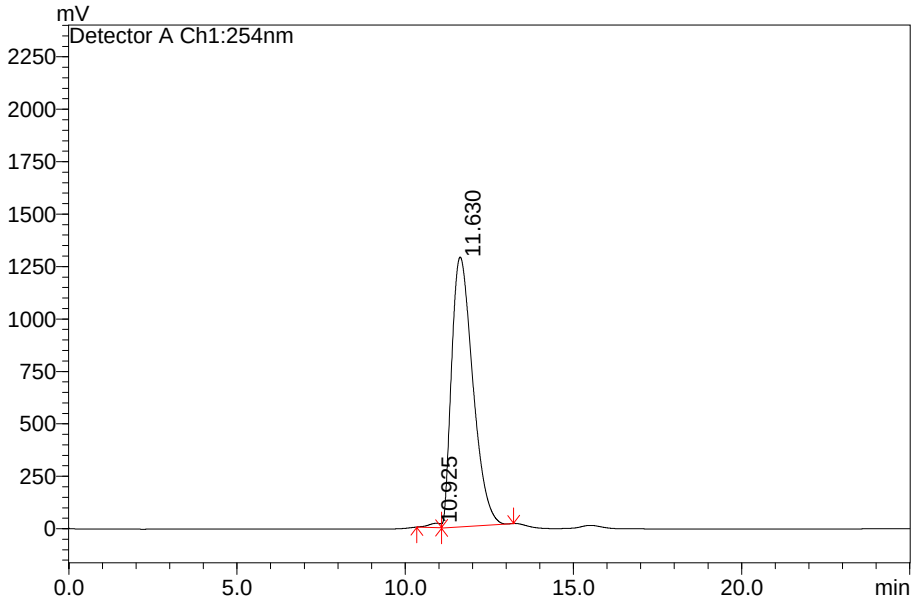
(*R*)-1,3-Diphenylpropyl benzoate. (97% ee) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 8 Hz, 2H), 7.54-7.16 (m, 13H), 7.03-6.99 (m, 1H), 2.76-2.69 (m, 2H), 2.45-2.40 (m, 1H), 2.26-2.21 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.9, 141.3, 140.7, 133.1, 130.5, 129.8, 128.7, 128.6, 128.5, 128.3, 128.1, 126.6, 126.1, 76.2, 38.2, 32.0. HRMS calcd for $C_{22}H_{21}O_2$ $[M+1]^+$ 317.1542, found 317.1543.

HPLC Chromatograms

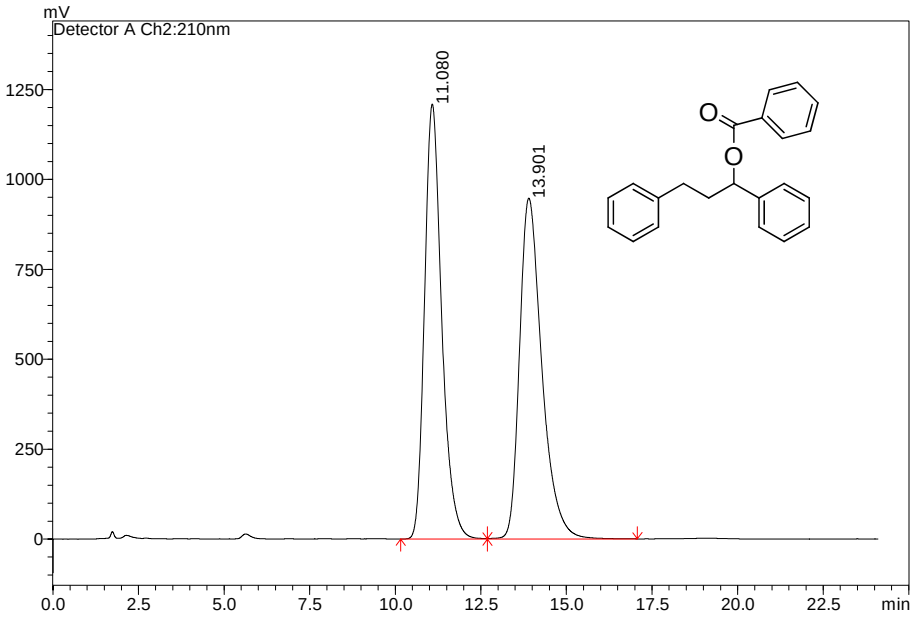


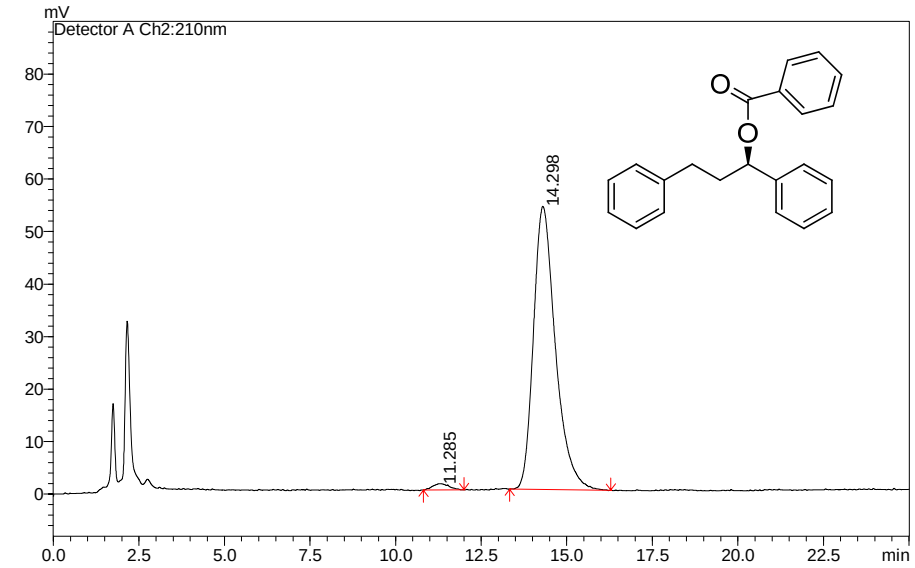
Chromatography conditions: Chiralpak ADH (4.6 × 250 mm), hexanes, 0.5 mL/min, 254 nm





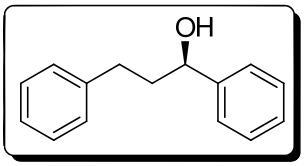
Peak#	Retention time (min)	Area%
1	10.92	0.89
2	11.63	99.10



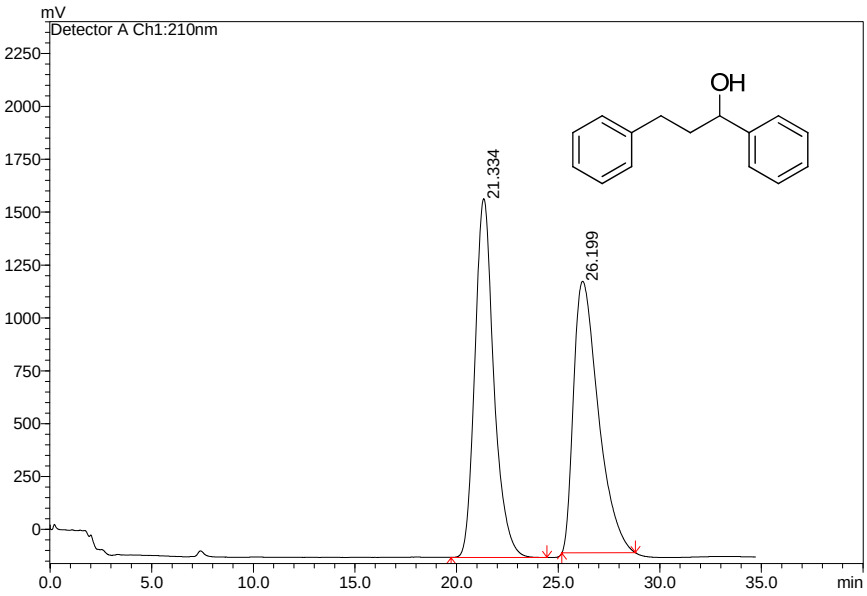


Peak#	Retention time (min)	Area%
1	11.28	1.58
2	14.29	98.41

Chromatography conditions: Chiralcel OD (4.6 × 250 mm), hexane/IPA (100:2), 1 mL/min, 210 nm.



(*R*)-1,3-Diphenylpropan-1-ol.[8,9] (98% ee) ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35-7.18 (m, 10H), 4.70-4.67 (m, 1H), 2.76-2.65 (m, 2H), 2.15-2.10 (m, 1H), 2.07-2.01 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.7, 141.9, 128.7, 128.6, 128.5, 127.8, 126.1, 126.0, 74.0, 40.6, 32.2.



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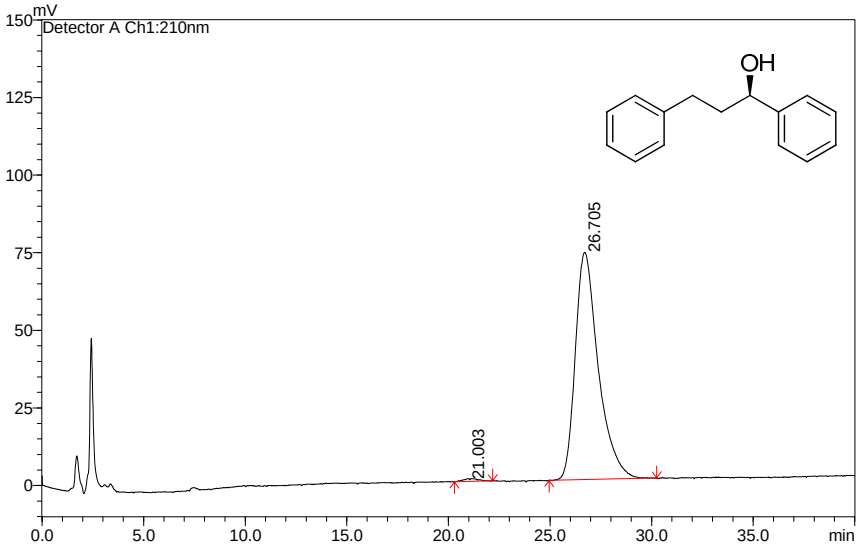

Peak#	Retention time (min)	Area%
1	21.003	0.78

2	26.705	99.28

Chromatography Conditions: Chiralcel OD (4.6 x 250 mm), hexane/IPA (95:5), 1 mL/min, 210 nm.

Literature References

(1) (a) Bhatt, R. K.; Ye, J.; Falck, J. R. *Tetrahedron Lett.* **1994**, *35* 4081–4084. (b) Mohapatra, S.; Bandyopadhyay, A.; Barma, D. K.; Capdevila, J. H.; Falck, J. R. *Org. Lett.* **2003**, *5*, 4759–4762.

(2) Paterson, I.; Paquet, T. *Org. Lett.* **2010**, *12*, 2158–2161.

(3) Smith, A. B., III; Kuerti, L.; Davulcu, A. H.; Cho, Y. S; Ohmoto, K. *J. Org. Chem.* **2007**, *72*, 4611–4620.

(4) Takami, K.; Yorimitsu, H.; Oshima, K. *Org. Lett.* **2002**, *4*, 2993–2995.

(5) Hermanson, J. R.; Hershberger, J. W.; Pinhas, A. R. *Organometallics* **1995**, *14*, 5426–5437.

(6) Takai, K.; Ichiguchi, T.; Hikasa, S. *Synlett* **1999**, 1268–1270.

(7) Ohta, T.; Yamato, Y.; Tahira, H.; Somei, M. *Heterocycles* **1987**, *26*, 2817–2822.

(8) Node, M.; Nishide, K.; Shigeta, Y.; Shiraki, H.; Obata, K. *J. Am. Chem. Soc*. **2000**, *122*, 1927–1936.

(9) Anthony, R.; Stoner, H. E. J.; Peterson, M. J.; Grover, V. K. *J. Org. Chem*. **2003**, *68*, 8092–8096.