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Supporting Information

Enhanced Enantioselectivity and Remarkable Acceleration of Lipase-Catalyzed Transesterification Using an Imizadolium PEG-alkyl Sulfate Ionic Liquid

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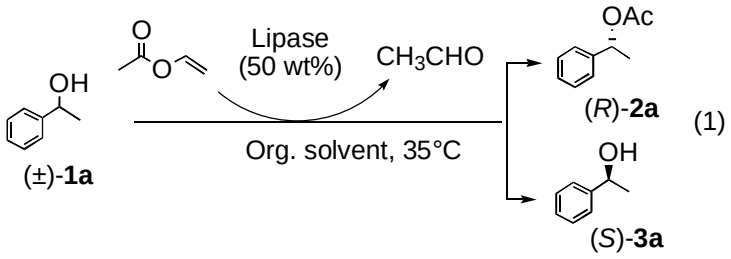
Experimental Section

General Procedures

Regents and solvents were purchased from common commercial sources and were used as received or purified by distillation over appropriate drying agents. Reactions requiring anhydrous conditions were carried out under argon with dry, freshly distilled solvents, and magnetic stirring. Reactions except the preparation of the ionic liquids were monitored by thin layer chromatography using silica gel plate and GC. Thin layer chromatography was performed with the indicated solvents and Wako gel B-5F. ^{1}H-NMR spectra and ^{13}C-NMR spectra were recorded on JEOL JNM MH-500 or JNM MH-400MHz spectrometer. Chemical shifts are expressed in ppm downfield from tetramethylsilane (TMS) in $CDCl_3$ as an internal reference. IR spectra were obtained on SHIMADZU FT-IR 8000 spectrometers. Optical rotation was measured with a JASCO DIP-370 digital polarimeter. The rate was determined by gas chromatography analysis (Quadrex bonded fused silica methyl silicone, ϕ 0.25 mm × 25 m, N_2) .The optical purity was determined by HPLC analysis using Daicel OD, OD-H, OB, AD, or OJ-H and capillary gas chromatography (Chiraldex G-TA, ϕ 0.25 mm × 20 m, 100 ºC, He). MALDI-TOF-MS spectra were obtained on BRUKER AutoFLEX-T2. SEM images were recorded on JEOL JSM-6390LV.

1-1. **Additive effect on the lipase-catalyzed transesterification**

Lipase PS-C-catalyzed acylation of 1-phenylethanol (1a) with additive in i-Pr$_2$O



(1)

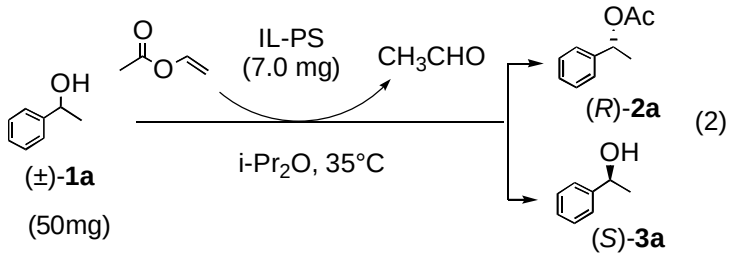
To a solution of (±)-**1a** (50 mg, 0.41 mmol), vinyl acetate (52.9 mg, 0.62 mmol) and an additive (0.04 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25 mg) and the mixture was stirred at 35 ºC. The reaction course was monitored by capillary GC-analysis and silica gel TLC. (*R*)-**2a** and (*S*)-**3a** were obtained by preparative silica gel thin layer chromatography (TLC). The enantioselectivity was determined by HPLC

analysis on a chiral column (Chiralcel OB, hexane: 2-propanol = 8 : 1, 200 : 1).

(*R*)-**2a**: **Rf** 0.55 (hexane/ethyl acetate = 4/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) 1.47 (3H, d, *J*= 6.9), 2.00 (3H, s), 5.81 (1H, q, *J*= 6.9), 7.19-7.29 (5H, m) **;** **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 21.25, 22.12, 72.22, 126.00, 127.77, 128.40, 141.59, 170.21; **IR** (neat, cm^{-1}) 2980, 1730, 1495, 1370, 1240, 1030, 940, 760.

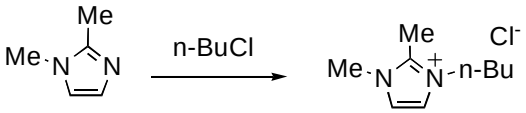
(S)-**3a**: **Rf** 0.25 (hexane/ethyl acetate = 4:1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.43 (3H, d, *J*= 6.4), 1.75 (1H, s, OH), 4.83 (1H, q, *J*= 6.4), 7.28-7.30 (5H, m) ; **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 25.01, 70.13, 125.30, 127.26, 128.33, 145.76; **IR** (neat, cm^{-1}) 3330, 3030, 2970, 2890, 1490, 1450, 1010, 900.

IL1-PS-catalyzed acylation of 1-phenylethanol (1a) in i-Pr$_2$O



To a solution of (±)-**1a** (50 mg, 0.41 mmol) and vinyl acetate (52.9 mg, 0.62 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (7.0 mg) and the mixture was stirred at 35ºC. The reaction course was monitored by capillary GC-analysis and silica gel TLC. (*R*)-**2a** and (*S*)-**3a** were obtained by preparative silica gel thin layer chromatography (TLC). The enantioselectivity was determined by HPLC analysis using a chiral column (Chiralcel OB, hexane: 2-propanol = 8 : 1, 200 : 1).

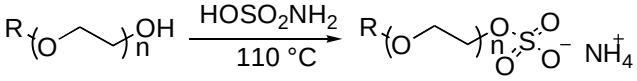
1-Butyl-2,3-dimethylimidazolium chloride



1,2-dimethylimidazole	FW.96.13	55.38 g	0.58 mol
1-chlorobutane	FW.92.57	53.33 g	0.58 mol

A solution of 1,2-dimethylimidazole (55.38 g, 0.58 mol) and 1-chlorobutane (53.33 g, 0.58 mol) was stirred for 24 h under reflux conditions. After being cooled to room temperature, excess 1-chlorobutane was removed under reduced pressure to give 1-butyl-2,3-dimethylimidazolium chloride ([bdmim][Cl]) as a half melted white solid and used it to the next reaction without further purification.

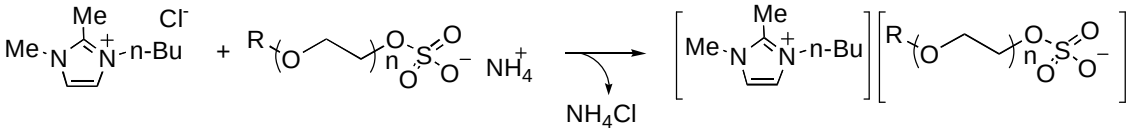
Ammonium polyoxyethylene(n) alkyl sulfate



Brij56	FW.683	13.7 g	20.0 mmol
Sulfamic acid	FW.97.09	1.94 g	20.0 mmol

A mixture of Brij56 (polyoxyethylene(10) cetyl ether)(13.7 g, 20.0 mmol) and sulfamic acid (1.94 g, 20.0 mmol) was stirred for 17 h at 110 ºC under argon and dried under reduced pressure at 66.7 Pa at 60 ºC for 3 h to give ammonium Brij56-sulfate as a white solid.

1-Butyl-2,3-dimethylimidazolium polyoxyethylene alkyl sulfate (IL1)



After the preparation of ammonium polyoxyethylene(10) cetyl sulfate and 1-butyl-2,3-dimethylimidazolium chloride, to an acetone solution (20 mL) these two crude products were added and the mixture was stirred for 24h at rt. Ammonium chloride which precipitated was removed by filtration through a sintered glass filter with a Celite pad. The filtrate was concentrated under vacuum for a little, and then added activated carbon and was stirred for 10 minutes. The activated carbon was removed by filtration through a sintered glass filter with a Celite pad and the filtrate was filtrated through Al_2O_3 (neutral type I, activated) short column. The filtrate was evaporated and dried under reduced pressure at 5 Torr for 24 h at 60 ºC to give 1-butyl-2,3-dimethylimidazolium polyoxyethylene(10) cetyl sulfate (13.59 g, 0.015 mol) as a yellowish solid at room temperature in 74.3% yield.

1-Butyl-2,3-dimethylimidazolium polyoxyethylene(10) cetyl sulfate (IL1) (from Brij 56): **mp** 35-37ºC; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.80 (3H, t, *J*= 7.4), 0.88 (3H, t, *J*= 7.3), 1.10-1.30 (32H, m), 1.29-1.31 (2H, m), 1.47-1.50 (4H, m), 1.70-1.73 (2H, m), 2.61 (3H, s), 3,36 (4H, t, *J*= 5.1), 3.49-3.62 (34H, m), 3.81 (3H, s), 4.00 (2H, t, *J*= 5.1), 4.07 (2H, t, *J*= 7.8), 7.24 (1H, s), 7.38 (1H, s); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 9.48, 13.20, 13.77, 19.23, 22.30, 25.73, 28.98, 29.11, 29.23, 29.31, 31.35, 31.54, 35.06, 48.01, 61.20, 65.78, 69.68, 69.05, 70.19, 71.12, 72.26, 120.17, 122.65, 143.57; **IR** (neat, cm^{-1}) 2916, 2851, 1468, 1350, 1252, 1115, 951, 845; **MALDI-TOF MS** (matrix: SA) found 1344 (average MW).

1-Butyl-3-methylimidazolium polyoxyethylene(10) cetyl sulfate (IL2) (from Brij 56): **mp** 36~37ºC; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.81 (3H+a, t, *J*= 6.8), 0.89 (3H, t, *J*= 7.4), 1.14-1.32 (31H+a, m), 1.49-1.52 (4H, m), 1.78-1.84 (2H, m), 3.09 (2OH, brd), 3.37 (4H, t, *J*= 6.9), 3.50-3.64 (32H+a, m), 3.65 (4H, t, *J*= 4.6), 3.95 (3H, s), 4.11 (2H, t, *J*= 4.6), 4.17 (2H, t, *J*= 7.3), 7.29 (1H, s), 7.40(1H, s), 9.42 (1H, s); **^{13}CNMR** (125 MHz, ppm, $CDCl_3$) d 13.31, 13.99, 19.32, 22.54, 29.20, 29.34, 29.46, 29.54, 31.90, 36.35, 49.58, 61.52, 69.89, 70.16, 70.41, 71.38, 72.41, 121.67, 123.54, 137.66; **IR** (neat, cm^{-1}) 3435, 2849, 2696, 2610, 1967, 1695, 1574, 1472, 1028, 843, 718, 625, 528; **MALDI-TOF MS** (matrix: SA) found 1079 (average MW).

1-Butyl-2,3-dimethylimidazolium polyoxyethylene(23) lauryl sulfate (IL1a) (from Brij35): **mp** 50-51 ºC; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.87-0.89 (5H, m) , 0.96 (3H, t, *J*= 7.3), 1.26 (18H+a, brd), 1.54-1.59 (2H, m), 1.77 (2H, quin, *J*= 7.6), 2.68 (3H, s), 3.45 (2H, t, *J*= 6.9), 3.57-3.73 (88H+ß, m), 3.78-3,80 (2H, m), 3.88 (3H, s), 4.09 (2H, t, *J*= 5.1), 4.13 (2H, t, *J*= 7.6), 7.33 (1H, d, *J*= 2.8), 7.49 (1H, d, *J*= 2.3); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 9.66, 13.36, 13.93, 19.39, 22.47, 25.88, 29.13, 29.27, 29.39, 29.42, 31.46, 35.24, 48.17, 61.45, 65.97, 69.84, 70.35, 71.32, 72.35, 120.71, 122.78, 143.70; **IR** (neat, cm^{-1}) 3420, 2880,1470,1340,1230, 1110, 950, 840; **MALDI-TOF MS** (matrix: SA) found 1722 (average MW)

1-Butyl-2,3-dimethylimidazolium polyoxyethylene(2) cetyl sulfate (IL1b) (from Brij52): **mp** 38-39 ºC; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.81 (3H, t, *J*= 6.9), 0.91 (3H, t, *J*= 7.4), 1.18-1.37 (28H+a, m),1.44-1.60 (2H, m), 1.74 (2H, quin, *J*= 7.6), 2.39 (1H+ß, brd, OH), 2.66 (3H,s), 3.34-3.41 (2H,m), 3.46-3.68 (8H+?, m), 3.86 (3H, s), 3.92 (1H, t, *J*= 6.9), 4.03-4.08 (2H, m),7.20 (1H, s) 7.38 (1H, d, *J*= 2.3); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 9.82, 13.38, 13.96, 19.43, 22.51, 25.19, 29.19, 29.33, 29.49, 29.53, 31.59, 31.75, 35.35, 48.30, 53.76, 65.97, 67.22, 69.84, 70.16, 70.38, 71.36, 72.3, 120.90, 122.88, 143.66; **IR** (neat, cm^{-1}) 3420, 3140, 2920, 2850, 1540, 1470, 1360, 1220, 1030; **MALDI-TOF MS** (matrix: SA) found 681 (average MW)

1-Butyl-2,3-dimethylimidazolium polyetylene glycol hexadecyl sulfate (IL1c) (from Bril58): **mp** 40-41 ºC; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.79-0.82 (3H, m), 0.90 (3H, t, *J*= 7.3), 1.18 (28H+a, brd), 1.31 (2H, m), 1.50 (2H,m), 1.72 (2H, brd), 2.64 (3H, s), 2.94 (3H, brd), 3.38 (2H, t, *J*= 6.9), 3.51-3.52 (2H, m), 3.58 (80H+ß, brd), 3.65 (2H, m), 3.84 (3H, s), 4.04-4.07 (4H, m) 7.24 (1H, brd), 7.42 (1H, brd); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 9.13, 12.96, 13.51, 18.93, 22.01, 25.43, 28.68, 28.82, 28.94, 28.99, 29.01, 31.08, 31.25, 34.73, 47.66, 60.81, 65.44, 68.54, 69.34, 69.40, 69.65, 69.89, 70.77, 71.26, 72.01, 120.43, 122.36, 143.29; **IR** (neat, cm^{-1}) 3410, 2860,

1540, 1450, 1350, 1250, 1110, 1030, 950, 840; **MALDI-TOF MS** (matrix: SA) found 1608 (average MW)

1-Butyl-2,3-dimethylimidazolium polyoxyethylene(2) oleyl sulfate (IL1d) (from Brij 92): **mp** -18- -15 ºC; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.81 (3H, t, *J*= 6.9), 0.90 (3H, t, *J*= 7.4), 1.18-1.20 (22H+a, m), 1.28-1.35 (2H, m), 1.47-1.48(2H, m), 1.72 (2H, q, *J*= 7.5), 2.63 (3H, s), 3.35-3.40 (2H, m), 3.48-3.51 (2H, m), 3.52-3.58 (4H, m), 3.65-3.67 (4H, m), 3.84 (3H, s), 3.91 (2H, t, *J*= 6.9), 4.03-4.08 (2H, m), 5.27-5.31 (2H, m), 7.24 (1H, d, *J*= 1.8), 7.41 (1H, d, *J*= 2.3); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 9.71, 13.36, 13.94, 19.41, 22.49, 25.75, 25.89, 27.01, 28.78, 28.93, 29.00, 29.12, 29.17, 29.32, 29.46, 29.51, 29.57, 31.55, 31.71, 32.42, 35.28, 48.25, 66.02, 67.27, 69.76, 69.82, 70.08, 70.33, 71.11, 120.86, 122.81, 129.62, 129.72, 143.6; **IR** (neat, cm^{-1}) 2920, 2850, 1590, 1540, 1470, 1220, 1120, 1030, 920, 760; **MALDI-TOF MS** (matrix: SA) found 654 (average MW)

1-Butyl-2,3-dimethylimidazolium polyoxyethylene(10) oleyl sulfate (IL1e) (from Brij 97): **mp** 38-39 ºC; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.82 (3H+a, t, *J*= 6.9), 0.91 (3H, t, *J*= 7.3), 1.20-1.25 (22H+ß, m), 1.31-1.35 (2H, m), 1.49-1.53 (2H+?, m), 1.73 (2H, quin, *J*= 7.8), 1.91-1.97 (4H, m), 2.63 (3H, s), 3.39 (2H, t, *J*= 6.9), 3.57-3.58 (2H, m), 3.59-3.61 (36H+e, m), 3.64-3.68 (2H, m), 3.83 (3H, s), 4.03-4.08 (2H, m), 5.28-5.30 (4H, m), 7.23 (1H, d, *J*= 2.3), 7.40 (1H, d, *J*= 1.8); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 9.15, 13.02, 13.58, 18.99, 22.09, 25.52, 26.60, 28.57, 28.65, 28.78, 28.88, 28.91, 29.04, 29.06, 29.11, 29.17, 31.16, 31.32, 32.01, 34.77, 47.72, 60.88, 65.54, 69.39, 69.47, 69.70, 69.97, 70.86, 72.09, 120.50, 122.41, 129.19, 129.26, 143.33; **IR** (neat, cm^{-1}) 3410, 2920, 2850, 1650, 1560, 1460, 1350, 1250, 1100; **MALDI-TOF MS** (matrix: SA) found 1086 (average MW)

1-Butyl-2,3-dimethylimidazolium [polyoxyethylene(100) stearyl ether] sulfonate (IL1f) (from Brij700): **mp** 54~55 ºC; **IR** (neat, cm^{-1}) 3410, 2880, 1630, 1560, 1540, 1470, 1450, 1350, 1280, 1250, 1110; **MALDI-TOF MS** (matrix: SA) found 3554 (average MW).

Preparation of IL1-supported lipase PS (IL1-PS) by lyophilization

0.1M Potassium Phosphate buffer (pH 7.2)	10 mL
Lipase PS-C	1.0 g
IL1	29.0 mg

To a buffer solution (pH 7.2, 0.1 M potassium phosphate buffer)(10 mL) was added 1.0 g commercial lipase PS-C (Amano). The mixture was centrifuged at 3,500 rpm for 5 minutes. IL1 (29.0 mg, ca. 3.1×10^{-2} mmol) was dissolved into the resulting supernatant, that involves ca. 3.1×10^{-4} mmol of lipase PS protein, and the mixture was lyophilized to give IL1-PS (344 mg) as a white powder. Using the same procedure, thirteen types of supported lipase PS were prepared (Table 1).

Table 1

Coating Material (CM)			Molar ratio/ Enzyme : CM	Lipase PS-C	Amounts of IL-supported PS
IL1	FW.915	14.5 mg	1 : 50	1.0 g	277 mg
IL1	FW.915	87.0 mg	1 : 300	1.0 g	361 mg
IL1	FW.915	145 mg	1 : 500	1.0 g	433 mg
IL2	FW.901	28.0 mg	1 : 100	1.0 g	252 mg
Salt1	FW.780	24.4 mg	1 : 100	1.0 g	235 mg
Brij56	FW.683	21.4 mg	1 : 100	1.0 g	228 mg

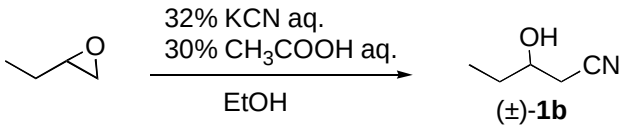
Salt1: $[NH_4][C_{16}H_{33}(OCH_2CH_2)_{10}OSO_3]$

Table 2

Coating material			Amount of Lipase PS	Supported Lipase PS
$[bmim]BF_4$	FW.226.0	7.5 mg	1.0 g	225 mg
$[bdmim]BF_4$	FW.240.1	7.1 mg	1.0 g	233 mg
$[bdmim]pentOSO_3$	FW.320.5	10.0 mg	1.0 g	227 mg
IL1a	FW.1432	44.8 mg	1.0 g	140 mg
IL1b	FW.563	17.7 mg	1.0 g	194 mg
IL1c	FW.1355	43.0 mg	1.0 g	254 mg
IL1d	FW.589	19.5 mg	1.0 g	207 mg
IL1e	FW.941	29.9 mg	1.0 g	204 mg
IL1f	FW.4908	152 mg	1.0 g	304 mg

Preparation of substrate alcohols

3-Hydroxypentanenitrile (1b)[13c]

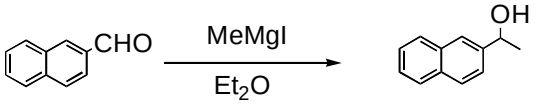


(±)-**1b**

1,2-epoxybutane	FW.72.11	10.8 g	150 mmol
KCN	FW.65.12	10.1 g	150 mmol
CH_3COOH	FW.60.05	9.0 g	150 mmol
EtOH		25 mL	

To a solution of 1,2-epoxybutane (10.8 g,150 mmol) in ethanol (25 mL) were added 32% KCN aqueous solution (150 mmol, 21 mL) and 30% CH_3COOH aqueous solution (150 mmol, 21 mL) dropwise at the same time at 60 ºC under argon atmosphere, then the mixture was stirred for 3.5 h. After being cooled to room temperature, the mixture was extracted with Et_2O and the combined organic layers were dried over $MgSO_4$, filtered, and evaporated. Silica gel flash column chromatography (hexane/ethyl acetate = 10/1-2/1) and subsequent Claisen distillation gave **1b** (7.76 g, 78 mmol) as a colorless oil in 52% yield: **Rf** 0.29 (hexane/ethyl acetate = 2/1); **bp** 160 ºC/12 Torr ; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.99 (3H, t, *J*= 7.3), 1.61-1.66 (2H, m), 2.51 (2H, dd, *J*= 6.4, 17.0), 2.58 (1H, dd, *J*= 4.8, 16.8), 3.89 (1H, quin, *J*= 6.4); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 9.55, 25.42, 29.24, 68.68, 117.91; **IR** (neat, cm^{-1}) 3430, 2970, 2940, 2250, 1470, 1420, 1120, 990.

1-(Naphtalen-2-yl)ethanol (1c) [25]



(±)-**1c**

2-Naphthaldehyde	FW.156.18	4.69 g	30 mmol	
MeMgI 0.98M in Et_2O		33.6 mL	33 mmol	(1.1eq)
Et_2O		40 mL		

To a diethyl ether (Et_2O) (40 mL) solution of 2-naphthaldehyde (4.69 g, 30 mmol) was added a Et_2O (33.6 mL) solution of methyl magnesium iodide (33 mmol) dropwise at 0 ºC, and the mixture was allowed to warm to room temperature with stirring for 2.5 h. The reaction was quenched by addition of saturated aqueous NH_4Cl solution then acidified by 2M-HCl, and extracted with Et_2O. The organic layer was washed with aqueous sodium hydrogen carbonate ($NaHCO_3$) and brine, dried over anhydrous $MgSO_4$ and evaporated. Silica gel flash column chromatography (hexane/ethyl acetate = 20/1 to 2/1) gave 1-(naphthalen-2-yl)ethanol (**1c**) (4.66 g, 27 mmol) in 90% yield. Using the

same procedure, alcohols **1d**, **1e**, **1f**, **1g**, **1h**, and **1i** were prepared: **Rf** 0.28 (hexane/ethyl acetate = 4/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.50 (3H, d, *J*= 6.4), 1.96 (1H, brd, OH), 4.98 (1H, q, *J*= 6.4), 7.38-7.43 (3H, m), 7.72-7.77 (4H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 24.96, 70.19, 123.67, 123.74, 125.61, 125.96, 127.54, 127.82, 128.09, 132.74, 133.17, 143.11; **IR** (KBr, cm^{-1}) 3310, 1510, 1360, 1280, 1120, 1070, 900, 860.

1-(Naphthalen-2-yl)propanol (1d) [26]***:*** **Rf** 0.22 (hexane/ethyl acetate = 7/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.85 (3H, t, *J*= 7.6), 1.73-1.85 (2H, m), 1.98 (1H, brd, OH), 4.67 (1H, t, *J*= 6.4), 7.37-7.41 (3H, m), 7.68-7.75 (4H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 10.02, 31.59, 75.84, 124.07, 124.60, 125.59, 125.97, 127.54, 127.80, 128.02, 132.81, 133.12, 141.84; **IR** (neat, cm^{-1}) 3350, 2960, 2880, 1510, 1110, 1020, 900, 820.

1-(Naphthalen-1-yl)ethanol (1e) [27]***:*** **Rf** 0.27 (hexane/ethyl acetate = 4/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.58 (3H, d, *J*= 6.4), 1.88 (1H, brd, OH), 5.58 (1H, q, *J*= 6.6), 7.38-7.44 (3H, m), 7.59 (1H, s), 7.69-7.80 (2H, m), 8.03 (1H, d, *J*= 8.2); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 24.33, 67.09, 121.96, 123.14, 125.51, 126.00, 127.91, 128.86, 130.25, 133.78, 141.31; **IR** (neat, cm^{-1}) 3370, 2970, 1510, 1370, 1170, 1110, 1070, 780.

1-(pyridine-3-yl)ethanol (1f) [28]***:*** **Rf** 0.35 (ethyl acetate/methanol = 20/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.44 (3H, d, *J*= 6.4), 3.44 (1H, brd, OH), 4.85 (1H, q, *J*= 6.4), 7.18-7.21 (1H, m), 7.67 (1H, d, *J*= 7.8), 8.34 (1H, d, *J*= 4.6), 8.42 (1H, s); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 24.95, 67.06, 123.39, 133.51, 141.83, 146.66, 147.52; **IR** (neat, cm^{-1}) 3250, 2870, 1580, 1430, 1300, 1090, 1050, 900

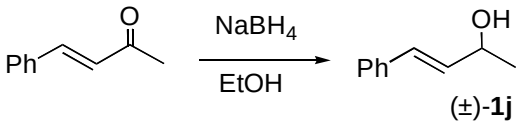
1-(pyridine-4-yl)ethanol (1g) [29]***:*** **Rf** 0.33 (ethyl acetate/methanol = 20/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.41 (3H, d, *J*= 6.4), 3.66 (1H, brd, OH), 4.82 (1H, q, *J*= 6.6), 7.23 (2H, dd, *J*= 0.9, 4.6), 8.38 (2H, dd, *J*= 1.4, 4.6); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 24.83, 67.94, 120.57, 148.70, 156.15; **IR** (neat, cm^{-1}) 3410, 2980, 2860, 1610, 1420, 1220, 1110, 1070.

1-(pyridine-2-yl)ethanol (1h) [30]***:*** **Rf** 0.47 (ethyl acetate/methanol = 20/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.50 (3H, d, *J*= 6.4), 4.89 (1H, q, *J*= 6.7), 7.18 (1H, dd, *J*= 4.9, 7.6), 7.33 (1H, d, *J*= 8.3), 7.68 (1H, dt, *J*= 1.7, 7.7), 8.50 (1H, d, *J*=4.6); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 24.02, 69.00, 119.68, 122.07, 136.75, 147.95, 163.28; **IR** (neat, cm^{-1}) 3350, 2970, 1600, 1440, 1120, 1080, 910, 790

5-phenyl-1-penten-3-ol (1i) [31]***:*** **Rf** 0.17 (hexane/ethyl acetate = 7/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.82-1.87 (2H, m), 2.04 (1H, brd, OH), 2.65-2.77 (2H, m), 4.12 (1H, q, *J*= 6.3), 5.13 (1H, d, *J*=9.2,), 5.24 (1H, d, *J*= 17.4), 5.86-5.93 (1H, m),

7.17-7.30 (5H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 31.54, 38.40, 72.41, 114.90, 125.77, 128.32, 140.86, 141.79; **IR** (neat, cm^{-1}) 3370, 2930, 2860, 1500, 1450, 1120, 1030, 990.

4-phenyl-3-butene-2-ol (1j) [32]

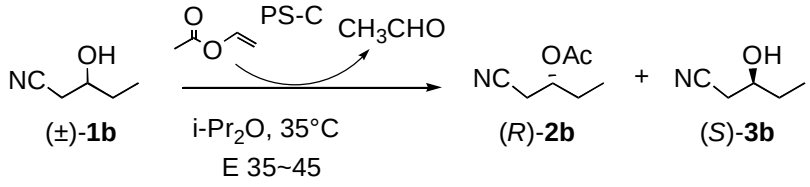


(±)-**1j**

(trans)-4-phenyl-3-buten-2-one	FW.146.19	10.0 g	68.4 mmol	
$NaBH_4$	FW.37.83	3.92 g	103.6 mmol	(1.5eq)
EtOH		250 mL		

To a solution of trans-4phenyl-3-buten-2-one (10.0 g, 68.4 mmol) in ethanol under argon atmosphere at 0 ºC was added $NaBH_4$ (3.92 g, 103.6 mmol) at one portion. The mixture was stirred at room temperature for 2 h and the ethanol solvent was removed by evaporation and the residue was dissolved into ethyl acetate. The combined organic layers were dried over $MgSO_4$. Silica gel flash column chromatography (hexane/ethyl acetate = 20/1-1/1) gave (±)-**1j** (9.69 g, 65.4 mmol) in 96% yield: **Rf** 0.15 (hexane/ethyl acetate = 7/1); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.37 (3H, d, *J*= 6.4), 2.38 (1H, brd, OH), 4.48 (1H, dquin, *J*= 0.9, 6.4), 6.26 (1H, dd, *J*= 6.4, 15.6), 6.56 (1H, d, *J*= 15.6), 7.21-7.39 (5H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 23.27, 68.65, 126.33, 127.46, 128.45, 129.14, 133.52, 136.62; **IR** (neat, cm^{-1}) 3340, 2970, 1740, 1490, 1460, 1190, 1100, 980.

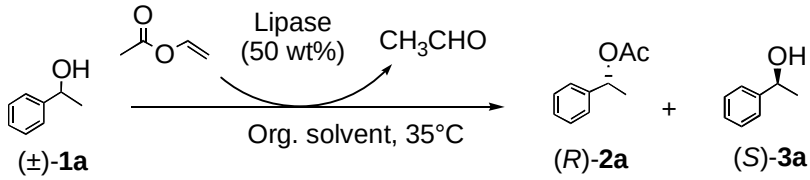
Optical resolution of 3-hydroxypentanenitrile (1b) via lipase-catalyzed reaction in i-Pr$_2$O solvent system; determination of the Initial rate



(±)-**1b**	FW.99.13	50.0 mg	0.50 mmol	
Vinyl acetate	FW.86.09	65.1 mg	0.76 mmol	1.5eq.
Lipase PS-C (Amano)		25.0 mg		(50 wt%)
i-Pr$_2$O		2.0 mL		

To a mixture of (±)-**1b** (50.0 mg, 0.50 mmol) and vinyl acetate (65.0 mg, 0.76 mmol) in diisopropylether (2.0 mL) was added Lipase PS-C (25.0 mg) and the mixture was stirred at 35 ºC. The reaction course was monitored by capillary gas chromatography and determined the initial rate.

Lipase PS-C-catalyzed acylation of 1-phenylethanol (1a)



(±)-**1a**	FW.122.16	50.0 mg	0.41 mmol	
Vinyl acetate	FW.86.09	54.8 mg	0.60 mmol	(1.5eq.)
Lipase PS-C (Amano)		25 mg		
i-Pr$_2$O		2.0 mL		

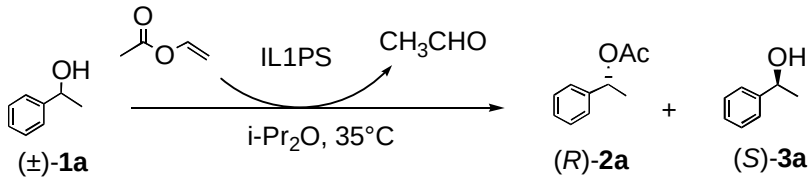
To a solution of (±)-**1a** (50 mg, 0.41 mmol) and vinyl acetate (54.8 mg, 0.60 mmol) in i-Pr$_2$O (2.0 mL) was added Lipase PS-C (25 mg) and the mixture was stirred at 35 ºC for 18 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded (*R*)-**2a** (20 mg, 0.12 mmol) in 30% yield and (*S*)-**3a** (18 mg, 0.15 mmol) in 36% yield.

(*R*)-**2a**; 62% ee (Chiralcel AD, hexane: 2-propanol = 99:1, 35ºC), t_R= 5.4 min for (*R*)-isomer and t_R= 6.1 min for (*S*)-isomer.

(*S*)-**3a**; 69% ee (Chiralcel OD-H, hexane: 2-propanol = 9:1, 35ºC), t_R= 9.5 min for

(*R*)-isomer and t_R=10.1 min for (*S*)-isomer.

IL1-PS-catalyzed *acylation of 1-phenylethanol (1a)*



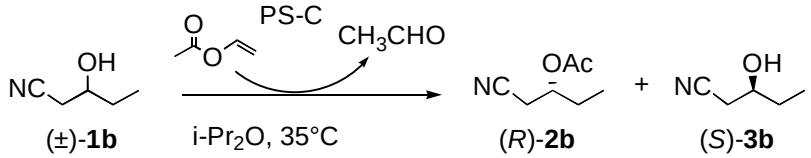
(±)-**1a** (*R*)-**2a** (*S*)-**3a**

a

(±)-**1a**	FW.122.16	51.5 mg	0.42 mmol	
Vinyl acetate	FW.86.09	60.4 mg	0.70 mmol	(1.7eq.)
IL1-PS		8.0 mg		
i-Pr_2O		2.0 mL		

To a solution of **(±)-1a** (51.5 mg, 0.42 mmol) and vinyl acetate (60.4 mg, 0.70 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (8.0 mg) and the mixture was stirred at 35 ºC for 2 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded (*R*)-**3a** (26.7 mg, 0.16 mmol) in 39% yield alcohol (*S*)-**1a** (24.7 mg, 0.20 mmol) in 48% yield. Remarkable enhanced enantioselectivity was obtained by this reaction.
(*R*)-**2a**: >99% ee; $[a]^{27}_D$ +105.6 (c 1.35, $CHCl_3$)
(*S*)-**3a**: 88% ee; $[a]^{27}_D$ -45.9 (c 1.05, $CHCl_3$)

Lipase PS-C-catalyzed acylation of 3-hydroxypentanenitrile (1b)



(±)-**1b** (*R*)-**2b** (*S*)-**3b**

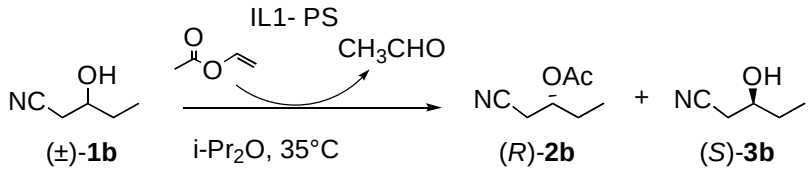
(±)-**1b**	FW.99.13	51.3 mg	0.52 mmol	
Vinyl acetate	FW.86.09	66.3 mg	0.77 mmol	(1.5eq.)
Lipase PS-C (Amano)		25.5 mg		50 wt%
i-Pr_2O		2.0 mL		

To a solution of (±)-**1b** (51.3 mg, 0.52 mmol) and vinyl acetate (66.3 mg, 0.77 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25.5 mg) and the mixture was stirred at 35 ºC for 260 minutes. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 2/1) afforded (*R*)-**2b** (22.9mg, 0.16mmol) in 31% yield

and (*S*)-**3b** (33.7 mg, 0.34 mmol) in 65% yield.

(*R*)-**2b**: **Rf** 0.53 (hexane/ethyl acetate = 2/1); 93% ee (Chiarldex G-TA T:100ºC), t_R= 10.6 min for (*R*)-isomer and t_R= 22.4 min for (*S*)-isomer; $[a]^{25}_D$ +67.4 (c 1.00, $CHCl_3$)
^{1}H NMR (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.97 (3H, t, *J*= 7.3), 1.69-1.84 (2H, m), 2.11 (3H, s), 2.68 (1H, dd, *J*= 5.1, 17.0), 2.72 (1H, dd, J= 5.1, 17.0), 4.91-4.96 (1H, m)
^{13}C NMR (125 MHz, ppm, $CDCl_3$) d 9.21, 20.70, 22.27, 26.11, 69.71, 116.22, 170.12
IR (neat, cm^{-1}) 2970, 2940, 2880, 2250, 1740, 1380, 1240, 1030
(*S*)-**3b**: 58%ee (OH? OAc, Chiarldex G-TA Temp: 100 ºC), t_R= 10.6 min for (*R*)-i somer and t_R= 22.4 min for (*S*)-isomer.

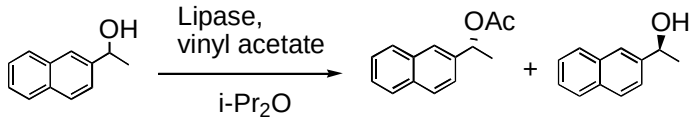
IL1-PS-catalyzed acylation of (±)-3-Hydroxypentanenitrile



(±)-**1b**	FW.99.13	50.0 mg	0.50 mmol	
Vinyl acetate	FW.86.09	65.0 mg	0.75 mmol	(1.5eq.)
IL1-PS		7.5 mg		
i-Pr_2O		2.0 mL		

To a solution of 3-hydroxypentanenitrile (±)-**1b** (50.0 mg, 0.50 mmol) and vinyl acetate (65.0 mg, 0.75 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (7.5 mg) and the mixture was stirred at 35 ºC for 1 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 2/1) afforded (*R*)-**2b** (20.6 mg, 0.15mmol) in 29% yield and (*S*)-**3b** (31.2 mg, 0.31 mmol) in 62% yield.
(*R*)-**2b**: 87% ee; $[a]^{27}_D$ +43.2 (c 1.50, $CHCl_3$)
(*S*)-**3b**: 80% ee; $[a]^{26}_D$ +1.69 (c 1.30, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-1-(naphtalen-2-yl)ethanol (1c)



(±)-**1c** (*R*)-**2c** (*S*)-**3c**

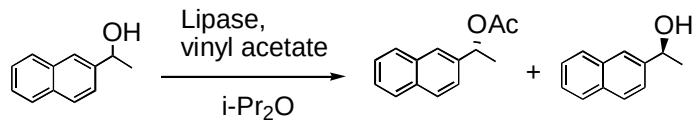
(±)-**1c**	FW.172.22	50.0 mg	0.29 mmol	
Vinyl acetate	FW.86.09	37.0 mg	0.44 mmol	(1.5eq.)
Lipase PS-C (Amano)		25 mg		
i-Pr_2O		2.0 mL		

To a solution of (±)-**1c** (50 mg, 0.29 mmol) and vinyl acetate (37.0 mg, 0.44 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25 mg). The mixture was stirred at 35 ºC for 24 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded (*R*)-**2c** (10.3 mg, 0.05 mmol) in 17% yield and alcohol (*S*)-**3c** (40.6 mg, 0.24 mmol) in 81% yield.

(*R*)-**2c**: **Rf** 0.59 (hexane/ethyl acetate = 4/1); >99% ee (Chiralcel OD, hexane: 2-propanol = 40:1, 35 ºC), t_R= 5.1 min for (*R*)-isomer and t_R= 5.9 min for (*S*)-isomer; $[a]^{25}_D$ +36.6 (c 1.00, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.62 (3H, d, *J*= 6.9), 2.10 (3H, s), 6.05 (1H, q, *J*= 6.6), 7.45-7.50 (3H, m), 7.81-7.85 (4H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 25.96, 26.75, 77.00, 128.66, 129.58, 130.62, 130.79, 132.23, 132.59, 132.92, 137.58, 137.74, 143.57, 174.93; **IR** (neat, cm^{-1}) 1740, 1510, 1370, 1240, 1070, 1020, 940, 820.

Alcohol (*S*)-**3c**; 7% ee (Chiralcel OB, hexane: 2-propanol = 200:1, 35ºC), t_R= 39.6 min for (*S*)-isomer and t_R= 45.0 min for (*R*)-isomer.

IL1-PS-catalyzed acylation of (±)-1-(naphtalen-2-yl)ethanol (1c)



(±)-**1c** (*R*)-**2c** (*S*)-**3c**

(±)-**1c**	FW.172.22	51.0 mg	0.30 mmol	
Vinyl acetate	FW.86.09	37.0 mg	0.44 mmol	(1.5eq.)
IL1-PS		7.5 mg		

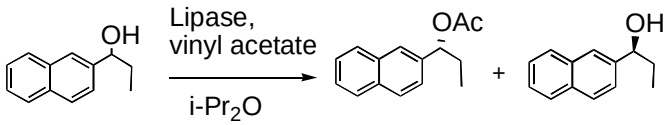
i-Pr_2O	2.0 ml

To a solution of (±)-**1c** (51 mg, 0.30 mmol) and vinyl acetate (37.0 mg, 0.44 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (7.5 mg) and the mixture was stirred at 35 ºC for 21.5 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded (*R*)-**2c** (12.4 mg, 0.06 mmol) in 20% yield and (*S*)-**3c** (39.5 mg, 0.23 mmol) in 77% yield.

(*R*)-**2c**: >99% ee; $[a]^{25}_D$ +88.1 (c 1.18, $CHCl_3$)

(*S*)-**3c**: 25% ee; $[a]^{26}_D$ -11.5 (c 1.03, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-1-(naphthalen-2-yl)propanol (1d)



(±)-**1d** (*R*)-**2d** (*S*)-**3d**

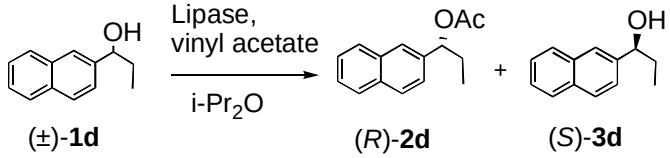
(±)-**1d**	FW.186.25	52.9 mg	0.28 mmol	
Vinyl acetate	FW.86.09	41.9 mg	0.44 mmol	(1.7eq.)
Lipase PS-C (Amano)		25 mg		
i-Pr_2O		2.0 mL		

To a solution of (±)-**1d** (52.9 mg, 0.28 mmol) and vinyl acetate (41.9 mg, 0.44 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25 mg) and the mixture was stirred at 35 ºC for 24 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 7/1) afforded (*R*)-**2d** (6.2 mg, 0.03 mmol) in 10% yield and (*S*)-**3d** (46.6 mg, 0.25 mmol) in 88% yield.

(*R*)-**2d**: **Rf** 0.47 (hexane/ethyl acetate = 7/1); >99%ee (Chiralcel OD, hexane: 2-propanol = 200:1, 35ºC), t_R= 13.3 min for (*S*)-isomer and t_R= 15.3 min for (*R*)-isomer; $[a]^{27}_D$ +7.83 (c 0.46, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 0.90 (3H, t, *J*= 7.3), 1.85-2.04 (2H, m), 2.08 (3H, s), 5.83 (1H, t, *J*= 7.1), 7.42-7.47 (3H, m), 7.79-7.82 (4H, m)**; ^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 9.89, 21.19, 29.11, 77.41, 124.28, 125.70, 125.92, 126.08, 127.57, 127.92, 128.17, 132.97, 133.05, 137.77, 170.32**; IR** (neat, cm^{-1}) 2970, 1740, 1510, 1370, 1240, 1020, 820, 750.

(*S*)-**3d**: 0.2% ee (Chiralcel OD, hexane: 2-propanol = 8:1, 35ºC), t_R=,8.0 min for (*S*)-isomer and t_R= 8.6 min for (*R*)-isomer.

IL1-PS-catalyzed acylation of (±)-1-(naphthalen-2-yl)propanol (1d)

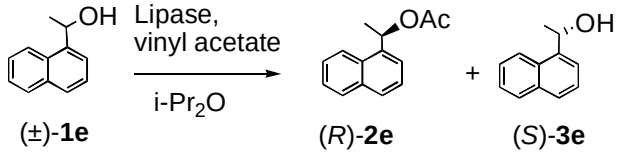


(±)-**1d** (*R*)-**2d** (*S*)-**3d**

(**±**)-**1d**	FW.186.25	52.2 mg	0.28 mmol	
vinyl acetate	FW.86.09	38.6 mg	0.45 mmol	(1.6eq.)
IL1-PS		7.8 mg		
i-Pr_2O		2.0 mL		

To a solution of 1-naphthalen-2-ylpropanol (±)-**1d** (52.2 mg, 0.28 mmol) and vinyl acetate (38.6 mg, 0.45 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (7.8 mg). The mixture was stirred at 35 ºC for 16 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 7/1) afforded (*R*)-**2d** (7.9mg, 0.03mmol) in 12% yield and (*S*)-**3d** (44.2 mg, 0.24 mmol) in 85% yield.
(*R*)-**2d**: >99% ee; $[a]^{29}_D$ +43.7 (c 0.65, $CHCl_3$)
(*S*)-**3d**: 7% ee; $[a]^{28}_D$ -4.14 (c 1.11, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-1-(naphthalen-1-yl)ethanol (1e)



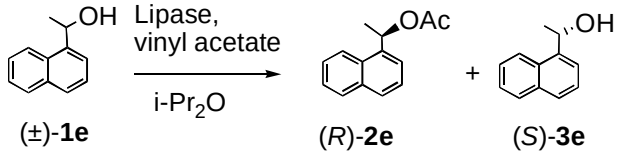
(±)-**1e** (*R*)-**2e** (*S*)-**3e**

(**±**)-**1e**	FW.172.22	52.4mg	0.30mmol	
Vinyl acetate	FW.86.09	41.4mg	0.48mmol	1.6eq.
Lipase PS-C (Amano)		25mg		50wt%
i-Pr_2O		2mL		

To a solution of (±)-**1e** (52.4 mg, 0.30 mmol) and vinyl acetate (41.4 mg, 0.48 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25 mg) and the mixture was stirred at 35 ºC for 24 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtered through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded (*R*)-**2e** (3.4 mg, 0.02 mmol) in 5% yield and (*S*)-**3e** (47.5 mg, 0.28 mmol) in 91% yield.
(*R*)-**2e**: **Rf** 0.55 (hexane/ethyl acetate = 4/1); >99% ee (Chiralcel OB, hexane: 2-propanol = 200: 1, 35 ºC), t_R=21.5 min for (*S*)-isomer and t_R=23.2 min for (*R*)-isomer; $[a]^{25}_D$ +22.6 (c 0.47, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.70 (3H, d, *J*= 6.9), 2.11

(3H, s), 6.65 (1H, q, *J*= 6.6), 7.44-7.54 (3H, m), 7.60 (1H, d, *J*= 7.3), 7.78-7.87 (2H, m), 8.08 (1H, d, *J*= 8.7)**;** ^{13}**C NMR** (125 MHz, ppm, $CDCl_3$) d 21.32, 21.64, 69.40, 123.10, 123.14, 125.31, 125.62, 126.25, 127.98, 128.39, 128.86, 130.20, 133.77, 137.36, 170.29**;** **IR** (neat, cm^{-1}) 2980, 1740, 1510, 1370, 1240, 1050, 800, 780.
(*S*)-**3e**: 6% ee (Chiralcel OB, hexane: 2-propanol = 40:1, 35 ºC), t_R=13.3 min for (*R*)-isomer and t_R= 19.9 min for (*S*)-isomer.

IL1-PS-catalyzed acylation of (±)-1-(naphthalen-1-yl)ethanol (1e)

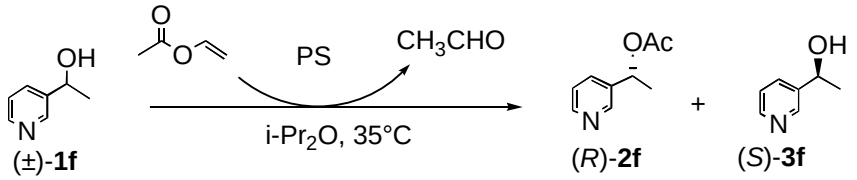


(±)-**1e** (*R*)-**2e** (*S*)-**3e**

(±)-**1e**	FW.172.22	50.7mg	0.29mmol	
vinyl acetate	FW.86.09	41.2mg	0.48mmol	1.6eq.
IL1-PS		7.5mg		
i-Pr_2O		2.0mL		

To a solution of (±)-**1e** (50.7 mg, 0.29 mmol) and vinyl acetate (41.2 mg, 0.48 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (7.5 mg) and the mixture was stirred at 35 ºC for 24 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded (*R*)-**2e** (6.9 mg, 0.03 mmol) in 11% yield and (*S*)-**3e** (41.3 mg, 0.24 mmol) in 82% yield.
(*R*)-**2e**: >99% ee; $[a]^{25}_D$ +48.1 (c 0.69, $CHCl_3$)
(*S*)-**3e**: 2% ee; $[a]^{25}_D$ -2.20 (c 1.00, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-1-(pyridine-3-yl)ethanol (1f)



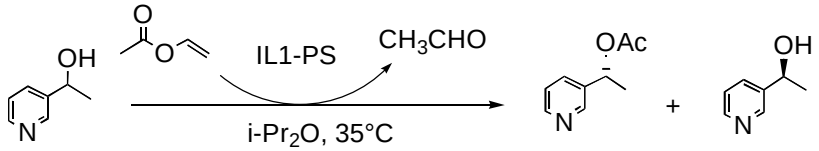
(±)-**1f** (*R*)-**2f** (*S*)-**3f**

(±)-**1f**	FW.123.15	50.0 mg	0.41 mmol	
Vinyl acetate	FW.86.09	52.4 mg	0.61 mmol	(1.5eq.)
Lipase PS-C (Amano)		25 mg		50 wt%
i-Pr_2O		2.0 mL		

To a solution of (±)-**1f** (50.0 mg, 0.41 mmol) and vinyl acetate (52.4 mg, 0.61 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25 mg) and the mixture was stirred at 35 ºC for 6.5 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC.

The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (ethyl acetate/methanol = 20/1) gave (*R*)-**2f** (24.0 mg, 0.15 mmol) in 35% yield and (*S*)-**3f** (26.2 mg, 0.21 mmol) in 52% yield.
(*R*)-**2f**: **Rf** 0.59 (ethyl acetate/methanol = 20/1); >99% ee (Chiralcel OB, hexane: 2-propanol = 40:1, 35,ºC), t_R= 14.5 min for (*S*)-isomer and t_R= 16.0 min for (*R*)-isomer; $[a]^{27}_D$ +86.1 (c 0.99, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.56 (3H, d, *J*= 6.4), 2.08 (3H, s), 5.91 (1H, q, *J*= 6.7), 7.30 (1H, d, J= 4.6), 7.69 (1H, d, *J*=6.4), 8.55 (1H, s), 8.63 (1H, s); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 20.91, 21.72, 69.84, 123.21, 133.63, 136.90, 147.56, 148.86, 169.81; **IR** (neat, cm^{-1}) 2980, 2940, 1740, 1580, 1370, 1240, 1070, 940.
(*S*)-**3f**: 69% ee (Chiralcel OB, hexane: 2-propanol = 8:1, 35,ºC), t_R= 6.9 min for (*S*)-isomer and t_R= 9.7 min for (*R*)-isomer.

IL1-PS-catalyzed acylation of (±)-1-(pyridine-3-yl)ethanol (1f)

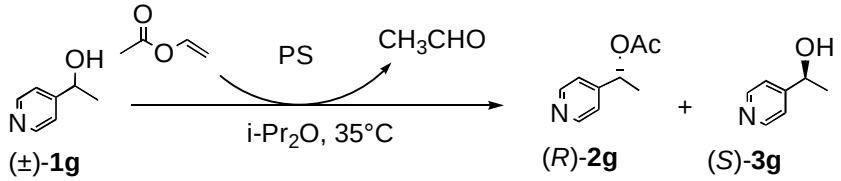


(±)-**1f** (*R*)-**2f** (*S*)-**3f**

(±)-**1f**	FW.123.15	50.0 mg	0.41 mmol	
Vinyl acetate	FW.86.09	57.0 mg	0.66 mmol	(1.6eq.)
IL1-PS		8.8 mg		
i-Pr_2O		2.0 mL		

To a solution of 1-(pyridine-3-yl)ethanol (±)-**1f** (50.0 mg, 0.41 mmol) and vinyl acetate (57.0 mg, 0.66 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (8.8 mg) and the mixture was stirred at 35 ºC for 3 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (ethyl acetate/methanol = 20/1) afforded (*R*)-**2f** (21.1 mg, 0.13mmol) in 31% yield and (*S*)-**3f** (33.6 mg, 0.27 mmol) in 67% yield.
(*R*)-**2f**: >99% ee; $[a]^{28}_D$ +86.3 (c 1.10, $CHCl_3$)
(*S*)-**3f**: 44% ee; $[a]^{27}_D$ -15.6 (c 1.00, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-1-(pyridine-4-yl)ethanol (1g)



(±)-**1g** (*R*)-**2g** (*S*)-**3g**

(±)-**1g**	FW.123.15	54.6 mg	0.44 mmol	
Vinyl acetate	FW.86.09	60.6 mg	0.70 mmol	(1.6eq.)

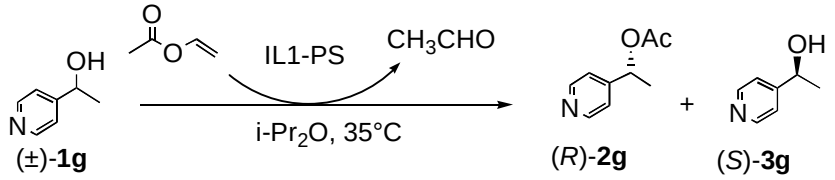
Lipase PS-C (Amano)	27.3 mg	50 wt%
i-Pr_2O	2.0 mL	

To a solution of (±)-**1g** (54.6 mg, 0.44 mmol) and vinyl acetate (60.6 mg, 0.70 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (27.3 mg). The mixture was stirred at 35 ºC for 12 h 20 min. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (ethyl acetate/2-propanol = 20/1) afforded acetate (*R*)-**2g** (31.5 mg, 0.19 mmol) in 43% yield and alcohol (*S*)-**3g** (24.3 mg, 0.20 mmol) in 45% yield.

(*R*)-**2g**: **Rf** 0.64 (ethyl acetate/ methanol = 20/1); >99% ee (Chiralcel OD, hexane: 2-propanol = 20:1, 35 ºC), t_R= 9.2 min for (*R*)-**2g** and t_R= 10.5 min for (*S*)-**2g**; $[a]^{27}_D$ +68.8 (c 1.00, $CHCl_3$) ; **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.43 (3H, d, *J*= 6.4), 2.03 (3H, s), 5.74 (1H, q, *J*= 6.6), 7.17 (2H, dd, *J*= 1.4, 4.6), 8.50 (2H, dd, *J*= 1.6, 4.4); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 20.87, 21.67, 70.47, 120.44, 149.65, 150.40, 169.76**; IR** (neat, cm^{-1}) 1740, 1600, 1560, 1370, 1240, 1070, 1030, 950.

(*S*)-**3g**: 84% ee (Chiralcel OD, hexane: 2-propanol = 8:1, 35ºC), t_R= 8.2 min for (*S*)-isomer and t_R= 8.9 min for (*R*)-isomer.

IL1-PS-catalyzed acylation of (±)-1-(pyridine-4-yl)ethanol (1g)



(±)-**1g** (*R*)-**2g** (*S*)-**3g**

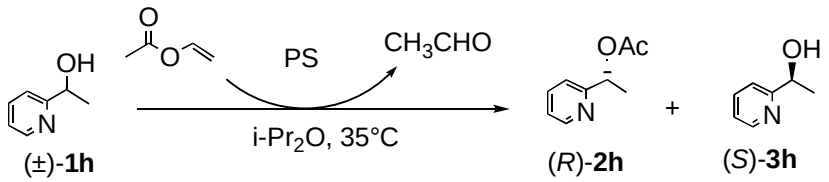
(±)-**1g**	FW.123.15	54.0 mg	0.44 mmol	
Vinyl acetate	FW.86.09	56.0 mg	0.65 mmol	(1.6eq.)
IL1-PS		8.8 mg		
i-Pr_2O		2.0 mL		

To a solution of (±)-**1g** (54.0 mg, 0.44 mmol) and vinyl acetate (56.0 mg, 0.65 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (8.8 mg) and the mixture was stirred at 35ºC for 2 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (ethyl acetate/methanol = 20/1) afforded (*R*)-**2g** (26.0 mg, 0.16 mmol) in 36% yield and (*S*)-**3g** (24.6 mg, 0.20 mmol) in 46% yield.

(*R*)-**2g**: >99% ee; $[a]^{25}_D$ +68.2 (c 1.60, $CHCl_3$)

(*S*)-**3g**: 58% ee; $[a]^{24}_D$ -28.2 (c 1.10, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-1-(pyridine-2-yl)ethanol (1h)



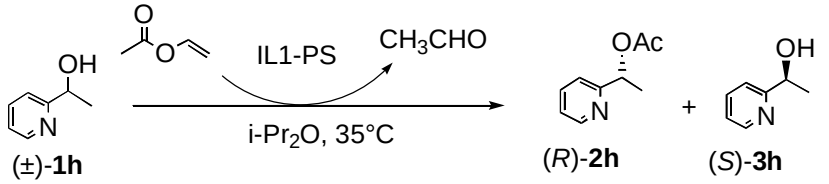
(±)-**1h**	FW.123.15	50.0 mg	0.41 mmol	
Vinyl acetate	FW.86.09	54.5 mg	0.63 mmol	(1.5eq.)
Lipase PS-C (Amano)		25 mg		50 wt%
i-Pr_2O		2.0 mL		

To a solution of (±)-**1h** (50.0 mg, 0.41 mmol) and vinyl acetate (54.5 mg, 0.63 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25 mg) and the mixture was stirred at 35 ºC for 28 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (ethyl acetate/methanol = 20/1) afforded (*R*)-**2h** (16.2 mg, 0.10 mmol) in 24% yield and (*S*)-**3h** (33. mg, 0.27 mmol) in 67% yield.

(*R*)-**2h**: **Rf** 0.74 (ethyl acetate/methanol = 20/1); >99% ee (Chiralcel OD, hexane: 2-propanol = 200:1, 35,ºC), t_R= 11.8 min for (*R*)-isomer and t_R= 21.9 min for (*S*)-isomer; $[a]^{26}_D$ +46.9 (c 0.35, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.60 (3H, d, *J*= 6.9), 2.12 (3H, s), 5.92 (1H, q, *J*= 6.7), 7.20-7.22 (1H, dd, *J*= 4.9, 7.6), 7.35 (1H, d, *J*= 7.8), 7.69 (1H, dt, *J*= 1.9, 7.8), 8.60 (1H, d, *J*= 4.5); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 20.50, 20.98, 72.70, 120.18, 122.50, 136.68, 148.92, 160.00, 169.99; **IR** (neat, cm^{-1}) 1740, 1590, 1440, 1370, 1240, 1070, 1030, 950.

(*S*)-**3h**: 33% ee (Chiralcel OD, hexane: 2-propanol = 8:1, 35,ºC), t_R= 5.1 min for (*R*)-isomer and t_R= 5.8 min for (*S*)-isomer.

IL1-PS-catalyzed acylation of (±)-1-(pyridine-2-yl)ethanol (1h)

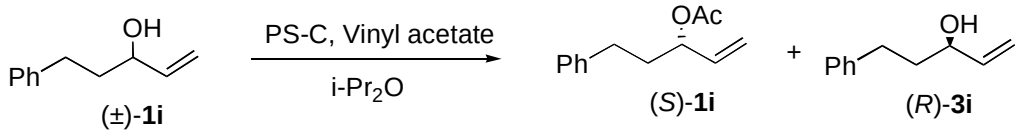


(±)-**1h**	FW.123.15	53.5 mg	0.43 mmol	
Vinyl acetate	FW.86.09	55.2 mg	0.64 mmol	(1.5eq.)
IL1-PS		8.5 mg		
i-Pr_2O		2.0 mL		

To a solution of (±)-**1h** (53.5 mg, 0.43 mmol) and vinyl acetate (55.2 mg, 0.64 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (8.5 mg) and the mixture was stirred at 35 ºC for 3 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove

the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (ethyl acetate/methanol = 20/1) afforded (*R*)-**2h** (30.0 mg, 0.18 mmol) in 41% yield and (*S*)-**3h** (30.4 mg, 0.25 mmol) in 57% yield.
(*R*)-**2h**: >99% ee; $[a]^{26}_{D}$ +115.6 (c 1.10, $CHCl_3$)
(*S*)-**3h**: 84% ee; $[a]^{27}_{D}$ -15.8 (c 1.00, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-5-phenyl-1-penten-3-ol (1i)

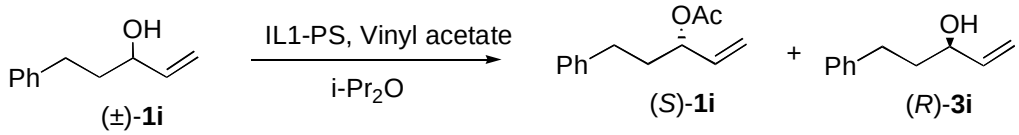


(±)-**1i**	FW.162.23	53.1 mg	0.33 mmol	
Vinyl acetate	FW.86.09	46.4 mg	0.54 mmol	(1.6eq.)
Lipase PS-C (Amano)		25 mg		50 wt%
i-Pr_2O		2.0 mL		

To a solution of (±)-**1i** (53.1 mg, 0.33 mmol) and vinyl acetate (46.4 mg, 0.54 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25 mg) and the mixture was stirred at 35 ºC for 24 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 7/1) afforded acetate (*S*)-**2i** (4.0 mg, 0.02 mmol) in 6% yield and alcohol (*R*)-**3i** (47.6 mg, 0.29 mmol) in 89% yield.

(*S*)-**2i**: **Rf** 0.53 (hexane/ethyl acetate = 7/1); >99% ee (Chiralcel OD, hexane: 2-propanol = 200:1, 35 ºC), t_R= 8.9 min for (*S*)-isomer and t_R= 9.4 min for (*R*)-isomer; $[a]^{27}_{D}$ -16.5 (c 0.40, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.87-2.02 (2H, m), 2.05 (3H, s), 2.60-2.70 (2H, m), 5.18-5.29 (3H, m), 5.81 (1H, ddd, *J*= 6.5, 10.6, 14.3), 7.16-7.29 (5H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 21.13, 31.37, 35.71, 74.25, 116.88, 125.92, 128.27, 128.37, 136.21, 141.25, 170.31; **IR** (neat, cm^{-1}) 2930, 2860, 1740, 1500, 1370, 1240, 1020, 930.
(*R*)-**3i**: 7% ee (Chiralcel OD, hexane: 2-propanol = 8:1, 35 ºC), t_R= 6.6 min for (*S*)-isomer and t_R= 8.4 min for (*R*)-isomer.

IL1-PS-catalyzed acylation of (±)- 5-phenyl-1-penten-3-ol (1i)

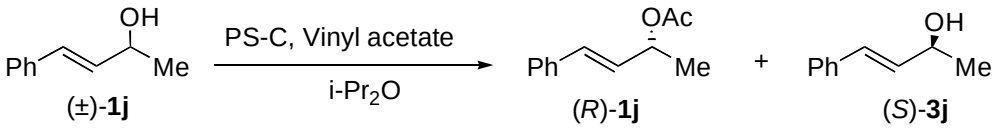


(±)-**1i**	FW.162.23	52.0 mg	0.32 mmol	
Vinyl acetate	FW.86.09	40.0 mg	0.46 mmol	(1.4eq.)
IL1-PS		7.5 mg		

i-Pr_2O		2.0 mL		

To a solution of (±)-**1i** (52.0 mg, 0.32 mmol) and vinyl acetate (40.0 mg, 0.46 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (7.5 mg) and the mixture was stirred at 35 ºC for 20 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, then the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 7/1) afforded acetate (*S*)-**2i** (13.6 mg, 0.07 mmol) in 21% yield and (*R*)-**3i** (39.0 mg, 0.24 mmol) in 75% yield.
(*S*)-**2i**: >99% ee; $[a]^{25}_D$ +2.73 (c 1.36, $CHCl_3$)
(*R*)-**3i**: 66% ee; $[a]^{25}_D$ +3.08 (c 1.17, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-4-phenyl-3-butene-2-ol (1j)

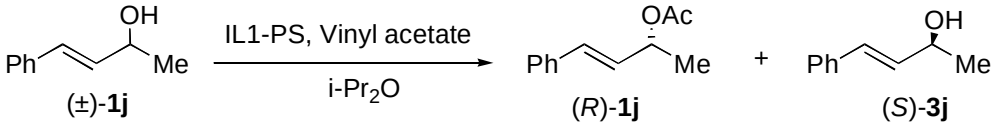


(±)-**1j** (*R*)-**1j** (*S*)-**3j**

(±)-**1j**	FW.148.17	52.6 mg	0.35 mmol	
Vinyl acetate	FW.86.09	43.6 mg	0.51 mmol	(1.5eq.)
Lipase PS		25.9 mg		
i-Pr_2O		2.0 mL		

To a solution of 4-phenyl-3-butene-2-ol (±)-**1j** (52.9 mg, 0.35 mmol) and vinyl acetate (43.6 mg, 0.51 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25.9 mg) and the mixture was stirred at 35 ºC for 15 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, then the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 7/1) afforded acetate (*R*)-**2j** (14.5 mg, 0.08 mmol) in 22% yield and alcohol (*S*)-**3j** (35.2 mg, 0.24 mmol) in 68% yield.
(*R*)-**2j**: **Rf** 0.48 (hexane/ethyl acetate = 7/1); 98% ee (Chiralcel OJ-H, hexane: 2-propanol = 9:1, 35ºC), t_R= 6.4 min for (*R*)-isomer and t_R= 6.9 min for (*S*)-isomer; $[a]^{25}_D$ +132.2 (c 1.00, $CHCl_3$); **^{1}H NMR** (400 MHz, ppm, $CDCl_3$, *J*= Hz) d 1.40 (3H, d, *J*= 6.6), 2.06 (3H, s), 5.52 (1H, dq, *J*= 6.6, 6.18 (1H, dd, *J*= 6.6, 15.7), 6.59 (1H, d, *J*= 15.7), 7.15-7.38 (5H, m); **^{13}C NMR** (100 MHz, ppm, $CDCl_3$) d 20.23, 21.25, 70.85, 126.43, 127.78, 128.44, 128.65, 131.40, 136.17, 170.15; **IR** (neat, cm^{-1}) 2980, 2930, 1740, 1450, 1370, 1240, 1150, 1040.
(*S*)-**3j**: 34% ee (Chiralcel OJ-H, hexane: 2-propanol = 9:1, 35 ºC), t_R= 7.8 min for (*S*)-isomer and t_R= 8.4 min for (*R*)-isomer; $[a]^{26}_D$ -6.1 (c 1.00, $CHCl_3$)

IL1-PS-catalyzed acylation of (±)-4-phenyl-3-butene-2-ol (1j)



(±)-**1j** (*R*)-**1j** (*S*)-**3j**

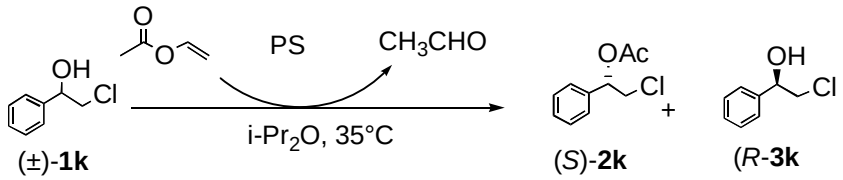
(±)-**1j**	FW.148.17	50.0 mg	0.34 mmol	
vinyl acetate	FW.86.09	43.6 mg	0.51 mmol	(1.5eq.)
IL1-PS		8.6 mg		
i-Pr_2O		2.0 mL		

To a solution of (±)-**1j** (50.0 mg, 0.34 mmol) and vinyl acetate (43.6 mg, 0.51 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (8.6 mg) and the mixture was stirred at 35ºC for 55 min. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, then the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 7/1) afforded acetate (*R*)-**2j** (23.9 mg, 0.13 mmol) in 37% yield and alcohol (*S*)-**3j** (26.6 mg, 0.18 mmol) in 53% yield.

(*R*)-**2j**: >99% ee; $[a]^{25}_D$ +137.0 (c 1.00, $CHCl_3$)

(*S*)-**3j**: 67% ee; $[a]^{26}_D$ -40.8 (c 1.00, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-2-chloro-1-phenylethanol (1k)



(±)-**1k** (*S*)-**2k** (*R*-**3k**

(±)-**1k**	FW.156.61	50.4 mg	0.32 mmol	
Vinyl acetate	FW.86.09	48.7 mg	0.57 mmol	(1.8eq.)
Lipase PS-C (Amano)		25 mg		50 wt%
i-Pr_2O		2.0 mL		

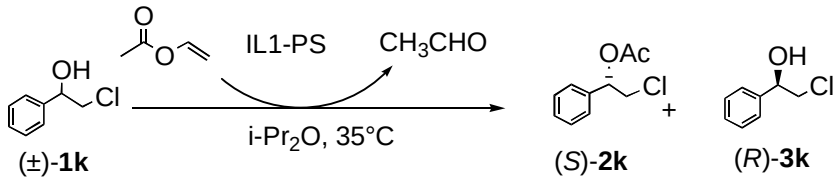
To a solution of (±)-**1k** (50.4 mg, 0.32 mmol) and vinyl acetate (48.7 mg, 0.57 mmol) in i-Pr_2O (2.0 mL) was added Lipase PS-C (25 mg). and the mixture was stirred at 35 ºC for 22 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, then the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded acetate (*S*)-**2k** (1.8 mg, 0.01 mmol) in 3% yield and alcohol (*R*)-**3k** (40.8 mg, 0.26 mmol) in 81% yield.

(*S*)-**2k**: **Rf** 0.27 (hexane/ethyl acetate = 4/1); 85% ee (Chiralcel OB, hexane: 2-propanol = 200:1, 35 ºC), t_R= 9.7 min for (*R*)-isomer and t_R= 11.4 min for (*S*)-isomer; $[a]^{25}_D$ +37.5 (c 0.16, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 2.12 (3H, s), 3.71 (1H, dd, *J*= 4.6), 3.78 (1H, dd, *J*= 8.0), 5.96 (1H, dd, *J*= 4.5, 7.8), 7.32-7.37 (5H, m) ; **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 20.86, 46.40, 74.96, 126.55, 128.59, 128.71, 137.10, 169.74 ; **IR** (neat, cm^{-1}) 2960, 1740, 1500, 1370, 1230, 1020, 730, 700.

(*R*)-**3k**: **Rf** 0.34 (hexane/ethyl acetate = 4/1); 4% ee (Chiralcel OB, hexane: 2-propanol = 200:1, 35 ºC), t_R= 26.8 min for (*R*)-isomer and t_R= 32.6 min for (*S*)-isomer; $[a]^{25}_D$ -9.32

(c 1.00, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 3.05 (1H, brd, OH), 3.61 (2H, dq, *J*= 8.5, 3.7), 4.83 (1H, dd, *J*= 3.7, 8.7), 7.32-7.34 (5H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 50.56, 73.91, 125.97, 128.30, 128.51, 139.90; **IR** (neat, cm^{-1}) 3400, 2900, 1490, 1450, 1200, 1070, 770, 700.

IL1-PS-catalyzed acylation of (±)-2-chloro-1-phenylethanol (1k)

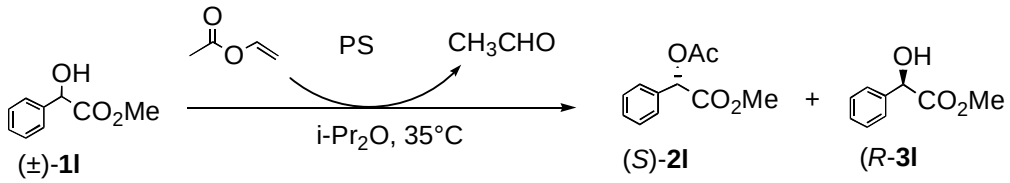


(±)-**1k** (*S*)-**2k** (*R*)-**3k**

(±)-**1k**	FW.156.61	50.9 mg	0.33 mmol	
Vinyl acetate	FW.86.09	48.7 mg	0.57 mmol	(1.7eq.)
IL1-PS		8.6 mg		
i-Pr_2O		2.0 mL		

To a solution of (±)-**1k** (50.9 mg, 0.33 mmol) and vinyl acetate (48.7 mg, 0.57 mmol) in i-Pr_2O (2.0 mL) was added IL1-PS (8.6 mg) and the mixture was stirred at 35 ºC for 22 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, then the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded acetate (*S*)-**2k** (9.3 mg, 0.05 mmol) in 14% yield and alcohol (*R*)-**3k** (39.5 mg, 0.25 mmol) in 78% yield.
(*S*)-**2k**: 98% ee; $[a]^{23}_D$ +84.6 (c 0.70, $CHCl_3$)
(*R*)-**3k**: 23% ee; $[a]^{24}_D$ -20.5 (c 1.20, $CHCl_3$)

Lipase PS-C-catalyzed acylation of (±)-Methyl mandelate (1l)



(±)-**1l** (*S*)-**2l** (*R*-**3l**

(**±**)-**1l**	FW.166.17	100.0 mg	0.60 mmol	
vinyl acetate	FW.86.09	77.7 mg	0.90 mmol	(1.5eq.)
Lipase PS-C (Amano)		50 mg		50 wt%
i-Pr_2O		4.0 mL		

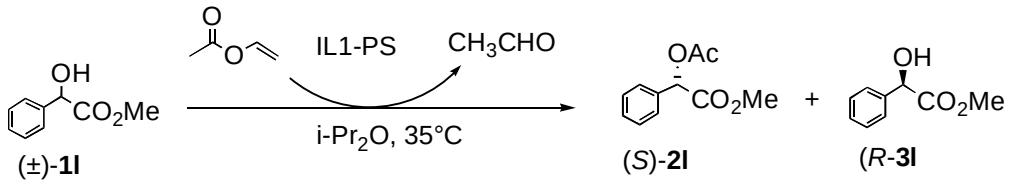
To a solution of (±)-**1l** (100.0 mg, 0.60 mmol) and vinyl acetate (77.7 mg, 0.9 mmol) in i-Pr_2O (4.0 mL) was added Lipase PS-C (50 mg) and the mixture was stirred at 35 ºC for 72 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, then the filtrate was concentrated under vacuum. Silica gel TLC

(hexane/ethyl acetate = 4/1) afforded acetate (*S*)-**2l** (11.9 mg, 0.06 mmol) in 10% yield and alcohol (*R*)-**3l** (89.8 mg, 0.54 mmol) in 90% yield.

(*S*)-**2l**: **Rf** 0.41 (hexane/ethyl acetate = 4/1); >99% ee (Chiraldex G-TA T: 100 ºC), t_R= 39.7 min for (*R*)-isomer and t_R= 47.0 min for (*S*)-isomer; $[a]^{24}_D$ +123.8 (c 1.10, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) 2.18 (3H, s), 3.71 (3H, s), 5.93 (1H, s), 7.38-7.48 (5H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 20.58, 52.48, 74.34, 127.54, 128.70, 129.16, 133.66, 169.20, 170.18; **IR** (neat, cm^{-1}) 2960, 1740, 1500, 1370, 1220, 1060, 740, 700.

(*R*)-**3l**: **Rf** 0.17 (hexane/ethyl acetate = 4/1); **mp** 54-56ºC; 16% ee (Chiraldex G-TA T:100 ºC), t_R= 30.8 min for (*R*)-isomer and t_R= 36.7 min for (*S*)-isomer; $[a]^{25}_D$ -18.0 (c 1.00, $CHCl_3$); **^{1}H NMR** (500 MHz, ppm, $CDCl_3$, *J*= Hz) d 3.72 (3H, s), 3.72 (1H, brd, OH), 5.17 (1H, s), 7.33-7.41 (5H, m); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$) d 52.87, 72.80, 126.51, 128.40, 128.51, 138.16, 174.00; **IR** (KBr, cm^{-1}) 3430, 1740, 1490, 1460, 1190, 1100, 980, 740.

IL1-PS-catalyzed acylation of D,L-Methyl mandelate (1l)



(±)-**1l** (*S*)-**2l** (*R*-**3l**

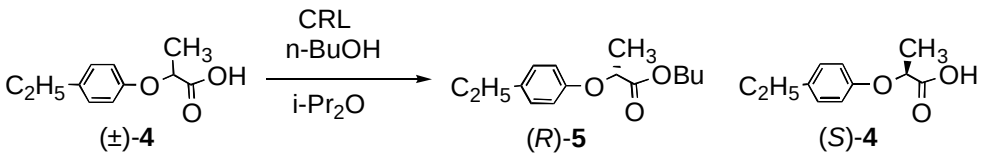
(±)-**1l**	FW.166.17	50.0 mg	0.30 mmol	
Vinyl acetate	FW.86.09	39.0 mg	0.45 mmol	(1.5eq.)
IL1-PS		7.5 mg		
i-Pr_2O		2.0 mL		

To a solution of Methyl mandelate (±)-**1l** (100.0 mg, 0.60 mmol) and vinyl acetate (77.7 mg, 0.90 mmol) in i-Pr_2O (4.0 mL) was added IL1-PS (10.8 mg) and the mixture was stirred at 35 ºC for 48 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, then the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded acetate (*S*)-**2l**(44.2 mg, 0.20 mmol) in 34% yield and alcohol (*R*)-**3l** (66.3 mg, 0.40 mmol) in 66% yield.

(*S*)-**2l**: >99% ee; $[a]^{26}_D$ +124.1 (c 1.08, $CHCl_3$)

(*R*)-**3l**: 54% ee; $[a]^{25}_D$ -89.1(c 1.01, $CHCl_3$)

CRL-catalyzed acylation of (±)- 2-(4-ethylphenoxy)propanoic acid *(4)*[20]

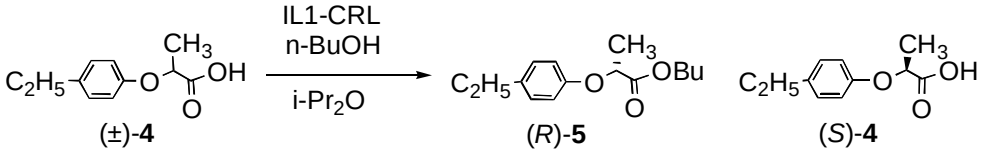


(±)-**4**	FW.194.23	50.0 mg	0.26 mmol	
1-BuOH	FW.74.12	58.0 mg	0.78 mmol	(3.0eq.)
CRL (Lipase MY, Meito)		25 mg		
i-Pr_2O		2.0 mL		

To a solution of (±)-**4** [20] (50 mg, 0.26 mmol) and 1-Butanol (58.0 mg, 0.78 mmol) in i-Pr_2O (2.0 mL) was added CRL (25 mg) and the mixture was stirred at 35 ºC for 60 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded (*R*)-**5** [20] (15 mg, 0.12 mmol) in 30% yield and (*S*)-**4** (36 mg, 0.15 mmol) in 36% yield.

(*R*)-**5**; 62% ee (Chiralcel OB, hexane: 2-propanol = 200:1, 35ºC), t_R= 4.0 min for (*R*)-isomer and t_R= 4.4 min for (*S*)-isomer.

(*S*)-**4**; 22% ee (Chiralcel OB, hexane: 2-propanol = 200:1, 35ºC), t_R= 4.3 min for (*R*)-isomer and t_R=5.5 min for (*S*)-isomer.

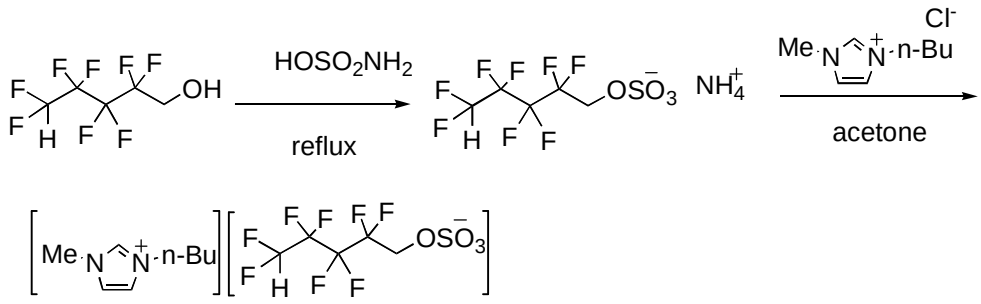


(±)-**4**	FW.194.23	50.0 mg	0.41 mmol	
1-BuOH	FW.74.12	54.8 mg	0.60 mmol	(1.5eq.)
IL1-CRL-a (Meito)		25 mg		
i-Pr_2O		2.0 mL		

To a solution of (±)-**4** (50 mg, 0.26 mmol) and 1-Butanol (58.0 mg, 0.78 mmol) in i-Pr_2O (2.0 mL) was added CRL (25 mg) and the mixture was stirred at 35 ºC for 32 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. The reaction mixture was filtrated through a sintered glass filter with a Celite pad to remove the lipase, and the filtrate was concentrated under vacuum. Silica gel TLC (hexane/ethyl acetate = 4/1) afforded (*R*)-**5** (24 mg, 0.12 mmol) in 37% yield and (*S*)-**4** (30 mg, 0.15 mmol) in 60% yield.

(*R*)-**5**; 92% ee. (*S*)-**4**; 34% ee

1-butyl-3-methylimidazolim 2,2,3,3,4,4,5,5-octafluoropentyl sulfate ([bmim][C5F8])[34]

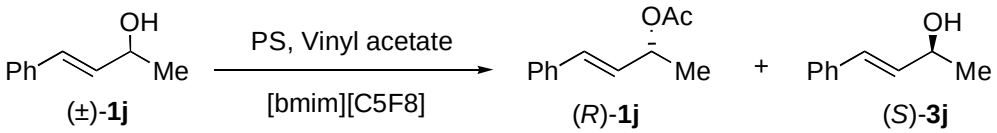


[bmim][C5F8]

A mixture of 2,2,3,3,4,4,5,5-octafluoropentanol (33.0 g, 0.14 mol) and sulfamic acid (13.6 g, 0.14 mol) was stirred at 130 ºC for 24 h under argon atmosphere and being cooled to room temperature to give ammonium 2,2,3,3,4,4,5,5-octafluoropentyl sulfate as a white precipitate. The ammonium salt was washed with hexane 3 times and evaporated to dryness. To an acetone (135 mL) solution of the salt was added [bmim][Cl] (23.6 g, 0.135 mol) and the resulting solution was stirred 24 h at room temperature to form ammnonium chloride (NH_4Cl) as a white precipitate. Precipitated NH_4Cl was removed by filtration through a sintered glass filter with a Celite pad and the filtrate was concentrated under vacuum to give [bmim][C5F8] as viscous oil. This was washed with a mixed solvent of hexane and ethyl acetate (4:1) and water, then diluted with acetone and treated with activated charcoal. Activated charcoal was removed by filtration through an sintered glass filter with a Celite pad and the filtrate was filtered through an Al_2O_3 (neutral type ?, activated) short column and finally the filtrate was lyophilized to give **[bmim][C5F8]** (40.2 g, 0.089 mol) as yellowish oil in 66% yield: **^{1}H NMR** (500 MHz, ppm , $CDCl_3$, *J*=Hz) d 0.95 (3H, t, *J*= 7.3), 1.32-1.40 (2H, m), 1.83-1.89 (2H, m), 3.98 (3H, s), 4.21 (2H, t, *J*= 7.4), 4.45 (2H, t, *J*= 14.7), 5.99-6.23 (1H, m), 7.32 (1H, s), 7.39 (1H, s), 9.18 (1H, s); **^{13}C NMR** (125 MHz, ppm, $CDCl_3$, *J*=Hz) d 12.99, 19.16, 31.78, 36.02, 49.65, 62.95 (t, $J_{C\text{-}F}$= 24.9), 107.53 (2-CF_2, t, $J_{C\text{-}F}$= 30.5, t, $J_{C\text{-}F}$= 253.3), 109.93 (3-CF_2, t, $J_{C\text{-}F}$= 25.8, t, $J_{C\text{-}F}$= 261.3), 110.63 (4-CF_2, t, $J_{C\text{-}F}$= 30.5, t, $J_{C\text{-}F}$= 263.2), 114.85 (CF_2H, t, $J_{C\text{-}F}$= 30.5, t, $J_{C\text{-}F}$= 253.3), 122.07, 123.62, 136.56; **^{19}F NMR** (470 MHz, ppm, $CDCl_3$, *J*= Hz) d 24.31 (2F, t, *J*= 51.8), 31.61 (2F, s), 36.25 (2F, s), 41.57 (2F, t, *J*= 11.5); **IR** (neat, cm^{-1}) 2880, 1510, 1460, 1270, 1240, 1170, 1130, 1040. Anal. Calcd for $C_{13}H_{18}F_8N_2O_3S$: C, 35.95; H, 4.18; N, 6.45. Found: C, 35.88; H, 4.19; N,

6.46.

Lipase PS-C-catalyzed acylation of 4-phenyl-3-butene-2-ol (1j) in [bmim][C5F8]; Recyclable use of enzyme



(±)-**1j** (*R*)-**1j** (*S*)-**3j**

(±)-**1j**	FW.148.17	59.0 mg	0.40 mmol	
Vinyl acetate	FW.86.09	50.2 mg	0.58 mmol	(1.5eq.)
Lipase PS-C		27.2 mg		
[bmim][C5F8]		1.0 mL		

To a mixture of 4-phenyl-3-butene-2-ol (±)-**1j** (59.0 mg, 0.35 mmol) and vinyl acetate (50.2 mg, 0.58 mmol) in [bmim][C5F8] (1.0 mL) was added Lipase PS-C (27.2 mg) and the mixture was stirred at 35 ºC for 24 h. The reaction course was monitored by capillary GC-analysis and silica gel TLC. To the reaction mixture was added 1.5 mL of diethyl ether to form biphasic layers and product acetate (*R*)-**2j** and alcohol (*S*)-**3j** were isolated from the ether layer. It was essential to repeat the extraction with ether from the reaction mixture 10 times.

Since the lipase was remained in the ionic liquid layer, it was possible to use the lipase repeatedly; the ionic layer was placed under reduced pressure at rt for 5 h to remove the ether and to the resulting ionic layer was added (±)-**1j** (59.0 mg, 0.35 mmol) and vinyl acetate (50.2 mg, 0.58 mmol) and the mixture was stirred at 35°C. Although it was possible to use the lipase repeatedly, the reaction rate was dropped significantly with reputation of the process. The results are described below.

The 1st run (24 h):
(*R*)-**2j**: 13% yield, 98% ee; $[a]^{27}_{D}$ +137.2 (c 1.00, $CHCl_3$)
(*S*)-**3j**: 87% yield, 25% ee; $[a]^{27}_{D}$ -5.5 (c 1.00, $CHCl_3$)

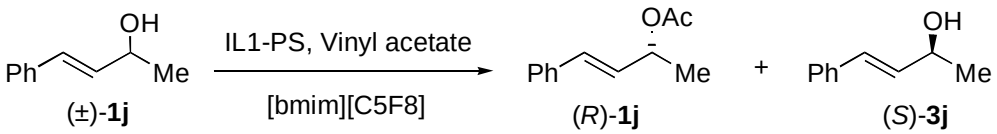
The 2nd run (24 h):
(*R*)-**2j**: 22% yield, 96% ee; $[a]^{27}_{D}$ +160.5 (c 0.40, $CHCl_3$)
(*S*)-**3j**: 77% yield, 16% ee; $[a]^{27}_{D}$ -11.6 (c 1.00, $CHCl_3$)

The 3rd run (24 h):
(*R*)-**2j**: 10% yield, 93% ee; $[a]^{28}_{D}$ +91.2 (c 0.70, $CHCl_3$)
(*S*)-**3j**: 67% yield, 10% ee; $[a]^{27}_{D}$ -12.2 (c 1.00, $CHCl_3$)

The 4th run (24 h):
(*R*)-**2j**: 6% yield, 93% ee; $[a]^{27}_{D}$ +74.9 (c 0.40, $CHCl_3$)
(*S*)-**3j**: 75% yield, 9% ee; $[a]^{27}_{D}$ -8.8 (c 1.00, $CHCl_3$)

The 5th run (24 h):
(*R*)-**2j**: 5% yield, 88% ee; $[a]^{28}_{D}$ +94.0 (c 0.30, $CHCl_3$)
(*S*)-**3j**: 60% yield, 5% ee; $[a]^{28}_{D}$ -9.2 (c 1.00, $CHCl_3$)

IL1-PS-catalyzed acylation of 4-phenyl-3-butene-2-ol in [bmim][C5F8]; Re cyclable use of enzyme



(±)-**1j** (*R*)-**1j** (*S*)-**3j**

(±)-**1j**	FW.148.17	50.0 mg	0.34 mmol	
Vinyl acetate	FW.86.09	43.6 mg	0.51 mmol	(1.5eq.)
IL1-PS		8.6 mg		
[bmim][C5F8]		1.0 mL		

To a mixture of (±)-**1j** (50.0 mg, 0.34 mmol) and vinyl acetate (43.6 mg, 0.51 mmol) in [bmim][C5F8] (1.0 mL) was added IL1-PS (8.6 mg) and the mixture was stirred at 35 ºC for 2.5 h. The reaction was greatly accelerated compare to that of commercial lipase PS-C and it was possible to demonstrate the reaction five times without any droop of the reaction rate with excellent enantioselectivity. The results are described below.

The 1st run (2.5 h):
(*R*)-**2j**: 32% yield, 98% ee; $[a]^{26}_{D}$ +119.6 (c 1.00, $CHCl_3$)
(*S*)-**3j**: 62% yield, 51% ee; $[a]^{26}_{D}$ -18.8 (c 1.00, $CHCl_3$)

The 2nd run (4.5 h):
(*R*)-**2j**: 22% yield, 96% ee; $[a]^{27}_{D}$ +126.6 (c 1.00, $CHCl_3$)
(*S*)-**3j**: 66% yield, 29% ee; $[a]^{26}_{D}$ -25.2 (c 1.00, $CHCl_3$)

The 3rd run (6 h):
(*R*)-**2j**: 30% yield, 96% ee; $[a]^{27}_{D}$ +153.8 (c 1.00, $CHCl_3$)
(*S*)-**3j**: 61% yield, 39% ee; $[a]^{26}_{D}$ -6.2 (c 1.00, $CHCl_3$)

The 4th run (8 h):
(*R*)-**2j**: 20% yield, 97% ee; $[a]^{26}_{D}$ +138.2 (c 1.00, $CHCl_3$)
(*S*)-**3j**: 77% yield, 29% ee; $[a]^{27}_{D}$ -1.4 (c 1.00, $CHCl_3$)

The 5th run (12.5 h):
(*R*)-**2j**: 18% yield, 97% ee; $[a]^{28}_{D}$ +147.0 (c 1.20, $CHCl_3$)
(*S*)-**3j**: 78% yield, 23% ee; $[a]^{27}_{D}$ -15.0 (c 1.00, $CHCl_3$)

Determination of the reaction rate of Lipase-catalyzed reaction

The reaction rate of the lipase-catalyzed reaction was determined by capillary GC-analysis as follows: the reaction mixture was sampled at appropriate reaction interval and determined % conversion by GC analysis, respectively. The reaction rate of Lipase PS-C-catalyzed reaction was determined based on these results until 60 min reaction as illustrated in Figure 3-1. On the other hand, since IL1-PS-catalyzed reaction proceeded very rapidly, the initial reaction rate was determined based on the graph of reaction course as illustrated in Figure 3-2.

Table 6-1. Typical results of Lipase-catalyzed acetylation of (±)-**1a.**

	Lipase PS-C	IL1-PS
Time (min.)	%conv.	%conv.
0	0	0
5	--	16.9
10	1.7	23.7
30	5.8	32.2
60	10.4	44.2
120	16.8	53.5

The reaction was carried out using 50 mg of Lipase PS-C (contains 0.5 mg of protein) or 7.0 mg of IL1-PS (contains 0.5 mg of protein) for 310 mM solution of (±)-**1a** in i-Pr_2O

On the other hand, the reaction of (±)-**1b** proceeded very rapidly as shown in Table 6-2. We determined the initial rate (V max) using graphs as illustrated in Figure 3-3.

Table 6-2. Typical results of Lipase-catalyzed acetylationof (±)-**1b**.

Time (min)	[bdmim][pentOSO$_3$]-PS	[bmim][BF_4]-PS	[bdmim][BF_4]-PS	IL1-PS	PS-C
	%conv.	%conv.	%conv.	%conv.	%conv.
0	0	0	0	0	0
1	10.7	5.8	6.4	22.3	0.7
5	20.2	7.2	10.8	52.3	6.8
10	29.2	8.4	---	64.1	16.6

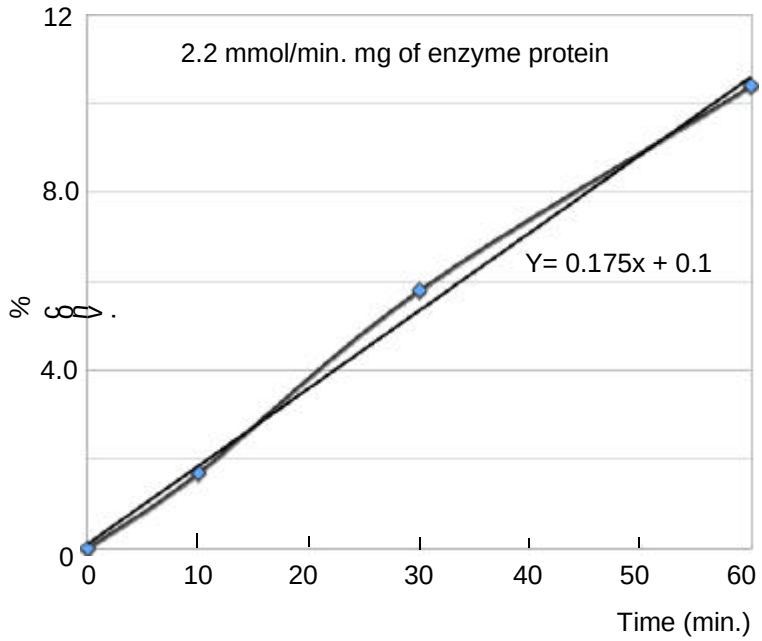


Figure 3-1. *Reaction time course of Lipase PS-C-catalyzed acetylation of (±)-**1a.** The reaction was carried out using 50 mg of Lipase PS (contains 0.25 mg of protein) for 310 mM solution of (±)-**1a** in i-Pr$_2$O*

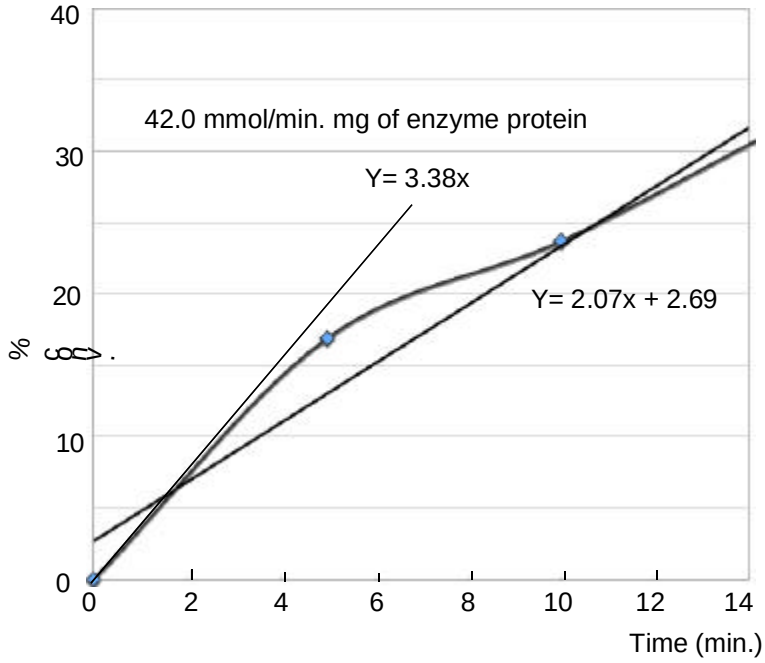
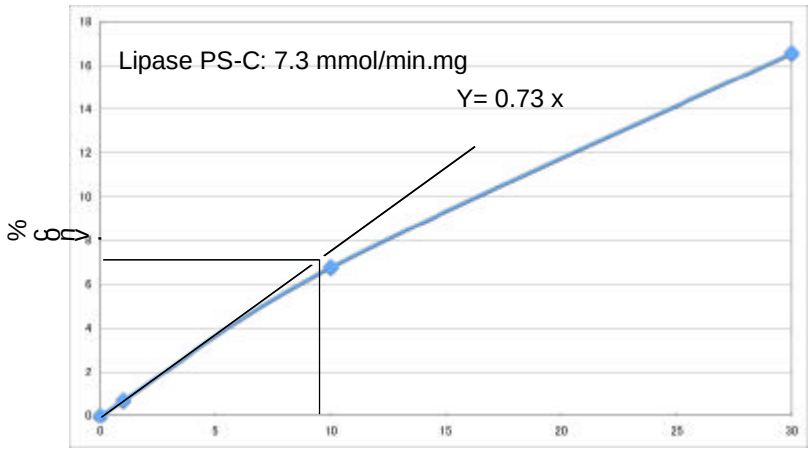
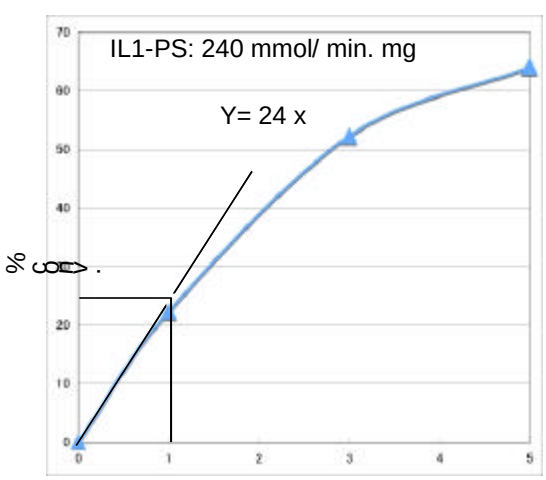


Figure 3-2. *Reaction time course of IL1-PS-catalyzed acetylation of (±)-**1a.** The reaction was carried out using 7.0 mg of IL1-PS (contains 0.25 mg of protein) for 310 mM solution of (±)-**1a** in i-Pr$_2$O*





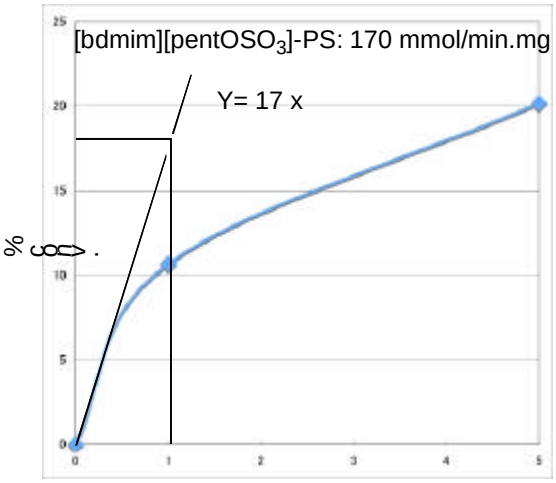


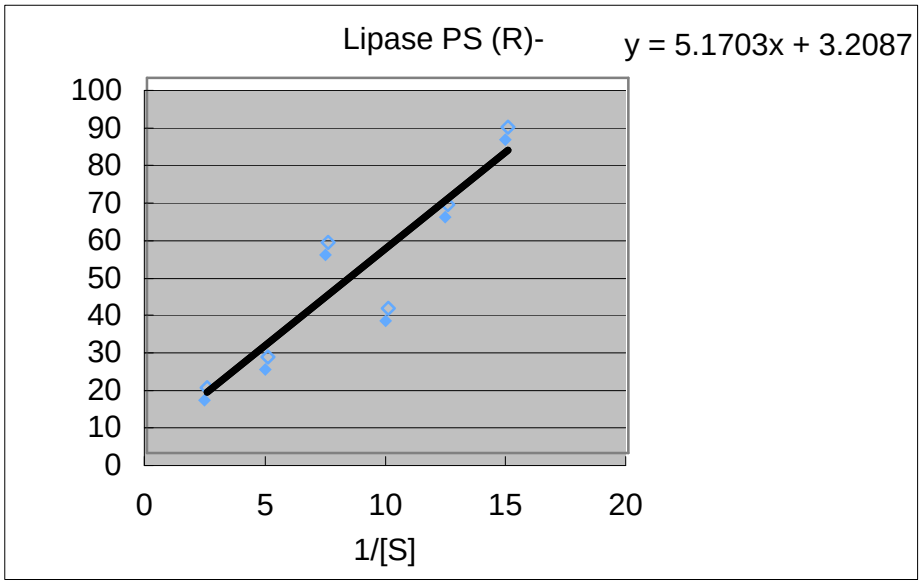
Figure 3-3. *Reaction time course of lipase-catalyzed acetylation of (±)-**1b**. The reaction was carried out using 7.0 mg of IL1-PS (contains 0.25 mg of lipase protein) for 250 mM solution of (±)-**1b** in i-Pr$_2$O*

Kinetics experiments for lipase PS-C or IL1-PS-catalyzed acetylation of 3-hydroxypentanenitirile (1b)

Lipase PS-C

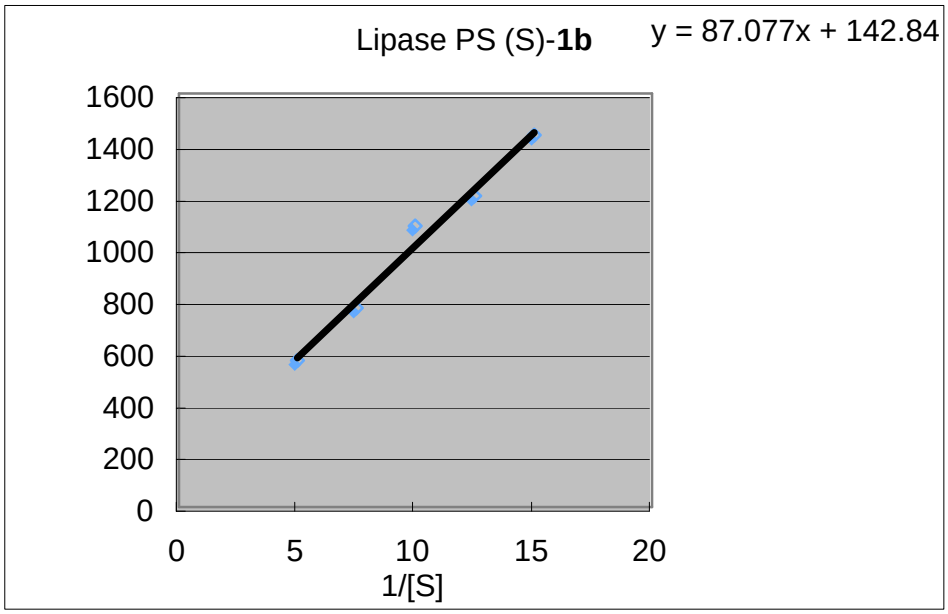
(*R*)-**1b:** V_{max} = 0.312(M min^{-1} mg^{-1}), K_m = 1.613(M), K_{cat} = 2.0x10^4(min^{-1}), K_{cat}/K_m = 1.3x10^4($M^{-1}min^{-1}$)

[S] (M)	V(M min^{-1}, mg^{-1})	1/[S] (M^{-1})	1/V(M^{-1} min, mg)
0.4	0.0576	2.5	17.4
0.2	0.0392	5	25.5
0.133	0.0178	7.5	56.2
0.1	0.026	10	38.5
0.08	0.0151	12.5	66.2
0.067	0.0115	15	87.0



(*S*)-**1b:** V_{max} = 0.007(M min^{-1} mg^{-1}), K_m = 0.61(M), K_{cat} = 4.6x10^2(min^{-1}), K_{cat}/K_m = 7.5x10^2($M^{-1}min^{-1}$)

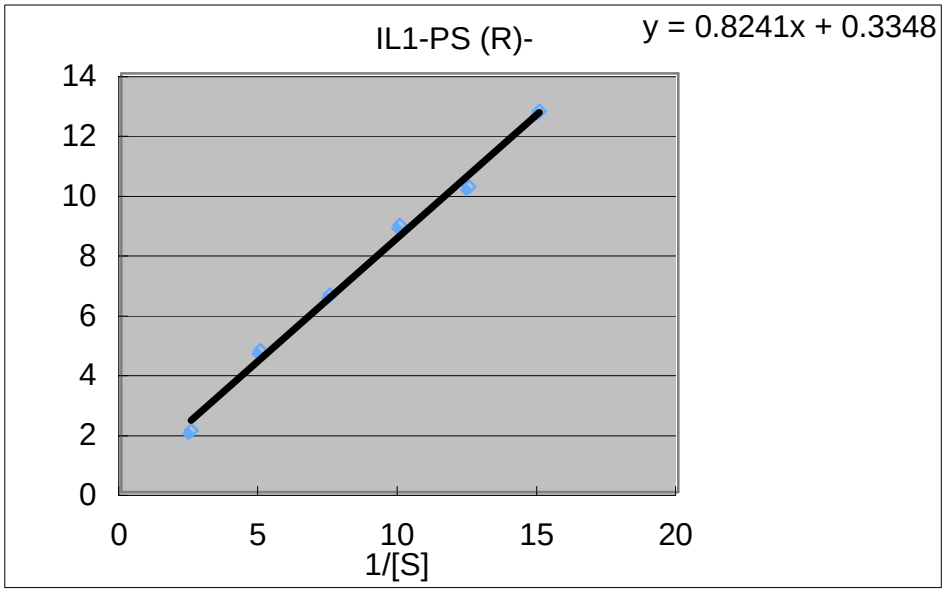
[S] (M)	V(M min^{-1}, mg^{-1})	1/[S] (M^{-1})	1/V(M^{-1} min, mg)
0.4	--	2.5	--
0.2	0.00176	5	568.2
0.133	0.0013	7.5	769.2
0.1	0.00092	10	1087.0
0.08	0.00083	12.5	1204.8
0.067	0.000695	15	1438.8



IL1-PS

(*R*)-**1b:** V_{max} = 2.99(M min^{-1} mg^{-1}), K_m = 2.46(M), K_{cat} = 2.0 x 10^5(min^{-1}), K_{cat}/K_m = 8.0 x 10^4($M^{-1}min^{-1}$)

[S] (M)	V(M min^{-1}, mg^{-1})	1/[S] (M^{-1})	1/V(M^{-1} min, mg)
0.4	0.485	2.5	2.1
0.2	0.211	5	4.7
0.133	0.1515	7.5	6.6
0.1	0.112	10	8.9
0.08	0.098	12.5	10.2
0.067	0.0785	15	12.7

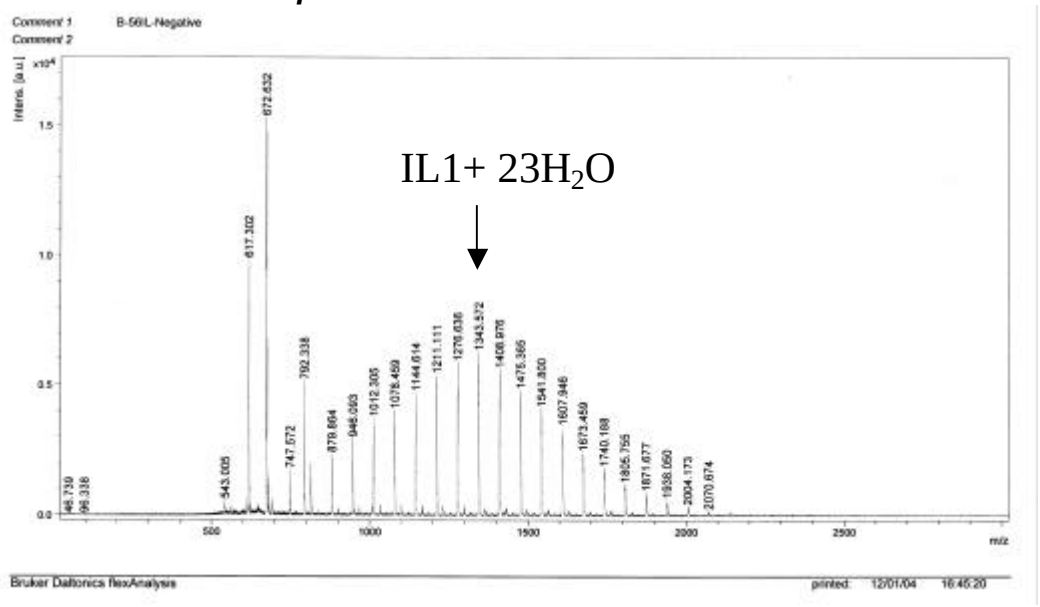


(*S*)-**1b:** V_{max} = 0.091(M min^{-1} mg^{-1}), K_m = 0.29(M), k_{cat} = $6.0x10^3$(min^{-1}), K_{cat}/K_m= $2.1x10^4$($M^{-1}min^{-1}$)

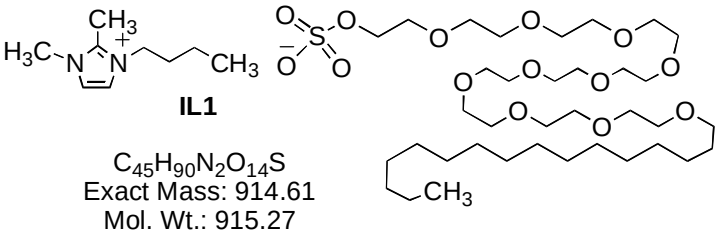
[S] (M)	v (M min^{-1} mg^{-1})	1/[S] (M^{-1})	1/v (M^{-1} min mg)
0.4	0.0545	2.5	18.3
0.2	0.0384	5	26.0
0.133	0.0249	7.5	40.2
0.1	0.0268	10	37.3
0.08	0.0195	12.5	51.3
0.067	0.0169	15	59.2

1-5. Investigation of the origin of this IL1-mediated activation

MALDI-TOF Mass spectra of IL1



Matrix: 3,5-dimethoxy-4-hydroxycinnamic acid (sinapinic acid).



IL1

$C_{45}H_{90}N_2O_{14}S$
Exact Mass: 914.61
Mol. Wt.: 915.27

IL1 was made from commercial Brij-56, which consisted with polymers with different number of polyoxyethylene groups, though the main component was reported as polyoxywethylen(10) cetyl ether. Therefore the molecular weight of the main component of IL1 was calculated as 915. Since the main signal of IL1 was found at 1343.572, we assumed that IL1 contains at least 23 water molecules according to the TOF-MS spectra.

SEM images of the ionic liquid coated lipase PS-C proteins.

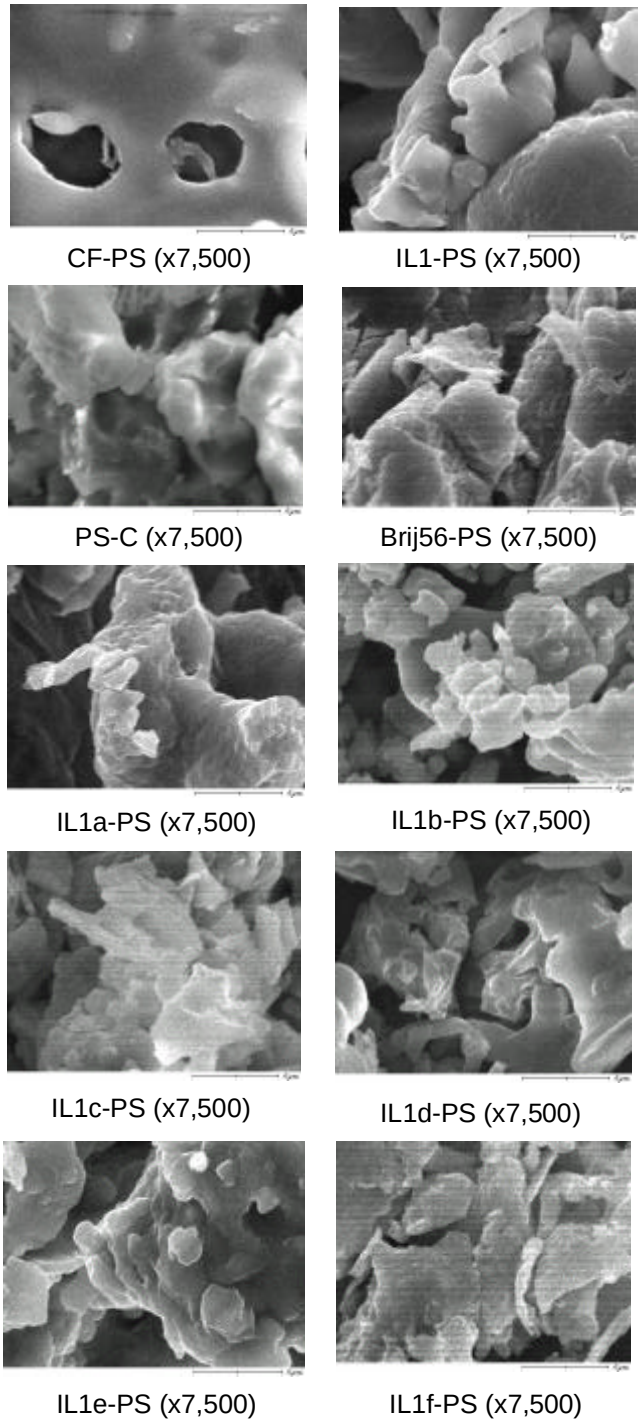


Figure 4. *Scanning Electron Micrographs (SEM) of CF-PS, PS-C, Brij56-PS, and seven types of Ionic Liquid coated PS, IL1-ILf at 7,500 magnitude*