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Steric effects in the design of chiral Schiff base–titanium complexes: new catalysts for asymmetric trimethylsilylcyanation of aldehydes

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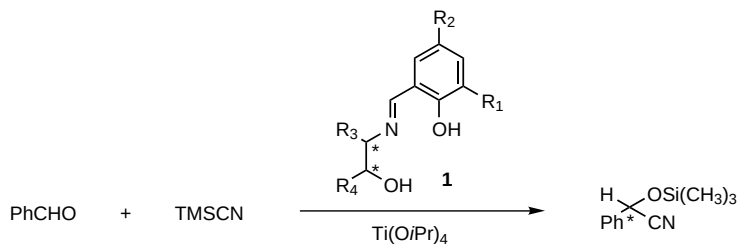
Abstract—New chiral Schiff base ligands derived from salicylaldehydes bearing bulky ring substituents were synthesized by reaction with various amino alcohols. These new ligands were used with titanium tetraisopropoxide to study steric effects on the enantioselectivity of the trimethylsilylcyanation of aldehydes. © 2002 Published by Elsevier Science Ltd.

1. Introduction

Optically active cyanohydrins are very useful synthons in organic synthesis, which can be transformed into chiral α-hydroxy carboxylic acids,[1,2] α-hydroxy aldehydes,[3] α-hydroxy ketones,[4] and β-amino alcohols.[2,5,6] Numerous efficient asymmetric methods to these molecules have been reported.[7–14] Among these, the Lewis acid-catalyzed addition of trimethylsilylcyanide to aldehydes has been accomplished with excellent enantioselectivity.[15–18] This asymmetric carbon–carbon bond forming process finds wide synthetic application in the pharmaceutical and agrochemical industries.[19] In a previous report from this laboratory we described the catalytic enantioselective trimethylsilylcyanation of benzaldehyde with up to 85% e.e. using catalytic amounts of titanium tetraisopropoxide and chiral Schiff-base ligands derived from *cis*-1-amino-2-indanol.[20]

In this study, we found that the enantioselectivity of the trimethylsilylcyanation reaction was dependent on the size of the R_1 group on the Schiff base ligand **1**, where R_3, R_4 = indanol backbone, Eq. (1).

Through NMR and X-ray analyses we found that when ligands with small R_1 substituents (R_1 = H, Br, OCH_3) *ortho* to the phenolic OH were combined with an equivalent of titanium tetraisopropoxide the predominant product was L_2^*Ti with a ligand to titanium ratio of 2:1. Only a small amount of $L^*Ti(O\text{-}i\text{-}Pr)_2$, which is believed to be the active catalyst, was observed by NMR along with some unreacted titanium tetraisopropoxide. The L_2^*Ti complex was found to be a very slow catalyst for the asymmetric addition of trimethylsilylcyanide to aldehydes because the catalyst is octahedral and sterically saturated. In contrast, when R_1 was large (e.g. *tert*-butyl), reaction of the ligand



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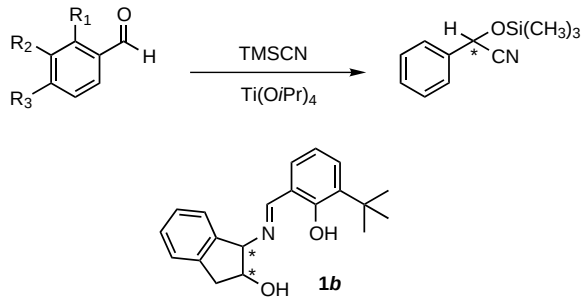
with titanium tetraisopropoxide gave only L*Ti(O-*i*-Pr)$_2$ by NMR. This species catalyzed the reaction efficiently and with high enantioselectivity (Table 1, entries 1–3).

2. Results and discussion

As a continuation of our initial study, we were interested in designing new Schiff base ligands, where R_1 would be very bulky (i.e. larger than *tert*-butyl). We have previously determined that the most enantioselective catalysts incorporated ligands in which R_1 was *tert*-butyl. Not only would such large substituents favor the formation of L*Ti(O-*i*-Pr)$_2$ species, but based on our earlier investigations, we believed that they might form more enantioselective catalysts. Aldehyde precursors for ligand syntheses with large R_1 substituents were prepared following the literature methods[21] and converted to Schiff base ligands on reaction with *cis*-1-amino-2-indanol. The Schiff bases were then combined with an equivalent of titanium isopropoxide to form the catalysts for the asymmetric trimethylsilylcyanation of benzaldehyde. The results of the asymmetric addition reactions are shown in Table 1. The results in entries 4–6 indicate that ligands with large R_1 groups and the conformationally rigid five-membered indanol did not result in an increase in the enantioselectivity or efficiency of the catalyst compared to the ligands where R_1 was a *tert*-butyl group (entries 1–3). A possible explanation for the low enantioselectivity and conversion with ligands **1d**–**1f** is that the large R_1 substituent does not allow facile coordination and activation of the aldehyde substrate.

In order to explore the steric effects of the ligand on the enantioselectivity of catalysts with different backbones, we replaced the rigid indanol ring with conformationally more flexible amino alcohol components. As shown in Table 1, the e.e. of the trimethylsilylcyanation improved with respect to ligands **1d**–**1f**. The best results were obtained when R_1 was an adamantyl group (entries 7, 10 and 13).

Next, a series of benzaldehyde derivatives was examined with the catalyst formed from ligand **1b** (Eq. (2)). The product e.e.s were the highest with *para* substituted aldehydes and were found to be lower when *meta* or *ortho* substituted aldehydes were employed. *para*-Anisaldehyde was an excellent substrate for catalyst **1b**, giving 95% e.e. in the asymmetric addition reaction.



(2)

The results described in Tables 1 and 2 and our previous study clearly indicate that steric crowding around the metal center is necessary for the formation of active and enantioselective catalysts in the asymmetric trimethylsilylcyanation of aldehydes with Schiff-base ligands and titanium isopropoxide. Similar effects have also been reported for the salen ligands, where steric factors play a major role in the asymmetric induction.[23] From our work, it appears that the size of the R_1 substituent and the bulk and conformational flexibility of the amino alcohol backbone must be balanced in designing new Schiff-base ligands. We are currently working on a series of structurally similar ligands with

Table 1. Enantioselective addition of trimethylsilylcyanide to benzaldehyde promoted by chiral Schiff base–titanium complexes[a]

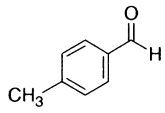
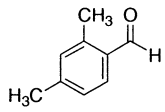
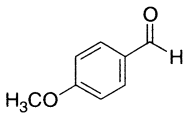
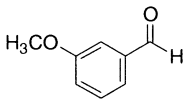
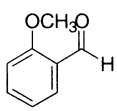
Entry	Schiff base	Configuration	R_1	R_2	R_3	R_4	Yield (%)	e.e.[b] (%) (Configuration)
1	**1a**	(*R*,*S*)	$C(CH_3)_3$	$C(CH_3)_3$	$CH_2C_6H_4$		62	70 (*R*)[c]
2	**1b**	(*R*,*S*)	$C(CH_3)_3$	H	$CH_2C_6H_4$		64	85 (*R*)[c]
3	**1c**	(*R*,*S*)	$C(CH_3)_3$	CH_3	$CH_2C_6H_4$		72	59 (*R*)[c]
4	**1d**	(*R*,*S*)	Adamantyl	CH_3	$CH_2C_6H_4$		25	44 (*S*)
5	**1e**	(*R*,*S*)	$C(CH_3)_2CH_2CH_3$	$C(CH_3)_2CH_2CH_3$	$CH_2C_6H_4$		36	27 (*R*)
6	**1f**	(*R*,*S*)	$C(CH_3)_2Ph$	$C(CH_3)_2Ph$	$CH_2C_6H_4$		17	12 (*R*)
7	**1g**	(*S*)	Adamantyl	CH_3	$C(CH_3)_3$	H	52	68 (*S*)
8	**1h**	(*S*)	$C(CH_3)_2CH_2CH_3$	$C(CH_3)_2CH_2CH_3$	$C(CH_3)_3$	H	38	55 (*R*)
9	**1i**	(*S*)	$C(CH_3)_2Ph$	$C(CH_3)_2Ph$	$C(CH_3)_3$	H	18	17 (*R*)
10	**1j**	(*R*)	Adamantyl	CH_3	Ph	H	50	55 (*S*)
11	**1k**	(*R*)	$C(CH_3)_2CH_2CH_3$	$C(CH_3)_2CH_2CH_3$	Ph	H	39	52 (*R*)
12	**1l**	(*R*)	$C(CH_3)_2Ph$	$C(CH_3)_2Ph$	Ph	H	20	15 (*R*)
13	**1m**	(*S*,*R*)	Adamantyl	CH_3	Ph	Ph	50	66 (*S*)
14	**1n**	(*S*,*R*)	$C(CH_3)_2CH_2CH_3$	$C(CH_3)_2CH_2CH_3$	Ph	Ph	40	54 (*R*)
15	**1o**	(*S*,*R*)	$C(CH_3)_2Ph$	$C(CH_3)_2Ph$	Ph	Ph	15	12 (*R*)
16	**1p**	(*S*)	Adamantyl	CH_3	$CH(CH_3)_2$	H	60	65 (*S*)

[a] All reactions were performed using 20% mol titanium tetraisopropoxide at –78°C in dichloromethane for 36 h. Each e.e. value is the result of a minimum of two runs.

[b] Enantioselectivities were determined as described in the Section 3.

[c] Ref. 20.

Table 2. Enantioselectivities in the asymmetric cyanohydration of different aldehydes

Entry	Compound	% Yield	% e.e. (Configuration)
1	**3a** 	62	50(*R*)[a]
2	**3b** 	48	21[b]
3	**3c** 	77	95(*R*)[a]
4	**3d** 	52	56(*R*)[a]
5	**3e** 	50	20(*R*)[c]

[a] Configuration was determined using Oguni's ligand.[15]
[b] Absolute configuration not assigned.
[c] Determined by comparison of the sign of specific rotation value with the literature value.[22]

subtle variations in the size of the substituents to optimize the catalysts and understand their mechanisms in the trimethylsilylcyanation of aldehydes.

3. Experimental

All manipulations involving titanium complexes were carried out under an inert atmosphere using standard Schlenk and vacuum line techniques.

Enantiomeric excesses were determined using a Hewlett–Packard 6890 gas chromatograph with a 30 m Supelco β-DEX column. The silyloxy cyanides were hydrolyzed with 1N HCl for 3 h to the alcohol and derivatized with acetic anhydride. The GC conditions were: oven temperature 150°C, flow rate 3 mL/min. The retention times (min) of the enantiomers derived from benzaldehyde were 11.42 (*R*) and 12.07 (*S*); **3a** 12.60 (*R*) and 13.15 (*S*); **3b** 17.00 (*R*) and 17.20 (*S*); **3c** 15.45 (*R*) and 15.77 (*S*); **3d** 15.00 (*R*) and 15.40 (*S*); **3e** 14.80 (*R*) and 15.10 (*S*).

Details of the general procedure for the synthesis of the Schiff bases, for the trimethylsilylcyanation reaction, and the experimental data for ligands **1a**–**1c** are reported in a previous work.[20]

3.1. Data for (1*R*,2*S*)-(+)-1-[*N*-(3′-adamantyl-5′-methylsalicylidene)amino]-2-indanol, 1d

Yellow solid (0.31 g, 95% yield): mp 220–225°C; $[\alpha]_D^{25} = +76.9$ ($c = 0.5$, CH_2Cl_2); IR (KBr) 3586, 2901, 2845, 1621 and 745 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 13.10 (brs, 1H), 8.60 (s, 1H), 7.30 (d, 1H, $J = 7.2$ Hz), 7.28 (t, 1H, $J = 7.4$ Hz), 7.22 (t, 1H, $J = 7.3$ Hz), 7.18 (d, 1H, $J = 7.2$ Hz), 7.10 (d, 1H, $J = 1.5$ Hz), 6.96 (d, 1H, $J = 1.5$ Hz), 4.78 (d, 1H, $J = 5.2$ Hz), 4.65 (q, 1H, $J = 5.2$ Hz), 3.23 (dd, 1H, $J_1 = 5.9$ Hz and $J_2 = 15.9$ Hz), 3.12 (dd, 1H, $J_1 = 5.9$ Hz and $J_2 = 15.9$ Hz), 2.29 (s, 3H), 2.13 (s, 6H), 2.05 (s, 3H) and 1.76 (s, 6H) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 168.07, 158.42, 140.98, 140.88, 137.70, 131.25, 130.01, 128.57, 127.12, 127.06, 125.50, 124.95, 118.37, 75.74, 75.22, 40.23, 39.66, 37.07, 39.90, 29.00 and 20.59 ppm. Anal. calcd for

$C_{27}H_{31}NO_2$: C, 78.02; H, 7.96. Found: C, 77.99; H, 7.95%.

3.2. Data for (1*R*,2*S*)-(−)-1-[*N*-(3′,5′-di-*tert*-amylsalicylidene)amino]-2-indanol, 1e

Yellow solid (1.20 g, 90% yield); mp 78–80°C; $[\alpha]_D^{25} = -21.8$ ($c = 1.2$, CH_2Cl_2); IR (KBr) 3576, 3450, 2949, 2884, 1620, 1457, 1158 and 750 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.60 (s, 1H), 7.26–7.17 (m, 5H), 7.10 (d, 1H, $J = 2.3$ Hz), 4.70 (d, 1H, $J = 5.3$ Hz), 4.60 (q, 1H, $J = 5.6$ Hz), 3.20 (dd, 1H, $J_1 = 5.6$ Hz and $J_2 = 15.9$ Hz), 3.10 (dd, 1H, $J_1 = 5.6$ Hz and $J_2 = 15.9$ Hz), 1.87 (q, 2H, $J = 6.5$ Hz), 1.60 (q, 2H, $J = 6.5$ Hz), 1.36 (s, 6H), 1.27 (s, 6H), 0.69 (t, 6H, $J = 7.1$ Hz) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 168.40, 158.07, 141.01, 140.88, 138.52, 135.22, 129.67, 128.51, 127.34, 127.01, 125.46, 124.98, 117.76, 75.60, 75.11, 39.60, 38.51, 37.21, 36.80, 32.54, 28.45, 27.37, 9.37 and 9.03 ppm. Anal. calcd for $C_{26}H_{35}NO_2$: C, 79.38; H, 8.90. Found: C, 79.42; H, 8.99%.

3.3. Data for (1*R*,2*S*)-(−)-1-[*N*-(3′,5′-Bis(α,α-dimethylbenzylsalicylidene)amino]-2-indanol, 1f

Yellow solid (1.48 g, 93% yield); mp 60–62°C; $[\alpha]_D^{25} = -42.4$ ($c = 0.5$, CH_2Cl_2); IR (KBr) 3549, 3387, 3033, 2960, 1630, 1458, 1093 and 761 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.46 (s, 1H), 7.35 (d, 1H, $J = 2.39$ Hz), 7.29–7.10 (m, 14H), 7.08 (d, 1H, $J = 2.39$ Hz), 4.69 (d, 1H, $J = 5.6$ Hz), 4.57 (q, 1H, $J = 5.6$ Hz), 3.15 (dd, 1H, $J_1 = 5.9$ Hz and $J_2 = 15.9$ Hz), 3.00 (dd, 1H, $J_1 = 5.9$ Hz and $J_2 = 15.9$ Hz), 1.71 (s, 6H), 1.64 (s, 6H) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 167.88, 157.79, 150.69, 150.41, 140.92, 140.69, 140.06, 136.40, 129.86, 128.53, 128.11, 127.88, 126.97, 126.76, 125.80, 125.69, 125.46, 125.16, 125.03, 118.03, 75.51, 75.06, 42.42, 42.14, 39.56, 30.85, 29.55 and 29.03 ppm. Anal. calcd for $C_{34}H_{35}NO_2$: C, 83.43; H, 7.15. Found: C, 83.55; H, 7.20%.

3.4. Data for (*S*)-(+)-2-[*N*-(3′-adamantyl-5′-methylsalicylidene)amino]-3,3-dimethyl-1-butanol, 1g

Yellow solid (0.31 g, 95% yield); mp 73–75°C; $[\alpha]_D^{25} = +0.5$ ($c = 1.61$, CH_2Cl_2); IR (KBr) 3403, 2908, 1628, 1454 and 1050 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 8.27 (s, 1H), 7.07 (d, 1H, $J = 2.2$ Hz), 6.91 (d, 1H, $J = 2.2$ Hz), 3.86 (dd, 1H, $J_1 = 3.0$ Hz and $J_2 = 11.4$ Hz), 3.79 (t, 1H, $J = 9.4$ Hz), 2.87 (dd, 1H, $J_1 = 2.8$ Hz and $J_2 = 9.0$ Hz), 2.27 (s, 3H), 2.16 (s, 6H), 2.12 (s, 3H), 1.78 (s, 6H) and 0.95 (s, 9H) ppm; ^{13}C NMR (50 MHz, $CDCl_3$): δ 167.01, 158.63, 137.59, 130.71, 129.86, 126.89, 118.37, 81.56, 62.61, 40.45, 37.30, 33.36, 29.24, 27.25 and 20.85 ppm. Anal. calcd for $C_{24}H_{35}NO_2$: C, 88.27; H, 8.04. Found: C, 88.35; H, 8.13%.

3.5. Data for (*S*)-(−)-2-[*N*-(3′,5′-di-*tert*-amylsalicylidene)amino]-3,3-dimethyl-1-butanol, 1h

Yellow solid (0.47 g, 99% yield); mp 70–73°C. $[\alpha]_D^{25} = -33.7$ ($c = 0.6$, CH_2Cl_2). IR (KBr) 3387, 2947, 2870, 1633, 1461 and 1276 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.80 (s, 1H), 7.71 (d, 1H, $J = 2.6$ Hz), 7.51 (d, 1H, $J = 2.2$ Hz), 4.36 (dd, 1H, $J_1 = 3.0$ Hz and $J_2 = 11.0$ Hz), 4.19 (t, 1H, $J = 11.0$ Hz), 3.36 (dd, 1H, $J_1 = 2.8$ Hz and $J_2 = 9.4$ Hz), 2.36 (q, 2H, 7.2 Hz), 2.06 (q, 2H, $J = 7.2$ Hz), 1.84 (s, 6H), 1.72 (s, 6H), 1.42 (s, 9H), 1.14 (t, 3H, $J = 7.2$ Hz) and 1.12 (t, 3H, $J = 7.8$ Hz) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 167.46, 158.28, 138.39, 135.14, 129.25, 127.20, 117.73, 81.58, 62.75, 38.75, 37.44, 37.06, 33.43, 32.81, 28.77, 28.67, 28.55, 27.64, 27.33, 9.72 and 9.37 ppm. Anal. calcd for $C_{23}H_{39}NO_2$: C, 76.45; H, 7.10. Found: C, 76.88; H, 7.40%.

3.6. Data for (*S*)-(+)-2-[*N*-(3′,5′-Bis(α,α-dimethylbenzylsalicylidene)amino]-3,3-dimethyl-1-butanol, 1i

Yellow solid (0.54 g, 92% yield); mp 50–53°C; $[\alpha]_D^{25} = -34.75$ ($c = 1.85$, CH_2Cl_2); IR (KBr) 3412, 2963, 2871, 1628, 1458, 1045 and 697 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.29–7.19 (m, 11H), 7.05 (d, 1H, $J = 2.4$ Hz), 3.81 (dd, 1H, $J_1 = 3.0$ Hz and $J_2 = 11.2$ Hz), 3.63 (t, 1H, $J = 9.4$ Hz), 2.82 (dd, 1H, $J_1 = 3.0$ Hz and $J_2 = 9.4$ Hz), 1.73 (s, 3H), 1.69 (s, 6H), 1.63 (s, 3H) and 0.83 (s, 9H) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 166.87, 157.92, 150.72, 150.55, 139.74, 136.56, 129.55, 128.07, 127.81, 126.77, 125.85, 125.69, 125.08, 117.86, 81.57, 62.37, 42.37, 42.22, 33.13, 30.87, 30.80, 30.31, 28.29 and 27.03 ppm. Anal. calcd for $C_{31}H_{39}NO_2$: C, 81.40; H, 8.53. Found: C, 81.80; H, 8.90%.

3.7. Data for (*R*)-(+)-2-[*N*-(3′-adamantyl-5′-methylsalicylidene)amino]-2-phenyl-1-ethanol, 1j

Yellow solid (0.38 g, 67% yield); mp 75–77°C. $[\alpha]_D^{25} = +126.5$ ($c = 0.8$, CH_2Cl_2); IR (KBr) 3366, 3036, 2889, 2849, 1623, 1444, 1244, 1059 and 692 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.42 (s, 1H), 7.39–7.24 (m, 5H), 7.08 (s, 1H), 6.90 (s, 1H), 4.44 (t, 1H, $J = 6.6$ Hz), 3.91 (d, 2H, $J = 7.0$ Hz), 2.26 (s, 3H), 2.17 (s, 6H), 2.08 (s, 3H), and 1.79 (s, 6H) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 167.72, 158.60, 139.79, 137.76, 131.28, 130.16, 129.08, 128.09, 127.50, 127.29, 118.59, 67.97, 40.51, 37.34, 37.15, 29.28 and 20.79 ppm. Anal. calcd for $C_{26}H_{31}NO_2$: C, 80.79; H, 7.73. Found: C, 80.91; H, 7.79%.

3.8. Data for (*R*)-(+)-2-[*N*-(3′,5′-di-*tert*-amylsalicylidene)amino]-2-phenyl-1-ethanol, 1k

Yellow oil (0.64 g, 93% yield); $[\alpha]_D^{25} = +95.4$ ($c = 1.9$, CH_2Cl_2); IR (KBr) 3397, 2947, 2870, 1623, 1425, 1271, 1057, 738 and 700 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.46 (s, 1H), 7.34–7.27 (m, 6H), 7.05 (s, 1H), 4.39 (t, 1H, $J = 6.8$ Hz), 3.84 (d, 2H, $J = 7.6$ Hz), 1.94 (q, 2H, $J = 7.2$ Hz), 1.59 (q, 2H, $J = 7.4$ Hz), 1.40 (s, 6H), 1.25 (s, 6H) and 0.65 (t, 6H, $J = 6.4$ Hz) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 167.49, 157.86, 139.60, 138.34, 134.88, 129.30, 128.69, 128.55, 127.68, 127.18, 117.73, 67.55, 50.39, 38.54, 37.22, 36.85, 32.60, 28.50, 27.48, 9.52, and 9.11 ppm. Anal. calcd for $C_{25}H_{35}NO_2$: C, 78.74; H, 9.18. Found: C, 78.90; H, 9.48%.

3.9. Data for (*R*)-(+)-2-[*N*-(3′,5′-Bis(α,α-dimethylbenzyl)salicylidene)amino]-2-phenyl-1-ethanol, 1l

Yellow solid (0.27 g, 51% yield); mp 56–58°C; $[\alpha]_D^{25}=+79.8$ ($c=1.61$, CH_2Cl_2); IR (KBr) 3406, 3033, 2956, 2861, 1628, 1447, 1033, 761 and 704 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.31 (s, 1H), 7.46 (d, 1H, $J=2.4$ Hz), 7.43–7.17 (m, 15H), 7.12 (d, 1H, $J=2.2$ Hz), 4.30 (t, 1H, $J=6.0$ Hz), 3.74 (d, 2H, $J=6.2$ Hz), 1.71 (s, 3H), 1.68 (s, 3H) and 1.64 (s, 6H) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 167.13, 157.49, 150.60, 150.47, 139.92, 139.43, 136.03, 129.40, 128.65, 128.40, 128.00, 127.85, 127.69, 127.16, 126.67, 125.63, 125.09, 118.00, 78.04, 67.34, 42.40, 42.16, 30.87, 30.28 and 28.54 ppm. Anal. calcd for $C_{33}H_{35}NO_2$: C, 83.02; H, 7.34. Found: C, 83.41; H, 7.84%.

3.10. Data for (1*S*,2*R*)-(+)-2-[*N*-3′-adamantyl-5′-methylsalicylidene)amino]-1,2-diphenylethanol, 1m

Yellow solid (0.39 g, 89% yield); mp 75–77°C. $[\alpha]_D^{25}=+0.75$ ($c=0.4$, CH_2Cl_2); IR (KBr) 3422, 2899, 2844, 1628, 1449, 1045 and 701 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.02 (s, 1H), 7.40–7.22 (m, 10H), 7.03 (d, 1H, $J=2.02$ Hz), 6.70 (d, 1H, $J=2.4$ Hz), 5.05 (d, 1H, $J=6.6$ Hz), 4.43 (d, 1H, $J=6.4$ Hz), 3.43 (s, 1H), 2.22 (s, 3H), 2.18 (s, 6H), 2.12 (s, 3H) and 1.8 (s, 6H) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 167.21, 166.74, 158.48, 140.54, 139.76, 137.52, 131.18, 130.80, 130.11, 129.85, 129.16, 128.67, 128.45, 128.17, 127.67, 127.17, 126.87, 118.49, 118.52, 80.90, 80.42, 78.84, 78.19, 40.88, 40.47, 40.09, 37.83, 37.43, 37.16, 29.54, 29.15, 21.04, 20.66, 0.40 and 0.10 ppm. Anal. calcd for $C_{32}H_{35}NO_2$: C, 77.80; H, 9.48. Found: C, 77.96; H, 9.57%.

3.11. Data for (1*S*,2*R*)-(−)-2-[*N*-3′,5′-di-*tert*-amylsalicylidene)amino]-1,2-diphenylethanol, 1n

Yellow oil (0.37 g, 86% yield); $[\alpha]_D^{25}=-18.6$ ($c=0.97$, CH_2Cl_2); IR (KBr) 3425, 3030, 2947, 2870, 1628, 1452, 1047 and 700 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.10 (s, 1H), 7.40–7.11 (m, 11H), 6.83 (d, 1H, $J=2.3$ Hz), 5.01 (d, 1H, $J=6.8$ Hz), 4.46 (d, 1H, $J=6.4$ Hz), 1.93 (q, 2H, $J=7.2$ Hz), 1.54 (q, 2H, $J=7.4$ Hz), 1.39 (s, 6H) 1.20 (s, 6H) and 0.62 (t, 6H, $J=7.4$ Hz) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 167.35, 158.03, 140.39, 139.74, 138.21, 134.91, 129.37, 128.78, 128.31, 128.17, 128.05, 127.41, 127.27, 117.81, 80.28, 78.55, 38.74, 37.36, 37.05, 32.81, 28.69, 28.57, 27.66, 9.70 and 9.26 ppm. Anal. calcd for $C_{31}H_{39}NO_2$: C, 81.49; H, 8.53. Found: C, 81.72; H, 8.90%.

3.12. Data for (1*S*,2*R*)-(−)-2-[*N*-3′,5′-Bis(α,α-dimethylbenzyl)salicylidene)amino]-1,2-diphenylethanol, 1o

Yellow solid (0.41 g, 83% yield); mp 52–54°C. $[\alpha]_D^{25}=-7.3$ ($c=2.27$, CH_2Cl_2); IR (KBr) 3412, 2963, 2862, 1623, 1444, 1027, 761 and 697 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.01 (s, 1H), 7.28–7.09 (m, 21H), 6.84 (d, 1H, $J=2.4$ Hz), 4.93 (d, 1H, $J=6.8$ Hz), 4.37 (d, 1H, $J=6.6$ Hz), 1.70 (s, 6H), 1.64 (s, 6H) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ 166.68, 157.60, 150.69, 140.22, 139.63, 139.41, 136.08, 129.41, 128.61, 128.15, 128.02, 127.91, 127.78, 127.14, 126.74, 125.78, 125.64, 125.05, 117.96, 80.18, 78.14, 42.33, 42.17, 30.78, 30.06 and 28.54 ppm. Anal. calcd for $C_{39}H_{39}NO_2$: C, 84.63; H, 7.05. Found: C, 85.01; H, 7.55%.

3.13. Data for *S*-(−)-2-[*N*-3′-adamantyl-5′-methylsalicylidene)amino]-3-methyl-1-butanol, 1p

Yellow solid (0.47 g, 61% yield); mp 58–60°C; $[\alpha]_D^{25}=-26.3$ ($c=0.13$, CH_2Cl_2); IR (KBr) 3373, 2960, 2906, 2860, 1630, 1453, 1246, 1026 and 740 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.29 (s, 1H), 7.08 (d, 1H, $J=2.0$ Hz), 6.92 (d, 1H, $J=2.2$ Hz), 3.77 (2dd, 2H, $J_1=2.4$ Hz and $J_2=10.4$ Hz), 3.01 (t, 1H, $J=10.0$ Hz), 2.28 (s, 3H), 2.17 (s, 6H), 2.08 (s, 3H), 1.9 (m, 1H), 1.78 (s, 6H), 0.95 (d, 3H, $J=2.8$ Hz) and 0.92 (d, 3H, $J=2.8$ Hz) ppm; ^{13}C NMR (50 MHz, $CDCl_3$) δ166.97, 158.63, 137.63, 130.78, 129.84, 126.97, 118.41, 78.14, 64.78, 40.49, 37.34, 37.12, 30.26, 29.27, 20.86, 19.97 and 19.05 ppm. Anal. calcd for $C_{23}H_{33}NO_2$: C, 77.74; H, 9.29. Found: C, 77.80; H, 9.33%.

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