Aminolysis of *N*-tosylaziridines: an approach to asymmetric synthesis of symmetric and unsymmetric chiral sulfonamide ligands

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Dedicated with respect to Professor Lutz Tietze on his 65th birthday

Abstract

The ring-opening of *N*-tosylaziridines with aliphatic amines can be efficiently catalyzed by lithium perchlorate to provide derivatives of the *trans*-1,2-diamine in high yields. The reaction was used in desymmetrization of several cyclic *N*-tosylaziridines using chiral amines. Using this strategy, an efficient synthesis was developed of chiral vicinal C_2 symmetric *bis*-(sulfonamides), unsymmetrical bis(sulfonamides) and other symmetric and unsymmetric ligands based on *trans*-1,2-cyclohexanediamine.

Keywords: Aminolysis, bis(sulfonamide) ligands, *trans*-1,2-cyclohexanediamine, lithium perchlorate, *N*-tosylaziridines

Introduction

The development of methods for the synthesis new chiral ligands are an important aspect in the advancement of catalytic asymmetric synthesis because small changes in the donating ability of a ligand or the size of its substituents can have a dramatic effect on the catalyst efficiency and enantioselectivity.[1-3] C_2-Symmetric bis(sulfonamide) ligands of the type **1** (Figure 1) are electronically different and bind well to early transition metals[4] and main-group elements.[5] This type of ligand has been used in the asymmetric Diels–Alder reaction,[5,6] the alkylation of aldehydes,[7] the cyclopropanation of allylic alcohols[8] and the amination of *N*-acyloxazolidones.[9] The chemistry of these ligands has been very well studied in the field of asymmetric synthesis. However, not much work has been done using unsymmetrical bis(sulfonamide) ligands of type **2**.[10,11] This is mainly due to their non-availability and difficulty in the mono-sulfonylation of the 1,2-diamine such as **3**. Palladium- catalyzed monoarylation of 1,2-diamine **3** has been developed, but the yields were not high.[12] Walsh and coworkers have developed a very good procedure for the synthesis of unsymmetrical bis(sulfonamides) via an amino-sulfonamide **4** from the

commercially available corresponding diamine.[13a,b] In this paper we describe full details of our work towards a general approach to this kind of chiral ligand, based on the aminolysis of aziridines.[13c]

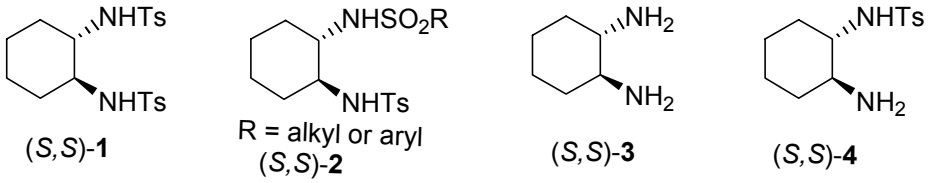


Figure 1. Cyclohexane-based symmetrical and unsymmetrical chiral ligands.

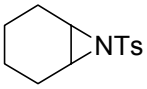
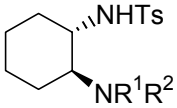
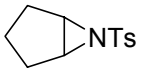
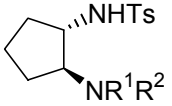
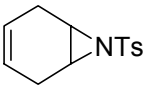
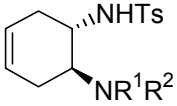
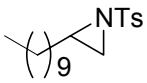
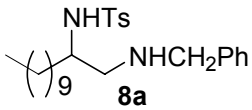
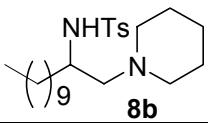
Results and Discussion

It was envisaged that if *N*-tosylcyclohexyl aziridine were opened with a benzylamine in a diastereoselective manner, the product could be converted into an amino-sulfonamide after debenzylation. With this idea, several *N*-tosyl aziridines were synthesized using known procedures.[14] Although ring-opening of such *N*-activated aziridines with aromatic amines has been studied extensively using Lewis acids,[15] little has been published on the opening with aliphatic amines.[16] At the outset, 10 mol.% of several Lewis acids such as $Cu(OTf)_2$ (70%), $Zn(OTf)_2$ (81%), $Sn(OTf)_2$ (78%), $YbCl_3$ (70%), $ErCl_3$ (68%), and $LiClO_4$ (88%), were screened for opening of *N*-tosylcyclohexyl aziridine (1 mmol) with benzylamine (1.25 mmol) in MeCN at room temperature over more than 24 h. From this study, it appeared that $LiClO_4$ is more effective, as indicated by isolated yields. Long reaction times at room temperature prompted us to try the same reaction at reflux temperature using $LiClO_4$ as a catalyst. To our delight, the reaction was complete in 4 h and the ring-opened product was obtained in 94% yield (Table 1, entry 1). The *trans*- stereochemistry in the product was deduced from the coupling constants (J = 10.5 Hz and 3.9 Hz) of the signal at 2.29 ppm (-C*H*-NH-) in the ^{1}H- NMR spectrum. The ring opening reaction was also tried with other amines such as phenylethylamine, piperidine, morpholine, and *N*-ethoxycarbonyl piperazine. In all cases, high yields of product were obtained (Table 1, entries 2-5). The reaction was extended to a few other *N*-tosyl aziridines and the results are summarized in Table 1. Aziridines derived from cyclopentene and cyclohexa-1,4-diene gave the ring-opened products in good to excellent yields (Table 1, entries 6-9). An acyclic terminal aziridine gave products resulting from terminal attack only (Table 1, entries 10 and 11).

Once the methodology for cleavage of *N*-tosylaziridines with aliphatic amines,[18] especially benzylamine, was established it was extended to chiral amines. Initially, (*R*)-α-methylbenzylamine (1.25 mmol) was used for desymmetrization of *N*-tosylcyclohexyl aziridine (1 mmol) in the presence of $LiClO_4$ (0.1 mmol) in MeCN. The reaction was complete in 6 h at reflux temperature and the product was obtained in 94% yield as a separable mixture of diastereomers in a 1:1 ratio (Table 2, entry 1). The reaction was scaled up to 25 g scale without any problem. The (*S*,*S*,*R*)-**9** diastereomer is more polar (R_f 0.28) than (*R*,*R*,*R*)-**9** (R_f 0.42). The

absolute stereochemistry was established by X-ray analysis (*vide infra*). The ring opening reaction proceeded well with (*R*)-3,3-dimethyl-2-butylamine also, and a separable mixture of diastereomers (1:1 ratio) was obtained in 82% yield (Table 2, entry 2). In all cases the diastereomeric ratio was determined by ^{1}H- NMR spectroscopy. The above reaction was extended to the tosylaziridine derived from cyclopentene also. Although good- to excellent yields of the ring-opened products were obtained, the diastereomers could not be separated by column chromatography. Another chiral amine, (*R*)-1-(3-methoxy phenyl)ethylamine, was also tried, but was no help (Table 2, entry 4). The mono tosylaziridine of cyclohexa-1,4-diene gave a similar result to that of cyclohexene, where diastereomers could be separated (Table 2, entry 6).

Table 1. Reaction of *N*-tosyl aziridines with aliphatic amines catalyzed by $LiClO_4$ in MeCN at reflux temperature[a]

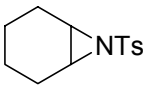
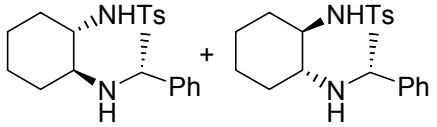
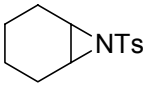
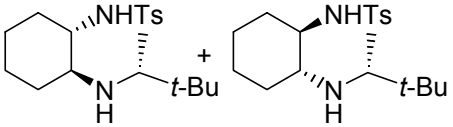
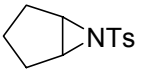
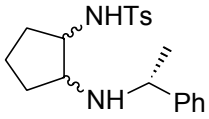
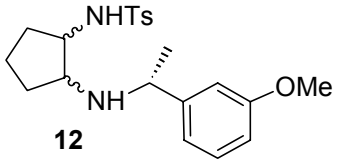
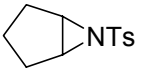
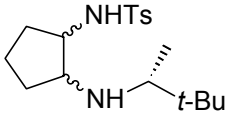
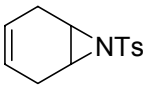
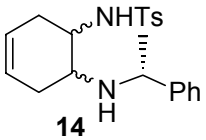
Entry	Aziridine	Products		% Yield (time) [b]
1.			**5a**[15a]; R^1 = H, R^2 = CH_2Ph	94 (4 h)
2.			**5b**[16b]; R^1 = H, R^2 = CH_2CH_2Ph	87 (5 h)
3.			**5c**; NR^1R^2 = piperidino	88 (2 h)
4.			**5d**; NR^1R^2 = morpholino	95 (5 h)
5.			**5e**; NR^1R^2 = *N*-ethoxycarbonyl piperazine	96 (2 h)
6.			**6a**[17]; R^1 = H, R^2 = CH_2Ph	88 (6 h)
7.			**6b**; NR^1R^2 = morpholino	93 (5 h)
8.			**7a**; R^1 = H, R^2 = CH_2Ph	92 (6 h)
9.			**7b**; NR^1R^2 = morpholino	92 (6 h)
10.		 **8a**		89 (4 h)
11.		 **8b**		90 (4 h)

[a] The ratio of *N*-tosylaziridine, aliphatic amine, and $LiClO_4$ was 1.0:1.25:0.1. [b] Isolated yield after column chromatography over silica gel, using hexane and ethyl acetate as eluents.

In order to prove the absolute stereochemistry of the product **9**, one of its diastereomers (the less polar) was methylated with MeI to prepare **15a** whose crystal structure (Figure 2)

proved it to be (*R,R,R*)-**9**. In order to show the versatility, several alkylated amines were synthesized (Scheme 1). Surprisingly, alkylation of (*R,R,R*)-**9** with 2-methoxybenzyl bromide under identical conditions did not give the desired product. Instead, the reaction took place on the nitrogen to which the tosyl group was attached, thus giving **16** in 72% yield (Scheme 1). The structure was confirmed by an X-ray crystal structure determination (Figure 2). This result is strange, especially given the fact that the same reaction with benzyl bromide provided **15f** where alkylation took place on the other nitrogen. The reason for this anomaly could be due to steric interaction between the methyl group on the chiral center and *ortho*-methoxy group on the benzyl bromide.

Table 2. Reaction of *N*-tosyl aziridines with chiral aliphatic amines catalyzed by $LiClO_4$ in MeCN at reflux temperature

Entry	Aziridines	Products[a,b]	% Yield (Time)[c]
1.		 (*S,S,R*)-**9** (*R,R,R*)-**9**	94 (6 h)
2.		 (*S,S,R*)-**10** (*R,R,R*)-**10**	82 (6 h)
3.		 **11**	79 (6 h)
4.		 **12**	93 (6 h)
5.		 **13**	80 (6 h)
6.		 **14**	83 (8 h)

[a] The ratio of N-tosylaziridine, chiral amine, and $LiClO_4$ was 1.0:1.25:0.1 and the products were obtained in 1:1 diastereomeric ratio. [b] The diastereomeric ratio was determined by ^{1}H- NMR spectroscopy in all cases. [c] The diastereomers separated on TLC only for entries 1, 2, and 6.

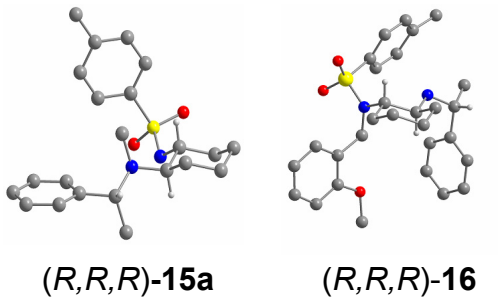
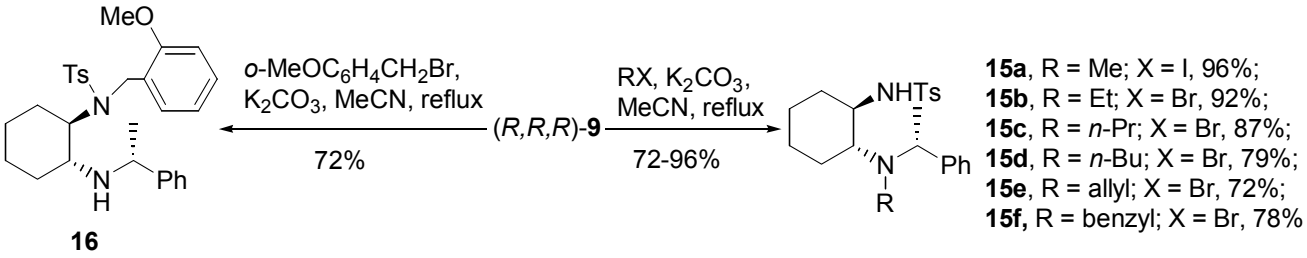


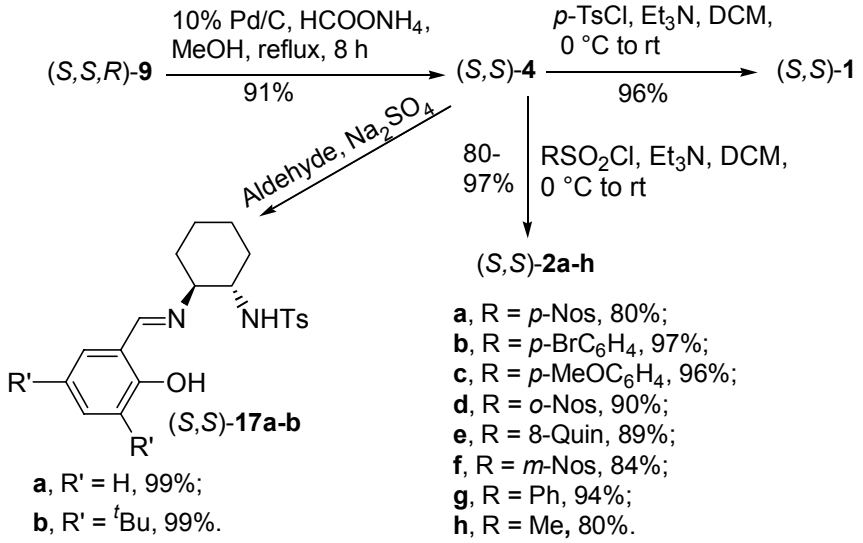
Figure 2. X-ray crystal structure of sulfonamides.[19]



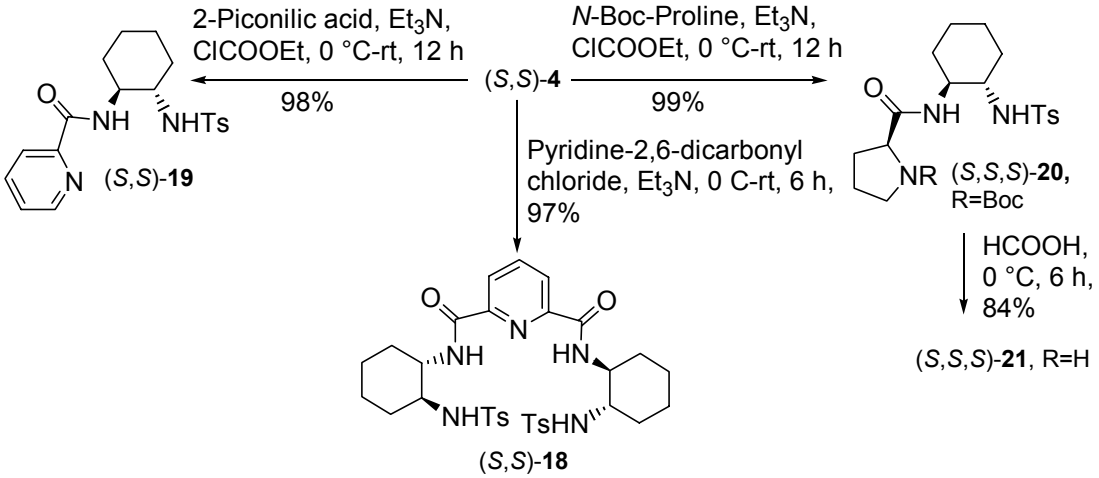
Scheme 1. Synthesis of sulfonamide ligands from an intermediate (*R*,*R*,*R*)-**9**.

After successful chromatographic separation of the enantiopure ring-opened product **9**, we planned to synthesize several chiral ligands. Thus, the (*S*,*S*,*R*)-**9** diastereomer was subjected to debenzylation (Pd/C and $HCOONH_4$) to provide the amino-sulfonamide (*S*,*S*)-**4** in 91% yield. This is an important precursor for several chiral ligands. For example, (*S*,*S*)-**4** was tosylated to provide the C_2 symmetric bis(sulfonamide) ligand (*S*,*S*)-**1**. Its treatment with various sulfonyl chlorides provided a series of enantiopure unsymmetrical vicinal bis(sulfonamide) ligands (*S*,*S*)-**2a-h** in good to excellent yields. The amino-sulfonamide (*S*,*S*)-**4** compound was also converted into an important chiral ligand **17** [10a] in quantitative yield.[13a]

Pyridine-based bis(amide) is also well known ligand to bind well to transition metal complexes.[20] These ligands are also important as far as enantioselective transformations are concerned. The aminosulfonamide (*S*,*S*)-**4** furnished the C_2-symmetric pyridyl bis(amide) bis(sulfonamide) ligand (*S*,*S*)-**18** when treated with 0.5 equivalent of 2,6-pyridinedicarbonyl dichloride in dichloromethane in the presence of triethylamine. Similarly, (*S*,*S*)-**19** was prepared using 3-picolinic acid (Scheme 3).[13b] We have synthesized L-Prolinamide based on *trans*-1,2-diaminocyclohexane (*S*,*S*,*S*)-**21** and (*R*,*R*,*S*)-**21** by the coupling of aminosulfonamide (*S*,*S*)-**4** with *N*-Boc- *L*-Proline followed by deprotection of the Boc group using HCOOH. These chiral ligands would be useful in asymmetric organocatalytic aldol reactions.[21]



Scheme 2. Synthesis of sulfonamide ligands from an intermediate (*R*,*R*,*R*)-**9**.



Scheme 3. *trans*-Cyclohexane-1,2-diamine- based symmetrical and unsymmetrical ligands.

In conclusion, we have developed an efficient method for the desymmetrization of *N*-tosyl aziridines in the presence of $LiClO_4$.[22] We have used the method to synthesize a variety of symmetrical and unsymmetrical chiral ligands based on *trans*-1,2-diaminocyclohexane. To the best of our knowledge, this is the first straightforward method for the synthesis of chiral unsymmetrical bis(sulfonamide) ligands based on *trans*-1,2-diaminocyclohexane.

Experimental Section

General Procedures. 1H- NMR spectra were recorded on a 400 MHz spectrometer. Chemical shifts are expressed in ppm downfield from TMS as internal standard, and coupling constants are reported in Hz. Routine monitoring of reaction was performed by TLC, using precoated silica gel TLC plates obtained from E-Merck. All the column chromatographic separations were done by using silica gel (Acme's, 60-120 mesh). The petroleum used was of boiling range 60-80 °C. Reactions that needed anhydrous conditions were run under an atmosphere of nitrogen or argon using flame-dried glassware. The organic extracts were dried over anhydrous sodium sulfate. Evaporation of solvents was performed under reduced pressure. Dichloromethane and acetonitrile were distilled over CaH_2, and THF over sodium and benzophenone.

General procedure for ring cleavage of *N*-tosylaziridine with amine in the presence of $LiClO_4$. An amine (1.25 mmol) was added to a solution of *N*-tosylaziridine (1 mmol) and $LiClO_4$ (0.1 mmol) in anhydrous acetonitrile (6 mL) under argon atmosphere at RT. The reaction mixture was refluxed until completion of the reaction (usually 4-8 h, monitoring by TLC). Most of the acetonitrile was removed *in vacuo* and the crude reaction mixture was partitioned between EtOAc and water. The organic layer was washed with water, brine, and dried over anhydrous sodium sulfate. It was concentrated *in vacuo* to give a crude product, which was purified by silica-gel column chromatography using EtOAc and hexane, to give the pure vicinal aminosulfonamide.

***N*-*trans*-(2-Benzylamino-cyclohexyl)-4-methyl-benzenesulfonamide (5a).** (Table 1, entry 1)**.** Yield 94%; White solid; mp 118-119°C; R_f 0.38 (30% EtOAc in petroleum); IR (film): 3267, 3022, 2909, 1595, 1329, 1160 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ 7.72 (d, *J* = 8.3 Hz, 2H), 7.33-7.18 (m, 7H), 3.67 (ABq, *J* = 78.8 Hz, 2H), 2.73 (m, 1H), 2.36 (s, 3H), 2.29 (ddd, *J* = 10.5, 10.5, 3.9 Hz, 1H), 2.05 (m, 2H), 1.65 (m, 2H), 1.12 (m, 1H), 1.18 (m, 2H), 1.01 (m, 1H); ^{13}C-NMR ($CDCl_3$ 100 MHz) δ : 143.11, 139.60, 137.23, 129.49, 128.37, 127.97, 127.07, 127.03, 59.60, 57.21, 49.75, 32.66, 30.90, 24.49, 24.42, 21.43; LCMS (EI, *m/z*) 358 (M^+); Anal. Calcd. for $C_{20}H_{26}N_2O_2S$: C, 67.01; H, 7.31; N, 7.81. Found: C, 67.28; H, 7.72; N, 8.07.

***N*-*trans*-[2-(2-Phenylethylamino)-cyclohexyl]-4-methyl-benzenesulfonamide (5b).** (Table 1, entry 2)**.** Yield 87%; White solid; mp 129-131°C (lit. mp 128 ^{0}C); R_f 0.42 (neat EtOAc); IR (thin film): 2928, 2856, 1598, 1449, 1159 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.65 (d, *J* = 8.0 Hz, 2H), 7.18-7.04 (m, 7H), 2.89-2.85 (m, 1H), 2.71-2.62 (m, 4H), 2.40-2.33 (m, 1H), 2.31 (s, 3H), 1.95 (m, 1H), 1.79 (m, 1H), 1.59-1.45 (M, 2H), 0.78-1.15 (m, 4H), LCMS (EI, *m/z*) 372 (M^+); Anal. Calcd. for $C_{21}H_{28}N_2O_2S$: C, 67.71; H, 7.58; N, 7.52. Found: C, 67.40; H, 7.67; N, 7.54.

***trans*-4-Methyl-*N*-(2-piperidin-4-yl-cyclohexyl)-benzenesulfonamide (5c).** (Table 1, entry 3)**.** Yield 88%; Colorless gel; R_f 0.40 (30% EtOAc in petroleum); IR (thin film): 3269, 2962, 1598, 1455, 1330, 1158 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.69 (d, *J* = 8.3, 2H), 7.22 (d, *J* = 8.1 Hz, 2H), 2.60-2.54 (m, 1H), 2.34 (s, 3H), 2.12-2.05 (m, 4H), 1.72-1.55 (m, 3H), 1.35-0.90 (m,

11H); LCMS (EI, *m/z*) 336 (M^+); Anal. Calcd. for $C_{18}H_{28}N_2O_2S$: C, 64.25; H, 8.39; N, 8.33. Found: C, 64.34; H, 8.48; N, 8.35.

***trans*-4-Methyl-*N*-(2-morpholin-4-yl-cyclohexyl)-benzenesulfonamide (5d).** (Table 1, entry 4)**.** Yield 95%; colorless gel; R_f 0.42 (30% EtOAc in petroleum); IR (thin film): 3267, 2960, 1598, 1458, 1329, 1158 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.77 (d, *J* = 8.3, 2H), 7.30 (d, *J* = 7.6 Hz, 2H), 3.49 (m, 4H), 2.70 (m, 1H), 2.45 (m, 1H), 2.42 (s, 3H), 2.12 (m, 4H), 1.75 (m, 3H), 1.76 (m, 5H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 143.3, 136.8, 129.6, 127.2, 67.2, 66.8, 53.4, 53.1, 31.9, 25.1, 24.1, 22.8, 21.5; LCMS (EI, *m/z*) 338 (M^+); Anal. Calcd. for $C_{17}H_{26}N_2O_3S$: C, 60.33; H, 7.74; N, 8.28. Found: C, 60.49; H, 7.81; N, 8.31.

***trans*-4-Methyl-*N*-(*N*'-ethoxycarbonylpiperizin-4-yl-cyclohexyl)-benzenesulfonamide (5e).** (Table 1, entry 5)**.** Yield 96%; Colorless gel; R_f 0.41 (30% EtOAc in petroleum); ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.66 (d, *J* = 8.3, 2H), 7.23 (d, *J* = 8.0 Hz, 2H), 3.99 (q, *J* = 7.1 Hz, 2H), 3.19 (bs, 4H), 2.62-2.58 (m, 1H), 2.34 (m, 1H), 2.33 (s, 3H), 2.15-2.05 (m, 5H), 1.63-1.57 (m, 3H), 0.89-1.23 (m, 7H); LCMS (EI, *m/z*) 409 (M^+); Anal. Calcd. for $C_{20}H_{31}N_3O_4S$: C, 58.65; H, 7.63; N, 10.23. Found: C, 58.73; H, 7.69; N, 10.21.

***N-trans*-(2-benzylamino-cyclopentyl)-4-methyl-benzenesulfonamide (6a).** (Table 1, entry 6)**.** Yield 88%; colorless gel; R_f 0.38 (30% EtOAc in petroleum); IR (thin film): 3269, 3029, 2901, 1598, 1330, 1159 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.76 (d, *J* = 8.3 Hz, 2H), 7.29 (m, 7H), 3.68 (ABq, *J* = 47.1 Hz, 2H), 3.26 (m, 1H), 2.83 (m, 1H), 2.39 (s, 3H), 1.91 (m 2H), 1.60 (m, 2H), 1.32 (m, 2H); ^{13}C NMR ($CDCl_3$ 100 MHz) δ: 143.4, 139.7, 137.3, 129.7, 128.4, 128.0, 127.2, 127.0, 64.4, 59.8, 52.0, 31.2, 29.9, 21.5, 20.7; LCMS (EI, *m/z*) 344 (M^+); Anal. Calcd. for $C_{19}H_{24}N_2O_2S$: C, 66.25; H, 7.02; N, 8.13. Found: C, 66.32; H, 7.09; N, 8.10.

***trans*-4-Methyl-*N*-(2-morpholin-4-yl-cyclopentyl)-benzenesulfonamide (6b).** (Table 1**,** entry 7)**.** Yield 93%; White solid; mp-95-97°C; R_f 0.78 (30% EtOAc in petroleum); IR (thin film): 3267, 2960, 1598, 1452, 1329, 1158 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.76 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.3 Hz, 2H), 4.85 (bs, 1H), 3.54 (m, 4H), 3.23 (m, 1H), 2.52 (m, 1H), 2.38 (s, 3H), 2.34 (m 2H), 2.25 (m, 2H), 1.93 (m, 1H), 1.61 (m, 3H), 1.41 (m, 2H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 143.5, 137.0, 129.6, 127.3, 71.9, 66.9, 55.0, 53.4, 50.2, 31.0, 22.6, 21.5, 20.6; LCMS (EI, *m/z*) 324 (M^+); Anal. Calcd. for $C_{16}H_{24}N_2O_3S$: C, 59.23; H, 7.46; N, 8.63. Found: C, 59.32; H, 7.54; N, 8.67.

***trans*-*N*-(6-Benzylamino-cyclohexyl-3-enyl)-4-methyl-benzenesulfonamide (7a).** (Table 1, entry 8)**:** Yield 92%; Colorless gel; R_f 0.41 (30% EtOAc in petroleum); IR (thin film): 3267, 3028, 2912, 1598, 1331, 1159 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.71 (d, *J* = 8.0 Hz, 2H), 7.25 (m, 7H), 5.51 (m, 2H), 3.67 (ABq, *J* = 53.9 Hz, 2H), 3.04 (m, 1H), 2.65 (m, 1H), 2.51 (m, 2H), 2.37 (s, 3H), 2.01 (m, 1H), 1.81 (m, 1H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 143.2, 139.7, 137.0, 129.5, 128.4, 127.9, 127.1, 124.5, 124.4, 55.1, 53.1, 50.2, 32.3, 31.1, 21.4; LCMS (EI, *m/z*) 356 (M^+); Anal. Calcd. for $C_{20}H_{24}N_2O_2S$: C, 67.38; H, 6.79; N, 7.86. Found: C, 67.51; H, 6.81; N, 7.89.

***trans*-4-Methyl-*N*-(6-morpholin-4-yl-cyclohex-3-enyl)-benzenesulfonamide (7b).** (Table 1, entry 9)**.** Yield 89%; White solid; mp-111-114°C; R_f 0.80 (30% EtOAc in petroleum); IR (thin

film): 3175, 2940, 1598, 1421, 1336, 1162 cm-1; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.77 (dd, *J* = 8.3, 1.7 Hz, 2H), 7.30 (d, *J* = 7.6 Hz, 2H), 3.49 (m, 4H), 2.70 (m, 1H), 2.45 (m, 1H), 2.42 (s, 3H), 2.12 (m, 4H), 1.75 (m, 3H), 1.76 (m, 5H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 143.3, 136.8, 129.6, 127.2, 67.2, 66.8, 53.4, 53.1, 31.9, 25.1, 24.1, 22.8, 21.5; LCMS (EI, *m/z*) 336 (M^+); Anal. Calcd. for $C_{17}H_{24}N_2O_3S$: C, 60.69; H, 7.19; N, 8.33. Found: C, 60.83; H, 7.23; N, 8.37.

(1-Benzylamino-2-decanyl)-4-methyl-benzenesulfonamide (8a). (Table 1, entry 10)**.** Yield 89%; colorless gel; R_f 0.39 (30% EtOAc in petroleum); IR (thin film): 3269, 3027, 2908, 1597, 1329, 1158 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.64 (d, *J* = 6.3 Hz, 2H), 7.62-7.12 (m, 7H), 3.52 (s, 2H), 3.11-3.14 (m, 1H), 2.31-2.42 (m, 2H), 2.29 (s, 3H), 1.03-1.34 (m, 18H), 0.80 (t, *J* = 6.8 Hz, 3H); LCMS (EI, *m/z*) 444 (M^+); Anal. Calcd. for $C_{26}H_{40}N_2O_2S$: C, 70.23; H, 9.07; N, 6.30. Found: C, 70.31; H, 9.09; N, 6.34.

(1-Piperidin-2-decanyl)-4-methyl-benzenesulfonamide (8b). (Table 1, entry 11)**.** Yield 90%; colorless gel; R_f 0.41 (30% EtOAc in petroleum); IR (thin film): 3269, 1597, 1457, 1331, 1160 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.69 (d, *J* = 8.3 Hz, 2H), 7.22 (d, *J* = 8.3 Hz, 2H), 3.01-2.94 (m, 1H), 2.34 (s, 3H), 2.23-2.03 (m, 5H), 1.59-1.74 (m, 1H), 1.13-1.34 (m, 24H), 0.84 (t, *J* = 6.4 Hz, 3H); LCMS (EI, *m/z*) 422 (M^+); Anal. Calcd. for $C_{24}H_{42}N_2O_2S$: C, 68.20; H, 10.02; N, 6.63. Found: C, 68.29; H, 10.09; N, 6.70.

***trans*-4-Methyl-*N*-[(1*S*,2*S*)-2-((*R*)-1-phenyl-ethylamino)-cyclohexyl]-benzenesulfonamide ((*S,S,R*)-9).** (Table 2, entry 1)**:** Yield 47%; white solid; mp-88-90°C; optical rotation $[\alpha]^{25}_D$ +70.28 (c 1.0, $CHCl_3$); R_f 0.28 (30% EtOAc in petroleum); IR (thin film): 3271, 2929, 2857, 1599, 1449, 1325, 1162 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.69 (d, *J* = 8.1 Hz, 2H), 7.25-7.17 (m, 5H), 7.15 (d, *J* = 8.0 Hz, 2H), 5.22 (bs, 1H, NH), 3.89 (m, 1H), 2.60 (m, 1H), 2.38 (m, 1H), 2.29 (s, 3H), 1.95 (m, 1H), 1.85 (m, 1H), 1.49 (m, 2H), 1.26 (d, *J* = 6.3 Hz, 3H), 1.89 (m, 2H), 1.02 (m, 2H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 144.6, 143.0, 137.5, 129.4, 128.4, 127.3, 127.0, 126.6, 58.5, 57.6, 55.7, 32.1, 31.6, 24.5, 24.2, 22.6, 21.4; LCMS (EI, *m/z*) 372 (M^+); Anal. Calcd. for $C_{21}H_{28}N_2O_2S$: C, 67.71; H, 7.58; N, 7.52. Found: C, 67.79; H, 7.63; N, 7.59.

***trans*-4-Methyl-*N*-[(1*R*,2*R*)-2-((*R*)-1-phenyl-ethylamino)-cyclohexyl]-benzenesulfonamide ((*R,R,R*)-9).** (Table 2, entry 1)**.** Yield 47%; white solid; mp-89-91°C; optical rotation: $[\alpha]^{25}_D$ +6.94 (c 1.0, $CHCl_3$); R_f 0.42 (30% EtOAc in petroleum); IR (thin film): 3271, 2930, 2857, 1601, 1449, 1325, 1161 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.75 (d, *J* = 7.1 Hz, 2H), 7.25 (m, 7H), 5.62 (bs, 1H), 3.81 (m, 1H), 2.50 (m, 1H), 2.38 (s, 3H), 2.30 (m, 1H), 2.18 (m, 1H), 1.96 (m, 1H), 1.61 (m, 2H), 1.25 (d, *J* = 5.6 Hz, 3H), 1.16 (m, 4H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 146.3, 143.1, 137.1, 129.5, 128.4, 127.2, 127.1, 126.4, 58.2, 58.0, 32.6, 32.0, 24.8, 24.2, 23.2, 21.5; LCMS (EI, *m/z*) 372 (M^+); Anal. Calcd. for $C_{21}H_{28}N_2O_2S$: C, 67.71; H, 7.58; N, 7.52. Found: C, 67.83; H, 7.65; N, 7.60.

***trans*-4-Methyl-*N*-[2-((*R*)-1,2,2-trimethyl-propylamino)-cyclohexyl]-benzenesulfonamide (10).** (Table 2, entry 2)**:** yield 82%; colorless gel; diastereomeric ratio = 1:1 (determined by ^{1}H-NMR); IR (thin film): 3269, 2934, 2861, 1597, 1446, 1328, 1161 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) for both diastereomers; δ: 7.69 (d, *J* = 8.0 Hz, 4H), 7.23 (d, *J* = 8.0 Hz, 4H), 2.45 (m, 2H), 2.35 (s, 3H), 2.35 (s, 3H), 2.28-1.95 (m, 6H), 1.59 (m, 4H), 1.15 (m, 10H), 0.87 (d, *J* = 6.6 Hz,

3H), 0.81 (m, 3H), 0.80 (s, 9H), 0.71 (s, 9H); ^{13}C NMR ($CDCl_3$ 100 MHz) for both diastereomers; δ: 143.0, 137.0, 136.9, 129.4, 129.4, 127.1, 61.8, 60.8, 58.5, 58.0, 57.3, 56.9, 35.2, 33.5, 32.9, 32.6, 31.8, 31.2, 26.5, 26.1, 24.7, 24.3, 24.0, 22.6, 21.4, 21.3, 19.3, 18.1, 14.7; LCMS (EI, *m/z*) 352 (M^+); Anal. Calcd. for $C_{19}H_{32}N_2O_2S$: C, 64.73; H, 9.15; N, 7.95. Found: C, 64.87; H, 9.19; N, 8.03.

***trans*-4-Methyl-*N*-[2-((*R*)-1-phenyl-ethylamino)-cyclopentyl]-benzenesulfonamide (11).** (Table 2, entry 3)**.** Yield 79%; colorless gel; diastereomeric ratio = 1:1 (determined by ^{1}H-NMR); IR (thin film): 3271, 2930, 2857, 1601, 1449, 1325, 1161 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) for both diastereomers; δ: 7.68 (m, 4H), 7.16 (m, 14H), 3.75 (m, 2H), 3.20 (m, 2H), 2.75 (q, *J* = 7.6 Hz, 1H), 2.51 (q, *J* = 8.3 Hz, 1H), 2.49 (s, 6H), 1.79 (m, 4H), 1.53 (m, 6H), 1.30 (m, 1H), 1.29 (m, 6H), 1.14 (m, 1H); ^{13}C- NMR ($CDCl_3$ 100 MHz) for both diastereomers; δ: 145.6, 144.6, 143.3, 143.2, 137.5, 137.3, 129.6, 128.5, 128.3, 127.1, 127.1, 127.0, 126.8, 126.6, 126.3, 63.3, 61.9, 60.2, 59.9, 56.9, 56.3, 30.8, 30.7, 30.6, 29.6, 29.3, 24.6, 23.9, 21.4, 20.6, 20.2; LCMS (EI, *m/z*) 358 (M^+); Anal. Calcd. for $C_{20}H_{26}N_2O_2S$: C, 67.01; H, 7.31; N, 7.81. Found: C, 67.21; H, 7.40; N, 7.81.

***trans*-*N*-{2-[(*R*)-1-(3-Methoxy-phenyl)-ethylamino]-cyclopentyl}-4-methyl-benzene-sulfonamide (12).** (Table 2, entry 4)**.** Yield 93%; Colorless gel; diastereomeric ratio = 1:1(determined by ^{1}H NMR); ^{1}H- NMR ($CDCl_3$, 400 MHz) for both diastereomers; δ: 7.76 (m, 4H), 7.28-7.16 (m, 6H), 6.85-6.74 (m, 6H), 3.81 (s, 3H), 3.80 (s, 3H), 3.78 (m, 1H), 3.71 (m, 1H), 3.21 (m, 2H), 2.74 (q, *J* = 7.6 Hz, 1H), 2.55 (q, *J* = 8.1 Hz, 1H), 2.40 (s, 6H), 1.87-1.72 (m, 2H), 1.63-1.42 (m, 4H), 1.37-1.10 (m, 12H); ^{13}C- NMR ($CDCl_3$ 100 MHz) for both diastereomers; δ: 159.7, 159.5, 147.4, 146.6, 143.2, 143.1, 137.5, 137.3, 129.5, 129.4, 129.2, 127.0, 127.0, 118.9, 118.6, 112.4, 112.2, 112.1, 111.6, 63.3, 61.9, 60.2, 59.8, 56.9, 56.2, 55.1, 55.0, 30.8, 30.7, 30.5, 29.5, 29.3, 24.6, 23.9, 21.3, 20.6, 20.2; LCMS (EI, *m/z*) 388 (M^+); Anal. Calcd. for $C_{21}H_{28}N_2O_3S$: C, 64.92; H, 7.26; N, 7.21. Found: C, 65.01; H, 7.29; N, 7.21.

***trans*-4-Methyl-*N*-[2-((*R*)-1,2,2-trimethyl-propylamino)-cyclopentyl]-benzenesulfonamide (13).** (Table 2, entry 5)**.** Yield 83%; colorless gel; diastereomeric ratio = 1:1(determined by ^{1}H-NMR); IR (thin film): 3269, 2929, 1598, 1328, 1160 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) for both diastereomers; δ: 7.74 (m, Hz, 4H), 7.24 (m, 4H), 5.06 (bs, 2H), 3.01 (m, 1H), 2.74 (m, 1H), 2.36 (s, 3H), 2.05 (q, *J* = 6.4 Hz, 1H), 1.96 (q, *J* = 6.6 Hz, 1H), 1.92-1.74 (m, 4H), 1.58-1.47 (m, 4H), 1.58-1.47 (m, 4H), 1.36-1.29 (m, 2H), 1.14-1.07 (m, 2H), 0.82 (d, *J* = 6.6 Hz, 3H), 0.81 (d, *J* = 6.4 Hz, 3H), 0.73 (s, 9H) 0.72 (s, 9H); ^{13}C NMR ($CDCl_3$ 100 MHz) for both diastereomers; δ: 143.9, 143.1, 137.5, 137.3, 129.5, 129.5, 127.5, 127.2, 127.1, 126.3, 64.8, 62.5, 61.0, 60.3, 59.9, 59.5, 46.6, 34.3, 33.9, 31.8, 30.8, 30.5, 29.8, 29.6, 26.8, 26.2, 26.2, 22.6, 21.5, 21.4, 20.9, 20.2, 19.4, 16.0, 14.4; LCMS (EI, *m/z*) 388.20 (M^+); Anal. Calcd. for $C_{18}H_{30}N_2O_2S$: C, 63.87; H, 8.93; N, 8.28; Found: C, 63.94; H, 9.00; N, 8.29.

***trans*-4-Methyl-*N*-[6-((*R*)-1-phenyl-ethylamino)-cyclohex-3-enyl]-benzenesulfonamide (14).** (Table 2, entry 6)**.** Yield 83%; colorless gel; diastereomeric ratio = 1:1 (determined by ^{1}H-NMR); IR (thin film): 3267, 3027, 2921, 1598, 1449, 1330, 1160 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) for both diastereomers; δ: 7.83-7.71 (m, 4H), 7.34-7.20 (m, 14H), 5.47 (m, 4H), 3.85 (m,

2H), 2.95 (m, 2H), 2.67-2.28 (m, 6H), 2.41 (s, 3H), 2.37 (s, 3H), 2.09-1.56 (m, 4H), 1.29 (d, *J* = 6.6 Hz, 3H), 1.25 (d, *J* = 6.4 Hz, 3H); ^{13}C- NMR ($CDCl_3$ 100 MHz) for both diastereomers; δ: 145.8, 144.4, 144.1, 143.2, 143.1, 137.2, 137.0, 129.5, 128.6, 128.4, 127.6, 127.2, 127.1, 126.6, 126.3, 124.7, 124.4, 124.4, 124.3, 121.5, 55.5, 54.4, 53.5, 53.4, 52.5, 38.5, 32.2, 32.1, 32.0, 31.3, 25.2, 23.3, 23.0, 21.4; LCMS (EI, *m/z*) 370 (M^+); Anal. Calcd. for $C_{21}H_{26}N_2O_2S$: C, 68.08; H, 7.07; N, 7.56. Found: C, 68.23; H, 7.09; N, 7.61.

General procedure for the synthesis of (*R,R,R*)-2-amino-sulfonamide ligand of *trans*-1,2-diaminocyclohexane. To a vigorously stirred solution of compound **(*R,R,R*)-9** (1 mmol) and K_2CO_3 (5 mmol) in MeCN (6 mL) was added alkyl halide (3 mmol) and the mixture refluxed for 2-24 h. After completion of the reaction the solid residue was filtered off and the filtrate evaporated and directly loaded for silica gel column chromatography to give the pure derivative of 2-amino sulfonamide.

***trans*-4-Methyl-*N*-{(*1R,2R*)-2-[methyl-((*R*)-1-phenyl-ethyl)-amino]-cyclohexyl}-benzenesulfonamide ((*R,R,R*)-15a)** (Scheme 1)**.** (Reagents and conditions: MeI, 70 °C, 2 h); Yield 96%; white solid; mp-112-115°C; optical rotation: $[\alpha]^{25}_D$ +28.72 (c 1.0, $CHCl_3$); R_f 0.58 (20% EtOAc in petroleum); IR (KBr pellet): 3172, 2938, 2857, 1598, 1451, 1340, 1162 cm^{-1}; ^{1}H-NMR ($CDCl_3$, 400 MHz) δ: 7.23 (d, *J* = 8.1 Hz, 2H), 7.36-7.22 (m, 5H), 7.28 (d, *J* = 8.0 Hz, 2H), 3.56 (m, 1H), 2.66 (ddd, *J* = 10.5, 10.3, 4.2 Hz, 1H), 2.41 (s, 3H), 2.19 (s, 2H), 1.74 (s, 3H), 1.61 (m, 1H), 1.50 (m, 1H), 1.32 (d, *J* = 6.6 Hz, 3H), 1.20 (m, 1H), 0.98 (m, 4H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 144.4, 143.0, 137.2, 129.4, 128.7, 127.3, 127.1, 61.6, 53.8, 32.6, 31.2, 29.7, 25.0, 24.1, 22.7, 21.5, 21.3; LCMS (EI, *m/z*) 372 (M^+); Anal. Calcd. for $C_{21}H_{28}N_2O_2S$: C, 67.71; H, 7.58; N, 7.52. Found: C, 67.85; H, 7.62; N, 7.58.

***trans*-4-Methyl-*N*-{(*1R,2R*)-2-[ethyl-((*R*)-1-phenylethyl)amino]cyclohexyl}benzene-sulfonamide ((*R,R,R*)-15b)** (Scheme 1)**.** (Reagents and conditions: EtBr, 70 °C, 6 h); yield 92%; colorless gel; optical rotation $[\alpha]^{25}_D$ +14.0 (c 1.0, $CHCl_3$); R_f 0.56 (20% EtOAc in petroleum); IR (thin film): 3348, 2933, 2859, 1599, 1449, 1333, 1153 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.75 (d, *J* = 8.0 Hz, 2H), 7.32-7.17 (m, 7H), 3.79 (m, 1H), 3.56 (m, 1H), 3.31-3.28 (m, 2H), 2.56 (bs, 1H), 2.35 (s, 3H), 1.83 (bs, 1H), 1.73 (m, 1H), 1.56 (m, 1H), 1.45 (m, 2H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.23 (d, *J* = 6.4 Hz, 3H), 1.21 (m, 1H), 0.93 (m, 2H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 147.2, 142.6, 138.3, 129.2, 127.7, 126.6, 126.3, 126.1, 62.5, 57.6, 56.7, 38.2, 33.9, 30.2, 25.3, 24.5, 24.1, 21.1, 16.6; LCMS (EI, *m/z*) 400 (M^+); Anal. Calcd. for $C_{23}H_{32}N_2O_2S$: C, 68.96; H, 8.05; N, 6.99. Found: C, 69.09; H, 8.06; N, 7.01.

***trans*-4-Methyl-*N*-{(*1R,2R*)-2-[^{n}-propyl-((*R*)-1-phenyl-ethyl)-amino]-cyclohexyl}-benzenesulfonamide ((*R,R,R*)-15c)** (Scheme 1)**.** (Reagents and conditions: *n*-PrI, 70 °C, 14 h); Yield 87%; colorless gel; optical rotation $[\alpha]^{25}_D$ +9.6 (c 1.0, $CHCl_3$); R_f 0.58 (20% EtOAc in petroleum); IR (thin film): 3344, 2930, 2858, 1599, 1450, 1335, 1152 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.74 (d, *J* = 8.0 Hz, 2H), 7.31-7.16 (m, 7H), 3.78-3.76 (m, 1H), 3.48 (bs, 1H), 3.17-3.12 (m, 2H), 2.51 (bs, 1H), 2.36 (s, 3H), 1.78-1.67 (m, 4H), 1.59 (m, 1H), 1.45-1.35 (m, 2H), 1.22 (d, *J* = 6.6 Hz, 3H), 1.11-0.96 (m, 1H), 0.93-0.90 (t, *J* = 7.3 Hz, 3H), 0.85 (m, 2H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 147.3, 142.6, 138.3, 129.3, 127.8, 126.7, 126.3, 126.2, 62.4,

57.7, 56.7, 34.0, 30.3, 25.4, 24.5, 24.3, 24.2, 21.2, 13.9, 11.3; LCMS (EI, *m/z*) 414 (M^+); Anal. Calcd. for $C_{24}H_{34}N_2O_2S$: C, 69.53; H, 8.27; N, 6.76. Found: C, 69.59; H, 8.30; N, 6.77.

***trans*-4-Methyl-*N*-{(*1R,2R*)-2-[^{n}-butyl-((*R*)-1-phenyl-ethyl)-amino]-cyclohexyl}-benzenesulfonamide ((*R,R,R*)-15d)** (Scheme 1)**.** (Reagents and conditions: *n*-BuBr, 70 °C, 24 h); yield 79%; colorless gel; optical rotation: $[\alpha]^{25}_D$ +11.3 (c 1.0, $CHCl_3$); R_f 0.57 (20% EtOAc in petroleum); IR (thin film): 3348, 2933, 2860, 1599, 1449, 1335, 1153 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.74 (d, *J* = 8.3 Hz, 2H), 7.30-7.16 (m, 7H), 3.79-3.76 (m, 1H), 3.46 (bs, 1H), 3.19-3.15 (m, 2H), 2.63 (bs, 1H), 2.36 (s, 3H), 1.76-1.56 (m, 6H), 1.48-1.45 (m, 2H), 1.37-1.26 (m, 2H), 1.22 (d, *J* = 6.3 Hz, 3H), 0.94 (t, *J* = 7.3 Hz, 3H), 0.85 (m, 2H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 147.4, 142.7, 138.3, 129.3, 127.9, 126.8, 126.4, 126.3, 62.5, 57.8, 56.7, 43.7, 34.0, 33.3, 30.4, 25.5, 24.5, 24.2, 21.3, 20.2, 13.6; LCMS (EI, *m/z*) 428 (M^+); Anal. Calcd. for $C_{25}H_{36}N_2O_2S$: C, 70.05; H, 8.47; N, 6.54. Found: C, 70.15; H, 8.51; N, 6.54.

***trans*-4-Methyl-*N*-{(*1R,2R*)-2-[allyl-((*R*)-1-phenyl-ethyl)-amino]-cyclohexyl}-benzenesulfonamide ((*R,R,R*)-15e)** (Scheme 1)**.** (Reagents and conditions: allyl bromide, 70 °C, 4 h); yield 72%; colorless gel; optical rotation: $[\alpha]^{25}_D$ +24.5 (c 1.0, $CHCl_3$); R_f 0.50 (20% EtOAc in petroleum); IR (thin film): 3339, 2929, 2857, 1598, 1449, 1335, 1157 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ; 7.65 (d, *J* = 8.3 Hz, 2H), 7.22-7.09 (m, 7H), 5.84-5.77 (m, 1H), 5.16 (d, *J* = 17.1 Hz, 2H), 5.04 (d, *J* = 10.0 Hz, 2H), 3.81 (d, *J* = 6.6 Hz, 2H), 3.68 (q, *J* = 6.6 Hz, 1H), 3.44 (bs, 1H), 2.43 (bs, 1H), 2.30 (s, 3H), 1.66-1.36 (m, 5H), 1.13 (d, *J* = 6.6 Hz, 3H), 0.90-0.87 (m, 1H), 0.79-0.76 (m, 2H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 147.5, 142.9, 138.3, 136.1, 129.5, 128.1, 127.1, 126.6, 126.4, 117.4, 62.9, 57.3, 56.7, 34.1, 30.8, 25.6, 24.6, 24.5, 21.4; LCMS (EI, *m/z*) 412 (M^+); Anal. Calcd. for $C_{24}H_{32}N_2O_2S$: C, 69.87; H, 7.82; N, 6.79. Found: C, 69.96; H, 7.88; N, 6.80.

***trans*-4-Methyl-*N*-{(*1R,2R*)-2-[benzyl-((*R*)-1-phenyl-ethyl)-amino]-cyclohexyl}-benzenesulfonamide ((*R,R,R*)-15f)** (Scheme 1)**.** (Reagents and conditions: $PhCH_2Br$, 70 °C, 8 h); yield 78%; colorless gel; optical rotation: $[\alpha]^{25}_D$ +30.6 (c 1.0, $CHCl_3$); R_f 0.54 (20% EtOAc in petroleum); IR (thin film): 3341, 2926, 2855, 1599, 1449, 1334, 1153 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.70 (d, *J* = 8.0 Hz, 2H), 7.49 (d, *J* = 7.1 Hz, 2H), 7.36-7.27 (m, 3H), 7.23-7.11 (m, 7H), 4.60-4.34 (ABq, *J* = 77.1, 15.4 Hz, 2H), 3.49 (m, 1H), 3.18-3.17 (m, 1H), 2.35 (s, 3H), 2.34 (m, 1H), 1.57-1.25 (m, 6H), 1.03 (d, *J* = 6.6 Hz, 3H), 0.88-0.65 (m, 2H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 147.5, 142.9, 138.4, 138.0, 129.5, 128.6, 128.4, 127.9, 127.5, 127.0, 126.5, 126.3, 62.7, 57.6, 56.1, 47.3, 33.8, 30.7, 25.6, 24.3, 24.2, 21.4; LCMS (EI, *m/z*) 412 (M^+); Anal. Calcd. for $C_{28}H_{34}N_2O_2S$: C, 72.69; H, 7.41; N, 6.06. Found: C, 72.81; H, 7.42; N, 6.09.

Synthesis and characterization of sulfonamide/Schiff base ligand (*S,S*)-17 (Scheme 2)**.** A solution of **(*S,S,R*)-9** (3g, 8.06 mmol) in *anhydrous* ethanol (32 mL) was added to a solution of ammonium formate (5.04 g, 80 mmol) under argon at RT. To this solution 10% Pd-C (1 g) was added and refluxed at 80-90 °C for 8 h. After completion of the reaction the organic solvent was filtered through a Celite bed and concentrated under reduced pressure to give the debenzylated product **(*S,S*)-4**, which was used without purification for the next steps.

A solution of compound **(*S,S*)-4** (1 mmol) and salicylaldehyde (1 mmol) in MeOH (10 mL) was treated with Na_2SO_4 (500 mg) and the reaction mixture was left at RT overnight. After completion of the reaction (checked by running TLC), the solid residue was filtered off and the filtrate concentrated. The crude material was purified by column chromatography over silica gel to give the pure sulfonamide/Schiff base ligand **(*S,S*)-17**; Yield 99%; yellow solid; mp 68-70°C; $[\alpha]^{25}_D$ -41.2 (c 1.0, $CHCl_3$); R_f 0.44 (30% EtOAc in petroleum); IR (KBr pellet): 3292, 2955, 2863, 1628, 1443, 1323, 1159, 1090 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 8.24 (s, 1H), 7.62 (d, *J* = 8.3 Hz, 2H), 7.37 (d, *J* = 2.2 Hz, 1H), 7.09 (d, *J* = 8.0 Hz, 2H), 6.97 (d, *J* = 2.4 Hz, 1H), 4.68 (d, *J* = 5.8 Hz, 1H), 3.20 (m, 1H), 2.97 (m, 1H), 2.33 (m, 1H), 2.26 (s, 3H), 1.74 (m, 3H), 1.42 (s, 9H), 1.29-1.33 (m, 4H), 1.26 (s, 9H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 166.7, 157.7, 142.9, 140.1, 137.1, 136.3, 129.5, 127.2, 126.8, 126.1, 117.5, 71.8, 57.5, 34.9, 34.0, 33.6, 32.7, 31.5, 29.4, 24.2, 23.7, 21.5; Anal. Calcd. for $C_{28}H_{40}N_2O_3S$: C, 69.38; H, 8.32; N, 5.78. Found: C, 69.72; H, 8.44; N, 5.79.

Synthesis and characterization of mixed bis-sulfonamide ligands of trans-1,2-cyclohexanediamine (Scheme 2)**.** To a stirred solution of compound **(*S,S*)-4** (1 mmol) and triethylamine (3 mmol) in dry CH_2Cl_2 (6 mL) was added the aryl- or alkyl- sulfonyl chloride (1.1 mmol) at 0 °C. The reaction mixture was gradually warmed to RT and then left for 6-8 h. After completion of the reaction (checked by TLC), it was diluted with 6 mL of CH_2Cl_2 and washed with 2*N* HCl, water, and brine. The organic layer was dried over *anhydrous* Na_2SO_4 and the solvent was evaporated. The crude material was purified by column chromatography over silica gel to get the pure mixed bis-sulfonamide ligands of *trans*-1,2-cyclohexanediamine.

(*S,S*)-2a. Yield 80%; pale yellowish solid; mp-215-217°C; $[\alpha]^{25}_D$ +5.4(c 1.0, $CHCl_3$); R_f 0.60 (50% EtOAc in petroleum); IR (KBr pellet): 3257, 2932, 2858, 1531, 1435, 1350 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 8.37 (d, *J* = 7.1 Hz, 2H), 8.13 (d, *J* = 6.8 Hz, 2H), 7.68 (d, *J* = 8.3 Hz, 2H), 7.31 (d, *J* = 8.3 Hz, 2H), 5.73 (d, *J* = 4.6 Hz, 1H, NH), 4.39 (d, *J* = 7.4 Hz, 1H, NH), 2.78 (m, 2H), 2.43 (s, 3H), 2.1-5-2.13 (m, 1H), 1.65-1.42 (m, 3H), 0.86-1.33 (m, 4H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 149.8, 145.7, 143.8, 136.6, 129.8, 128.5, 126.7, 124.2, 57.7, 55.8, 33.9, 32.7, 24.3, 23.8, 21.4; MS (FAB) 454 (M^+ +1); Anal. Calcd. for $C_{19}H_{23}N_3O_6S_2$: C, 50.32; H, 5.11; N, 9.27. Found: C, 50.43; H, 5.15; N, 9.27.

(*S,S*)-2b. Yield 97%; white solid; mp-175-177°C; $[\alpha]^{25}_D$ -8.6 (c 1.0, $CHCl_3$); R_f 0.42 (30% EtOAc in Petroleum ether); IR (thin film): 3282, 2937, 2860, 1327, 1159 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ : 7.78 (d, *J* = 8.6 Hz, 2H), 7.73 (d, *J* = 8.3 Hz, 2H), 7.66 (d, *J* = 8.6 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 5.46 (d, *J* = 4.6 Hz, 1H, NH), 4.91 (d, *J* = 6.3 Hz, 1H, NH), 2.80 (bs, 2H), 2.42 (s, 3H), 2.16-1.91 (m, 1H), 1.68-1.55 (m, 2H), 0.93-1.09 (m, 5H); ^{13}C NMR ($CDCl_3$ 100 MHz) δ : 143.7, 139.2, 136.9, 132.3, 129.8, 128.8, 127.5, 127.0, 57.0, 56.2, 33.3, 32.7, 24.2, 23.9, 21.5; MS (FAB) 487 (M^+), 489 (M^+ +2); Anal. Calcd. for $C_{19}H_{23}BrN_2O_4S_2$: C, 46.82; H, 4.76; N, 5.75. Found: C, 46.91; H, 4.79; N, 5.75.

(*S,S*)-2c. Yield 96%; white solid; mp-135-137°C; $[\alpha]^{25}_D$ -7.0 (c 1.0, $CHCl_3$); R_f 0.40 (50% EtOAc in petroleum); IR (KBr pellet): 3291, 2940, 2869, 1597, 1420, 1324, 1158 cm^{-1}; ^{1}H-NMR ($CDCl_3$, 400 MHz) δ : 7.81 (d, *J* = 8.8 Hz, 2H), 7.75 (d, *J* = 8.3 Hz, 2H), 7.31 (d, *J* = 8.3

Hz, 2H), 6.78 (d, *J* = 8.3 Hz, 2H), 5.13 (d, *J* = 5.6 Hz, 1H, NH), 5.09 (d, *J* = 5.6 Hz, 1H, NH), 3.86 (s, 3H), 2.75 (bs, 2H), 2.42 (s, 3H), 1.99-2.00 (m, 1H), 1.81-1.79 (m, 2H), 1.54-1.53 (m, 2H), 1.15-1.09 (m, 3H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 162.8, 143.5, 136.9, 131.4, 129.7, 129.3, 127.1, 114.2, 56.4, 55.5, 33.0, 29.6, 24.0, 21.5; MS (FAB) 439 (M^+ +1); Anal. Calcd. for $C_{20}H_{26}N_2O_5S_2$: C, 54.77; H, 5.98; N, 6.39. Found: C, 54.89; H, 5.97; N, 6.40.

(*S,S*)-2d. Yield 90%; pale yellowish solid; mp-89-91°C; $[\alpha]^{25}_D$ -12.87 (c 1.0, $CHCl_3$); R_f 0.60 (50% EtOAc in petroleum); IR (thin film): 3297, 2937, 2861, 2360, 1596, 1163 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 8.14 (dd, *J* = 7.2, 2.4 Hz, 1H), 7.87-7.56 (m, 3H), 7.73 (d, *J* = 8.8 Hz, 2H), 7.30 (d, *J* = 8.4 Hz, 2H), 5.43 (d, *J* = 6.8 Hz, 1H, NH), 5.10 (d, *J* = 6.8 Hz, 1H, NH), 3.17-3.13 (m, 1H), 2.90-2.86 (m, 1H), 2.42 (s, 3H), 1.89-1.81 (m, 2H), 1.57-1.56 (m, 2H), 1.24-1.13 (m, 4H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 147.6, 143.5, 137.0, 134.0, 133.7, 133.0, 130.7, 129.7, 129.5, 128.2, 127.0, 125.3, 60.4, 57.2, 56.5, 33.0, 24.0, 23.8, 21.5; MS (FAB) 454 (M^+ +1); Anal. Calcd. for $C_{19}H_{23}N_3O_6S_2$: C, 50.32; H, 5.11; N, 9.27. Found: C, 50.45; H, 5.12; N, 9.29.

(*S,S*)-2e. Yield 89%; White solid; mp-96-99°C; $[\alpha]^{25}_D$ -32.3 (c 1.0, $CHCl_3$); R_f 0.29 (50% EtOAc in petroleum); IR (thin film): 3270, 2929, 2857, 2359, 2338, 1429, 1162 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 9.01 (dd, *J* = 4.1, 1.7 Hz, 1H), 8.42 (dd, *J* = 7.3, 1.4 Hz, 1H), 8.30 (dd, *J* = 8.6, 1.7 Hz, 1H), 8.09 (dd, *J* = 8.1, 1.2 Hz, 1H), 7.76 (d, *J* = 8.3 Hz, 2H), 7.67 (t, *J* = 7.6 Hz, 1H), 7.58-7.55 (m, 1H), 7.29 (d, *J* = 8.3 Hz, 2H), 5.87 (d, *J* = 6.3 Hz, 1H), 5.49-5.48 (m, 1H), 2.97-2.94 (m, 1H), 2.81-2.76 (m, 1H), 2.42 (s, 1H), 2.15-2.12 (m, 1H), 1.65 (bs, 1H), 0.94-1.52 (m, 6H); ^{13}C-NMR ($CDCl_3$ 100 MHz) δ : 151.4, 143.1, 143.0, 137.0, 136.0, 133.6, 131.0, 129.6, 128.9, 127.4, 126.9, 125.7, 122.4, 57.3, 56.4, 33.5, 32.3, 24.2, 23.7, 21.6; MS (FAB) 460 (M^+ +1); Anal. Calcd. for $C_{22}H_{25}N_3O_4S_2$: C, 57.49; H, 5.48; N, 9.14. Found: C, 57.62; H, 5.49; N, 9.15.

(*S,S*)-2f. Yield 84%; yellow solid; mp-185-187°C; $[\alpha]^{25}_D$ -12.9 (c 1.0, $CHCl_3$); R_f 0.39 (40% EtOAc in petroleum); IR (KBr pellet): 3315, 3222, 2937, 2864, 1607, 1535, 1325, 1158 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 8.73 (s, 1H), 8.42 (d, *J* = 8.0 Hz, 1H), 8.29 (d, *J* = 7.6 Hz, 1H), 7.79 (t, *J* = 8.1 Hz, 1H), 7.66 (d, *J* = 8.0 Hz, 2H), 7.29 (d, *J* = 8.0 Hz, 2H), 5.77 (d, *J* = 5.6 Hz, 1H), 4.71 (d, *J* = 7.8 Hz, 1H), 2.89-2.77 (m, 2H), 2.42 (s, 3H), 2.11-2.04 (m, 1H), 1.62-1.47 (m, 3H), 1.18-1.01 (m, 4H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 148.1, 143.8, 142.4, 136.9, 133.1, 130.7, 129.8, 127.0, 122.4, 60.4, 57.9, 56.0, 34.0, 32.6, 23.9, 21.5; MS (FAB) 454 (M^+ +1); Anal. Calcd. for $C_{19}H_{23}N_3O_6S_2$: C, 50.32; H, 5.11; N, 9.27. Found: C, 50.47; H, 5.12; N, 9.29.

(*S,S*)-2g. Yield 94%; White solid; mp-110-112°C; $[\alpha]^{25}_D$ -15.3 (c 1.0, $CHCl_3$); R_f 0.59 (40% EtOAc in Petroleum ether); IR (KBr pallet): 3283, 2932, 2869, 1420, 1324, 1162 cm^{-1};^{1}H NMR ($CDCl_3$, 400 MHz) δ : 7.90-7.86 (m, 2H), 7.74 (d, *J* = 8.8 Hz, 2H), 7.60-7.51 (m, 3H), 7.31 (d, *J* = 8.0 Hz, 2H), 5.22 (d, *J* = 6.0 Hz, 1H, NH), 5.01 (d, *J* = 6.4 Hz, 1H, NH), 2.78 (bs, 2H), 2.42 (s, 3H), 1.87-1.74 (m, 2H), 1.54-1.53 (m, 2H), 0.97-1.08 (m, 4H); ^{13}C NMR ($CDCl_3$ 100 MHz) δ : 143.5, 139.9, 136.9, 132.7, 129.7, 129.1, 127.1, 127.0, 56.7, 56.4, 33.2, 32.9, 24.1, 24.0, 21.5; MS (FAB) 409 (M^+ +1); Anal. Calcd. for $C_{19}H_{24}N_2O_4S_2$: C, 55.86; H, 5.92; N, 6.86. Found: C, 55.99; H, 5.97; N, 6.86.

(*S,S*)-2h. Yield 80%; White solid; mp-98-101 °C; $[\alpha]^{25}_D$ -45.3 (c 1.0, $CHCl_3$); R_f 0.41 (60% EtOAc in petroleum); IR (KBr pallet): 3284, 2939, 2860, 1446, 1320, 1158, 1091 cm^{-1}; ^{1}H-

NMR ($CDCl_3$, 400 MHz) δ : 7.76 (d, *J* = 8.3 Hz, 2H), 7.32 (d, *J* = 8.6 Hz, 2H), 5.09 (d, *J* = 7.6 Hz, 1H, NH), 4.85 (d, *J* = 6.8 Hz, 1H, N*H*), 3.22 (m, 1H), 3.05 (s, 3H), 2.98-2.79 (m, 1H), 2.43 (s, 3H), 2.17-2.15 (m, 1H), 1.71-1.60 (m, 4H), 1.33-1.05 (m, 3H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 143.7, 137.3, 129.9, 127.0, 57.6, 56.9; 41.5, 24.5, 24.3, 21.5; MS (FAB) 347 (M^+ +1); Anal. Calcd. for $C_{14}H_{22}N_2O_4S_2$: C, 48.53; H, 6.40; N, 8.09. Found: C, 48.69; H, 6.41; N, 8.10.

Synthesis of *C*$_2$-symmetric pyridyl bis(amide) bis(sulfonamide) ligand (*S*,*S*)-18. 2,6-Pyridinedicarbonyl dichloride (1.1 mmol) was slowly added to a solution of (*S*,*S*)-**4** (1 mmol) and triethylamine (5 mmol) in dichloromethane (5 mL) at 0 °C. The mixture was stirred at RT for 6 h. The resulting solution was washed with water, then brine, and dried. Solvent removal and purification over silica gel by column chromatography gave the pure product **(*S*,*S*)-18**; yield 97%; white solid; mp-158-160°C; $[\alpha]^{25}_D$ -38.3 (c 1.0, $CHCl_3$); R_f 0.40 (80% EtOAc in petroleum); IR (KBr pellet): 3344, 2933, 2861, 1667, 1538, 1447, 1322, 1156, 1090, 1007 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.55 (d, *J* = 7.8 Hz, 2H), 8.20 (d, *J* = 7.8 Hz, 2H), 7.95 (t, *J* = 7.8 Hz, 1H), 7.71 (d, *J* = 8.0 Hz, 4H), 7.04 (d, *J* = 8.1 Hz, 4H), 5.61 (d, *J* = 8.3 Hz, 2H), 3.78-3.80 (m, 2H), 3.33-3.35 (m, 2H), 2.23 (s, 6H), 2.19-2.20 (m, 2H), 1.81-1.87 (m, 3H), 1.63-1.66 (m, 4H), 1.09-1.47 (m, 7H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 164.1, 148.3, 142.8, 138.4, 138.3, 129.4, 126.5, 124.4, 57.3, 53.7, 34.1, 31.9, 25.1, 24.3, 21.4; Anal. Calcd. for $C_{33}H_{41}N_5O_6S_2$: C, 59.35; H, 6.19; N, 10.49. Found: C, 59.66; H, 6.26; N, 10.47.

Synthesis of pyridyl amide sulfonamide ligand (*S*,*S*)-19. A solution of 2-picolinic acid (1 mmol) and triethylamine (3 mmol) in *anhydrous* THF (5 mL) was treated with ethyl chloroformate (1.1 mmol) at 0 °C for 30 min. A solution of (***S***, ***S***)-**4** (1 mmol) in THF (5 mL) was added dropwise and the reaction mixture was left at RT overnight. After completion of the reaction (checked by TLC), most of the THF was removed in *vacuo* and the crude reaction mixture was partitioned between EtOAc and water. The organic layer was washed with water, brine, and dried over *anhydrous* sodium sulfate. It was concentrated *in vacuo* to give a crude product, which was purified by silica gel column chromatography using EtOAc and hexane to give pure **(*S*,*S*)-19**; Yield 98%; White solid; mp 180-182°C; $[\alpha]^{25}_D$ -1.2 (c 1.0, $CHCl_3$); R_f 0.40 (50% EtOAc in petroleum); IR (KBr pallet): 3319, 3062, 2937, 2859, 1657, 1594, 1516, 1443, 1318, 1154, 1084, 1000 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 8.42 (d, *J* = 4.9 Hz, 1H), 8.11 (d, *J* = 7.6 Hz, 1H), 7.88 (dt, *J* = 15.4, 7.8, 1.4 Hz, 1H), 7.65 (d, *J* = 8.0 Hz, 2H), 7.53 (d, *J* = 8.0 Hz, 2H), 7.45 (m, 1H), 6.75 (d, *J* = 8.1 Hz, 2H), 6.01 (d, *J* = 5.6 Hz, 1H), 3.76-3.84 (m, 1H), 2.96-3.04 (m, 1H), 2.22-2.26 (m, 1H), 2.12 (s, 3H), 1.95-1.98 (m, 1H), 1.73-1.78 (m, 3H), 1.25-1.51 (m, 3H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ : 165.4, 148.8, 147.7, 142.1, 137.8, 137.3, 129.1, 126.5, 126.2, 122.3, 60.2, 51.9, 34.9, 32.2, 24.5, 24.4, 21.3; Anal. Calcd. for $C_{19}H_{23}N_3O_3S$: C, 61.10; H, 6.21; N, 11.25; Found: C, 61.34; H, 6.32; N, 11.29.

(***S*,S,*S*)-20.** The procedure was same as the synthesis of (***S*,*S***)-**19** except *N*-Boc-L-Proline was used instead of 2-Picolinic acid; Yield 99%; White solid; mp-184-186°C; $[\alpha]^{25}_D$ -74.0 (c 1.0, $CHCl_3$); R_f 0.45 (60% EtOAc in Petroleum ether); IR (KBr pallet): 3310, 2934, 2866, 1668, 1534, 1393, 1327, 1250, 1162, 1091, 912 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ : 7.69 (d, *J* = 8.0 Hz, 2H), 7.25 (br, 2H), 7.20 (br, 1H, NH), 6.03 (bs, 1H, NH), 3.69 (d, *J* = 7.8 Hz, 2H), 3.47 (br,

1H), 3.32 (m, 1H), 3.21 (m, 1H), 2.92 (m, 1H), 2.41 (s, 3H), 2.30 (br, 1H), 1.67-2.17 (m, 7H), 1.43 (s, 9H), 1.19-1.33 (m, 4H); Anal. Calcd. for $C_{23}H_{35}N_3O_5S$: C, 59.33; H, 7.58; N, 9.02; Found: C, 59.61; H, 7.62; N, 9.09.

(***R*,*R*,*S*)-20.** The procedure was the same as for the synthesis of (***S*,S,*S*)-20** except that amino sulfonamide (***R*,*R*)-4** was used; yield 90%; white solid; mp-186-188°C; $[\alpha]^{25}_D$ -27.5 (c 1.0, $CHCl_3$); R_f 0.65 (80% EtOAc in petroleum); ^{1}H- NMR ($CDCl_3$, 400 MHz) δ : 7.72 (d, *J* = 8.3 Hz, 2H), 7.27 (d, *J* = 8.1 Hz, 2H), 6.52 (br, 1H), 4.24 (bs, 1H), 3.56-3.66 (m, 2H), 3.03- (br, 1H), 2.41 (s, 3H), 2.21 (br, 1H), 2.05 (br, 2H), 1.84 (m, 1H), 1.59-1.67 (m, 5H), 1.46 (s, 9H), 1.16-1.27 (m, 4H); Anal. Calcd. for $C_{23}H_{35}N_3O_5S$: C, 59.33; H, 7.58; N, 9.02; Found: C, 59.59; H, 7.63; N, 9.09.

Synthesis of (2S, 1'S, 2'S)-pyrrolidine-2-carboxylic acid [2'-(4-methylphenylsulfonamido)-cyclohexyl]-amide (*S*,S,*S*)-21. The *N*-Boc protected amido sulfonamide was added portionwise to a chilled solution of formic acid at 0 °C and reaction mixture was stirred at the same temperature for 6-8 h. After completion of the reaction (checked by TLC), most of the HCOOH was removed in *vacuo* and the crude reaction mixture was basified with 25% ammonia solution. It was partitioned between EtOAc and water. The organic layer was washed with water, brine, and dried over *anhydrous* sodium sulfate. It was concentrated *in vacuo* to give a crude product, which was purified by silica gel column chromatography using EtOAc and hexane to give pure (***S*,S,*S*)-21.** Yield 84%; white solid; mp-168-170°C; $[\alpha]^{25}_D$ -29.5 (c 1.0, $CHCl_3$); R_f 0.30 (5% MeOH in CH_2Cl_2); IR (KBr pellet): 3366, 3287, 3123, 2956, 2862, 1634, 1529, 1454, 1320, 1161, 1100, 914, 810 cm^{-1}; ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.62 (br, 2H), 7.53 (d, *J* = 8.8 Hz, 2H), 7.16 (br, 2H), 6.13 (bs, 1H), 3.54 (dd, *J* = 8.8, 6.1 Hz, 1H), 3.48 (br, 1H), 2.78-2.87 (m, 3H), 2.28 (s, 3H), 1.99-2.02 (m, 1H), 1.57-1.91 (m, 7H), 1.10-1.21 (m, 4H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 175.0, 142.3, 138.6, 129.1, 126.4, 59.7, 58.3, 51.7, 46.4, 33.2, 31.9, 30.1, 25.3, 24.3, 24.1, 21.0; Anal. Calcd. for $C_{18}H_{27}N_3O_3S$: C, 59.15; H, 7.45; N, 11.50. Found: C, 59.30; H, 7.53; N, 11.51.

Synthesis of (2S, 1'R, 2'R)-pyrrolidine-2-carboxylic acid [2'-(4-methylphenylsulfonamido)-cyclohexyl]-amide (*R*,*R*,*S*)-21. Yield 90%; white crystalline solid; mp-172-174 °C; $[\alpha]^{25}_D$ +10.4 (c 1.0, $CHCl_3$); R_f 0.25 (5% MeOH in CH_2Cl_2); ^{1}H- NMR ($CDCl_3$, 400 MHz) δ: 7.88 (d, *J* = 8.3 Hz, 1H), 7.56 (m, 2H), 7.09 (m, 2H), 6.29 (bs, 1H), 3.68-3.72 (m, 1H), 3.44 (bs, 1H), 2.82-2.91 (m, 3H), 2.23 (s, 3H), 1.87-2.00 (m, 1H), 1.42-1.85 (m, 7H), 1.04-1.10 (m, 4H); ^{13}C- NMR ($CDCl_3$ 100 MHz) δ: 174.2, 142.9, 139.3, 129.7, 126.7, 60.2, 57.7, 52.6, 46.9, 32.7, 32.4, 30.7, 25.9, 24.8, 23.7, 21.5; Anal. Calcd. for $C_{18}H_{27}N_3O_3S$: C, 59.15; H, 7.45; N, 11.50. Found: C, 59.37; H, 7.49; N, 11.63.

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